



BioAssemblyBot™



http://www.advancedsolutions.com/brands/life_sciences.aspx

<http://www.tsimsoftware.com/>

v1.11

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BioAssemblyBot™ User Manual



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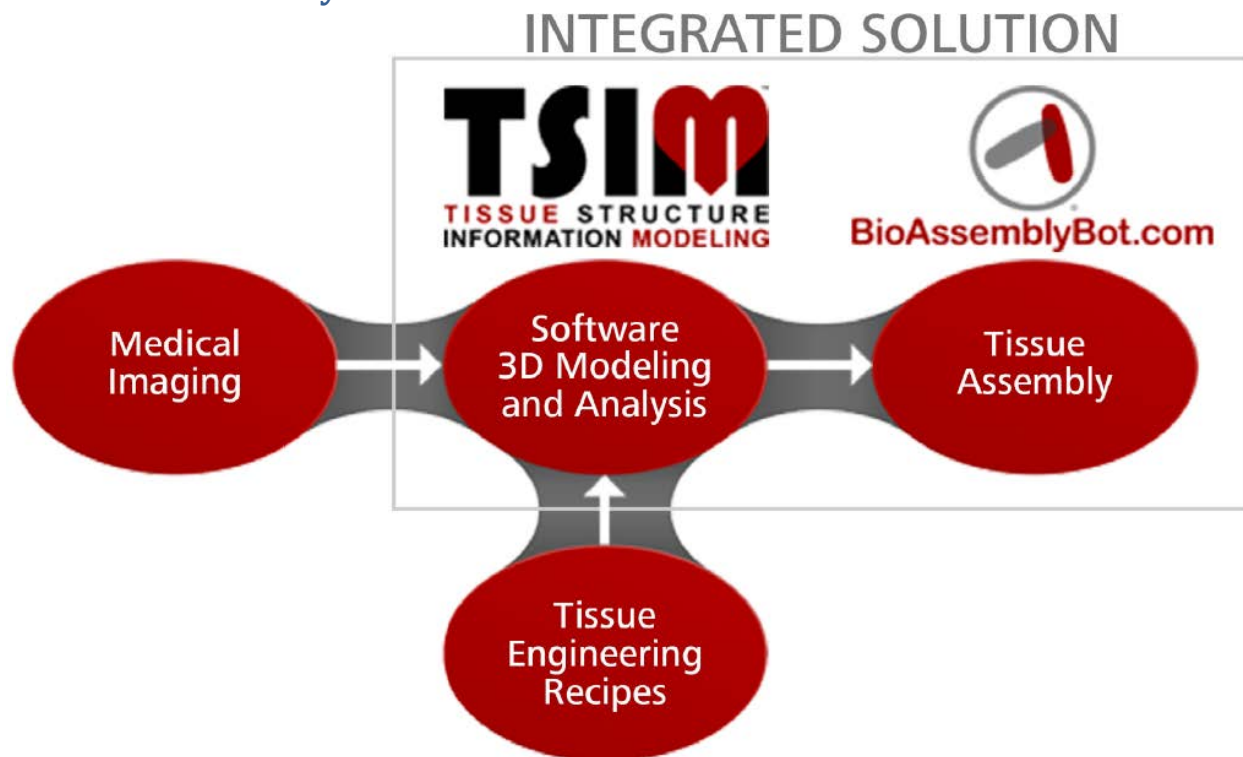


Other Documentation

In addition to this User Manual, the user manuals provided by Epson for the robot and robot controller have also been provided. These manuals are referenced in this BioAssemblyBot™ user manual to provide a better understanding of these products.

In particular, please read the Maintenance sections of the Epson robot controller and Epson robot manuals for proper maintenance on the robot and robot controller.

About BioAssemblyBot™






BioAssemblyBot™ is an integrated tabletop workstation with a multi-axis robot that facilitates 3D tissue printing of composite geometric shapes. The multi-axis robot design is the next stage of evolution in 3D printing technology and is well suited for the surgical precision required to assemble functional tissue structures. The BioAssemblyBot™ can print with many types of bioinks, up to 8 materials per print, or even more if equipped with Ambient Dual Dispense tools. Additionally, it can heat bioinks with the Heating tool, cool bioinks with the Cooling tool, and UV irradiate them with the Ambient Light tool. Prints can be automated with the Pick And Place tool, which automatically loads well plates before printing in them.

Coupled with the Tissue Structure Information Modeling (TSIM™) software, the BioAssemblyBot™ provides a comprehensive integrated software and hardware technology platform to model and print 3D tissue structures. TSIM™ is an intuitive software tool that empowers doctors and scientists to design, visualize, and analyze 3D computer models of complex tissue structures. TSIM™ provides a comprehensive platform including medical imaging analysis, biological construct modeling, and fabrication. Starting with industry standard data (e.g. medical imaging), TSIM™ guides the user through the construction of a biological model capable of being simulated, analyzed, and fabricated.

Safety

Notation

The following symbols are included to indicate the necessary safety considerations. The descriptions below associated with each symbol are the possible outcomes if the instructions with these symbols are not followed.

 WARNING	Possible serious injury or death.
 WARNING	Possible harm to people caused by electric shock.
 CAUTION	Possible harm to people or physical damage to equipment and facilities.

Assembly and Maintenance Safety

Please read this section to understand safe assembly and maintenance procedures.

Only trained personnel should be assembling and maintaining the BioAssemblyBot™. Please also see the Safety and Maintenance sections of the Epson robot controller and robot user manuals.



- Do not operate the BioAssemblyBot™ with safeties or Emergency Stop disabled or malfunctioning. Operating the BioAssemblyBot™ in either of these conditions is extremely hazardous and may result in serious bodily injury and/or serious damage to the BioAssemblyBot™, as the safeties cannot perform their intended function in an emergency.



WARNING

- Do not remove or modify any parts of the BioAssemblyBot™. Removal or parts, improper maintenance, or modification may not only cause improper functioning of the BioAssemblyBot™, but also serious safety problems.



WARNING

- Connect the AC power cable to a 120-Volt power receptacle for BioAssemblyBots™ installed in the USA, 240-Volt power receptacles for Britain, and 220-Volt power receptacles for France. To shut off power to the BioAssemblyBot™, pull out the power plug from the receptacle.



WARNING

- Connect the power cable, air hose, and network cabling properly. Do NOT place unnecessary strain on the cables or air hose. Doing so may cause damage to the cables or air hose or disconnection. Damaged components are extremely hazardous and may result in electric shock and improper function.



CAUTION

- Make sure the air feed has a minimum inlet pressure of 90 psi. Make sure the pressure is constant; tools can be accidentally dropped by the BioAssemblyBot™ if the pressure drops significantly (5 psi) below this point.

Print Safety

Please read this section to understand safe printing procedures.



WARNING

- Stay clear of the BioAssemblyBot™ and do not place any body parts in, on, or near the printer until printing or calibration movements are completed. Components of the BioAssemblyBot™ will move during a print.
- Never touch a Heating tool during a print, or after a print, without first allowing it to cool. The heating tool can take up to 60 minutes to completely cool down.



WARNING

- Do not allow components of the BioAssemblyBot(tm) to come into contact with liquid, with the exceptions of:
 - stage surface or stage print guides
 - petri dishes, well plates, slides, stage overlays
 - material barrels
 - dispensers on barrels (needles, nozzles, etc.)

Wet electrical components are extremely hazardous and may result in electric shock and/or improper function. Never touch wet electrical components.

Emergency Features

The BioAssemblyBot™ is equipped with an emergency stop. Pushing in (engaging) the emergency stop button turns on the brakes for every axis of the robot. When the brakes are on, the BioAssemblyBot™ does not move. To disengage the emergency stop button, twist it clockwise. See the images below to assess the status of the button.

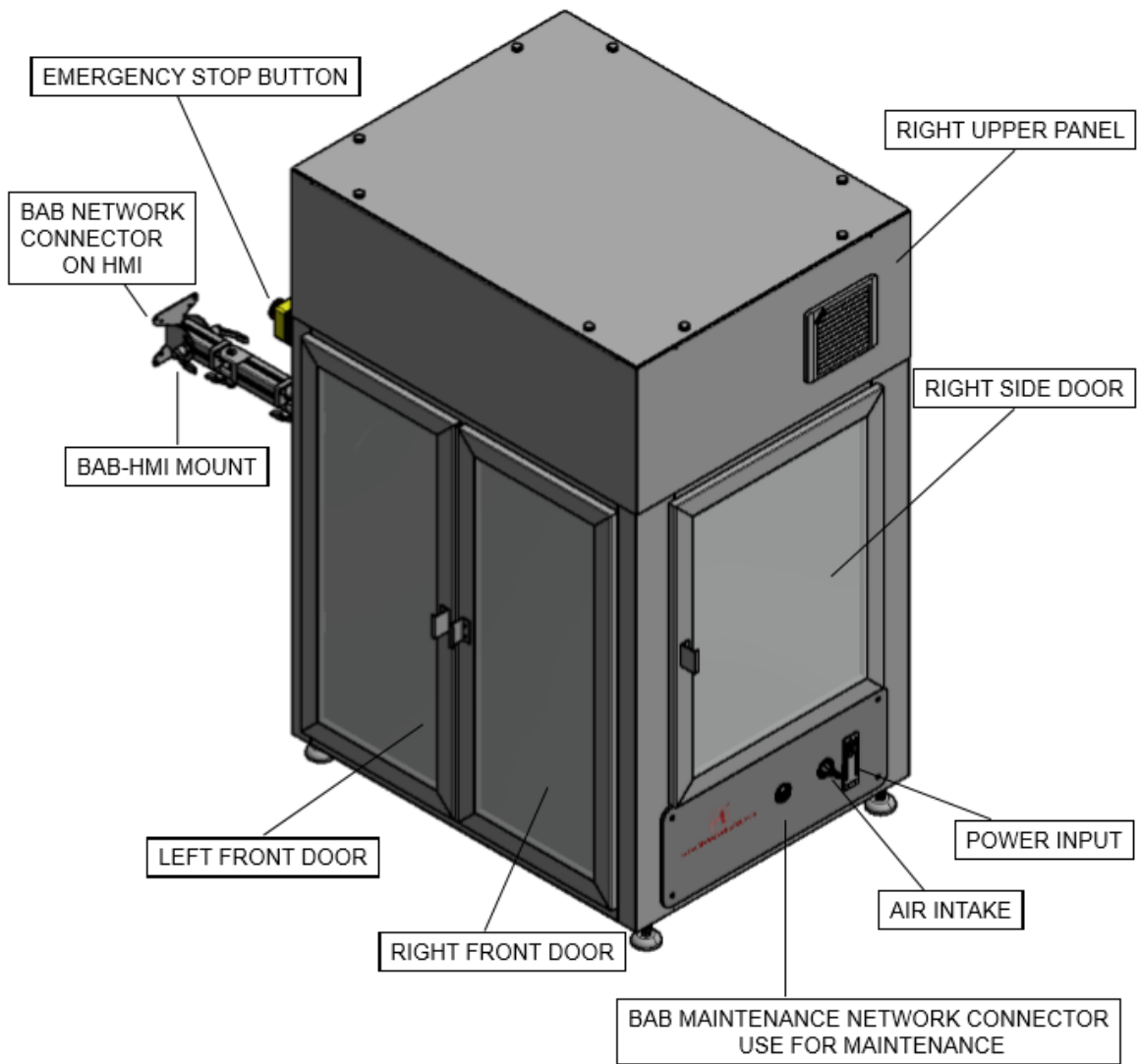
DISENGAGED

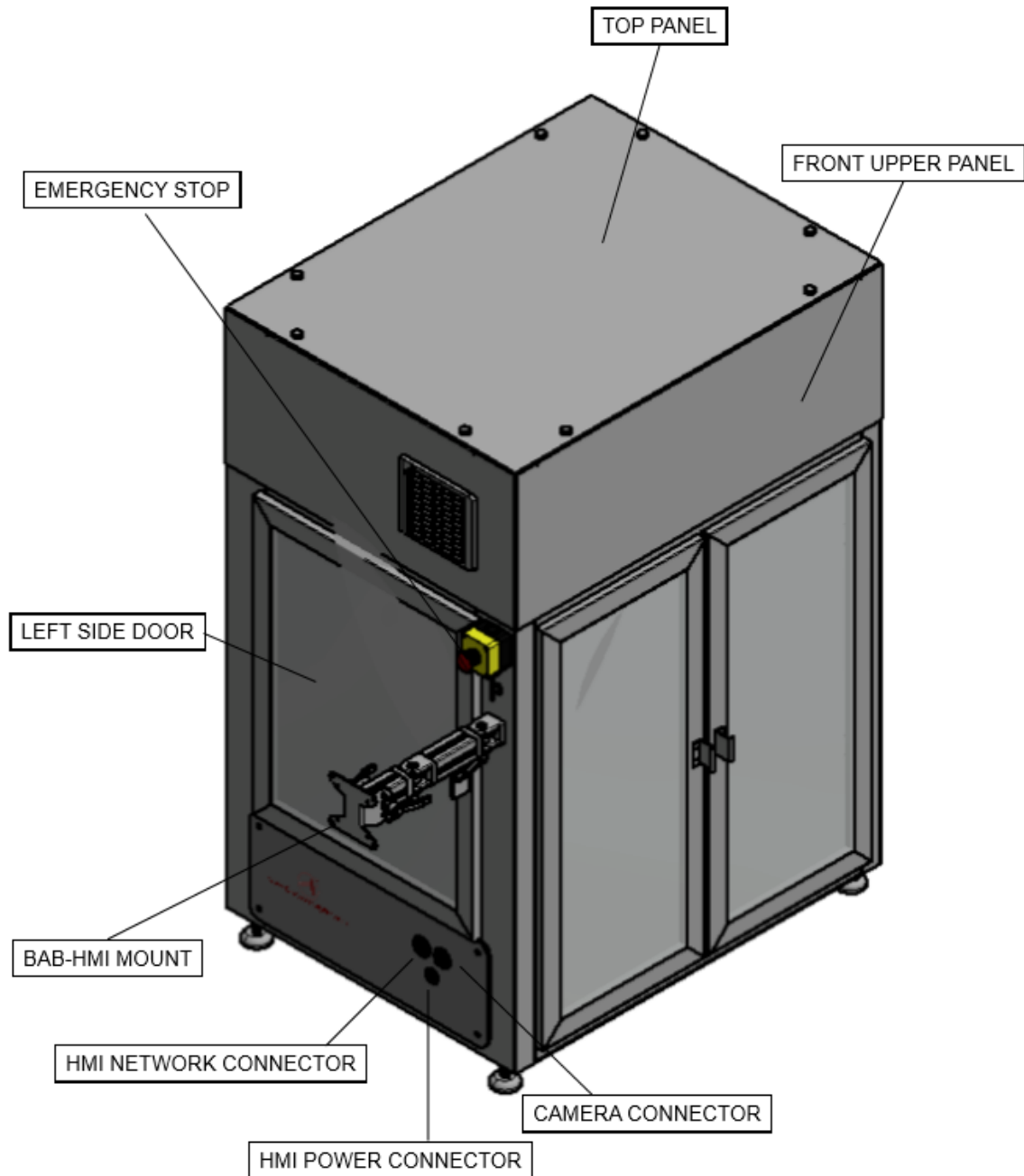


ENGAGED



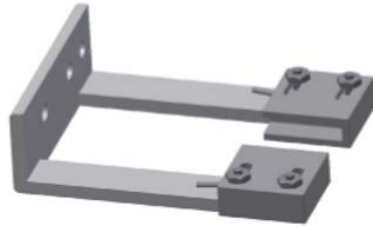
BioAssemblyBot™ Hardware



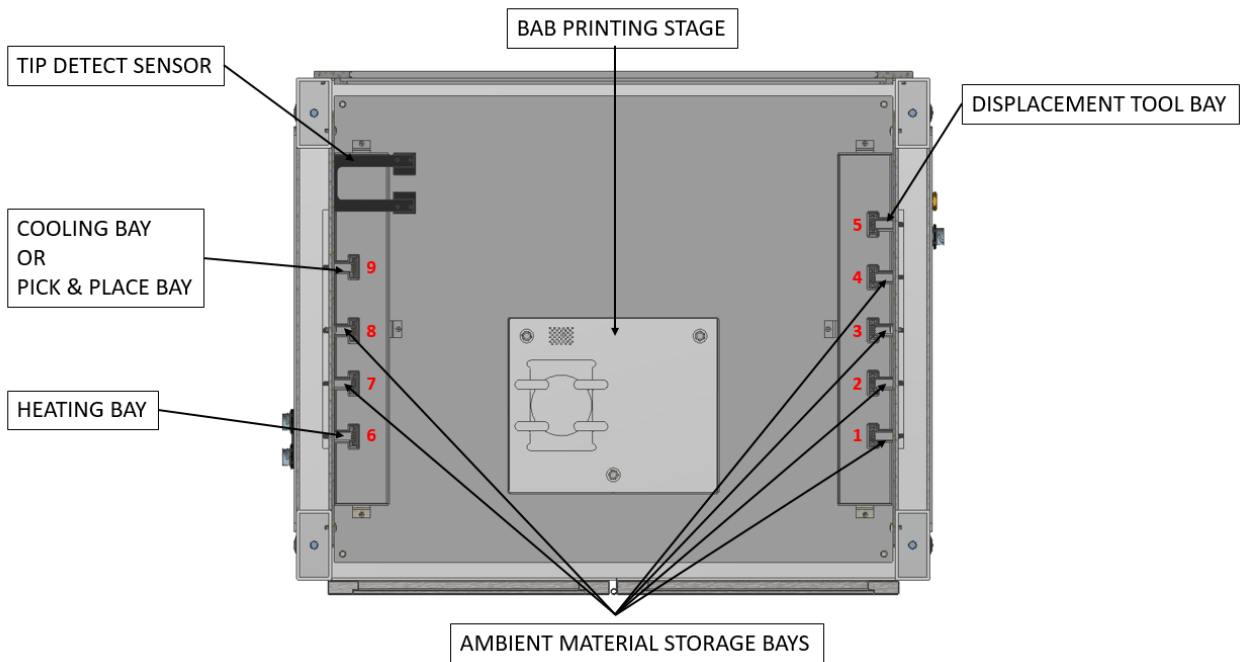


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TIP DETECT SENSOR



ROBOT / ROBOT ARM

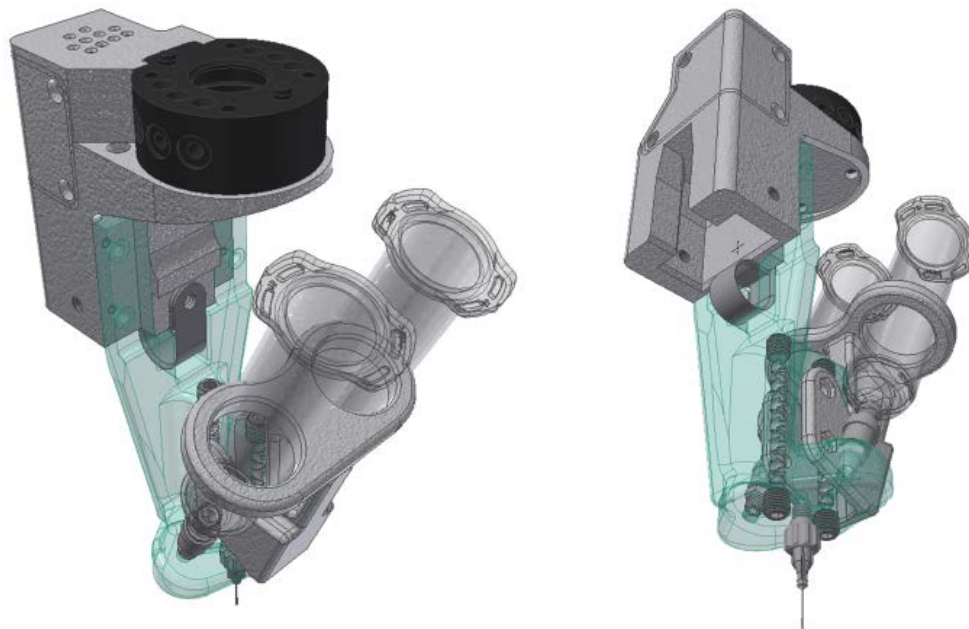


BioAssemblyBot™ Tools

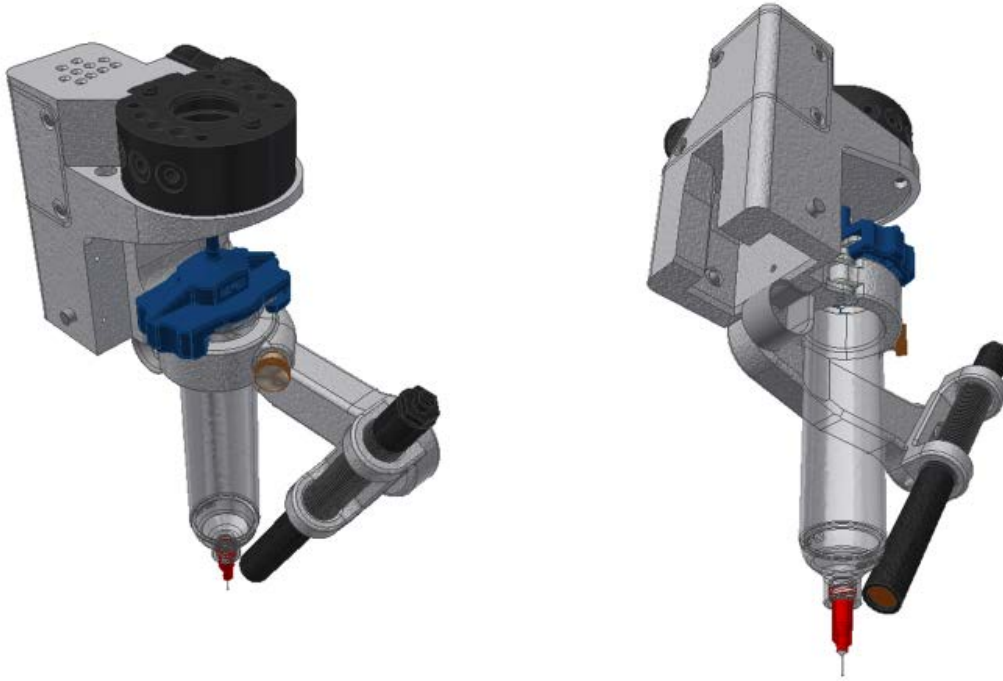
Ambient Tool



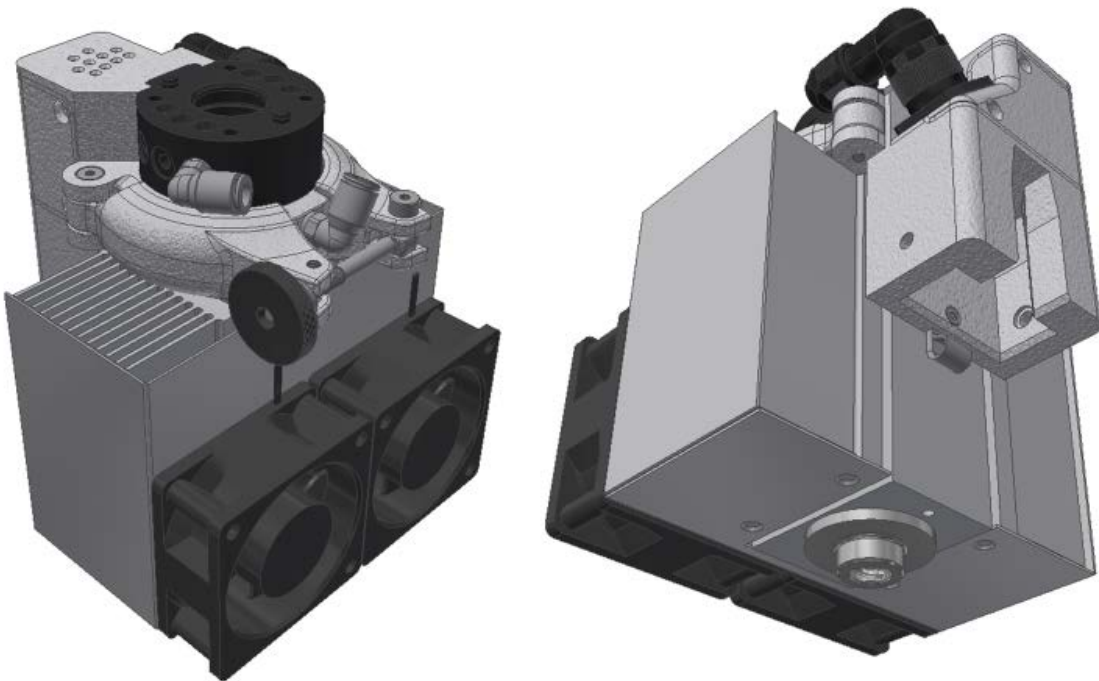
Ambient Dual Dispense Tool



Ambient Light Head Tool

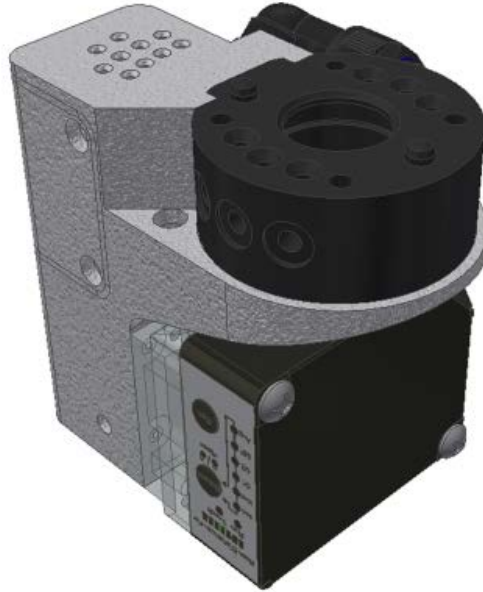


Cooling Tool

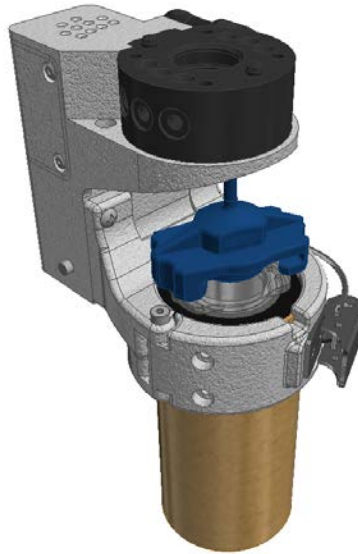


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Displacement Tool



Heating Tool

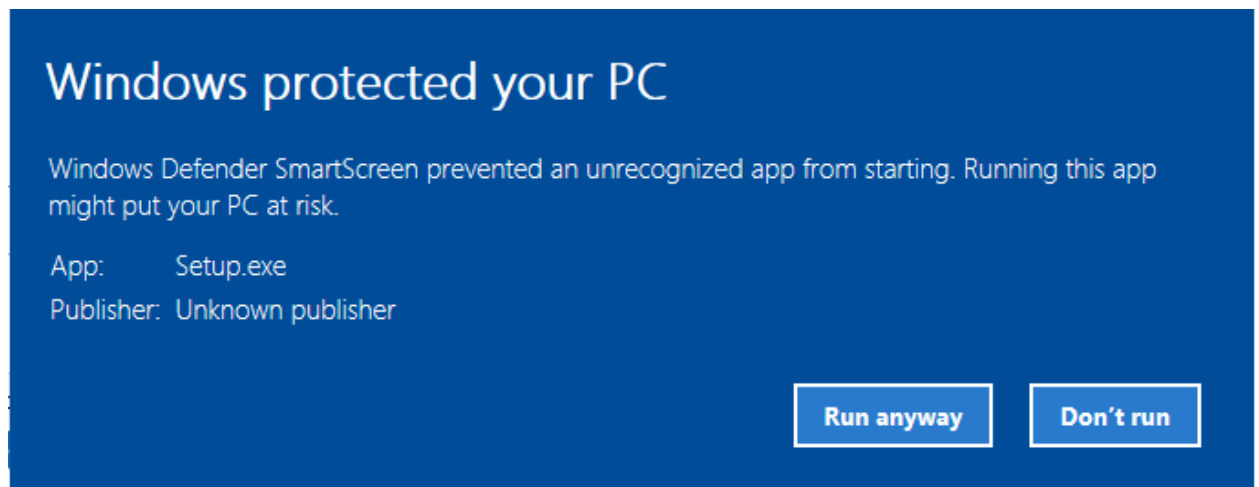
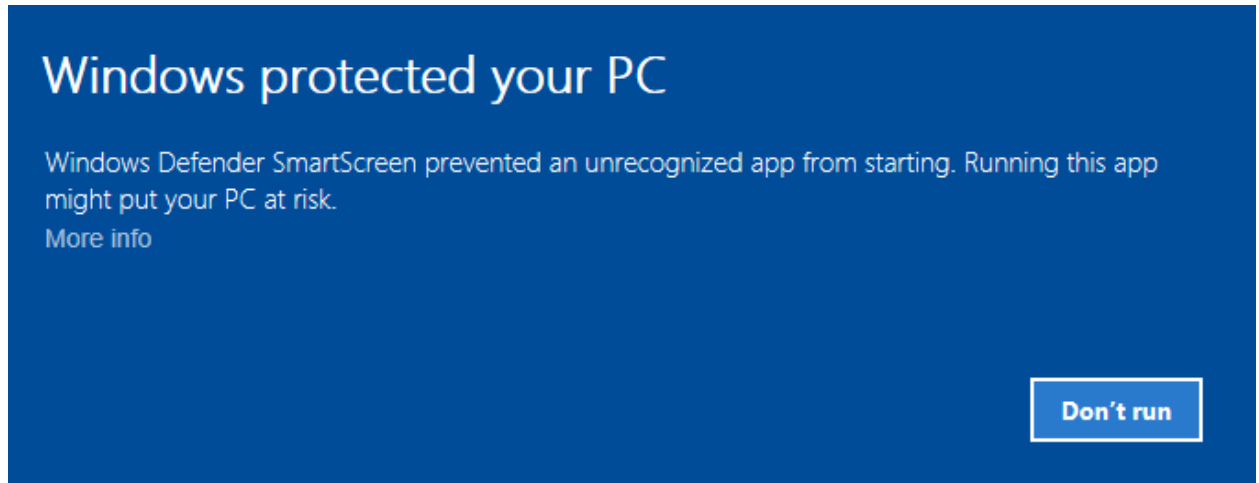


TSIM™ Installation

1. On a Windows 10 PC, download TSIM from:
http://updates.tsimsoftware.com/squirrel_internal/Setup.exe

2. Run Setup.exe.

If you get a Windows SmartScreen warning, choose *More Info*, then choose *Run Anyway*.



3. An ASI Licensing prompt will appear. Enter your TSIM™ license key from Advanced Solutions, Inc. in the *Product Key* section, and choose *Checkout*. The status will change from red Unlicensed text to green Licensed text.
4. Choose *Close* on the bottom right. TSIM will start.

BioAssemblyBot™ Human Machine Interface (HMI)

The BAB-HMI provides controls, settings, and current state information of the BioAssemblyBot™. The main sections are Status, Print, Control, and Calibration, and are present at the top of every screen. Some sections of the main menu have subsections; for example, Move and Other can be found under Control. To exit the HMI application, click the very top right BioAssemblyBot™ logo.

Status Screen

In the Status screen, the BioAssemblyBot™ functions can be monitored. The BioAssemblyBot™ icon in the top left below the menu displays a colored dot to indicate the status:

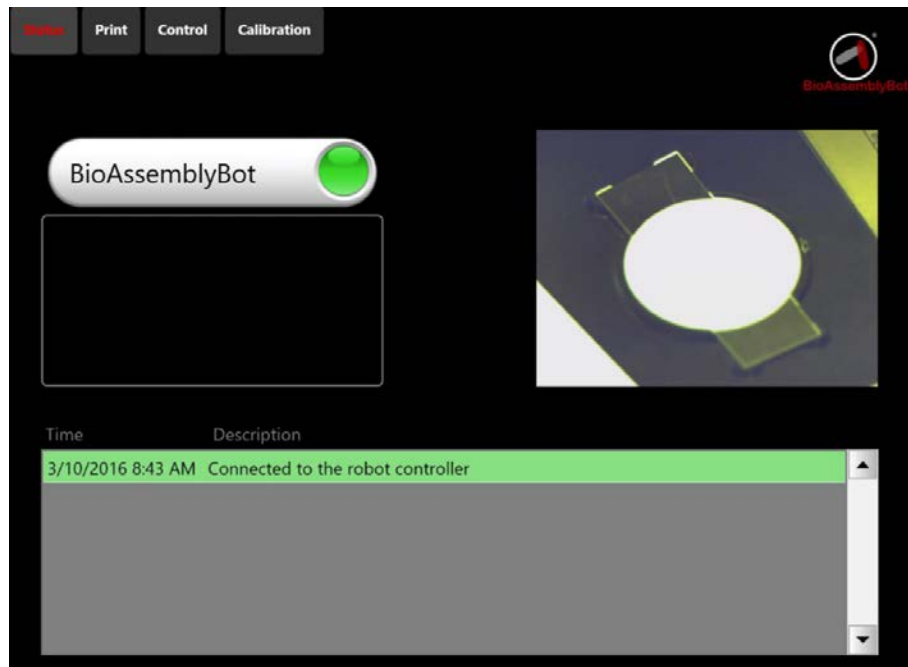
- Green Everything is working properly and ready for printing.
- Yellow One or more door safeties are open.
- Red Emergency stop engaged, error with printer hardware, or hardware initializing.

Green status allows a print to start. Yellow and Red disable most of the robot functionality.

Directly below the BioAssemblyBot™ icon is a box that will display print status.

The lower half of the screen contains a chronological event log of connections, print tasks, and errors. This can be used to determine Yellow or Red status; for example, if an event exists showing that the right door was opened, but there is not a “right door closed” event, the conclusion can be drawn that the right door needs to be closed.

The right side of the screen features a streaming video of the print.



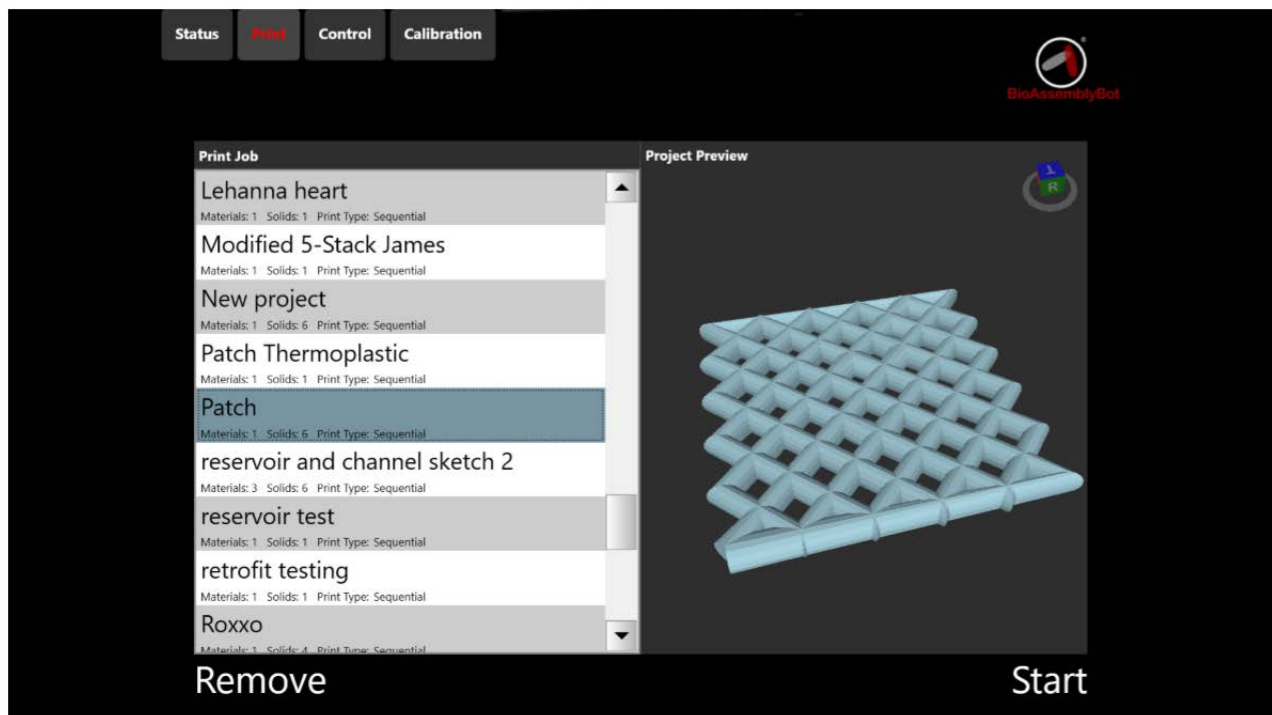
Print

The print screen displays a list of available print jobs, and a 3D preview of the currently selected job. The list of print jobs includes the name of the print, from TSIM™, the number of materials the print requires, the number of separate objects the model had in TSIM™, and whether the print is Sequential or Concurrent.

In Project Preview, the print job can be zoomed, panned, and rotated to adjust the viewing perspective.

Selecting a print job and clicking *Start* will initiate printing and move to the Load Materials screen.

Clicking *Remove* will delete the print job from the HMI.



Load Materials

In the Load Materials screen, the user is prompted to the materials needed for the print.

For each material in this print, the material name is listed in a bay. Materials are typically bioinks. Materials are loaded into tools.

Tools

Each tool on the BioAssemblyBot™ has its own set of capabilities:

- Ambient
 - Dispenses a bioink at ambient temperature at desired automatic pressure. This tool holds up to 30 CC of bioink material, but can be easily adapted for 10 CC and 5 CC.
- Ambient Dual Dispense
 - Dispenses two bioinks at ambient temperature at different desired automatic pressures. A mixing chamber in the tool handles blending the materials for the print. This tool holds up to 30 CC of bioink material in each chamber, but each chamber can be easily adapted for 10 CC and 5 CC.
- Ambient Light
 - Dispenses a bioink at ambient temperature at desired automatic pressure, and can irradiate the material as it's being printed, for crosslinking or other purposes. The tool irradiates at 365 nm up to 400 mw/cm² with the installed lens¹.
- Heating tool
 - Heats bioink up to 150 C and maintains that temperature during a print. This tool holds up to 30 CC of bioink material.
- Cooling tool
 - Cools bioink down to 10 C and maintains that temperature during a print. This tool holds up to 30 CC of bioink material.
- Displacement
 - Measures the stage² to ensure a level surface for printing.
- Pick And Place
 - Allows printing automation by picking well plates from a source tower, printing within them, then puts the well plates in a destination tower.

Each tool uses a wide variety of needles and nozzles, but all needles and nozzles can be used on all tools interchangeably.

¹ Ambient Light Tools with other heads can irradiate at 385 or 405 nm, and depending on lens, up to 3 W/cm².

² See Calibration > Stage Level.

Load Pick And Place Towers

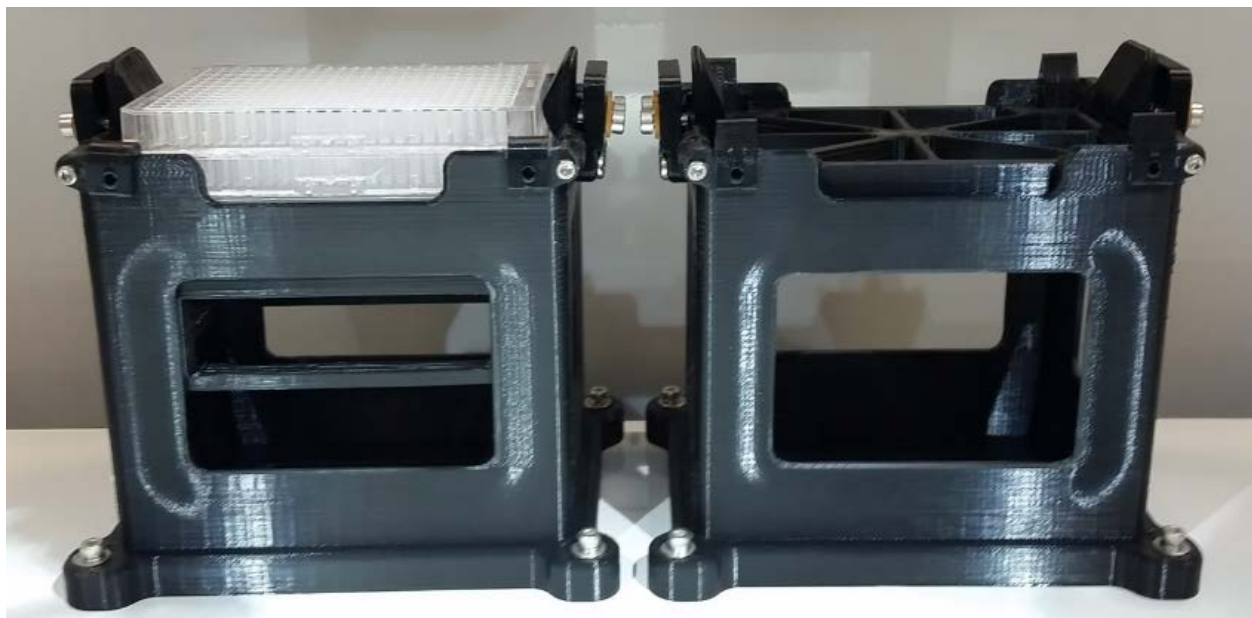
If your print requires well plates, you have two options, depending on your BioAssemblyBot™ capabilities:

Manual Placement:

If your BioAssemblyBot's™ stage is equipped with a well plate recess, open the BioAssemblyBot™ doors, and manually place the well plate in recess. In TSIM™, align your print with the location of the well plate, and set the Tip To Stage Offset to the depth of the placed well plate. Aligning a print to a well plate with small well plates can be time consuming; it is recommended dialing in the bottom left and top right well plate positions before attempting a full print.

Automatic Placement:

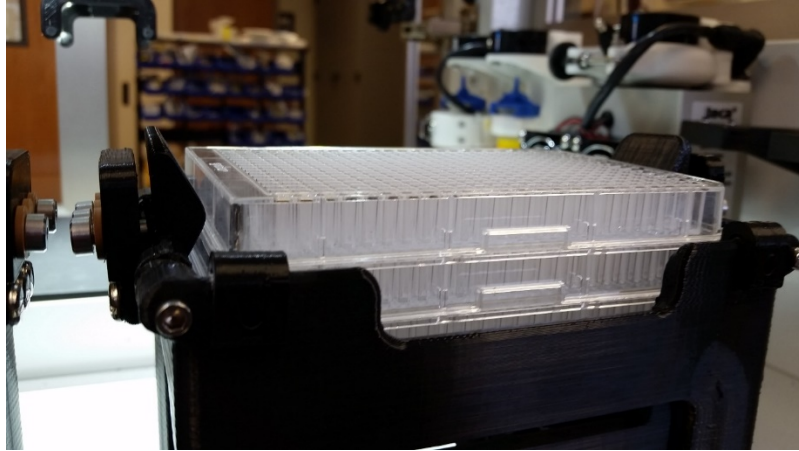
If your BioAssemblyBot's™ stage is equipped with a well plate recess, Pick And Place tool, and Source and Destination towers, place at least one empty well plate in the Source tower. From the front of the BioAssemblyBot™, the Source tower is on the left, and Destination on the right.



In the above picture, the Source tower on the left is holding three towers, and the Destination tower is empty.

Well plates are typically symmetrical, so left/right orientation does not matter when loading the plates in the tower, but the wells must be facing up when the well plates are placed in the tower. Once the tower is loaded, make sure the top well plate is level, at the correct height, and fed in correctly, per the diagrams below, or damage can occur to the Pick and Place tool.

CORRECT HEIGHT



WRONG HEIGHT: Well plate is too low



WRONG HEIGHT: Well Plate is misfed



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It is recommended to use the TSIM™ 384 template file provided with BioAssemblyBots™ equipped with Pick And Place. In TSIM™, make sure to check the “pick and place” option, and choose “384” for the number of wells in your print, and create the desired print. Proceed with the print as normal. Upon print start, the BioAssemblyBot™ will first engage the Pick And Place tool, remove the top well plate from the Source tower, and place it in the well plate indentation on the stage. The print will proceed as normal afterward. When the print completes, the BioAssemblyBot™ will reengage the Pick and Place tool, and put the completed print in the Destination tower.

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Load Material Screen And Tools

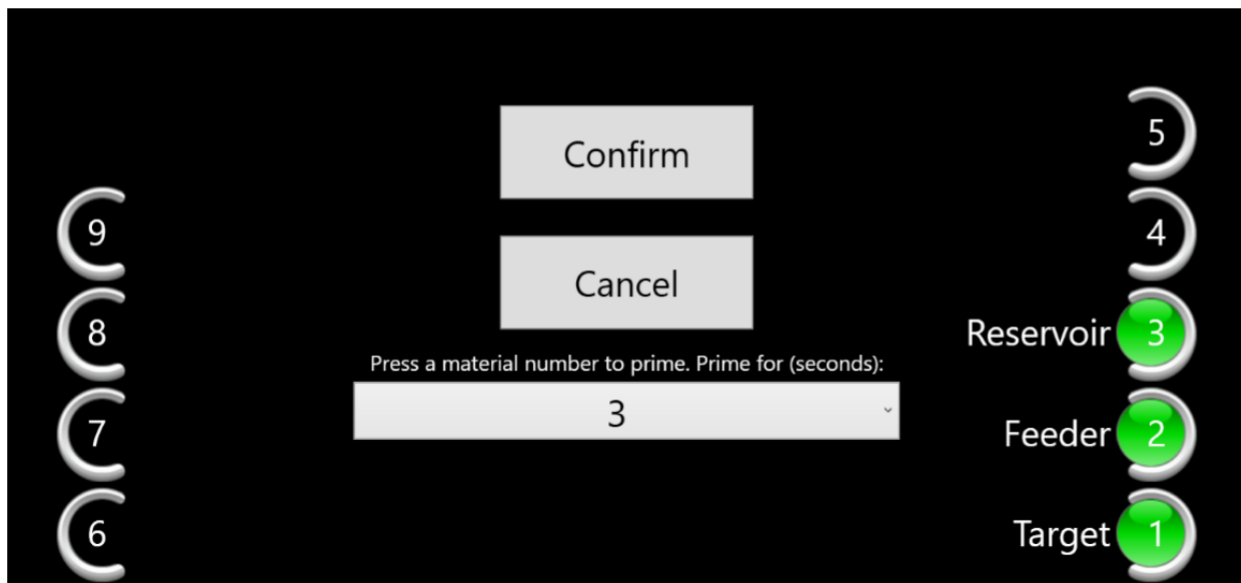
Load the appropriate materials by opening the BioAssemblyBot™ doors, removing the tools, loading the bioinks into the tools as required, placing the tools back in the appropriate bays, then closing the doors.

Tool types are automatically detected by the robot when the doors are closed; the circular icon with a number in it indicates if the tool type in each bay is suitable for this print or unsuitable.

- Green The tool in this bay is suitable for this print.
- Red The tool in this bay does not have the required capabilities for this print. Please replace it with an appropriate tool³.
- Black This bay is not used for this print.

Do note that the BioAssemblyBot™ cannot detect the material type inside of a barrel on a tool, and it is the user's responsibility to make sure the right material is loaded in the tool.

To assist with this, the name of the material from TSIM™ is displayed next to the circular icon.



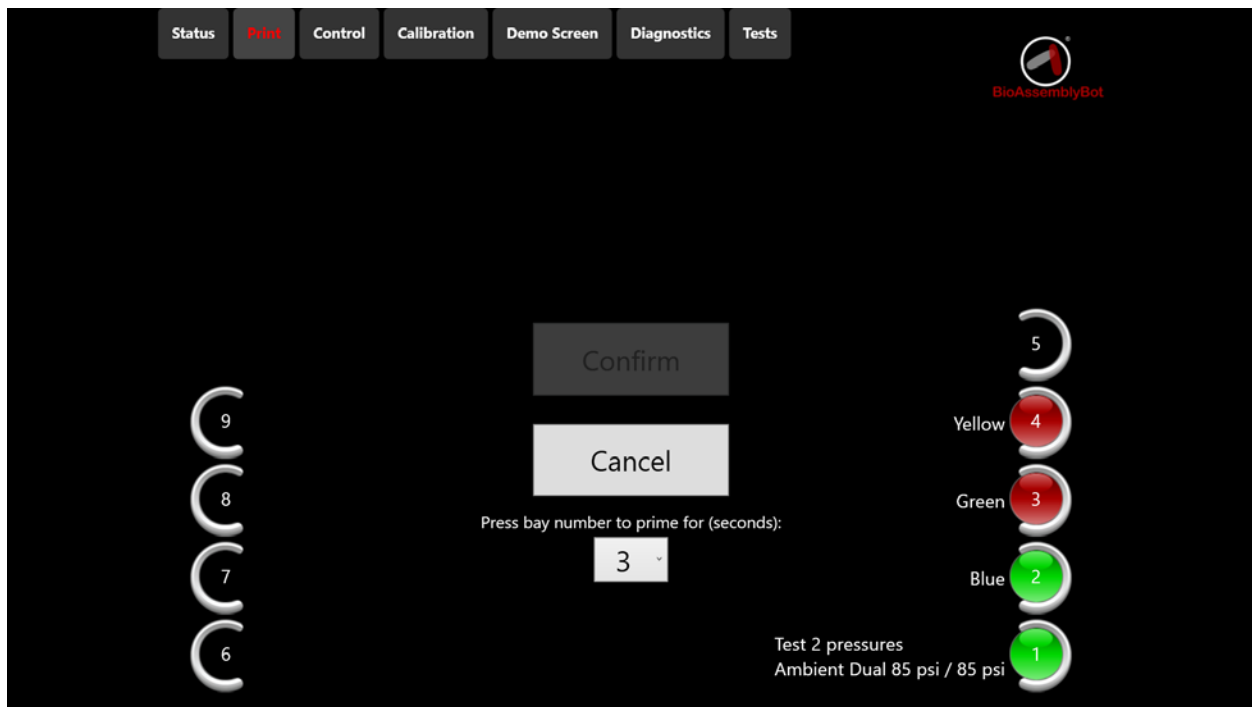
³ Please review the Calibration > Storage Bays screen and documentation if you need a refresher on what tools and printing capabilities your individual BioAssemblyBot™ has.

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If your print requires the Ambient Light Head Tool, information on lens orientation and lens type to use is also displayed, along with the desired irradiation values. Please make sure the correct lens is on the tool, and the lens is pointed in the proper orientation before proceeding.



If your print requires the Ambient Dual Dispense Tool, information on both pressures is also displayed.



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Some materials flow slowly through a needle, or require high pressures. Priming a needle will fill the needle full of the material, at the possible expense of some wasted material. If a material's needle needs to be primed beforehand:

- Open the doors and place a receptacle in the center of the robot's stage.
- Close the doors and click on the circular icon for which tool needs to be primed.
- The BioAssemblyBot™ will pick up the tool, then dispense for the number of seconds indicated in the dropdown. Only one material can be primed at a time.

When all materials needed for the print are loaded, select *Confirm* to initiate the print, or *Cancel* to go to the previous screen.

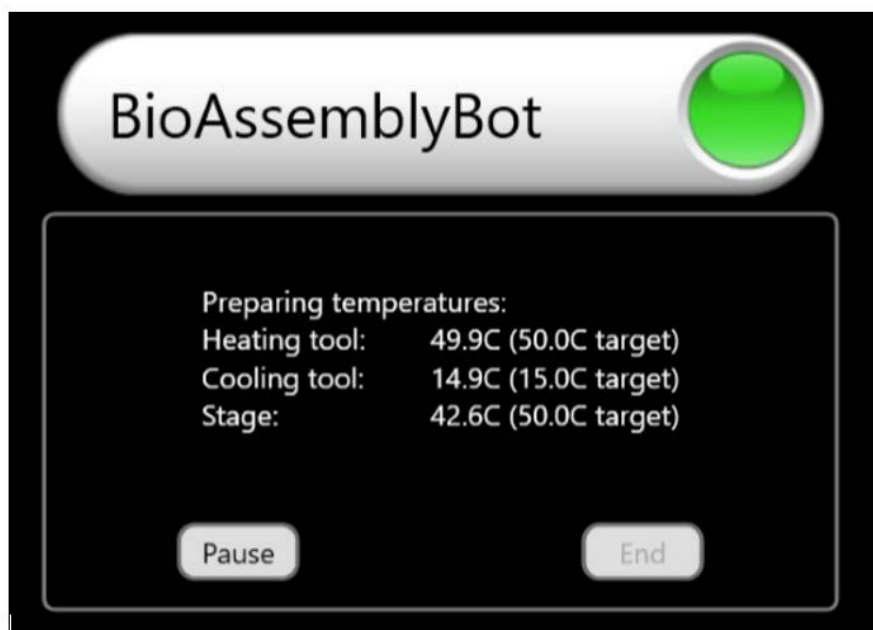
If *Confirm* is selected, the print will start, and return the user to the Status screen.

Printing

The Status box in the Status screen will show the status of the current print.

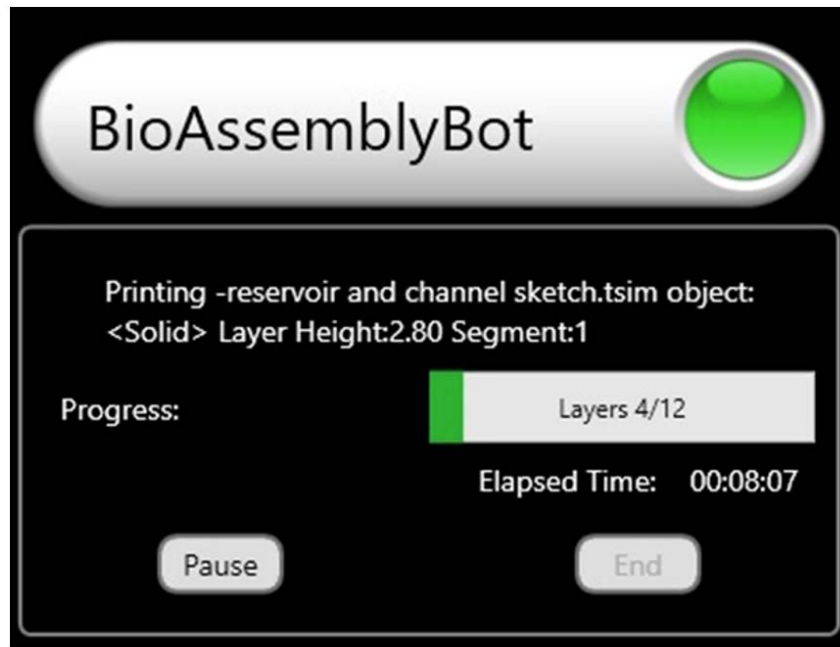
If the current print requires heated or cooled materials, and the BioAssemblyBot™ is equipped with the necessary tools and stage, temperature preparation is the first step. The current and target temperatures of the heating tool, cooling tool, and stage are displayed in the status box. When the target temperatures are reached, the status window will indicate this, then hold the temperatures. By clicking *Resume*, the BioAssemblyBot™ will start the print.

Note that if the BioAssemblyBot™ is unable to reach target temperatures after 120 minutes, or if the temperatures are reached but the print is not resumed, the print will automatically end.

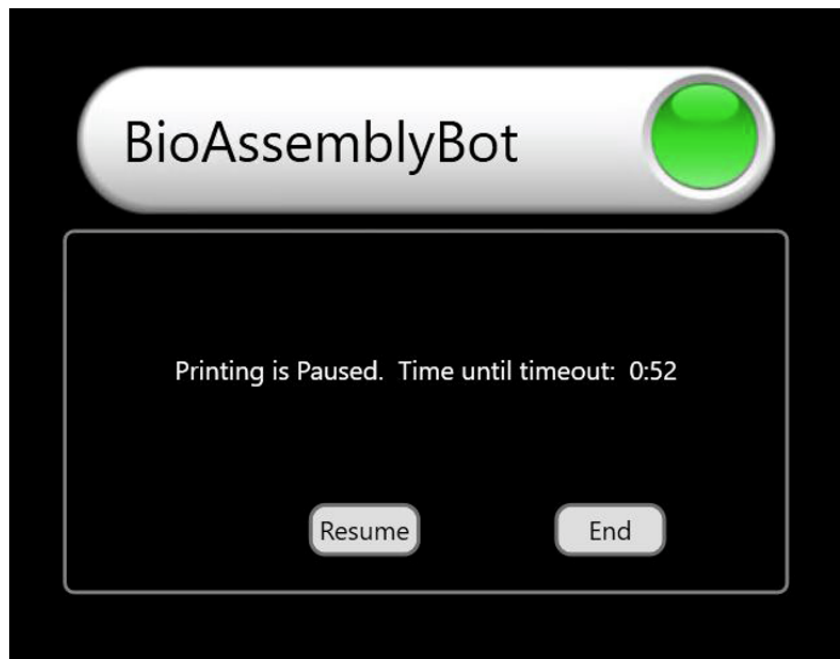


While the BioAssemblyBot™ is printing, the progress of the print is displayed. The progress is shown via number of layers printed so far vs. total layers in the print. Each layer consists of either a tube/spline or a cross section of the 3D model being printed. Cross section depths are determined by the layer's material "Line Height" value in TSIM™.

If the current print requires heated or cooled materials, and the BioAssemblyBot™ is equipped with the necessary tools and stage, the status box will also display the temperature of the current tool on the robot arm and temperature of the stage.



The *Pause* button in the status box can be used to pause the current print. If *Pause* is clicked, the robot will complete its current action, then move into paused mode. In paused mode, two more options are available: *Resume* and *End*.



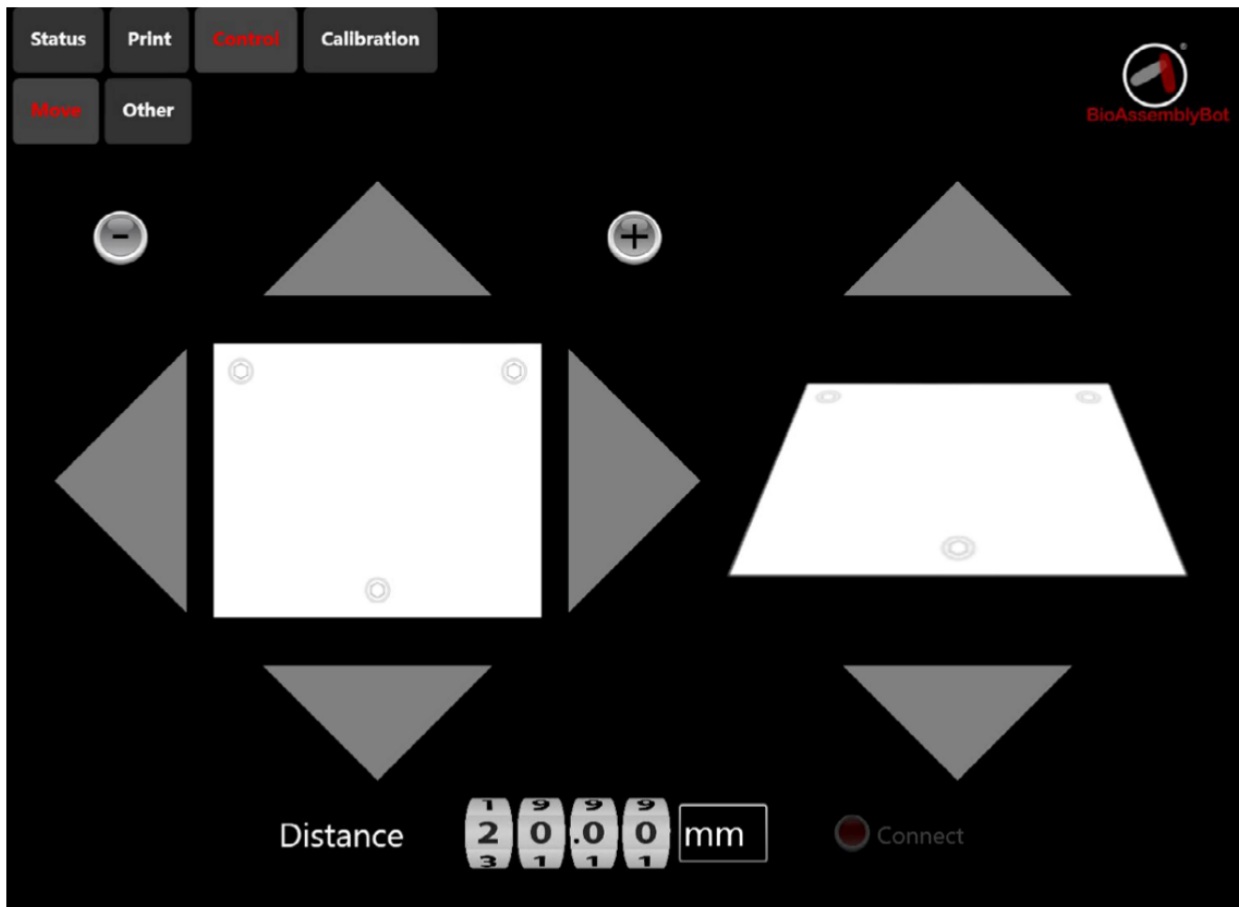
Clicking *Resume* will continue the paused print. Clicking *End* will cancel the print and return the current tool back to its bay. Note that paused mode will end after a displayed time, and the print will be automatically ended.

Control

The control functions allow a user to perform robot tasks manually. These include positioning the robot arm, resetting the BioAssemblyBot™ hardware, retrieving and returning tools, checking air pressure, and turning off and on the brakes and lights. If the BioAssemblyBot™ is equipped with a HEPA fan, it can be turned off and on. If the BioAssemblyBot™ is equipped with a Pick and Place tool, the gripper can be released.

Move

Move allows manual positioning of the robot arm.



The left side of the screen features an overhead view of the stage. The arrows around this view act as buttons that move the robot along the x axis and y axis.

The right side of the screen contains a side view of the stage. The arrows above and below this move the robot along up and down the z axis.

The number of mm the robot moves is specified in the Distance value at the bottom of the screen.

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The plus and minus signs rotate joint 6 (J6) on the robot arm the number of degrees listed in the Distance control. For example, if the Distance control was set to 20 mm, and + was clicked, the robot would move 20 degrees counterclockwise. See page 7 of the Epson Robot User Manual for a diagram of the robot labeled with possible joint movements.



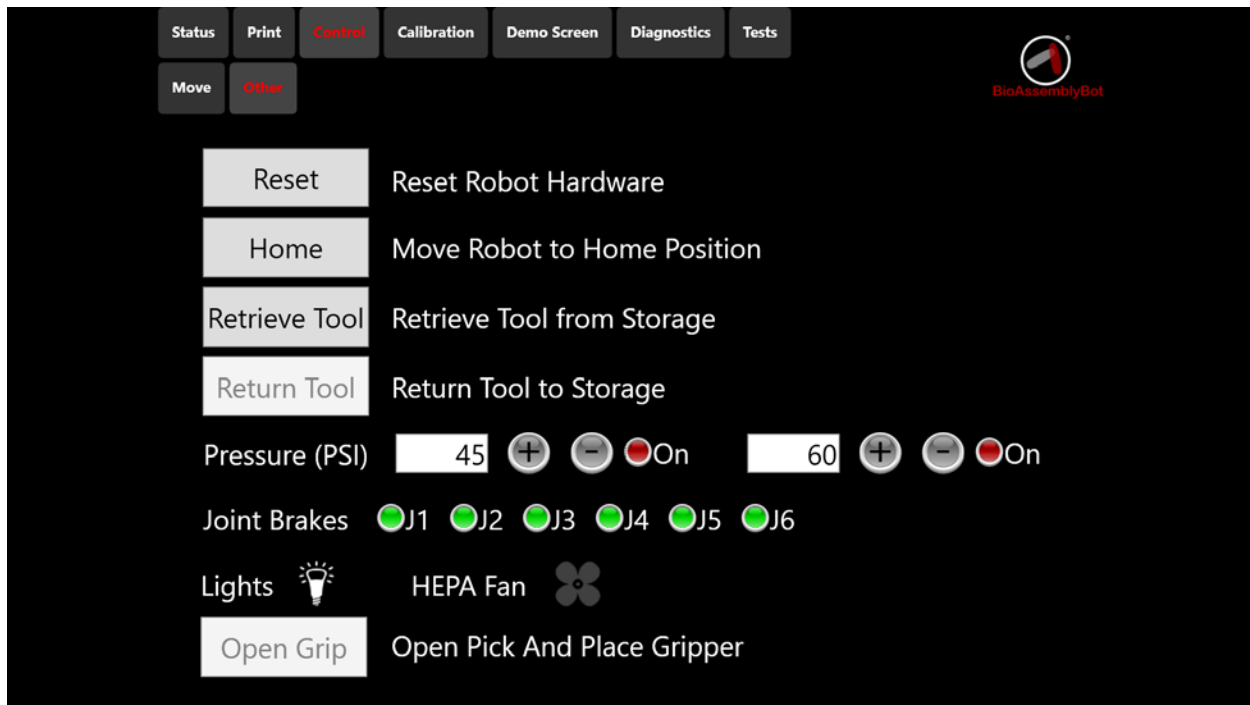
CAUTION

Use the X/Y/Z move features with caution. It is possible to cause the robot arm, or tools on the robot arm, to collide with other objects in Move.

Use the J6 joint rotation feature with caution. In some configurations, it is possible to turn the robot arm around J6 too far, which can damage the robot arm attachments.

Other

Other allows a large series of manual actions to be performed on the BioAssemblyBot™.



- *Reset* - Reset power to the BioAssemblyBot™ hardware.
- *Home* - Move the BioAssemblyBot™ arm to the Home position. The Home position places the robot arm in the center of the BioAssemblyBot™ frame. Home is used as a default resting position.
- *Retrieve Tool* – Picks up a tool from a Storage Bay to the arm. If your BioAssemblyBot™ can detect tools, all bays with tools are listed to pick up.
- *Return Tool* - Returning a tool from the arm to a Storage Bay. If your BioAssemblyBot™ can detect tools, all bays without tools are listed to return the tool.
- *Pressure* - Turn an air line’s air pressure on or off, and set a manually dispensed pressure in psi.
 - The button next to *On* indicates whether the that the pressure is currently on or off; green indicates on, red off. Pushing the button toggles pressure on and off.
 - The + and - buttons allow 1 psi changes, and can be applied when the pressure is on.
 - If pressure is left on, and no actions above are occurring, pressure will automatically turn off after a period of time.
 - Depending on the strength of your air pressure source, turning multiple air lines on can trigger the ‘low pressure’ warning. Low pressure disables most functionality. To restore functionality, hit the *Reset* button, which will restart the system and turn air lines off.

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- *Joint Brakes* - Turn off brakes on the robot at each individual joint. Joints are indicated in the Motion Range section of the Epson robot user manual, but are also labeled with small 'J1' – 'J6' labels on the BioAssemblyBot™ itself. The button next to the joint number indicates whether the brake is on or off; green indicates on, red off. Touch the circle to toggle brakes on and off.



- Use caution when turning off brakes. The weight of the robot will cause the robot to free fall which could cause damage if the robot were to collide with a storage bay, the stage, etc.

CAUTION

- *Lights* - Turn the BioAssemblyBot™ frame's LED lights on and off. Note: This only affects the lights on the BioAssemblyBot™ frame, and does not turn on the UV controlled lights on the UV tool, if your BioAssemblyBot™ is equipped with such.
- *HEPA Fan* - Turn on and off the BioAssemblyBot's™ HEPA filter, if your BioAssemblyBot™ is equipped with such. It is recommended to keep the HEPA filter off when the BioAssemblyBot™ is not in use.
- *Open Grip* - Open the Pick and Place tool's gripper, if it is currently on the BioAssemblyBot™ robot arm, and your BioAssemblyBot™ is equipped with such.

Calibration

All calibration has been performed beforehand during BioAssemblyBot™ creation, and is not required at system startup.

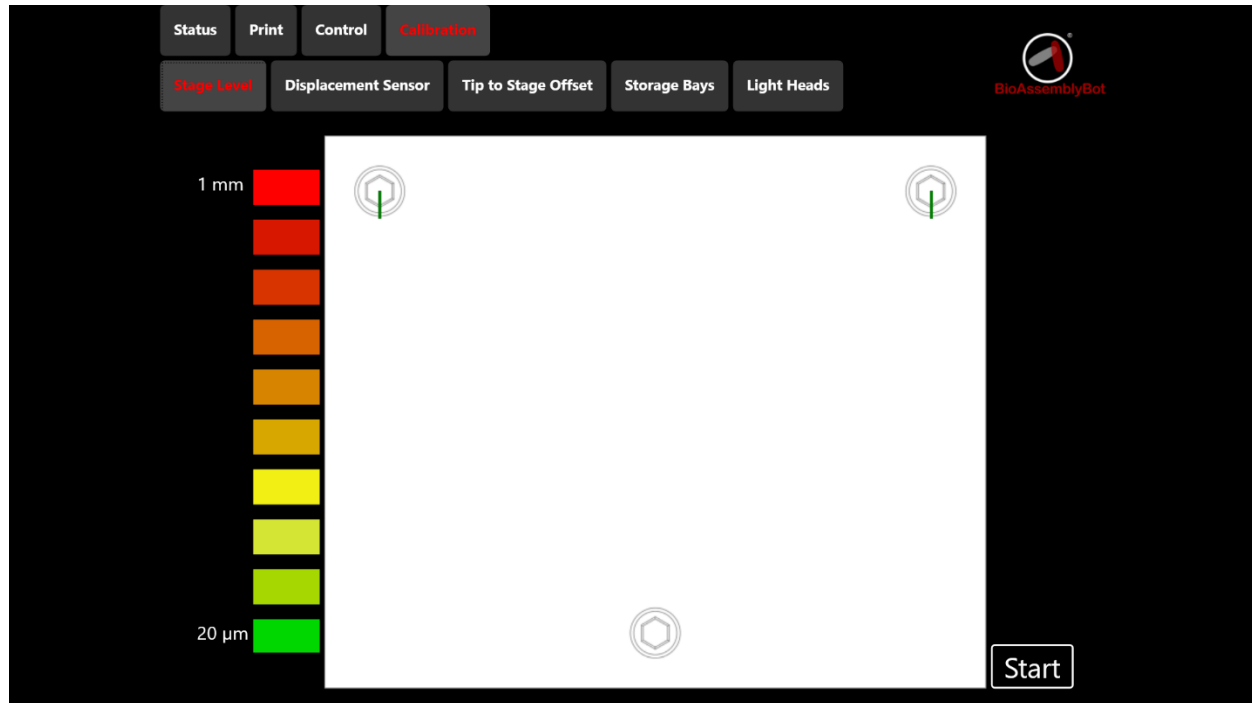
Depending on the needs of upcoming prints, the *Tip To Stage Offset and Light Heads* calibration, might be required:

- Tip to Stage Offset calibration allows the user to “dial in” a surface with a different height from the last print surface.
- Light Heads calibration is performed beforehand on BioAssemblyBots™ that are equipped with an Ambient Light tool. This calibration must be redone after 100 hours of light head usage elapses.

Stage Level

A level stage is essential to producing quality 3D prints, as it provides a flat and even surface for the BioAssemblyBot™ to print on. Leveling the stage has been performed beforehand during BioAssemblyBot™ creation and is not required, unless one of the following events happens:

- The stage has sustained any sort of disturbance, such as a heavy object dropped on it.
- Stage bolts have been turned by a user.



CAUTION

If your BioAssemblyBot™ is equipped with Pick And Place functionality, do not level the stage. Current Pick And Place functionality is not compatible with Stage Leveling, and significant adjustments to stage height (1 mm) will result in well plates being placed incorrectly.



To level the stage:

1. Ensure the displacement tool is in the displacement bay.
2. Ensure the stage is clear of all materials and tools.
3. Click *Start* to determine if the stage is level. The BioAssemblyBot™ will pick up the displacement tool, then take distance readings at three points on the BAB stage, one near each bolt. The first reading will be a baseline; the second and third determine adjustments that need to be made. Afterwards, the BioAssemblyBot will put the displacement tool back into the displacement bay.
4. Results will be presented after the operation is complete, similar to the following:



These values indicate if a bolt needs to be adjusted, and if so, by how much.

If the result is “Within Tolerance” for a bolt, do not adjust the bolt, as the stage is level in this area. If there are arrows with a degree value next to a bolt, find a 13mm socket wrench, and follow the instructions below:

Arrow Direction	Instruction
	Turn the bolt <i>clockwise</i> . The degree measurement indicates the amount to turn, where 360° would be a full circle.
	Turn the bolt <i>counterclockwise</i> . The degree measurement indicates the amount to turn, where 360° would be a full circle.

Note: If the result is a negative degree value, turn the bolt opposite of the arrow’s indication

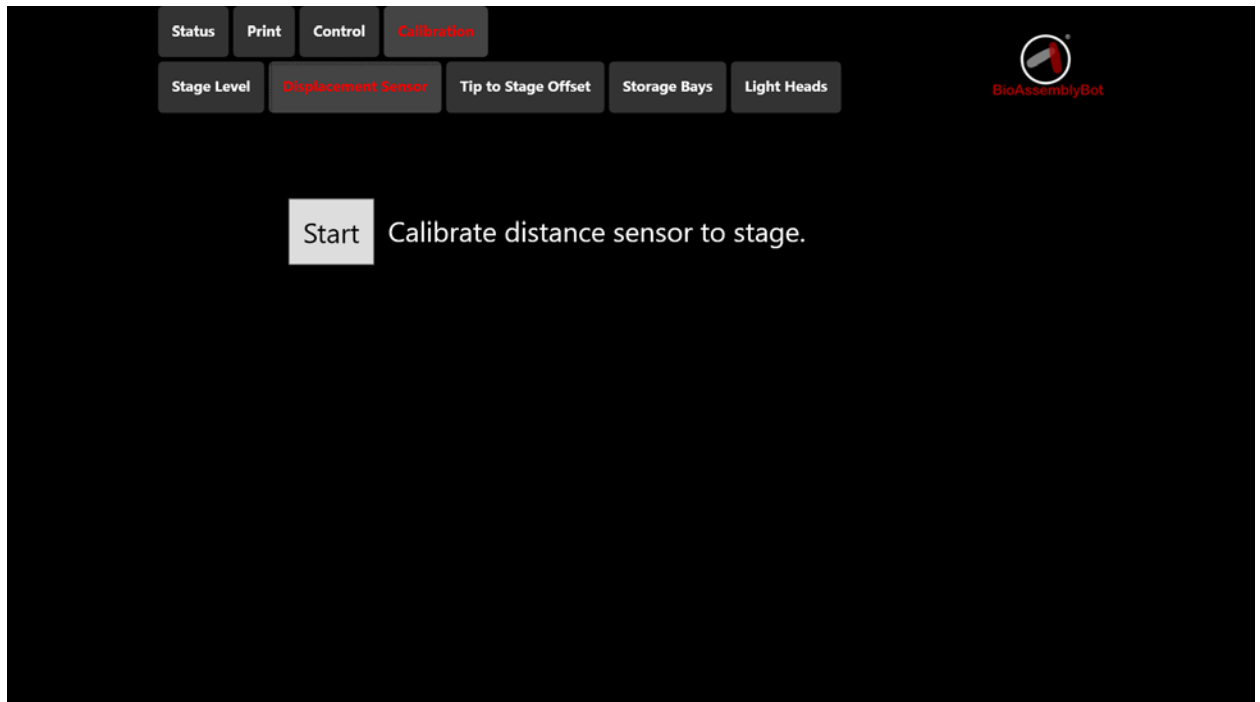
- Repeat steps 3 and 4 until both readings are “Within Tolerance”. Expect about three iterations before both values are within tolerance; the amount to turn each bolt should lessen each time.

If, after five iterations, there has been no progress towards leveling, calibrate the displacement tool (see the Displacement Sensor section below), then repeat steps 1-5.

Displacement Sensor

The displacement sensor is used to calibrate the stage level. The displacement tool has been calibrated during BioAssemblyBot™ creation and is not required to be performed by the user, unless one of the following events happen:

- The displacement tool sustains any sort of disturbance, such as being dropped.
- A new displacement tool is received from Advanced Solutions, Inc.
- Stage leveling seems to be overly difficult to complete.



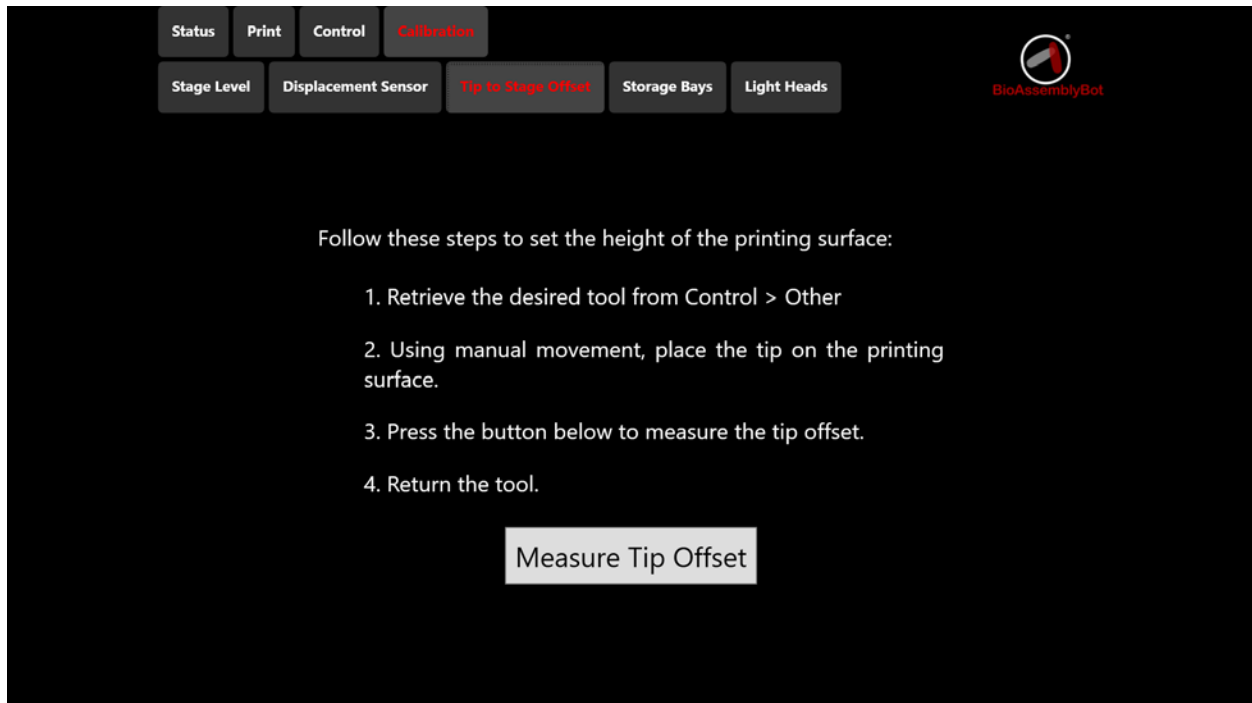
To calibrate the displacement/distance sensor:

1. Ensure the displacement tool is in the displacement bay.
2. Ensure the stage is clear of all materials and tools.
3. Click *Start*. The BioAssemblyBot™ will pick up the displacement tool, then slowly move closer to the stage along the z axis, then return the tool.

Tip To Stage Offset

Tip To Stage Offset is used to alter the height of the surface printed on. This has been calibrated to the stage level during BioAssemblyBot™ creation. It is required to be performed by the user when:

- Switching between prints on slides, petri dishes, well plates, or any surface placed on the stage. It should be done any time a user is printing on a surface with a different height from the last print's surface. *Redoing the same print does not require this step. Altering needle lengths does not require this step.*



Follow these steps to set the height of the printing surface:

1. Retrieve the desired tool from Control > Other
2. Using manual movement, place the tip on the printing surface.
3. Press the button below to measure the tip offset.
4. Return the tool.

Measure Tip Offset

To set Tip To Stage Offset:

1. Ensure the needle that will be used for the upcoming print is on one of the tools.
2. In the Control > Other screen, click *Retrieve Tool*. Pick the tool from step 1.
3. In the Control > Move screen, move the robot arm until the bottom tip of the needle is touching the printing surface. *Take care to move the robot arm in small increments to avoid damage to the needle, barrel, or printing surface.*



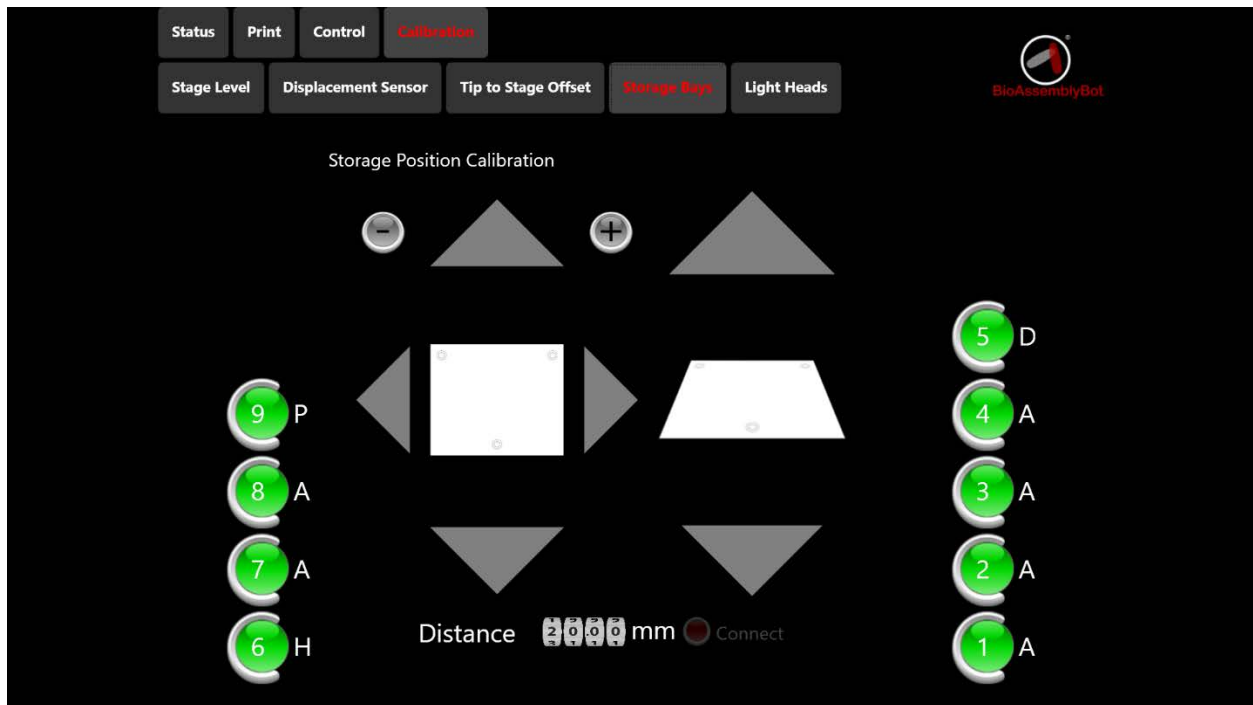
CAUTION

4. Press the *Measure Tip Offset* button.
5. In the Control > Other screen, click *Return Tool*. Return the tool to the same bay as step 2.

Storage Bays

This screen is used to calibrate the position of each storage bay for tool storage. Each bay has been calibrated during BioAssemblyBot™ creation. It is not recommended this be performed by the user, unless one of the following events happen:

- The storage bay icon is colored in Red or Grey, as described below.
- Repeatedly, both the robot arm and tool get stuck and the robot seems to be unable to move when the robot arm retrieves or returns a tool from a specific bay.



The circular icon with a number in it indicates the status:

- Green Location information exists for the bay, and is believed to be correct.
- Red An error has occurred. Calibrate the bay.
- Grey The bay is not calibrated. No location information exists for the bay.

The letter next to the bay indicates what type of tools can be used:

- A Ambient, Ambient Light, and Ambient Dual Dispense tool can be used.
- C Cooling tool can be used.
- D Displacement tool can be used.
- H Heating tool can be used.
- P Pick and place tool can be used.

To calibrate a storage bay:

1. Familiarity with the controls under Control > Move is strongly recommended. Please review this section before proceeding.
2. Remove any tools from the robot arm.
3. Put the appropriate tool type in the bay to be calibrated.
 - a. If the bay has an A: use an Ambient, Ambient Light, or Ambient Dual Dispense tool.
 - b. If the bay has a D: use a Displacement tool.
 - c. If the bay has a H: use a Heating tool.
 - d. If the bay has a C: use a Cooling tool.
 - e. If the bay has a P: use a Pick and Place tool.
4. Using the controls provided (or the controls under Control > Move, which are slightly larger):
 - a. Turn the robot arm. If the tool is on the right side of the robot (bays 1-5), turn it 90 degrees counterclockwise with the + icon. If the tool is on the left side of the robot (bays 6-9), turn it 90 degrees clockwise with the – icon. You may need to adjust this further by small degree increments
 - b. Move the robot arm directly above the bay.



CAUTION

c. Move the robot arm down small increments at a time. Start with tens of mm, then adjust to a single mm, then fractions of a single mm as you get the robot arm closer to the tool. The circular metal piece in the center of the robot arm needs to match up exactly with the hole in the center of the tool. The white box on the front of the robot arm needs to match up *exactly* (≤ 0.1 mm) with the white housing on the front of the tool.



CAUTION

Take care to move the robot arm in small increments to avoid damage to the tool or bay. Do not force or push the tool downward using the robot arm. If the tool moves during this process, the alignment is probably off or you're forcing it.

It is strongly recommended to review this process by repeatedly viewing the robot arm and tool from multiple angles. This will avoid collisions and damage.

- d. Move the robot arm down in small increments so the arm and tool are mated. Ideally, the robot arm and tool stay apart in Z by approximately 1-2 mm. Keep an eye on the *Connect* button to the right of the Distance setting. It will change from a disabled state to an enabled state once the robot arm gets close to the tool.
 - i. If it turns green, this means the tool and robot arm are matched up well. Push the green button, and the robot will attempt to pick up the tool.

- ii. If it stays red, this means the connections to tool and robot arm are not matched up well. If the robot arm and tool seem ok otherwise (no obvious twisting, robot arm 1-2 mm off top of tool), push the red button, and the robot will attempt to pick up the tool.
- e. If the robot successfully picks up the tool:
 - i. Push the *Connect* button again to release it. Make sure it is released.
 - ii. Click on the number of the bay you have just calibrated. (Visually check to make sure this is the right bay.) Choose the prompt to save this confirmation.
 - iii. Go into Control > Other and click the *Home* button.
 - iv. In Control > Other, click the *Retrieve Tool* button. Pick up the tool you just calibrated. If you hear any odd scraping/grinding sounds, or the robot suddenly stops moving during retrieval, proceed to step f, below.
 - v. In Control > Other, click the *Return Tool* button. Put the tool back in the same bay. If you hear any odd scraping/grinding sounds, or the robot suddenly stops moving during return, proceed to step f, below. Otherwise, you are done with this bay.
- f. If the robot fails to retrieve or return the tool: review and redo steps a-e to get a closer calibration.

If the robot fails to pick up the tool AND appears to no longer be responsive (or if the tool twists in some way): In Control > Other, click the *Reset* button. The system will reset, and the controls will enable. If the tool is engaged, click the *Connect* button to disengage it. Review and redo steps a-e to get a closer calibration.

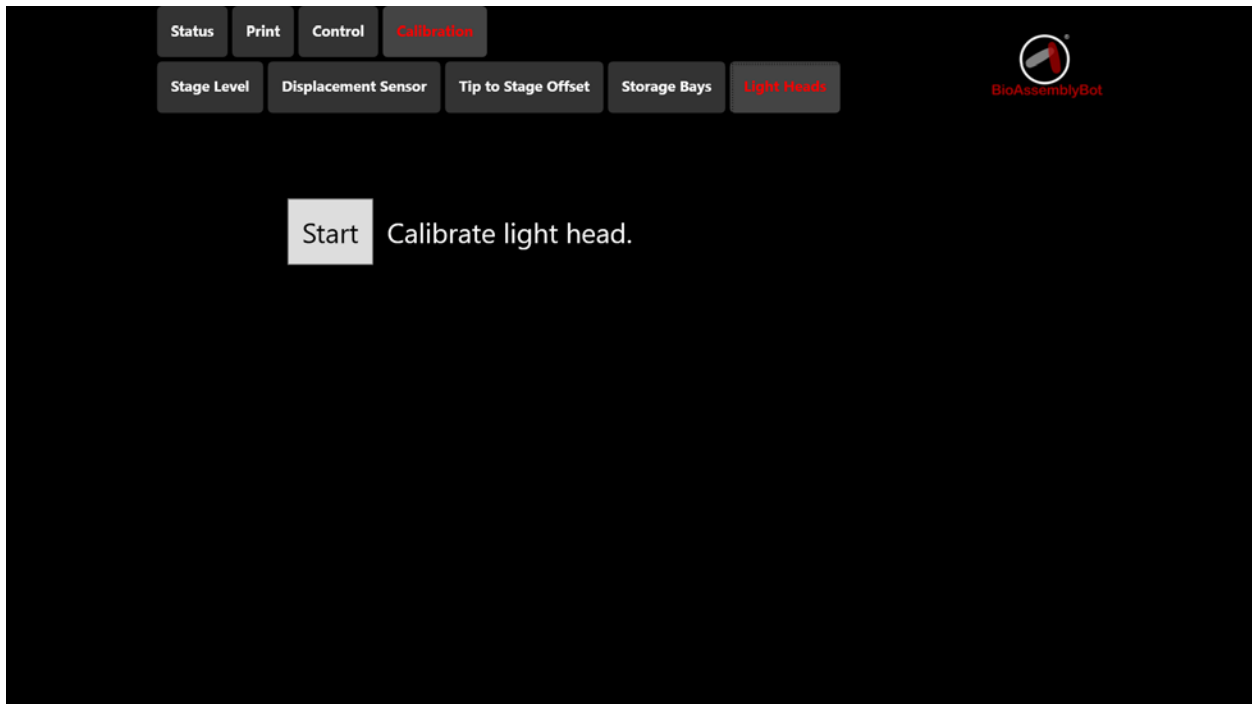
- ⇒ It can often be helpful to have a second set of eyes from another perspective to ensure that you're matching the parts up correctly.
- ⇒ The buttons under the Control > Move screen are identical to those on this screen, but slightly larger. If you're misclicking a lot, switch to this screen when moving, then switch back to save the successful values.

Light Heads

This screen is enabled for BioAssemblyBots™ equipped with an Ambient Light tool. All Ambient Light tools have been calibrated during BioAssemblyBot™ creation, and are equipped with 100 hours of usage.

Calibration is required when:

- 100 hours of print time have elapsed. As the print heads are used, their maximum range gradually decreases. After this, recalibration is required to ensure the BioAssemblyBot™ is outputting the desired irradiance.



To calibrate a light head:

1. Move the light head on the tool to the 'downward' position rather than the 'pointed at light head' position.



CAUTION

2. Remove any light head shielding on the lens, but leave the lens on the head. *Be careful not to touch the glass surface of the lens; skin oils can damage the lens if they are not removed before the head is used again.*

3. Click the *Start* button. Choose the bay that contains the Ambient Light tool to calibrate.

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4. The head will be automatically calibrated and returned to the bay. The new irradiance range of the head will be displayed. These irradiance values can be used in materials in TSIM™.

Troubleshooting and FAQ

When should I do the Tip to Stage Offset calibration?

Tip To Stage Offset is recommended for when you're switching between prints on different surfaces.

For example:

Your print requires a petri dish, and in your TSIM™ model, you created an object to print directly on TSIM™'s virtual stage. You should put the petri dish on the BioAssemblyBot™ stage, then go into Tip to Stage Offset calibration, then touch the needle to the petri dish inside surface, and store that height value. This will offset the print to the correct height. You print, the print looks good, you remove the print.

You decide you want to re-print this object and put a new petri dish on the stage, same as the last. There is no need to redo Tip to Stage Offset calibration since it's the same petri dish geometry – just print and it'll do the same thing.

Finally, you decide you want to re-print this object, but do it on top of a 'bed' of collagen. You put a new petri dish in, same as the last, but this one is half full of collagen. You redo Tip to Stage Offset calibration, but this time, you touch the needle to the top of the 'bed' of collagen, and store that height value. This will, again, offset the print to the correct height, which prints on top of the collagen.

When should I do the Light Head calibration?

To avoid a UV-required print stopping in the middle, after approximately 95 hours of print time has occurred on the BioAssemblyBot™ since the last calibration. If the print head time "elapses" in the middle of a print, the head will not function again until recalibrated, so it is recommended to recalibrate before this occurs.

The HMI controls are disabled and/or I can't hit *Start* or *Confirm* to begin a print?

Most likely, this is due to a door being open, the emergency stop is engaged, or the system is just starting up. If the system is starting up, wait several minutes, and it will resolve itself. If not, check all doors, and re-open and reclose them if necessary. Make sure the emergency stop is disengaged.

All BioAssemblyBots™ will display messages on the Status screen™ which indicate when and which doors have been opened and closed (or emergency stop engaged/released), but BioAssemblyBots™ made in 2017 and beyond have an additional signal that indicates a safety has been triggered. *When in doubt, reopen and reclose the doors.*

Failing this, review the icon in the Status screen. If it is red, review the messages to see if a hardware component has failed. The most likely failure is a 'Low Pressure Warning' due to the input air connection being too low; ensure the pressure fed into the BioAssemblyBot™ is a consistent 90 psi. For any other hardware failures, contact Advanced Solutions Life Sciences for support.

Tool retrieval or tool return failed repeatedly?

Most likely, this is due to the air pressure being too low. Check your pneumatic connection. The air pressure fed into the BioAssemblyBot™ should be 90 psi. Air pressure significantly less (5 psi) can cause tool retrieval or return failure. Remember that “house air” is often shared by multiple research areas in a facility, causing dips. If pressure dips at exactly the time a tool is retrieved or returned, it can cause a failure.

Alternately:

- The storage bay calibration data could be missing or incorrect if a user altered the values in the Calibration > Storage Bay screen. Check to see if the bay is Red or Grey per the section above.
- If a certain tool is repeatedly failing, move it to another bay and re-attempt the retrieval or return. If it continues to fail, the tool may be damaged; please contact ASI Life Sciences support.

The robot arm is stuck in a bad position. How do I resolve it?

Go into Control > Move in the main menu, and by using the arrow controls, carefully move the robot to a position in the center of the machine. When it's close to the center, go into Control > Other and hit the *Home* button.

If the robot does not move when a button is clicked, or the controls are disabled, go into Control > Other, and choose the Reset button. The controls will disable if they aren't already, and the system will restart in several minutes, and reenables the controls. You can now attempt to move it again under Control > Move.

The robot arm is stuck in a bad position. How do I resolve it?

Go into Control > Move in the main menu, and by using the arrow controls, carefully move the robot to a position in the center of the machine. When it's close to the center, go into Control > Other and hit the *Home* button.

How do I resolve a misfeed/incorrect height on a well plate in a Tower?

Open the doors. Push down on the well plates in the Tower with your hand until the well plates are 10-20 mm down. Release the well plate on the top. The plates should feed into the correct orientation and be at the right height level.

Well plate pickup failed repeatedly?

Check to ensure that there are well plates in the Source tower, at the correct height, and no misfeeds occur. Please see the diagrams in Load Pick And Place Tower, Automatic Alignment.

My well plate moves slightly when the Pick and Place tool places it?

The Pick and Place tool should place the well plate very close to the edge of the stage inset – within 0.5 mm. If the well plate moves slightly when the Pick and Place tool releases it, the most likely scenario is that the tool is slightly tacky from use. Rub a very small amount of cornstarch on the four plastic grippers on the Pick and Place tool.

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Alternately:

- Check the sides of the well plate. If the sides do not match the geometry shown in the pictures in Load Pick and Place Tower, Automatic Alignment, then the Pick and Place tool cannot pick up this type of well plate. Please contact tsimssupport@advancedsolutions.com for suitable well plates.