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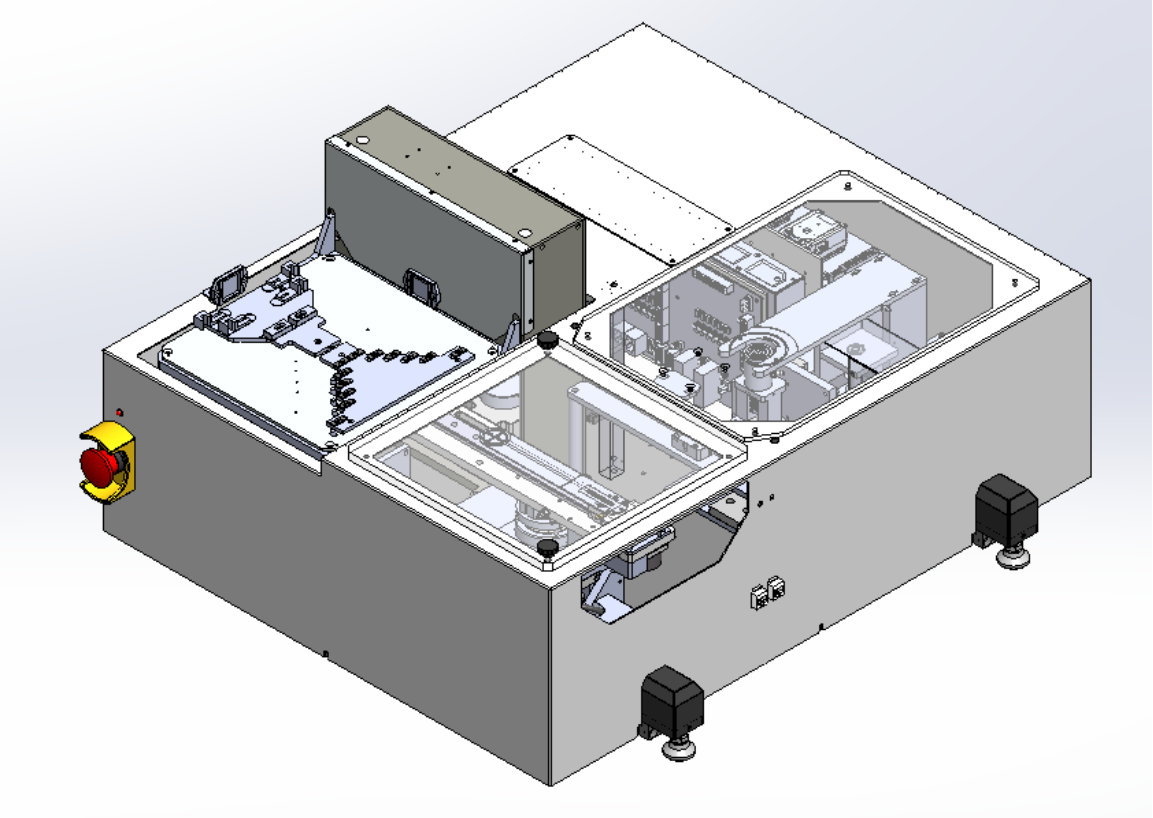

Wafer Handler

Software Manual

Version 1.6 06/18/2015

Nanotronics Automation Handler Control Software

This manual covers the SMP-28, the SMMP-468, and the SMM-468.

First Time Setup

It is recommended that the handler be powered up before starting the software. Remember to turn on the main system power at the back of the unit before pressing the power on button near the front of the unit (on the left side). This will eliminate a "Cannot Communicate" error which occurs when the handler is not powered up.

The first thing displayed when the software starts is called the Startup Form and shows the Nanotronics Automation logo and the words "Please Log In". It is labeled "Handler Control is initializing..." in the title bar. After a few seconds the log in screen will appear. The default password for Administrator is "\\\\\". The default password for User is "password". For first time setup, log in as Administrator. The default COM port is probably wrong, so you will probably get a "Can't talk to handler!" error. To fix the error, open the setup panel and select the correct COM port. (Most of the other options in Setup will not appear.) Make sure to save the settings. You may need to restart the software for the change to take effect.

Once you have the COM port configured correctly, the startup form will close and the main GUI will open. A prompt will appear asking if you want to home the loader; it is recommended that you do so. Once the loader has homed, open the setup panel. Check all of the positions to make sure they are correctly aligned. Also, check the cassette settings – the elevator first wafer height, spacing, and stroke. The best way to check the elevator settings is to move to the first wafer position on the setup panel, disable the end effector motor, and manually move the end effector into the cassette to make sure it does not crash and that it picks up the wafer when it is moved into the "put" position. Finally, check the mapper settings on the "Other Settings" tab – test run the mapper and then adjust the first wafer Z, starting height, and ending height until the mapper detects all of the wafers and also detects cross slotted wafers. Each time the mapper is tested the new test results appear at the bottom of the results

text box.

Once you have everything configured correctly, close the setup panel. The size of the currently loaded cassette should appear next to the wafer selection buttons at the lower left part of the screen. The system is now ready to use.

Handler Control Overview

The primary purpose of the handler is to load wafers to an inspection stage, wait for them to be inspected, and return them to the cassette. Some handler models have an extra station which allows for more operations to be performed on the wafer – alignment, notch/flat finding, topside macro inspection, or backside macro inspection. The handler software is able to detect the operations that are possible for a given handler system and automatically adjusts the visible options accordingly.

Basic Operation

1. Select the wafers you wish to be inspected.

Left click on a slot number button to select a wafer. Clicking multiple times toggles between several different operations, including no operation. Right clicking on a button displays a menu from which any operation can be enabled or disabled. If prealign is available, prealign is required for topside or backside macro.

2. Place the cassette on the handler.

The cassette size will be reported to the right of the slot number buttons. If it does not appear, the cassette is not properly loaded. If it is incorrect, the cassette may be improperly loaded or the system may be improperly configured.

3. Press "Start Cassette".

If the "Auto-Map Cassette" check box is checked, the system will map the cassette before loading any wafers. If the cassette is already mapped it will not be re-mapped until it is removed and replaced. If any slots are vacant, the corresponding number button will become blank. If any slots are cross-slotted the system displays an error message and will not attempt to remove wafers from the cassette.

4. When a wafer is loaded on the stage, move the stage from the home position. Perform inspection.
5. Return the stage to the home/load position. Wait for the handler to return the sample to the cassette.
6. Repeat for each wafer to be inspected. The slot number buttons will change color as each wafer is inspected.
7. Remove the cassette.

Inspection may be paused or canceled at any time. If inspection is paused the system may not stop moving right away. To cancel inspection, press the "Reset Cassette" button. The loader will attempt to

replace all wafers in the cassette and will not perform additional inspection until "Start Cassette" is clicked again.

Recipes

A recipe is a set of wafers to be inspected. To create a recipe, select the wafers you wish to inspect. Make sure that the correct operations are selected, e.g. topside macro inspection vs backside macro inspection or both. Click the "Add..." button. A window will appear which will ask you to name the recipe. If you enter a name and select "OK", the name will appear in the list of recipes above the slot number buttons. Selecting that recipe will change the current wafer selection to whatever was selected when the "Add..." button was clicked. The wafer orientation is also remembered.
There are several system-defined recipes at the top of the list. These cannot be removed, and the wafer orientation for these recipes is not remembered. The number of wafers selected for the Random recipe can be configured in the Options panel.

Interlocks

An interlock is a sensor which prevents (or permits) loading to a specific position. By default, each loader comes with a single stage position sensor, which is configured to use a single interlock. Standard options for the loader include a rotatable stage with a rotation position verification switch and a wafer protrusion sensor for the cassette, so there could potentially be three interlocks on a system. Custom configurations are also possible.

At the core, what an interlock does is quite simple. Just before the loader picks up or places a wafer, it checks for defined interlocks for that position (cassette, macro/align, and/or stage). If there is a defined interlock, it MUST be active, or the loader will not pick/place from/to that position. (The polarity can be changed in the software.) If the interlock sensor is not active, then an error message is displayed to the user.

The stage is a slightly special case: In order to signal that the stage inspection has begun, the system waits for an interlock on the stage to go inactive. Then the system waits for all stage interlocks to go active again, at which point it picks the wafer up from the stage.

Setting up an interlock is handled in the Setup panel. The interlock is referred to by a short description string; for example, "Stage Switch". The IO used and the position can be configured, as well as the error displayed to the user when the interlock is out of position (e.g. "Please return stage to load/unload position.").

Warnings/Issues

Do not let the computer running the handler go into "sleep mode". Windows does not properly re-open the COM ports when the computer goes to sleep, and the only way to fix it is to either restart the computer or unplug the USB-Serial adapter and plug it back in.

Basic Description of How to Setup the Loader

The loaders are set up and configured at the factory. Setup is typically initially performed with 6 inch wafers, or with the wafer size the customer requests. The following is an overview of the setup process – for details of the functions of specific settings or buttons, check the detailed description.

On systems with a prealigner, the prealigner is configured first. A small camera is placed above the prealign station and centered to the spinning chuck when the chuck is in the UP position. Then the spinning chuck is placed in the DOWN position and the end effector is extended to the align position. The align position is adjusted until the center of the end effector is at the center of the camera.

Adjust the cassette position until the center of the end effector is over the center of the elevator. Then retract the end effector and place the cassette on the elevator. Move to the first wafer and disable the end effector motor, then move the end effector over to the cassette and verify that the end effector does not hit the wafer as it goes into the cassette (also that it does not hit the wafer below it). The end effector should be quite close to the bottom of the wafer. Then put the elevator into the "put" position and verify that the wafer can be removed from the cassette without touching the cassette.

Once wafers can be safely picked out of the cassette, pick a wafer and move the wafer over to the prealign station. Verify that the center of the wafer is lined up with the center of the prealigner. Adjust the cassette pickup position as required. Make sure to check wafers 25 and 1 as these may be slightly different if the elevator platform is not level, or if the cassette is warped. Verify that an aligned wafer does not hit the cassette when it is returned to the cassette.

Attempt to map the cassette. The mapper results will appear on the setup panel with the "target" wafer ranges on the left and the "detected" wafer ranges on the right (possibly below if the wafer was detected as a cross-slotted wafer). Usually only the first wafer position needs to be reconfigured, but the mapper start and end height may need to change if the wafer can't see slot 1 or 25 or if the wafer is detecting the H-bar or the top of the cassette. Sometimes the elevator platform will need to be adjusted to make the cassette easier to map; the platform has 2 screws on each corner which can be used to adjust the cassette so that the wafers are level. Also, sometimes you may need to adjust the sensitivity of the wafer mapper sensor mounted on the side of the robot. To adjust the sensitivity, move the robot to the aligner position. Flip up the clear plastic cover covering the top of the mapper sensor amplifier, mounted on the side of the robot. Use the gray right and left arrows to adjust the sensitivity – typical values for the sensitivity range between 7000 and 9000, depending on the thickness of the wafers and how level the wafers are when they are in the cassette. (Thicker wafers require smaller numbers or they may be falsely detected as cross slotted wafers, and thinner wafers require larger numbers or the mapper may miss some wafers.) Newer models have two black metal bars across the mapper sensor which improve the resolution of the sensor; for these models, the sensitivity should be set to about 50.

Detailed Descriptions of Button Functions

Different loader models have slightly different configurations of buttons on the setup panel and on the main GUI. Typically, the only differences are that for models without a certain feature, the panel that controls the options for that feature does not appear. Also, "macro" and "align" are sometimes used interchangeably as one, the other, both, or neither can be present. Other differences will be explained when they appear.

Setup Panel Buttons

On the right side of the setup panel we have four buttons, a drop down list, and a group of labels. Most of the setup panel is occupied by a tabbed dialog with 6 tabs. Starting from the top, the controls on the right side are labeled:

1. "Stop" button - This button is disabled unless the user has issued a movement command from the setup panel. Clicking this button cancels the current movement command and issues a hard stop command to all motors on the handler. The system should be re-homed as the hard stop usually creates position errors. However, the setup panel will not force you to re-home the system.
2. "Save Settings" button - Saves the current settings to the .ini file. If changes have been made and have not been saved they will be lost if the software is exited.
3. "Exit Setup" button - Closes the setup panel. The end effector is retracted as a precaution.
4. "Enable Tooltips" check box - Enables or disables the display of tooltips in the setup panel.
5. "Check Cassette Switches" check box - This controls the automatic detection of the cassette while the setup panel is open, as some steps of configuring the handler require that the cassette be removed.
6. "Current Cassette Size" combo box – This selects the current set of alternate settings for the current wafer size. Elevator positions, alternate cassette drop off positions, mapper settings, and prealign settings are all dependent on the current wafer settings and may change when the cassette size or cassette settings change.
7. "Adv. Cassette Settings" button – Opens a new window which allows for changes to advanced cassette configurations. This includes allowing or disabling a wafer size, setting up alternate configurations for the same cassette, changing the displayed label for the cassette size, and enabling or disabling specific slot numbers for a given cassette size.
8. "Status of Last Action" labels – These display information about the last action taken by the setup panel. Simple actions such as turning the end effector vacuum on and off do not cause a report; the reports are typically generated for actions that require the handler to physically move. The display shows if the action was canceled before it completed (e.g. if the Stop button was pressed), if there were any errors, and the error message if there was an error.

These controls are always visible. The rest of the buttons in the setup panel are only visible when a

certain tab is selected. I will describe each tab from left to right.

The first tab is labeled "Diagnostics" and contains commands related to homing and initializing the system, testing vacuum, and testing loading/unloading of wafers. It is divided into 10 groups of buttons arranged into 3 columns. There is also 1 more button which is not in a group and is found at the lower left-hand corner, labeled "Initialize System". I will describe each group of buttons by column from left to right.

The first group of buttons is labeled "Vacuum Control". It contains 4 buttons and 4 labels.

1. "Stage Vac Now On" / "Stage Vac Now Off" - Controls the vacuum to the stage. Clicking the button when it says Stage Vac Now On will turn off the stage vacuum. Clicking the button when it says Stage Vac Now Off will turn on the stage vacuum. Below this button is a label which says "Sensor Reports: On" when the stage vacuum sensor senses vacuum and "Sensor Reports: Off" when the stage vacuum sensor does not sense vacuum. The sensor is only checked when the button is clicked, and the system waits for the Stage Vacuum Delay to elapse before checking the sensor.
2. "End Effector Vac Now On" / " End Effector Vac Now Off" - Controls the vacuum to the end effector. Clicking the button when it says End Effector Vac Now On will turn off the end effector vacuum. Clicking the button when it says End Effector Vac Now Off will turn on the end effector vacuum. Below this button is a label which says "Sensor Reports: On" when the end effector vacuum sensor senses vacuum and "Sensor Reports: Off" when the end effector vacuum sensor does not sense vacuum. The sensor is only checked when the button is clicked, and the system waits for the End Effector Vacuum Delay to elapse before checking the sensor.
3. "Flip Vac Now On" / " Flip Vac Now Off" - Controls the vacuum to the flip arm of the macro inspection station, which is used for backside macro inspection. For models with a prealigner but without backside inspection, this is labeled "Align" instead of "Flip" and controls the vacuum to the align platform. Clicking the button when it says Flip Vac Now On will turn off the flip arm vacuum. Clicking the button when it says Flip Vac Now Off will turn on the flip arm vacuum. Below this button is a label which says "Sensor Reports: On" when the flip arm vacuum sensor senses vacuum and "Sensor Reports: Off" when the flip arm vacuum sensor does not sense vacuum. The sensor is only checked when the button is clicked, and the system waits for the Flip Vacuum Delay to elapse before checking the sensor.
4. "Spin Vac Now On" / " Spin Vac Now Off" - Controls the vacuum to the spinning chuck of the macro inspection station, which is used for topside macro inspection and prealign. Clicking the button when it says Spin Vac Now On will turn off the spin chuck vacuum. Clicking the button when it says Spin Vac Now Off will turn on the spin chuck vacuum. Below this button is a label which says "Sensor Reports: On" when the spin chuck vacuum sensor senses vacuum and "Sensor Reports: Off" when the spin chuck vacuum sensor does not sense vacuum. The sensor is only checked when the button is clicked, and the system waits for the Spin Vacuum Delay to elapse before checking the sensor.

The second group of buttons is labeled "Load/Unload Test". It contains 6 buttons and 1 drop down list. A large label on top warns the user that these buttons subvert some of the collision prevention systems of the handler and should be used responsibly. The drop down list is labeled as a list of cassette slot numbers which are used when testing loading or unloading to the cassette.

The buttons in this group are:

1. "Get Stage" - Attempts to pick up a wafer from the stage. The wafer will be on the end effector when this finishes.
2. "Put Stage" - Attempts to place a wafer on the stage. Will fail if there is no wafer on the end effector.
3. "Get Macro" - Attempts to pick up a wafer from the macro inspection station. The wafer will be on the end effector when this finishes.
4. "Put Macro" - Attempts to place a wafer on the macro inspection station. Will fail if there is no wafer on the end effector.
5. "Get Cassette" - Attempts to pick up a wafer from the currently selected slot number of the cassette. Beware: Make sure the correct cassette size is currently selected on the "Positions" tab, make sure the cassette is properly loaded, and make sure the wafer is properly loaded in the cassette. The wafer will be in the end effector when this finishes.
6. "Put Cassette" - Attempts to place a wafer in the currently selected slot number of the cassette. Beware: Make sure the correct cassette size is currently selected in the "Positions" tab, make sure the cassette is properly loaded, make sure the selected cassette slot is empty, and make sure the wafer is properly aligned (eg. A wafer that was manually placed on the end effector will collide with the cassette if it is placed in the cassette.). Will fail if there is no wafer on the end effector.

And the last button in the column, the only one not in a group, is labeled "Initialize System". This button runs the homing routine performed by the software on start-up.

Moving to the top of the second column, the first group of buttons in the second column is labeled "Robot Rotation Control". It allows for homing and testing the robot rotation drive. The 6 buttons in this group are:

1. "Initialize and Home Rotation" - Initializes and homes the rotation drive.
2. "Macro" - Rotates the robot so that it is pointing to the macro inspection station.
3. "Stage" - Rotates the robot so that it is pointing to the stage.
4. "Start" - Starts a continuous robot rotation cycle. The robot will move to each position in a regular pattern until the cycle is stopped.
5. "Elevator" - Rotates the robot so that it is pointing to the cassette elevator.
6. "Stop" - Cancels a continuous robot rotation cycle.

The second group of buttons in the second column is labeled "Robot Up/Down Control". It allows for homing and testing of the robot up/down drive. The three buttons in this group are:

1. "Initialize and Home Up/Down" - Initializes and homes the robot up/down drive.
2. "Up" - Moves the robot to the Up position.
3. "Down" - Moves the robot to the "Down" position.

The third group of buttons in the second column is labeled "End Effector" and has only one button, "Initialize and Home End Effector". This button initializes and homes the end effector.

The fourth group of buttons in the second column is labeled "Elevator Control". It allows for homing and testing of the elevator drive. It is particularly useful for testing if the elevator will stall at a given speed with a given load. It contains 5 buttons, one drop down list and one text box. The text box is

labeled "Speed:" and sets a motor speed override (VM, or Maximum Velocity from the Motors tab) which is used for the movement commands issued by the buttons in this group and only for the movement commands issued by the buttons in this group. The buttons are:

1. "Initialize and Home Elevator" - Initializes and homes the elevator.
2. "Elevator Up" - Moves the elevator up until it hits the limit switch or the "Elevator Stop" button is pressed.
3. "Elevator Stop" - Issues a soft stop command to the elevator.
4. "Elevator Down" - Moves the elevator down until it hits the limit switch or the "Elevator Stop" button is pressed.
5. "Limit Cycle" - Re-homes the elevator, then moves it up and down the number of times that is currently shown in the drop down list, which contains numbers from 1 to 15.

Moving to the third column, the first group in the third column is labeled "Macro Flip Up/Down Control". It allows for homing and testing of the flip arm drive. The three buttons in this group are:

1. "Initialize and Home Macro Flip" - Initializes and homes the macro flip arm drive.
2. "Up" - Moves the flip arm into the Up position.
3. "Down" - Moves the flip arm into the Down position.

The second group in the third column is labeled "Macro Move Up/Down Control". It allows for homing and testing the Macro Up/Down drive. The three buttons in this group are:

1. "Initialize and Home Macro Up/Down" - Initializes and homes the macro up/down drive.
2. "Up" - Moves the macro up/down drive into the Up position (Not the Wobble position, used for topside macro inspection).
3. "Down" - Moves the macro up/down drive into the Down position.

The third group of buttons in the third column is labeled "Macro Spin Control". It allows for testing the macro spin drive, which does not home. The four buttons in this group are:

1. "Right" - Spins the drive to the right. Keeps moving until stopped.
2. "Left" - Spins the drive to the left. Keeps moving until stopped.
3. "Stop" - Stops spinning the drive.
4. "Spin to 0" - Spins the drive back to "0", or the drive's orientation the last time a wafer was loaded onto the macro inspection station.

The fourth, group of buttons in the third column is labeled "Macro Wobble Control". It allows for homing and testing the X and Y wobble drives used for topside macro inspection. The 8 buttons in this group are:

1. "Initialize X Wobble" - Initializes and homes the X wobble drive.
2. "Initialize Y Wobble" - Initializes and homes the Y wobble drive.
3. "X Up" - Moves the X wobble drive to the Up position.
4. "Y Up" - Moves the Y wobble drive to the Up position.
5. "X Home" - Moves the X wobble drive to the Home (level) position.
6. "Y Home" - Moves the Y wobble drive to the Home (level) position.
7. "X Down" - Moves the X wobble drive to the Down position.
8. "Y Down" - Moves the Y wobble drive to the Down position.

The last group of buttons is labeled "Aligner" and contains only one button, labeled "Initialize and Home Aligner". This button initializes and homes the align drive.

The second tab is labeled "Positions". This tab allows for configuring the positions of the robot and the elevator. The positions for each motor are included in a separate box. The boxes for the three robot motion axes are on the left, and the elevator configuration box is on the right.

Starting at the top left, we have the "Rotation (R)" group. The four positions for the rotation are:

1. Stage. "Move to Stage" moves to this position, which is indicated by the number in the box labeled "Stage Position (Degrees):" and should be facing towards the stage, directly away from the cassette. Adjusting this number while the robot is in the stage position will automatically rotate the robot to the newly configured position.
2. Cassette. "Move to Cassette" moves to this position, which is indicated by the number in the box labeled "Cassette Position (Degrees):" and should be facing towards the cassette elevator. Proper alignment can be verified with an alignment tool. Adjusting this number while the robot is in the cassette position will automatically rotate the robot to the newly configured position.
3. Macro or Align. "Move to Macro" moves to this position, which is indicated by the number in the box labeled "Macro Position (Degrees):" and should be facing towards the macro inspection station or prealigner, as appropriate. Adjusting this number while the robot is in the macro position will automatically rotate the robot to the newly configured position.
4. Mapping. "Move to Map" moves to this position, which is indicated by the number in the box labeled "Map Position (Degrees):" and should be facing away from the cassette so that the wafer mapper sensor laser is centered on the reflector – frequently the same position as the stage position. Adjusting this number while the robot is in the mapping position will automatically rotate the robot to the newly configured position.

The next group is the "End Effector (T)" group. There are four end effector positions. A check box at the bottom, labeled "Motor Enabled", can be used to remove holding current from the end effector motor. This is useful for preventing crashes while attempting to verify rotation position alignment and cassette size elevator height alignment. Checking the check box re-homes the end effector and turns on the hold current; un-checking the check box turns off the hold current.
The end effector positions are:

1. Stage. "Move to Stage" moves to this position, which is indicated by the number in the box labeled "Stage Position (mm):". The button is disabled unless the rotation drive is in the stage position. Adjusting this number while the end effector is in the stage position will automatically move the end effector to the newly configured position.
2. Cassette. "Move to Cassette" moves to this position, which is indicated by the number in the box labeled "Cassette Position (mm):". The button is disabled unless the rotation drive is in the cassette position. Adjusting this number while the end effector is in the cassette position will automatically move the end effector to the newly configured position.
3. Macro or Align. "Move to Macro" moves to this position, which is indicated by the number in the box labeled "Macro Position (mm):". The button is disabled unless the rotation drive is in the macro position. Adjusting this number while the end effector is in the macro position will automatically move the end effector to the newly configured position.
4. Retracted. "Retract" moves to this position, which is indicated by the number in the box labeled "Retract Position (mm):". The end effector should be completely retracted while in this position to prevent collisions when rotating – this will be true if the configured number is negative. Adjusting this number while the end effector is in the retracted position will automatically move

the end effector to the newly configured position.

The last group in the column, the last group of robot positions, is labeled "Up Down (U)". The two positions for the robot up/down are:

1. Up. "Move Up" moves to this position, which is indicated by the number in the box labeled "Up Position (mm):" and should be at the peak of the robot's vertical travel. Adjusting this number while the robot is in the up position will automatically move the robot to the newly configured position. The robot is in this position to pick or place wafers in the cassette. Note that the handler uses a rotating cam for vertical motion and so adjusting the configured position by a certain number of millimeters does not always cause the robot to move a specific distance.
2. Down. "Move Down" moves to this position, which is indicated by the number in the box labeled "Down Position (mm):" and should be at the bottom of the robot's vertical travel. Adjusting this number while the robot is in the down position will automatically move the robot to the newly configured position.

At the bottom of the column but outside of a group is a text box labeled "Increment:". This controls the increment for the boxes with up/down arrows. Clicking an up/down arrow (or pressing the up or down arrow keys while the cursor is on one of these boxes) will adjust the displayed number by the number shown in this text box.

The group on the right-hand side is labeled "Elevator Positions (Cassette Size Specific)" and contains controls for configuring elevator settings for different cassette sizes, as well as alternate drop off positions. The controls for moving the elevator are near the bottom in a box labeled "Move to Wafer". From top to bottom, the controls in this group are:

1. "Wafer Spacing (mm):" - this box controls the space between each wafer for the selected cassette size. A standard 6 inch cassette is 4.75 mm, and a standard 8 inch cassette is 6.35 mm.
2. "Stroke (mm):" - this text box controls the distance the elevator moves to pick up or place a wafer in the cassette. It should be around half of the distance between the wafers.
3. "Wafer #1 Z (mm):" - this text box controls the position of the elevator when preparing to pick up the first (bottom) wafer in a cassette of the given size.

Within the "Move to Wafer" group, we have a button, two selector buttons, a drop down menu, and a text box. The drop down menu is labeled "Wafer #" and has a list of the numbers 1 to 25. These correspond to slot numbers in the cassette. When one of these numbers is selected, the system computes the final position number for that slot based on the current settings and displays it in the text box. This is either the number for when the system is not holding a wafer or the number for when the system is holding a wafer. The position where the system is not holding a wafer is the "Get Position" and is selected when the select button labeled "Get Position" is marked. The position where the system is holding a wafer is the "Put Position" and is selected when the select button labeled "Put Position" is marked. To actually move to the position indicated by the text box, click the "Move to Wafer" button.

Underneath the "Move to Wafer" group, we have two more text boxes and two more check boxes. These control alternate cassette positions which can be used if the given wafer size's cassette holds the wafer so that it is not perfectly centered to the hbar, or if the cassette is mounted in a nonstandard position, or if the cassette is slightly tipped, etc. The alternate position is only for the cassette position, and only for the rotation and the end effector. This alternate position can be used when picking up a

wafer, when dropping off a wafer, or both.

At the bottom of the right side we have a group of controls labeled "Cassette Position Interpolation". This is used when the cassette platform must be leveled such that the wafers in the cassette are level but the cassette itself is not; this results in the pickup/drop-off position being slightly different for each wafer in the cassette. The controls in this group are:

1. "Enable Interpolation" check box - When this is checked, the cassette position for the R and T drives is controlled by the interpolation settings and the slot number. The cassette position and the alternate cassette position are not used.
2. Start Slot number box - This is the first wafer used to define the interpolation; typically wafer 1 but if slot 1 is not available another slot can be used.
3. End Slot number box - This is the last wafer used to define the interpolation; it must be higher in the cassette than the start slot for interpolation to work properly. Typically slot 25 but could be another slot number, particularly for a cassette with more or less than 25 slots.
4. Rotation (R) Start number box - This stores the rotation cassette position at the start slot.
5. Rotation (R) End number box - This stores the rotation cassette position at the end slot. Rotation positions for other slots will be calculated based on the positions for the start and end slots.
6. End Effector (T) Start number box - This stores the end effector cassette position at the start slot.
7. End Effector (T) End number box - This stores the end effector cassette position at the end slot. End effector positions for other slots will be calculated based on the positions for the start and end slots.
8. Move to Cassette Start Button - Moves to the cassette position used for the starting slot. Will first retract the end effector, then move the elevator to the start wafer position, then rotate and extend.
9. Move to Cassette End Button - Moves to the cassette position used for the ending slot. Will first retract the end effector, then move the elevator to the end wafer position, then rotate and extend.

The next tab is labeled "Macro Inspection Station". For systems with only a prealigner and no macro inspection, this tab is labeled "Prealign Settings". For systems with no macro or prealigner this tab does not appear. This tab allows for configuring the positions of the macro inspection station and settings related to performing topside macro inspection, backside macro inspection, and/or prealign. It contains 7 groups of controls. Five of the groups allow testing and configuration of five of the macro inspection station drives. One allows for testing of the spin drive, which has no configured positions. The remaining group allows for configuring the actions taken during macro inspection. This group is in the upper left hand corner and will be described first. The controls in this group, from top to bottom, are:

1. "X Wobble Speed:" text box – This box controls the speed at which the X axis moves when moving between the Up and Down positions as part of a topside macro inspection operation.
2. "Y Wobble Speed:" text box – This box controls the speed at which the Y axis moves when moving between the Up and Down positions as part of a topside macro inspection operation.
3. "Spin Speed:" text box – This box controls the speed at which the chuck spins during a topside macro inspection operation.
4. "Macro Duration (seconds):" text box – This box controls the duration of a topside macro

inspection operation. This is a maximum as the operation can be aborted early by operator intervention.

5. "Flip Duration 1 (seconds):" text box – This box controls the duration of the first flip performed during a backside macro inspection operation. Setting this to a negative number will cancel the first backside inspection flip – the second flip may or may not still be performed based on the setting for Flip Duration 2.
6. "Flip Duration 2 (seconds):" text box – This box controls the duration of the second flip performed during a backside macro inspection operation. Setting this to a negative number will cancel the second backside inspection flip – the first flip may or may not still be performed based on the setting for Flip Duration 1.
7. "Check Level" button – This button moves the Z to the Up position briefly and then back down, and cycles vacuum. It makes it easily apparent if the X and Y wobble axes are not level.
8. "Test Run Prealign" button – This button runs the prealign process as currently configured. Will fail if there is no wafer on the aligner.
9. "Test Manual Macro Control" button – This button starts the manual macro control dialog, allowing for manual control of the topside macro inspection operation.
10. "Test Topside Inspection" button – This button runs a topside macro inspection as currently configured. Will fail if there is no wafer on the macro inspection station.
11. "Align Sensor Test Window" button – This button opens a separate window which helps configure the prealign sensor. The window has instructions displayed near the top right corner. These settings do not usually need to be changed, but may affect the accuracy of the aligner.
12. "Test Backside Inspection" button – This button runs a backside macro inspection as currently configured. Will fail if there is no wafer on the macro inspection station.
13. "Pick Up Wafer" button - Picks up the wafer on the macro inspection station so that it is on the spinning chuck.
14. "Put Down Wafer" button - Puts the wafer on the spinning chuck down onto the flipper arm (or align platform).

The last group of controls in the left hand column allows for testing the spinning chuck, which does not need to be configured. The three controls in this group are:

1. "Move to 0" button – Returns the drive to the orientation it was in the last time that a wafer was loaded onto the macro inspection station.
2. "Rotate (rotations from 0)" text box – Defines how far to move when the button is pressed. Measured in number of rotations, so "0.5" will rotate 180 degrees.
3. "Spin This Many Rotations" button – Moves the drive to the offset indicated by the amount of motor counts shown in the Rotate text box.

At the bottom of one of the columns is a text box labeled "Increment"; changing the number shown in this text box will change the amount incremented or decremented when any of the up/down arrows on the text boxes which have up/down arrows are clicked.

Moving to the right column, the first group of controls is labeled "Up Down (Z)" and contains controls for configuring and testing the positions for the vertical motion of the spinning chuck of the macro inspection station. The three positions are:

1. Up. "Move Up" moves to this position, which is indicated by the number in the box labeled "Up Position (mm):". This should be just high enough above the flipper arm (when the flipper arm is

in the Down position) that the wafer can spin on the spinning chuck without crashing. This button is disabled unless the flipper arm is in the Down position. Adjusting this number while the spinning chuck is in the up position will automatically move the spinning chuck to the newly configured position.

2. Wobble. "Move Wobble" moves to this position. This should be at the very top of the range of vertical motion of the spinning chuck. This button is disabled unless the flipper arm is in the Down position. This position is set at the factory and cannot be edited by the user. This button does not appear for system which do not have topside macro inspection capability.
3. Down. "Move Down" moves to this position, which is indicated by the number in the box labeled "Down Position (mm):". This should be at the bottom of the range of vertical motion of the spinning chuck. Adjusting this number while the spinning chuck is in the down position will automatically move the spinning chuck to the newly configured position.

The second group of controls in the right hand column is labeled "Flip (F)" and allows for configuring and testing the positions of the flipper arm. The two flipper arm positions are:

1. Up. "Move Up" moves to this position, which is indicated by the number in the box labeled "Up Position (mm):". This button is disabled unless the spinning chuck is in the Down position. Adjusting this number while the flip arm is in the up position will automatically move the flip arm to the newly configured position.
2. Down. "Move Down" moves to this position, which is indicated by the number in the box labeled "Down Position (mm):". This should be slightly past the point at which the flipper arm comes to rest on the hard stops. Adjusting this number while the flip arm is in the down position will automatically move the flip arm to the newly configured position.

The third group of controls in the right hand column is labeled "Wobble Y (Y)" and allows for configuring and testing the positions of the Y axis of motion for the spinning chuck of the macro inspection station. The three positions are:

1. Up. "Move Up" moves to this position, which is indicated by the number in the box labeled "Up Position (mm):". This button is disabled unless the spinning chuck is in the Wobble position. Adjusting this number while the Y wobble drive is in the up position will automatically move the Y wobble drive to the newly configured position.
2. Home. "Move Home" moves to this position, which is indicated by the number in the box labeled "Home Position (mm):". This position should be completely level with the flipper arm. Adjusting this number while the Y wobble drive is in the home position will automatically move the Y wobble drive to the newly configured position.
3. Down. "Move Down" moves to this position, which is indicated by the number in the box labeled "Down Position (mm):". This button is disabled unless the spinning chuck is in the Wobble position. Adjusting this number while the Y wobble drive is in the down position will automatically move the Y wobble drive to the newly configured position.

The next group of controls in the right hand column is labeled "Wobble X (X)" and allows for configuring and testing the positions of the X axis of motion for the spinning chuck of the macro inspection station. The three positions are:

1. Up. "Move Up" moves to this position, which is indicated by the number in the box labeled "Up Position (mm):". This button is disabled unless the spinning chuck is in the Wobble position. Adjusting this number while the X wobble drive is in the up position will automatically move the X wobble drive to the newly configured position.

2. Home. "Move Home" moves to this position, which is indicated by the number in the box labeled "Home Position (mm):". This position should be completely level with the flipper arm. Adjusting this number while the X wobble drive is in the home position will automatically move the X wobble drive to the newly configured position.
3. Down. "Move Down" moves to this position, which is indicated by the number in the box labeled "Down Position (mm):". This button is disabled unless the spinning chuck is in the Wobble position. Adjusting this number while the X wobble drive is in the down position will automatically move the X wobble drive to the newly configured position.

The last group of controls in the right hand column is labeled "Align (A)" and allows for moving the align drive home. The align drive has only one position, and it is configured at the factory and is not editable by the end user. The "Move Home" button moves the align drive to the home position.

The next tab is labeled "Settings". It contains several options allowing features of the handler system to be enabled or disabled. On the left are two check boxes, and on the right are several labeled text boxes, with a combo box below it. I will describe the check boxes first.

1. "Center Wafer Twice during Prealign" - On systems with a prealigner, this causes the centering portion of the prealign process to be performed twice, increasing accuracy but taking longer to complete.
2. "Disable Stage Vacuum" - Prevents the loader from turning on the stage vacuum or checking the stage vacuum sensor while running a cassette cycle.

The four text boxes are:

1. "End Effector Vacuum Delay (ms):" - This controls the delay between when the end effector vacuum solenoid is turned on or off and when the sensor is checked. This delay gives the system time for the vacuum pressure to change. It is measured in milliseconds.
2. "Stage Vacuum Delay (ms):" - This controls the delay between when the stage vacuum solenoid is turned on or off and when the sensor is checked. This delay gives the system time for the vacuum pressure to change. It is measured in milliseconds.
3. "Flip Vacuum Delay (ms):" - This controls the delay between when the flip vacuum solenoid is turned on or off and when the corresponding sensor is checked. This delay gives the system time for the vacuum pressure to change. It is measured in milliseconds.
4. "Spin Vacuum Delay (ms):" - This controls the delay between when the spin vacuum solenoid is turned on or off and when the corresponding sensor is checked. This delay gives the system time for the vacuum pressure to change. It is measured in milliseconds.
5. "Encoder Tolerance" - This controls the amount of error that the elevator encoder can detect without causing the system to halt. This may need to be slightly increased if the lead screw wears out a little bit and starts having more backlash than it did at the factory.

The combo box is labeled "Communication Port" and controls which COM port is used to communicate with the handler. It is pre-populated with all of the valid COM port numbers on the computer. Changes to this setting require a software restart to take effect.

The next tab is labeled "Motors" and contains settings which control the movement of all the axes in the system. For each of the motors, there is a small group of controls. The controls are the same for all

of the motors and I will only describe them once. The largest control shows the values of any drive variables which have been set to something other than the default value. Variables set to the default value are not displayed. The commonly used variables are:

1. "VM:" - (Maximum Velocity) – The highest speed the motor moves.
2. "A:" - (Acceleration) – Acceleration for the motor in steps/second.
3. "D:" - (Deceleration) – Deceleration for the motor in steps/second.
4. "HC:" - (Holding Current) – Controls the amount of force used to keep a motor from moving.
5. "RC:" - (Run Current) – Controls the amount of current that goes to the motor. Too little current can stall a motor, and too much current can damage the handler.

The other controls include two combo boxes and a check box. The combo boxes control the IO port used for the positive and negative limit switch. Not all drives have both of these switches; for drives that do not have one of these switches this setting has no effect. These settings cannot be edited by the user and are displayed for information purposes only. The "Active High" check box inverts the polarity of the limit switches. Changes to motor settings do not take effect until the motor is re-initialized, typically by re homing the handler.

The next tab is labeled "I/O Configuration" and allows for viewing the state of all the inputs in the system. For each of the general purpose inputs and limit switch inputs, the current state can be viewed. The button near the lower left corner which is labeled "Check Input Values" causes the system to read the values of all of the inputs (both general purpose and limits) and update the results.

Also on this tab is a control which allows for the polarity of the stage switch to be changed. If the system is equipped with a stage rotation sensor or cassette protrusion sensor, the polarities of these sensors can also be adjusted. Checking the checkbox next to the given sensor inverts the polarity for that sensor.

The last tab is labeled "Cassette Specific Settings" and contains controls which allow for configuring the mapper and the prealign settings. The first group of controls is labeled "Mapper Settings" and allows for configuring and testing the mapper. The controls in this group are:

1. "Starting Height:" box – This box controls the height at which the mapper sensor turns on when mapping the cassette. This height should be well below the height of the first wafer, but not so far below that the mapper sensor's laser hits the H-Bar of the cassette.
2. "Ending Height:" box – This box controls the height at which the mapper sensor turns off when mapping the cassette. This height should be well above the last wafer, but not so far above the last wafer that the mapper sensor's laser hits the top of the cassette or the cassette elevator hits the bottom limit switch.
3. "First Wafer Location:" box – This box indicates the height at which the first wafer is located.
4. "Margin of Error:" box – This box controls the margin of error for detecting a wafer, which is the number of millimeters above or below the wafer's position the sensor is 'allowed' to detect the wafer without marking it as cross-slotted or double-stacked. The minimum value depends on the thickness of the wafers, and the maximum value depends on the spacing of the wafers – if the value is larger than the Wafer Spacing (configured on the Positions tab) the mapper will not be able to detect cross slotted wafers, and if the value is more than double the thickness of the wafers the system may not be able to detect double stacked wafers.
5. "Mapping Speed:" text box – This text box controls the speed at which the elevator moves

during a mapping operation.
6. "Test Mapper" button – This button runs the mapper using the current settings.
7. "Laser On" button – This button turns on the mapper laser (useful for verifying that the laser is aligned correctly to hit the reflector.)
8. "Laser Off" button – This button turns off the mapper laser.
9. "Mapper Test Results:" text box – This text box shows the results of the mapper runs started by clicking the Test Mapper button. The results list the cross slotted wafers first, the detected wafers second, and the positions at which a wafer was sensed (listed as start – finish) last.

From top to bottom, the controls in the other group are:
1. "Use Flat Finding" check box – If the wafer has a flat and not a notch, this check box should be checked. "Notch finding" will still find a flat but will be less accurate, "Flat finding" will not find a notch.
2. "Allow Macro Inspection" check box – Prevents the system from attempting to place this size wafers on the macro inspection station. Used for small wafers on systems with a macro station which cannot safely handle those wafers.
3. "Prealign Offset (mm):" - Controls how far to move the align drive when prealigning. If the wafer is perfectly centered on the spinning chuck, moving this number of millimeters should move the wafer so that the edge of the wafer is exactly in the middle of the align sensor beam.
4. "Wafer Flat Depth (mm):" - When looking for the wafer flat or notch, the wafer will be moved to the prealign offset and this much further, then rotated. The point of the flat/notch that is closest to the center of the wafer should still cover part of the align sensor beam when the wafer is in this position and perfectly centered.
5. "Flat/Notch Find Speed:" - Controls the speed at which the spinning chuck is rotated when looking for the flat or notch. Will need to be slower if the notch is small.

That's all of the buttons on the Setup panel.

Main GUI Buttons

Many of the buttons on the main GUI are only visible in certain situations. For example in the center of the screen are 5 buttons used for error handling that are only visible when an error has occurred and have different labels and functions depending on the error. Just below them are two larger buttons only visible when a wafer has been loaded onto the macro inspection station; the "Next Macro Inspection Stage" causes the macro operation currently being performed to finish and the next stage of macro inspection (back macro, or replacing the wafer in the cassette, or loading it on the stage) to take place. The "Manual Control" button opens the Manual Macro Control dialog which allows for manual control of topside macro inspection operations. These buttons never appear if there is no topside macro inspection available. Near the bottom of the column of buttons on the right side of the GUI are two buttons which might be hidden; they are visible if logged in as Administrator and not visible if logged in as User. One is labeled "Setup" and clicking it shows the Setup panel; the other is labeled "Options" and clicking it shows the Options panel, which is similar to the setup panel.

Most of the controls on the main GUI are divided into two columns, one on the right and the other on

the left. The controls on the left are in a group labeled "Cassette Slot Selection". At the top of this group is a list of available recipes. These can be created by the user. There are several system-defined recipes at the top of the list. These cannot be removed, and the wafer orientation for these recipes is not remembered. Clicking the "Add..." button will open a dialog allowing you to set the name for a new recipe. Setting the name to the same name as an existing recipe will cause the existing recipe to be overwritten; the user will be prompted to continue and has the option to cancel. The recipe created will be whatever the wafer selection is when the Add button is clicked. Clicking the "Save" button causes the current settings to be saved as the current selected recipe. Clicking the "Delete" button will cause the currently selected recipe to be removed. Deleting all recipes except the system recipes will cause a set of default recipes to appear if the software is restarted without creating any recipes. "Save" and "Delete" are only visible if the user is logged in as Administrator.
Underneath the Add and Delete buttons is a color code for the wafer selection colors. This cannot be edited from the main GUI but the colors can be changed in the Options screen. Underneath this color code are 25 buttons numbered 1 through 25. These correspond to the 25 wafers in a standard cassette. Each wafer can be selected for Stage and Macro inspection, Stage Inspection Only, Macro inspection Only, or nothing (Don't Run). Clicking on one of the wafer slot buttons cycles through these options as long as the wafer has not started running in the current cassette cycle. Right clicking on one of these buttons shows a smaller menu where individual operations can be enabled or disabled without having to click through all four options; this also allows the user to enable only topside or backside macro inspection. If the wafer has run or is running, clicking on the cassette slot button toggles between the normal status display and a black button with a red "XX" indicating that the wafer is a reject. When the mapper runs, any cassette slot button that corresponds to an empty cassette slot is disabled and cannot be edited; the slot displays the requested operations based on the recipe, but the system will skip the wafer.
Several controls are located in the lower middle of the GUI. I will now describe the controls which are always visible; they are:

1. "View as Checkbox Grid" button – This button opens a new window with a large number of check boxes, one for each wafer for each operation. This allows for complicated recipes to be edited more easily. Note that on systems with both a prealigner and a macro inspection station, wafers must be prealigned to perform backside or topside inspection.
2. "Auto-Map Cassette" check box – If this check box is checked, the mapper will automatically run at the start of each cassette cycle, as long as it has not already been run. Also, if the cassette is removed during a cassette cycle, the mapper will run again when it is replaced. If this option is disabled, the mapper will only run when the Map Cassette button is pressed.
3. "Current Alternate Settings" combo box – This allows selecting different settings for the same size cassette (meaning a cassette which hits the same cassette size sensor switches). For example it could be used to have different pick up points for thick or thin wafers, or different prealign settings for silicon or glass wafers. Cannot be edited while a cassette cycle is running.
4. "Wafer Orientation" text box – The wafer will be rotated this number of degrees when it is placed on the stage. Macro inspection must be enabled for the wafer or it will not be rotated.

5. "Always Do Manual Macro" check box – If this check box is checked, the system will always open the manual macro control dialog when a topside macro inspection operation is performed.

The rest of the controls on the main GUI are in a column on the right side of the GUI. The first seven of these are in a group labeled "Loader Control" and allow for starting, stopping, pausing, and canceling a cassette cycle. They are:

1. "Start Cassette" button – This button starts a cassette cycle.
2. "Reset Cassette" button – Terminates the current cassette cycle and returns all wafers to the cassette. Also resets the mapper data.
3. "Release Stage Vac" button – This button releases the stage vacuum. The wafer on the stage must be removed to continue. Does nothing if the stage vacuum is currently disabled.
4. "Pause" button – This button causes the system to temporarily stop until the Pause button is pressed again. While paused, this button will read "Resume". The movement commands in progress when this button is pressed will be allowed to finish, which prevents position errors.
5. "Map Cassette" button – This button runs the mapper. The results will be indicated on the cassette slot buttons. This button is only enabled if there is no cassette cycle currently running.
6. "Auto Restart" check box – If this check box is checked, the system will automatically start a new cassette cycle a few seconds after the current cassette cycle finishes. Clicking Reset Cassette clears this check box If this option is disabled the system will not start another cassette cycle until Start Cassette is clicked.

The next group of three buttons is labeled "Misc" and contains three buttons. They are:

1. "Re-home Handler" - Causes the handler to re-home itself. Usually not needed unless the Halt Operation button was clicked or the power to the handler was interrupted.
2. "Exit Program" - Causes the program to exit. Disabled unless there is no cassette cycle running.
3. "Help" - Opens a .pdf file with help information.

The last button is labeled "Log Out" and causes the log in screen to reappear so that the user can log in as administrator (or vice versa).

Options Screen Buttons

The options screen has a number of settings, many of which affect the appearance of the GUI but some of which affect the work flow of the system. It has three columns of controls as well as a separate group of controls at the bottom left corner labeled "Interop Options".
The first column of controls contains a number of check boxes; they are:

1. "Pause on Empty Cassette Slots" - Used primarily when mapping is disabled. Causes the handler to treat a failure to grab a wafer from the cassette as an error – normally it is considered to be an empty slot and will be skipped.
2. "Require Selected Wafers to be Present" - If this is checked, then all the wafers selected by the current recipe must be present when the mapper runs. If any wafers are missing, the system will throw an error and the cassette must be replaced and remapped to continue.
3. "Load Wafers from Top (25) to Bottom (1)" - If checked, wafers are run starting with 25 and with 1 as the last wafer to run. This prevents delays when the mapper runs, as after the mapper finishes it is near the position to load wafer 25. Defaults to on.
4. "Run Topside Inspection During Stage Inspection" - Only applies to systems with a topside macro inspection station. Causes the topside macro inspection to be run while the wafer is on the stage, and continued until stage inspection finishes. If this is not checked, then topside inspection will not be performed until after stage inspection is finished.
5. "Enable Continuous Operation" - Used for testing. Causes the system to simulate stage

inspection lasting between 20 and 50 seconds. Also causes the system to restart a cassette cycle without waiting for the cassette to be removed if the "Auto Restart" check box (on the main GUI) is checked.

6. "Enable Tool Tips" - Enables or disables the display of tooltips on the options screen as well as on the main GUI.
7. "Select wafers from Mapped Wafers (when using system recipe)" - If this is checked, then the wafer selection when using a system recipe will be updated when the cassette is mapped such that all of the selected wafers are present in the cassette.

The next column of controls contains three text boxes, they are:

1. "Base Font Size" - Controls the size of the main GUI. 8.25 is the default. Values larger than 16 are not permitted.
2. "Check Cassette Interval (milliseconds)" - Controls how often the cassette sensors are checked. Checking too fast can cause the handler to respond more slowly to other commands. Checking too slowly can cause the handler to fail to detect a cassette being rapidly removed and replaced.
3. "Log Message Display Interval (milliseconds)" - Controls how fast the messages on the main GUI cycle between different messages when there is more than one status message to display.

A number box is at the bottom of this column; it is labeled "Number of Random Wafers for Random Recipe:" and controls the number of wafers that will be selected to run when using the Random system recipe.

Underneath these two columns is the group labeled "Interop Options". The controls in this group are:

1. "Enable Interop" check box – Must be checked for the interop feature to work. The interop feature will either write to a file or run a program when a wafer is loaded to the stage.
2. "Write to File" radio button – If this is checked, the system will write the given command to the end of the given file.
3. "Execute Program" radio button – If this is checked, the system will run the specified program. Command line options should be included with the name of the program. The interop file name text is not used.
4. "Filename:" text box – Specifies the file to be used. Not used when executing a program.
5. "Command:" text box – If writing to a file, specifies the string to write. If running a program, specifies the program to run and any command line options to be used.

The third column contains a group labeled "Slot Colors" with four buttons beneath the group. The group contains 10 buttons. Each button controls one of the colors used for wafers in a particular stage of running (or configured to perform certain operations). Each button opens a small dialog which allows you to select a new color. The four buttons below this group are:

1. "Change User Password" - Opens a new window which changes the user password. The user password must be entered to change the password. Setting the password to nothing (leaving the box blank) disables the password and causes the system to automatically log in as User when the software first starts.
2. "Change Admin Password" - Opens a new window which changes the administrator password. The administrator password must be entered to change the password.
3. "OK" - Saves all changes. Any invalid values (for example entering "1000--" in the Check

Cassette Interval text box) will be discarded. The user will be notified that value was discarded.

4. "Cancel" - Closes the window without making changes.