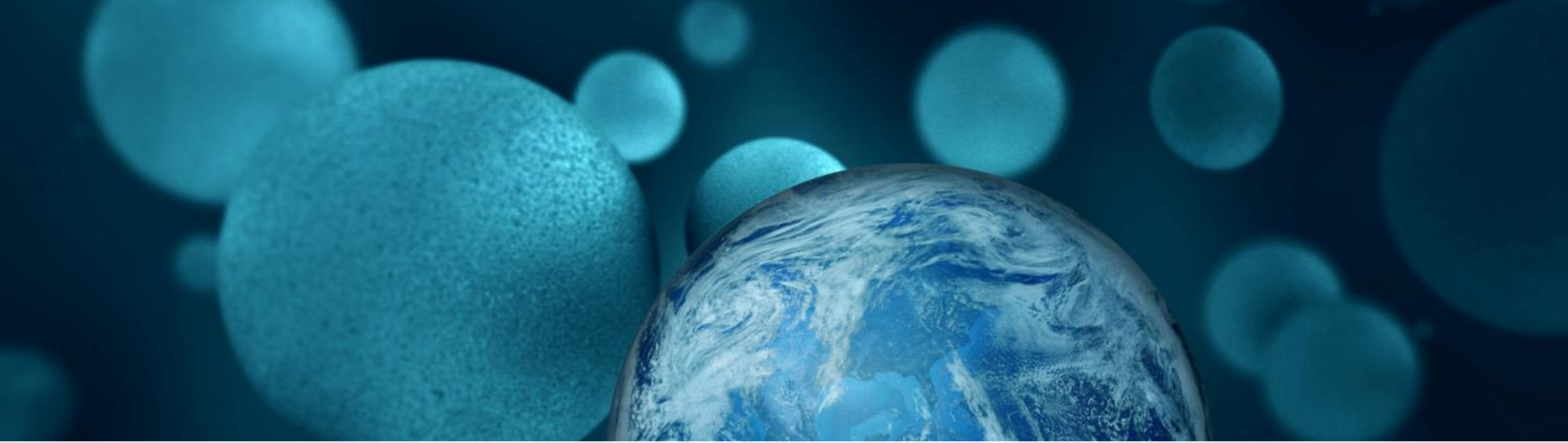


ThermoFisher SCIENTIFIC

Comprehensive Momentum 6 Training

Module 4

After completing Module 4, trainees will be able to:

Section 1: Standard Containers

- Add or change a standard container including setting grip offset.

Section 2: Understanding Motion

- Differentiate between locations, paths and regions.
- Describe the saved locations used by a mover during a run.

Section 3: Teaching, Testing and Healing with Momentum

- Use the Teach Wizard in Momentum to manually re-teach nest locations.
- Use the Teach with Vision Wizard in Momentum to re-teach, test and heal nest locations.

Section 4: MoverTeach

- Use MoverTeach to safely control the speed and direction of the mover
- Intervene at the mover to recover from an error

Section 5: MoverTeach

- Use MoverTeach to re-teach a nest location
- Use Mover Teach to change an existing path in the Motion Database

Section 1: Standard Containers

- As already shown, the properties of a new process container or inventory container template can be set quickly by using the container's "Type" property to select the standard container.

- What if a container your lab uses is not present in the container list?
  - Add it of course!

- Good things to know about Momentum's library of standard containers.
  - can be used in any process
  - they are stored in a container database, separate from the Momentum database (containerTypes.cfg)
  - they can be exported and imported between container databases

Reminder – Container Categories

Watch this video for more information on the Container features.

Note – Access to the internet is required.

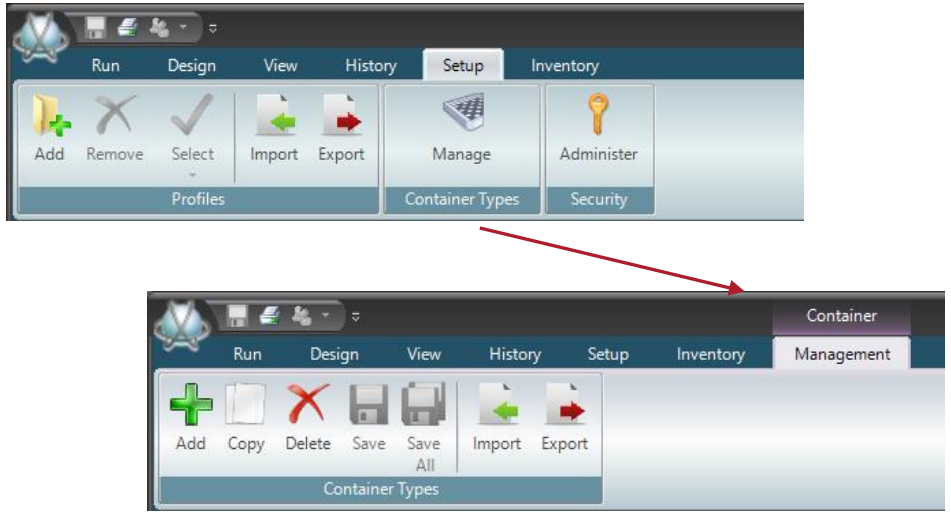
Adding & Changing Standard Container Properties

- The changes to standard containers are at the profile level are global – can be seen and used in all processes.
- Both Process or Inventory can be based on a standard container.
- Profile level changes are made when,
  - adding a new container type to the library
  - changing the properties used by the mover

Configuring by Adding a Type to the Standard Container Library

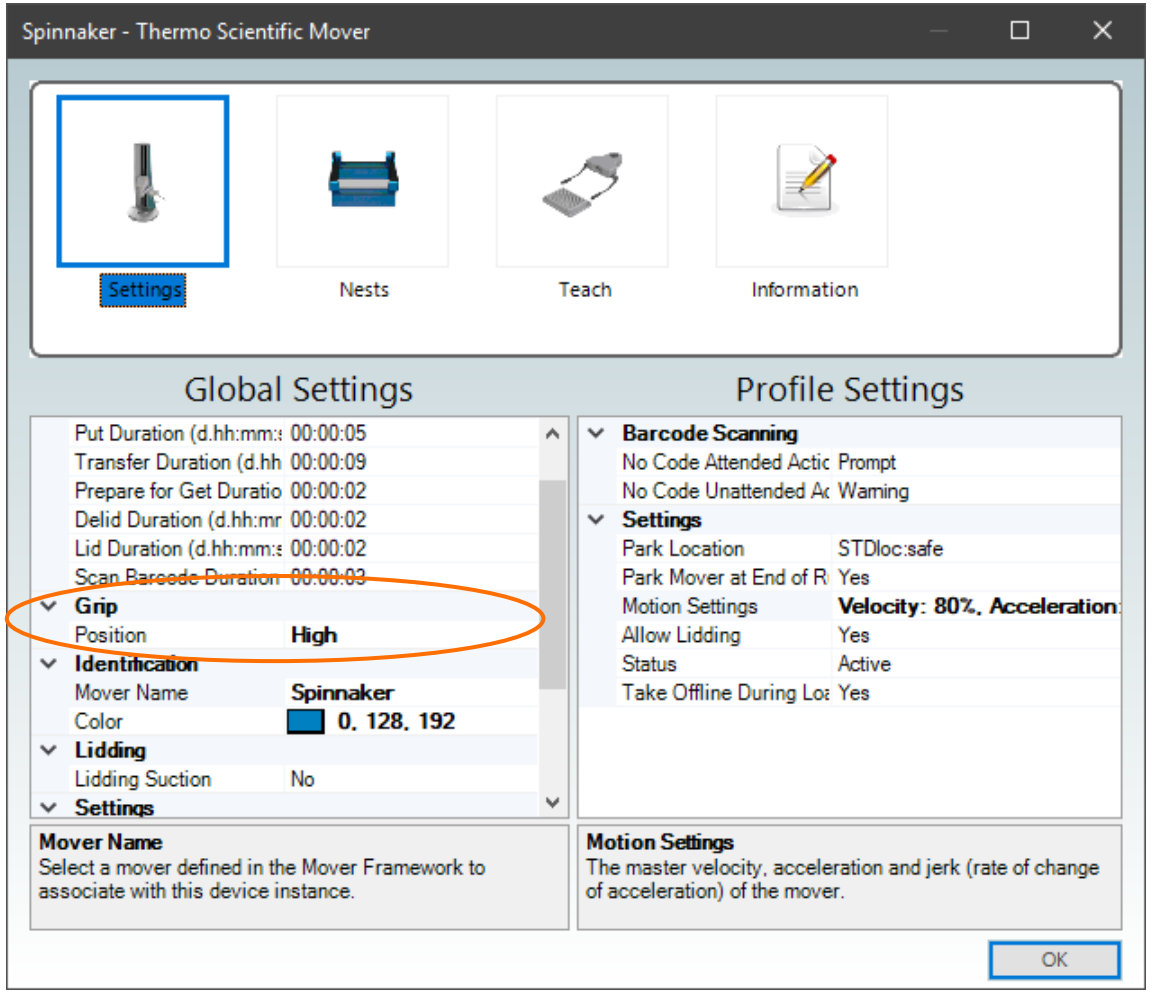
I don’t see my plate type

- it is best to use an existing container type as a starting point
- copy a container type and re-name it appropriately
- edit individual properties as described (dimensions)
- save
- container type is ready to use after the editor has been closed



Critical Detail – Using the Standard Container Library

- Momentum is designed for multiple-mover systems
  - different movers could have different grippers
  - some grippers must be taught to grip slightly lower, other grippers must be taught to grip slightly higher
- each mover has a grip position: Low or High
  - when this mover grips the container, this mover uses the container's low settings or high settings
- container settings in library
  - Low: dimensions used when mover grip taught low
  - High: dimensions used when mover grip taught high
- for each mover (Low or High), configure the appropriate offset (Low or High) for each container
  (distance from surface 3 mm and 6.35mm)



Smart Jig

Spinnaker Grip Position: High vs. Low

Movement Properties Defined

Grip Offset

- relative to mover's taught locations in nests, the distance (higher or lower) for the gripper when moving this container

Lidded Offset

- relative to non-lidded gripping position, the distance for the gripper when moving this container when it has a lid on

Mover Lidding Grip Offset

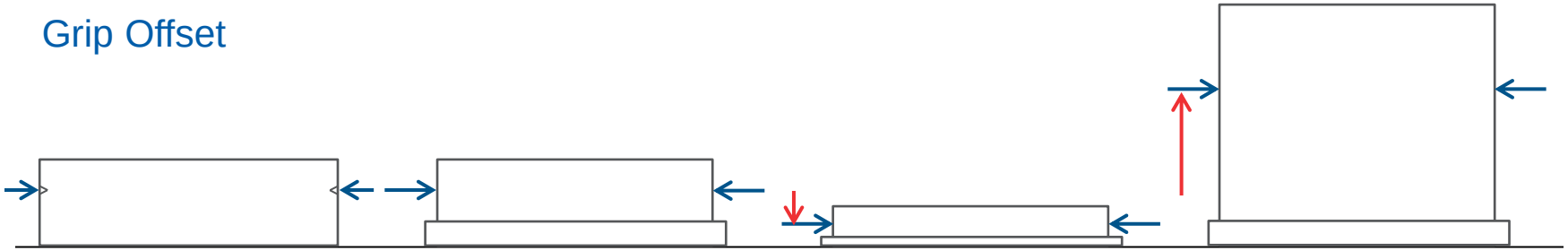
- relative to mover's taught locations, the distance for the gripper when the mover takes off or puts on the lid

Grip Force

- force used when gripping the plate (typical 70%, smooth hard plates 85%, bendable PCR plates 30%, no adjustment needed and use mover's default = "0")

Examples of Offset

Grip Offset



teach jig taught height	standard plate	shallow plate	deep-well block
	identity	- 4 mm	+ 15 mm

Lidded Offset

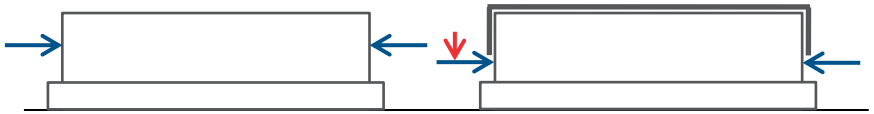
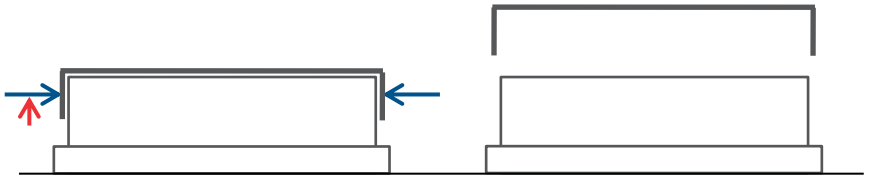


plate	plate with lid
identity	- 2 mm

Mover Lidding Grip Offset



grip lid	lift lid
+ 1 mm	

Determining Offset Properties

teach jig taught height

6.35 mm

Offset – the distance (higher or lower) for the gripper when moving this container compared to the taught height

Lid

2 mm

Grip offset 2 – 6.35 = - 4.35 mm

Plate

7.35 mm

Grip offset 7.35 – 6.35 = 1.00 mm

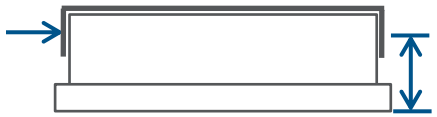
Lidded offset is always negative to the plate offset

Lidded

3 mm

Lidded offset 7.35 – 3 = - 3.35 mm

Lidding mm



11 mm

Mover Lidding

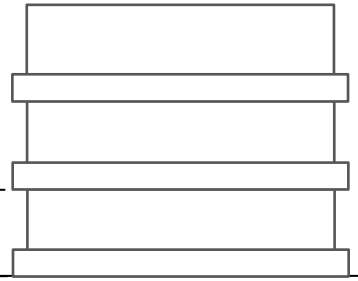
Grip offset 11 – 6.35 = + 4.65

Dimension Properties

Plate Height

14.4 mm bottom of plate to top of same plate when standing alone

Plate Stacking Height



12.2 mm bottom of plate to bottom of next plate when nested together

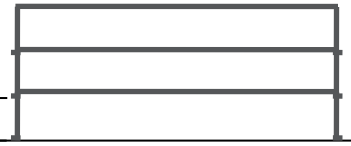
Plate Lidded Height

16.6 mm bottom of plate to top of lid

Lid Height

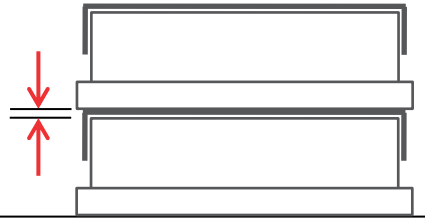
7.9 mm bottom of lid to top of same lid when standing alone

Lid Stacking Height



5.9 mm bottom of lid to bottom of next lid when nested together

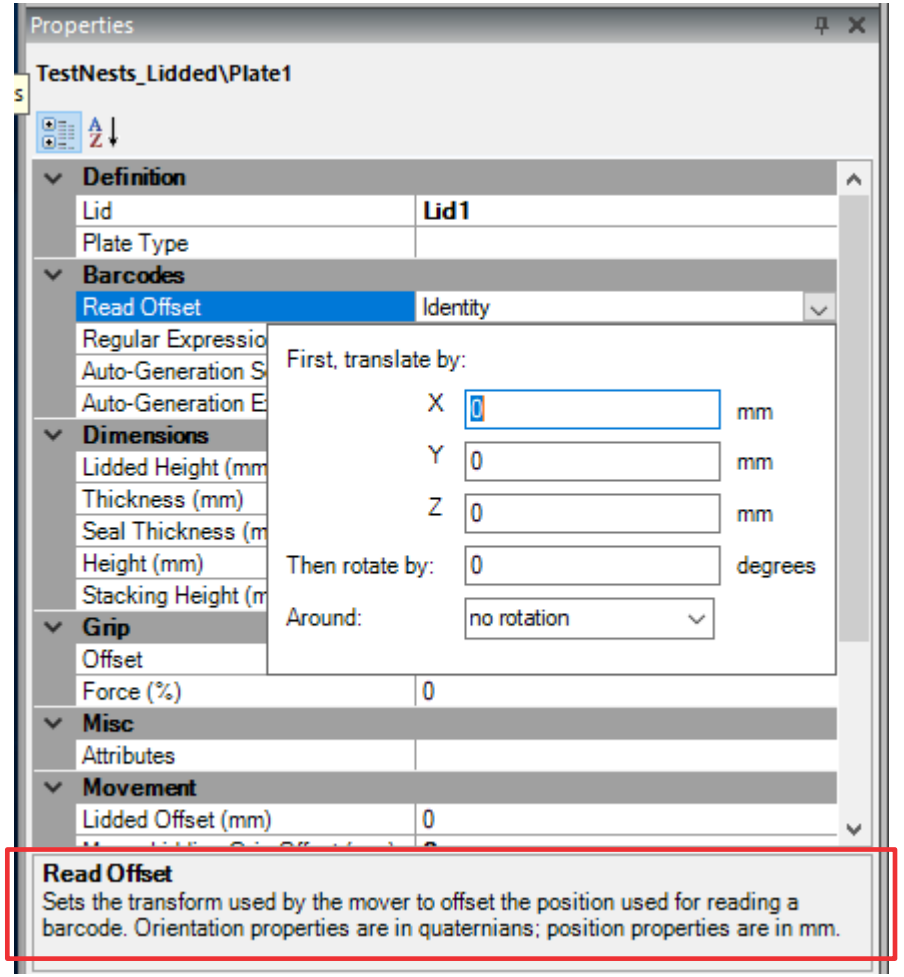
Lid With-Plate Stacking Height Delta



2.1 mm difference between stack of plate-without-lid and stack of plate-with-lid

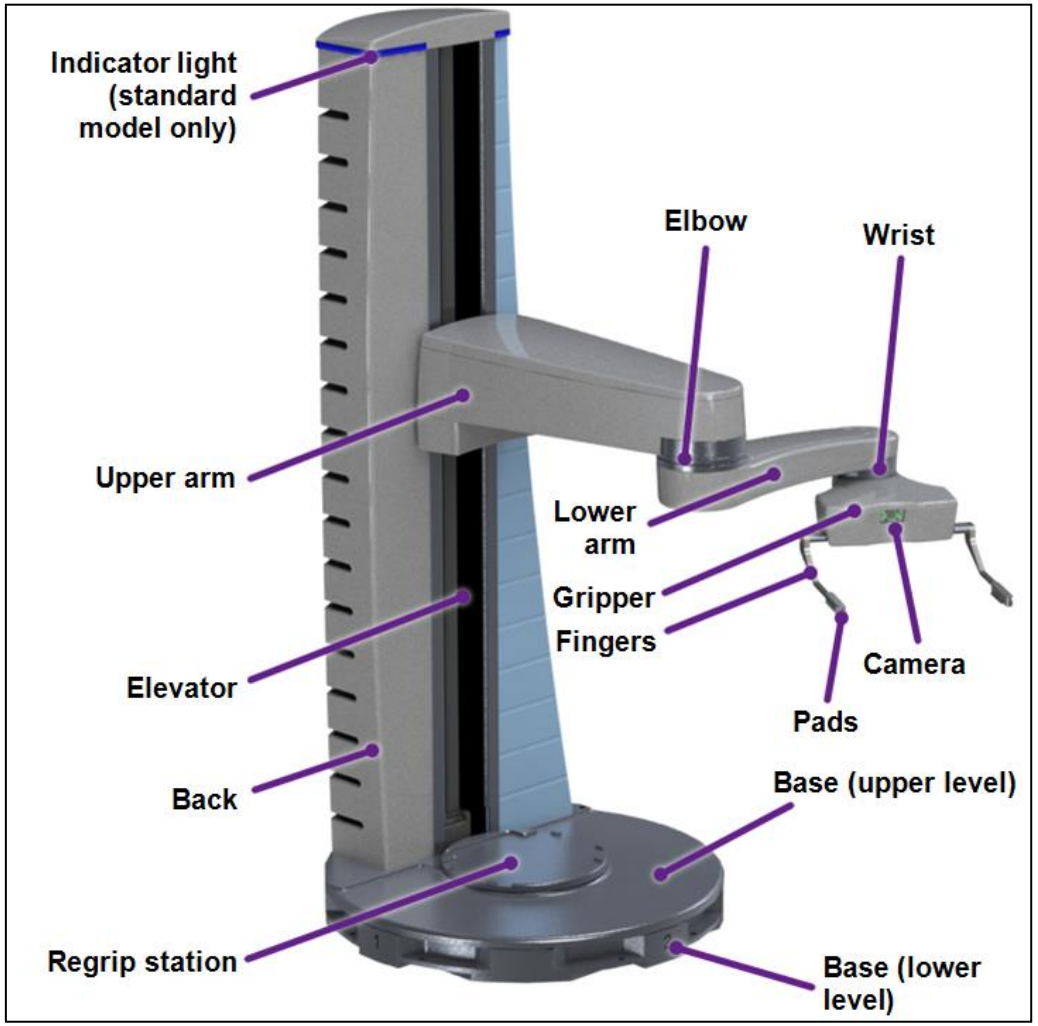
Read Offset

- If the barcode is obstructed, the read offset can be adjusted.
- Before adjusting offset, it is important to test if the barcode read failures are:
  - nest dependent (only some nests might have obstructions)
  - barcode labeling irregularities
  - plate type dimensions



Section 2: Understanding Motion

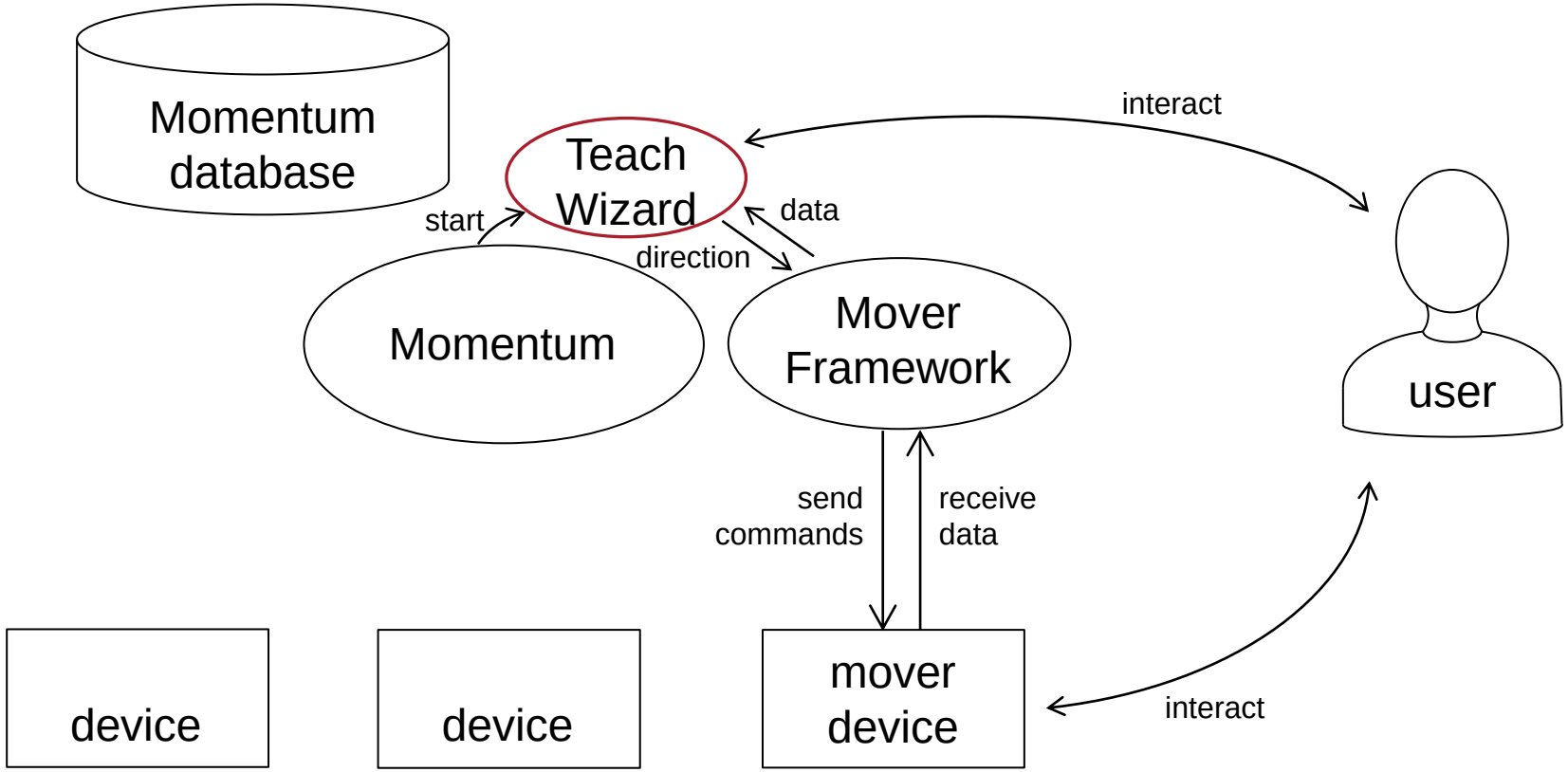
Anatomy of the Spinnaker



Controlling the Mover: Spinnaker

Teach Nest Locations with Momentum	Intervening (error recovery)
Momentum Vision Teach Wizard	MoverTeach
Momentum Teach Manually Wizard	Direct control of mover

Flow of Information – Momentum Teach Wizard



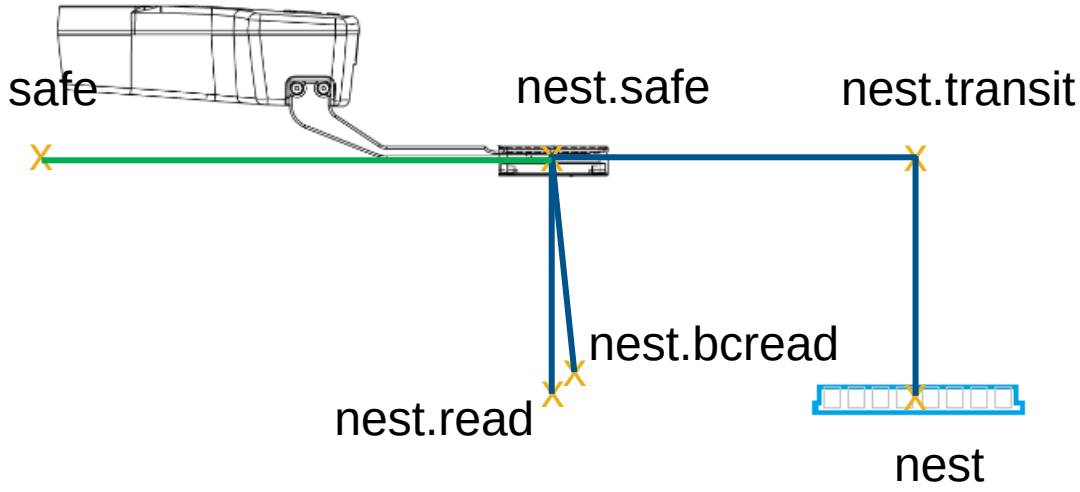
- Teach Wizard
  - a software wizard started from within Momentum, controls the teaching process, directs the mover and displays direction to the user
  - Locations are stored in MoverFramework and accessed by Momentum during runs

Interacting Effectively with Movers

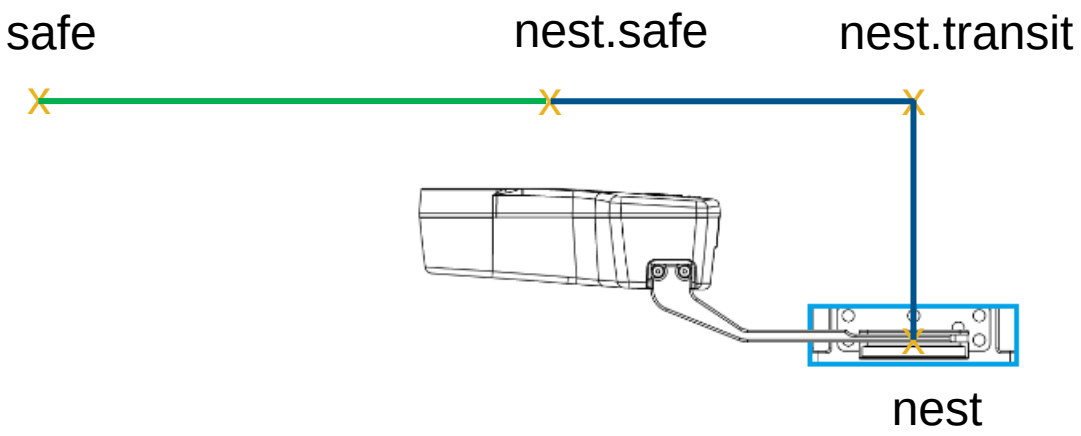
- A basic understanding of movers/motion can help users to determine the best course of action to take with a mover.
- movers travel in a defined manner
- travel can be considered a map of collision-free points to a set destination
- the map is stored to a Motion Database and accessed by Momentum

Understanding Motion

- the map contains
  - locations – points in space known to the mover
  - paths – connects the locations
    - nest.safe to nest.transit to nest
    - nest.safe to nest.read
    - nest.safe to nest.bcread
  - regions – connects the location nest.safe (end of path) to device's safe

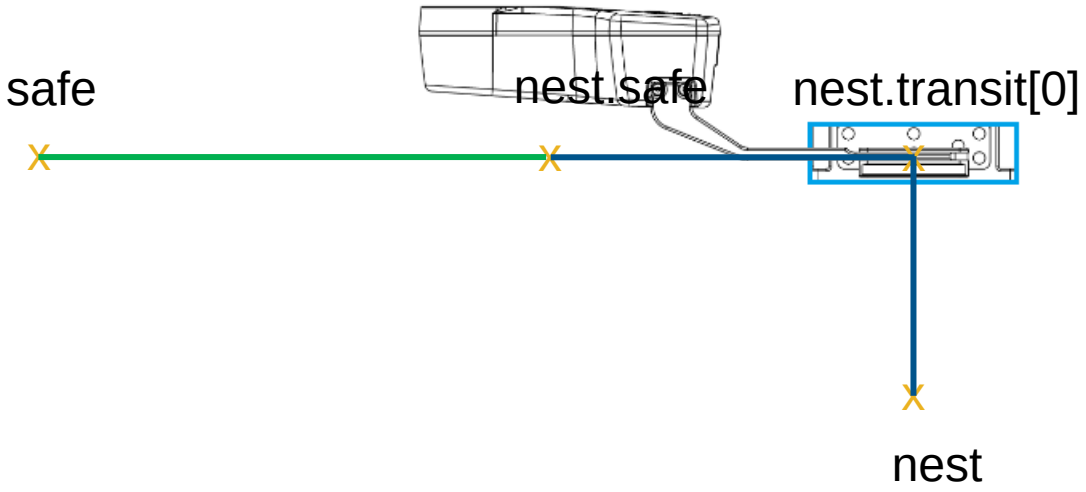


Location – Nest



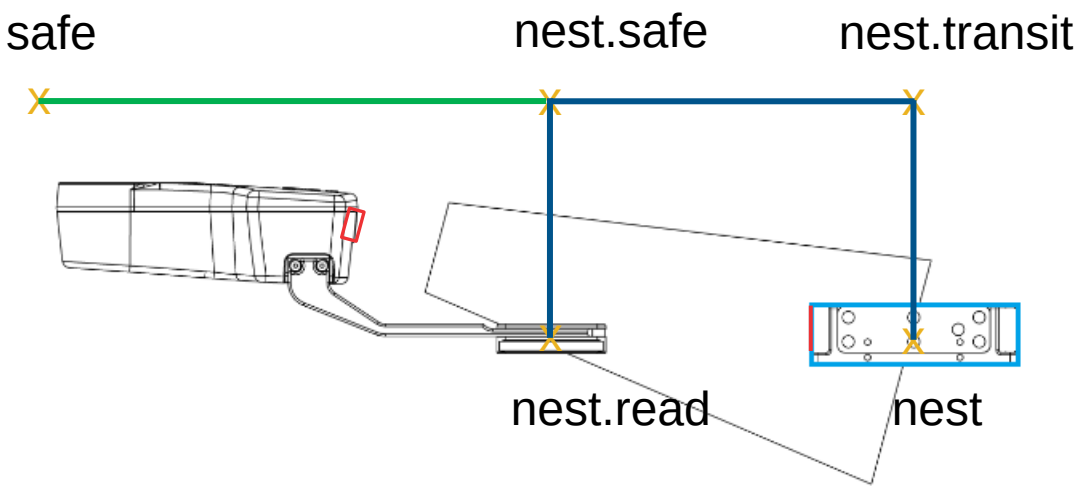
- nest
  - the place for the container
  - gripper opens/closes

Location – Nest.transit[0]



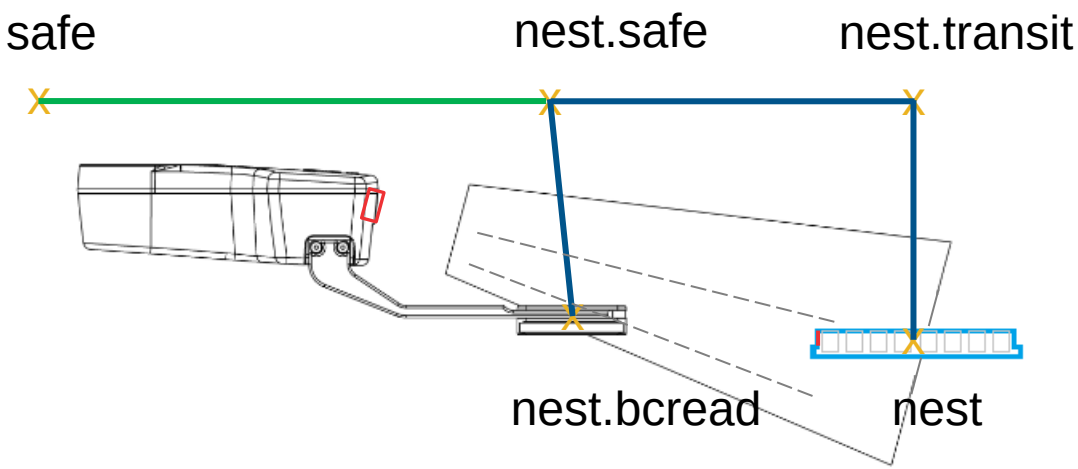
- nest.transit[0]
  - a location in transit from the nest to the safe
  - transit[0] is vertical from the nest

Location – SmartJig Reading



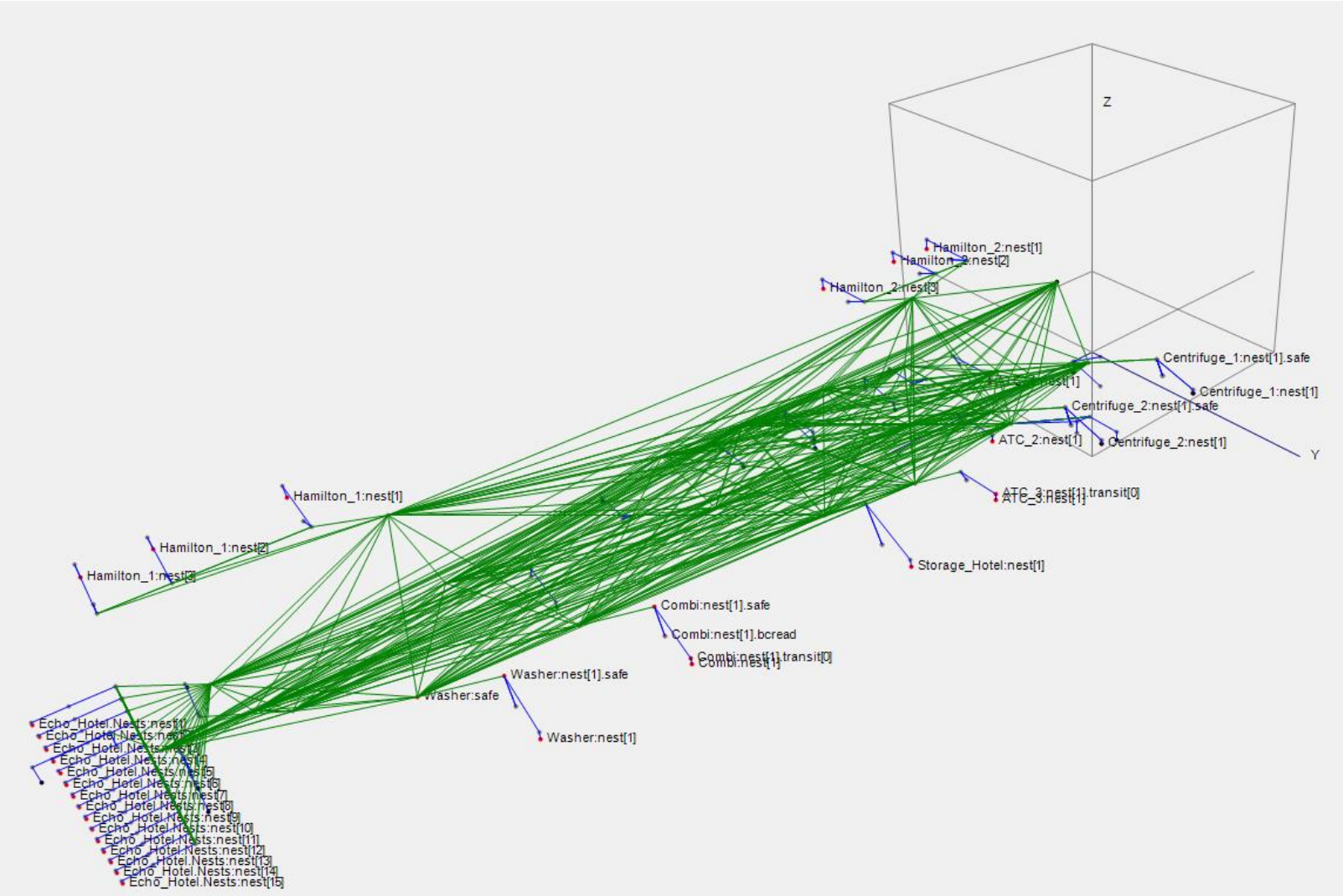
- nest.read
  - the camera in the gripper is at a defined distance and angle for acquiring an image of the target face (domino symbol) of the SmartJig
  - calculated using extrapolation (math rule)
    - from nest to nest.read

Location – Barcode Reading



- nest.bcread
  - the camera in the gripper is at a defined distance and angle for acquiring an image of the barcode on a microplate
  - for reading barcodes on specific containers, offset can be applied in container definition

Visualizer of Paths and Regions



Section 3: Teaching, Testing and Healing with Momentum

Re-Teaching or Intervening

- A device is serviced and not in exactly the same place
  - you re-teach the nest(s) of the device with the same tool used to teach

- Mover is not consistently picking up or putting containers

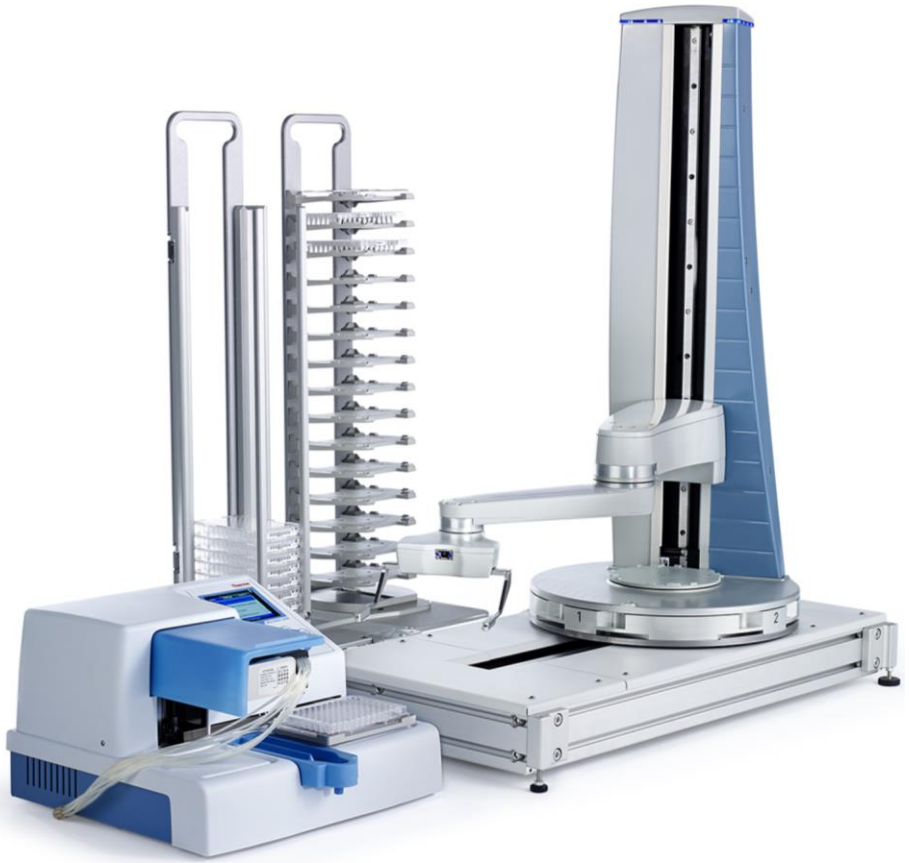
Teaching Nest Locations

Watch this video for an introduction to Teaching Locations.

Note – Access to the internet is required.

Teach or Re-teach with Vision – Overview

- Spinnaker uses its camera
- takes a picture of a target in the nest
- calculates the position of the nest in space



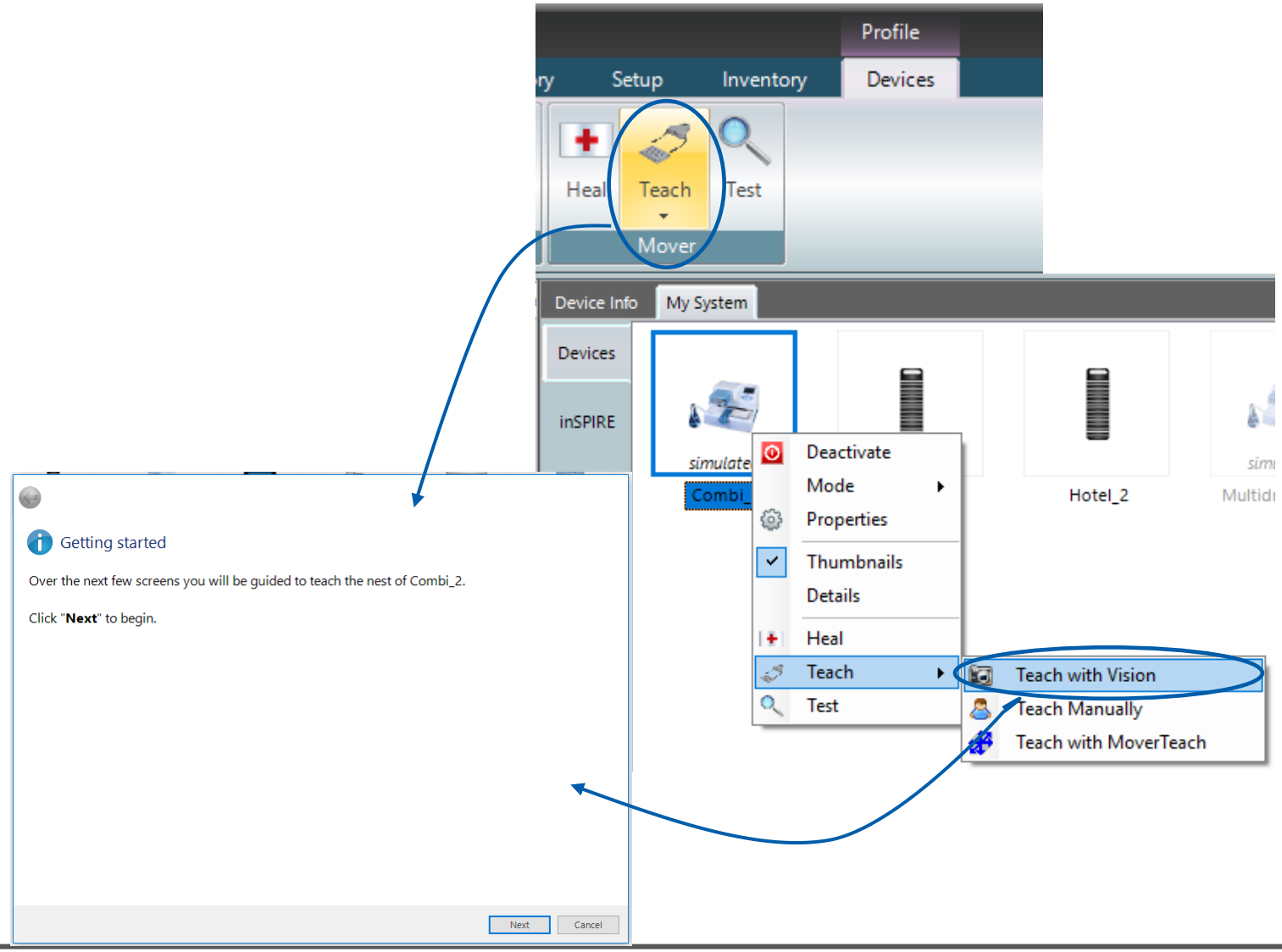
Starting to Teach

- accessed through Momentum
- select profile, then Devices tab
- select Teach

OR

- select the device to teach
- right click on the device

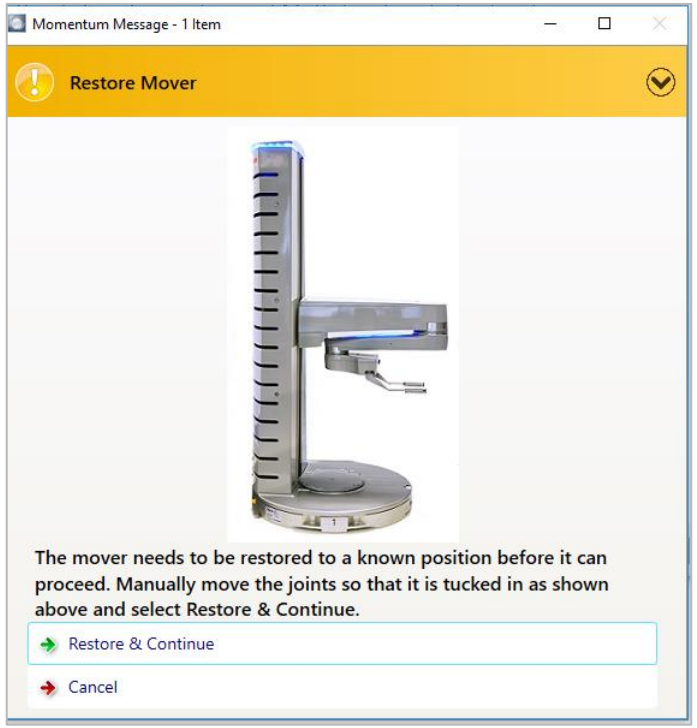
- select Teach with Vision
  - teaching wizard starts



ThermoFisher SCIENTIFIC

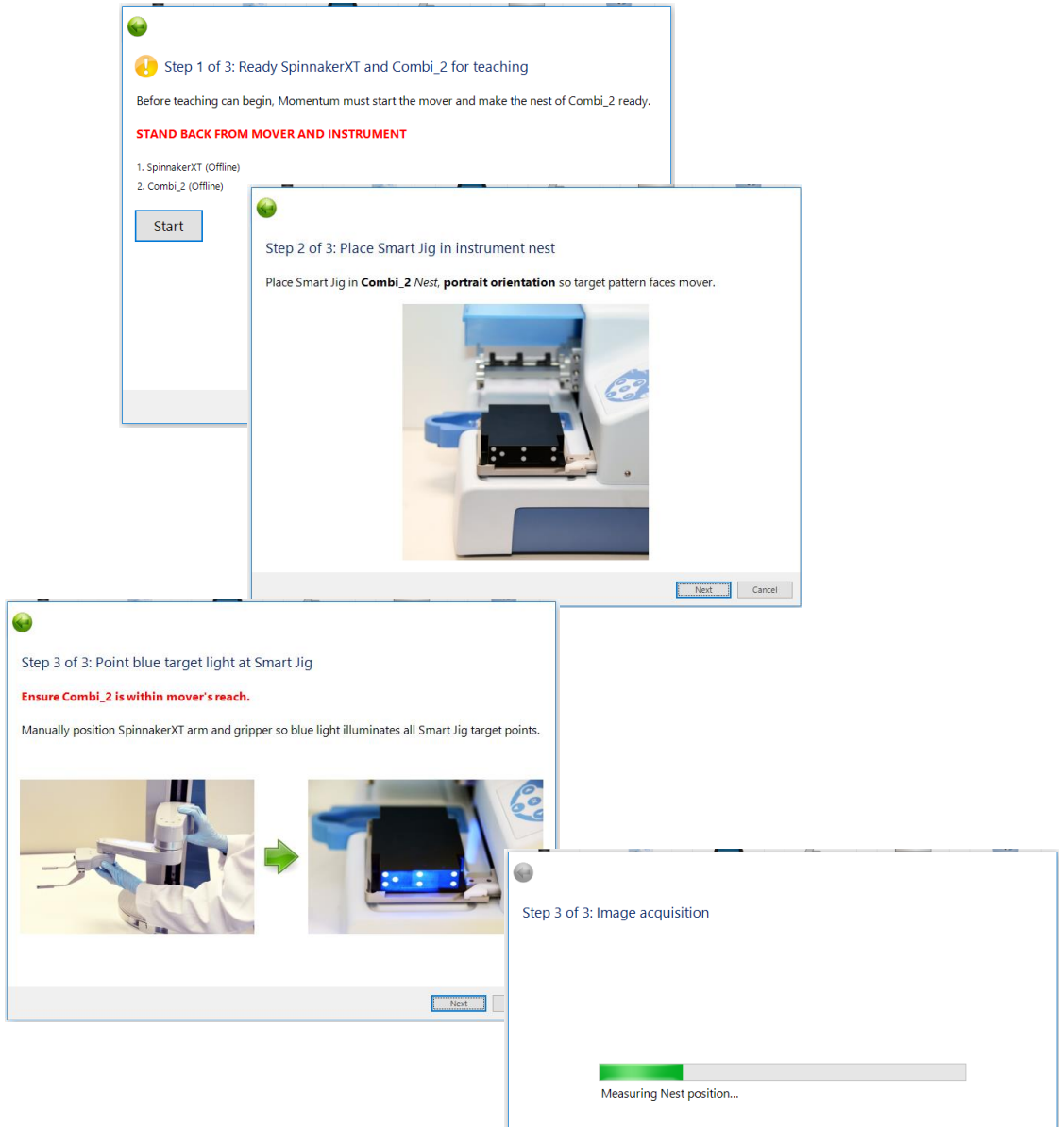
Possible Warning

- The mover must be in a location known to Momentum
- In a situation where the mover has been halted, Momentum will alert the User to manually adjust the mover



Ready, Set, Go

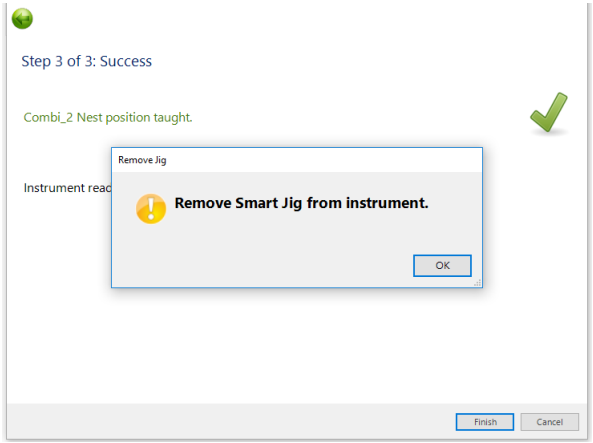
- Devices readied by Momentum
- Place SmartJig in nest
- Manually position the Spinnaker
  - Momentum limps the Spinnaker
  - point the blue lights at the target
- Momentum determines nest
  - takes image
  - calculates position of nest
  - saves to mover database

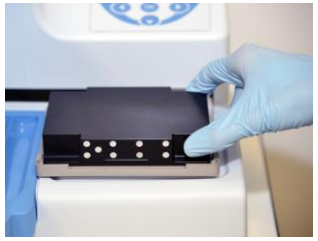


ThermoFisher SCIENTIFIC

Finish, Park, Remove

- Finish Teaching
- Remove SmartJig from nest
- Momentum parks the Spinnaker





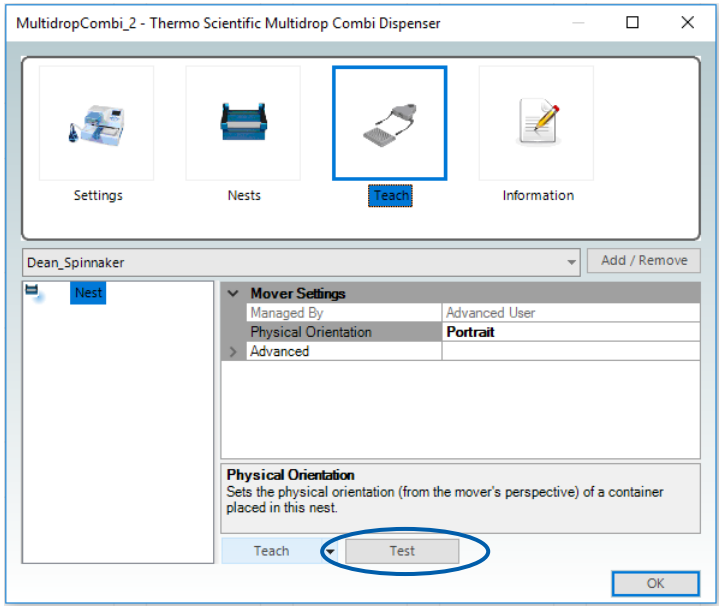
ThermoFisher SCIENTIFIC

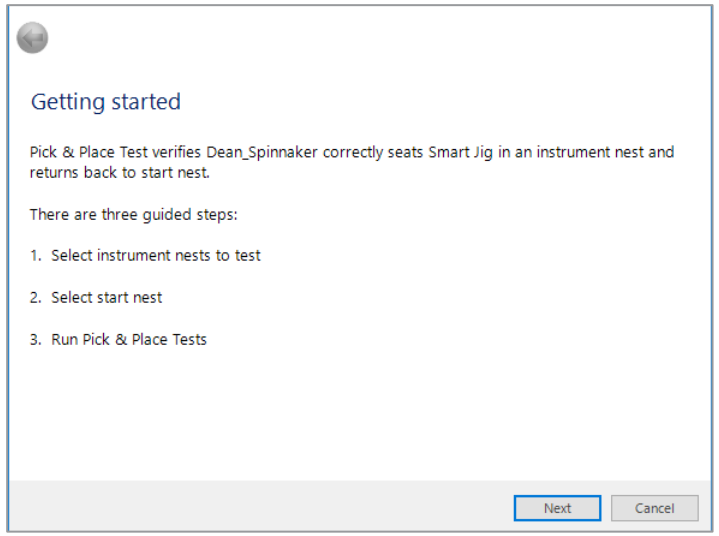
Testing Taught Nest Locations

- SmartJig starts in its starting nest
- Momentum moves the SmartJig to the test nest
- evaluate
  - SmartJig in nest properly?

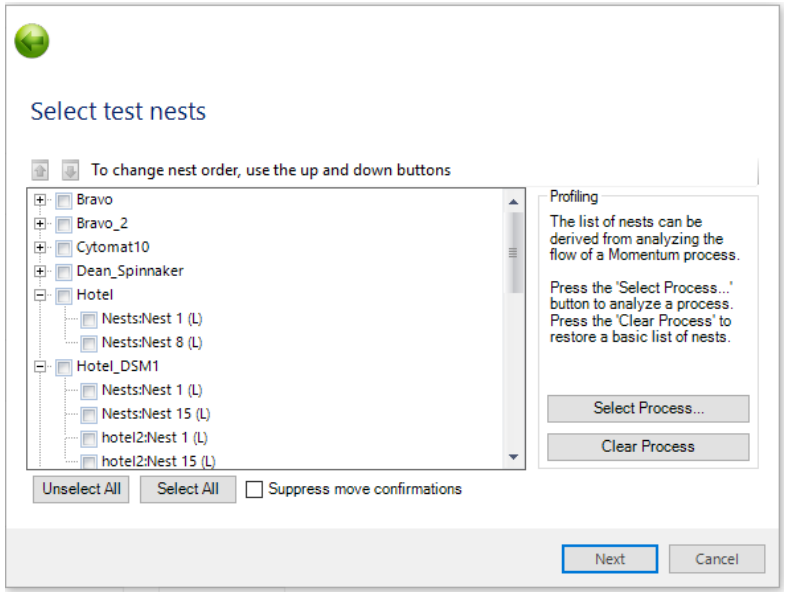
Testing Taught Nest Locations

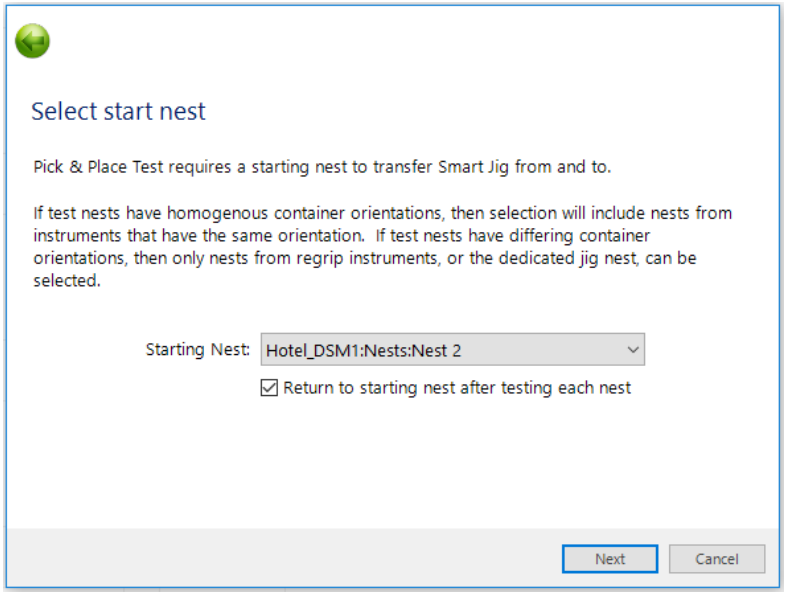
- Test Wizard using the Teach Jig





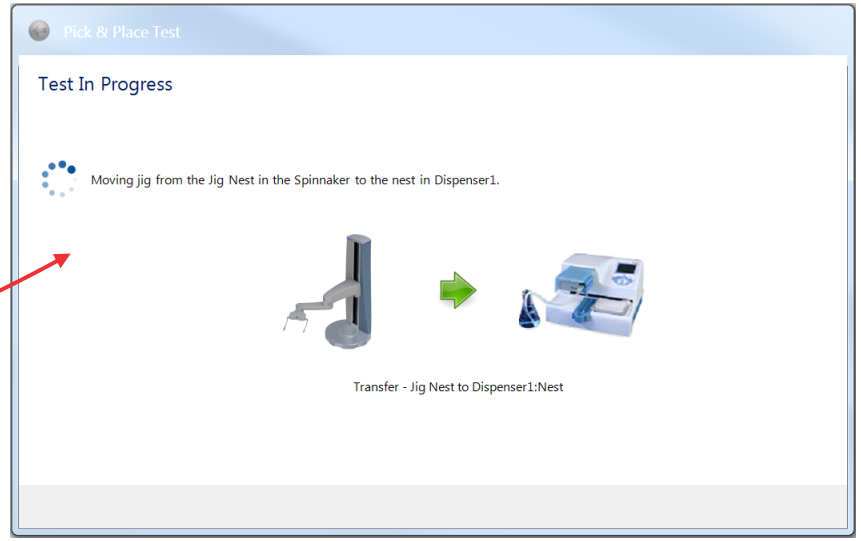
Test Function – Select, Select, Place

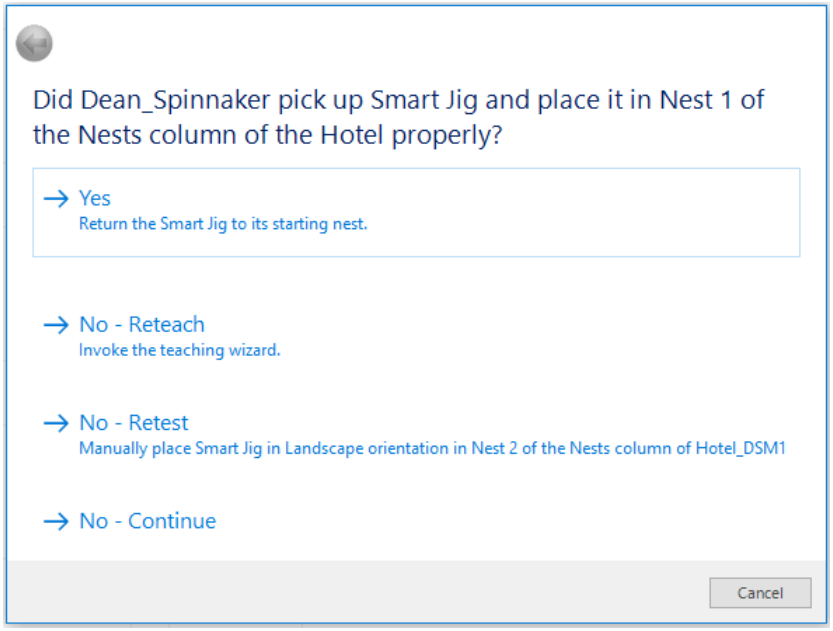




Test Function – Run, Evaluate

- Spinnaker moves the SmartJig to the test nest
  - waits for user evaluation of result

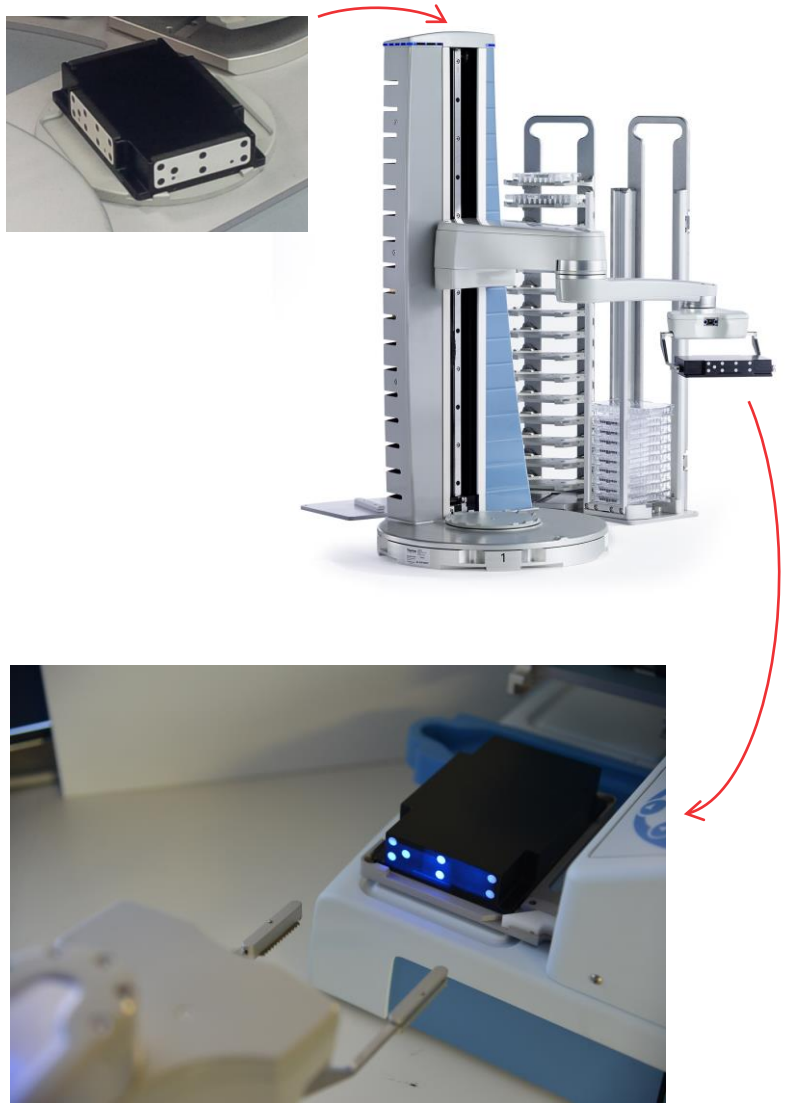




- jig placed in nest properly → finished
- jig not placed in nest properly → reteach
- jig not placed in nest properly → retest

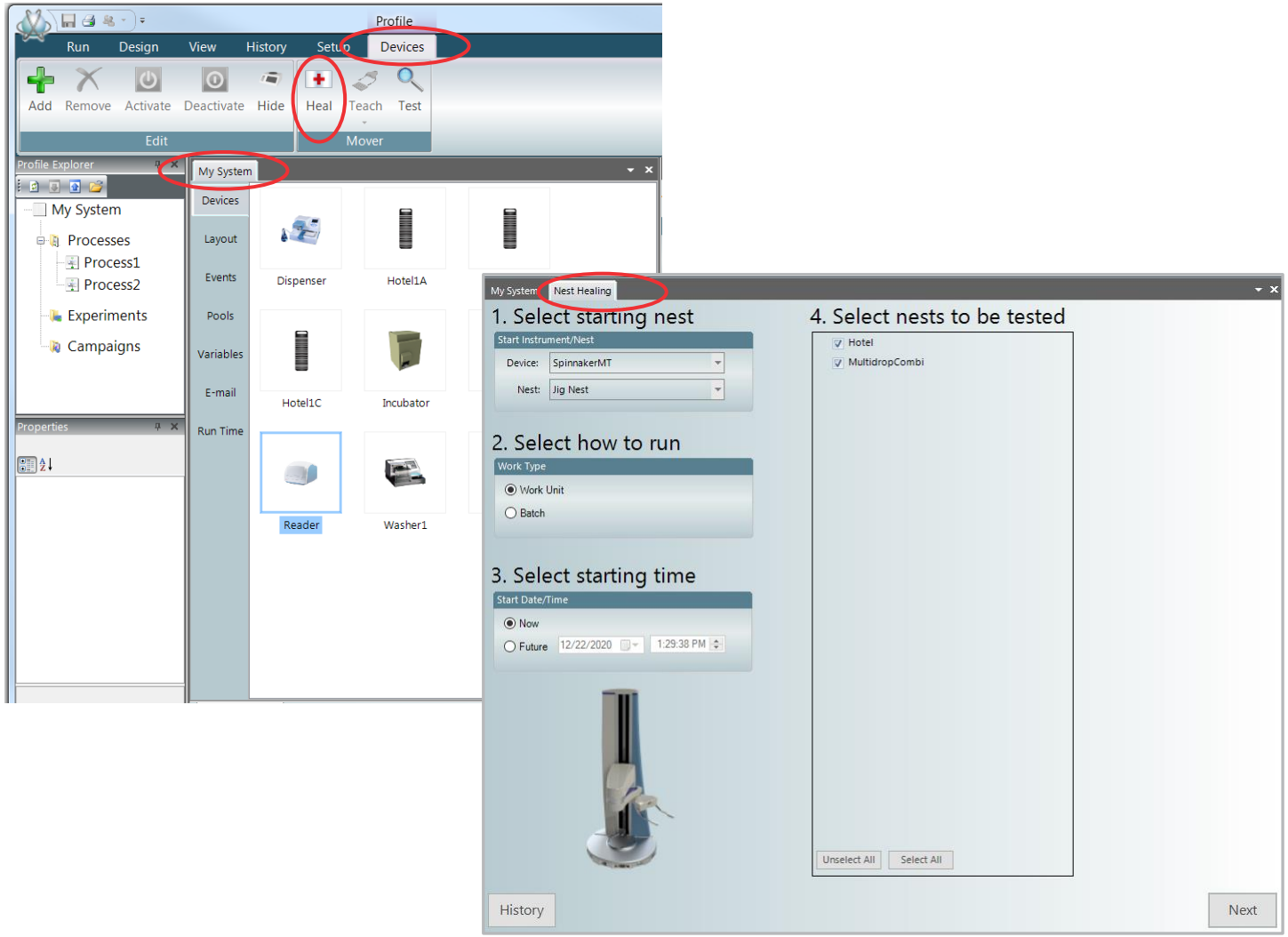
Heal

- Used if a nest location has changed slightly
- Realigned during device maintenance
- Momentum automatically
  - moves the SmartJig to the test nest
  - takes an image and calculates the current position of the nest
  - compares the current position to the existing location
  - if necessary, re-teaches (saves the current position as the location)



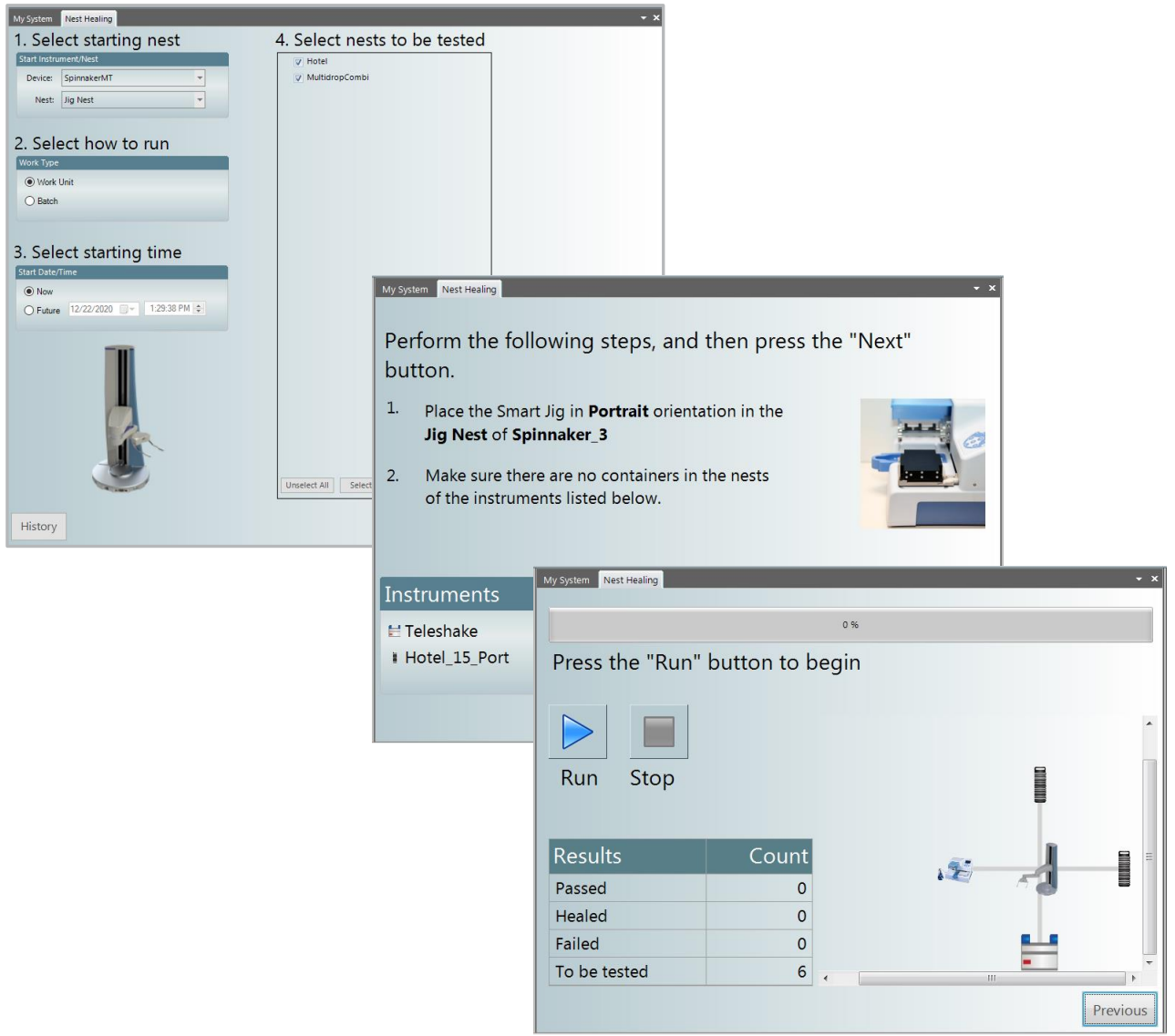
Heal

- accessed through Devices ribbon
- in Mover section, select Heal
  - Nest Healing window opens



Setting-up Heal

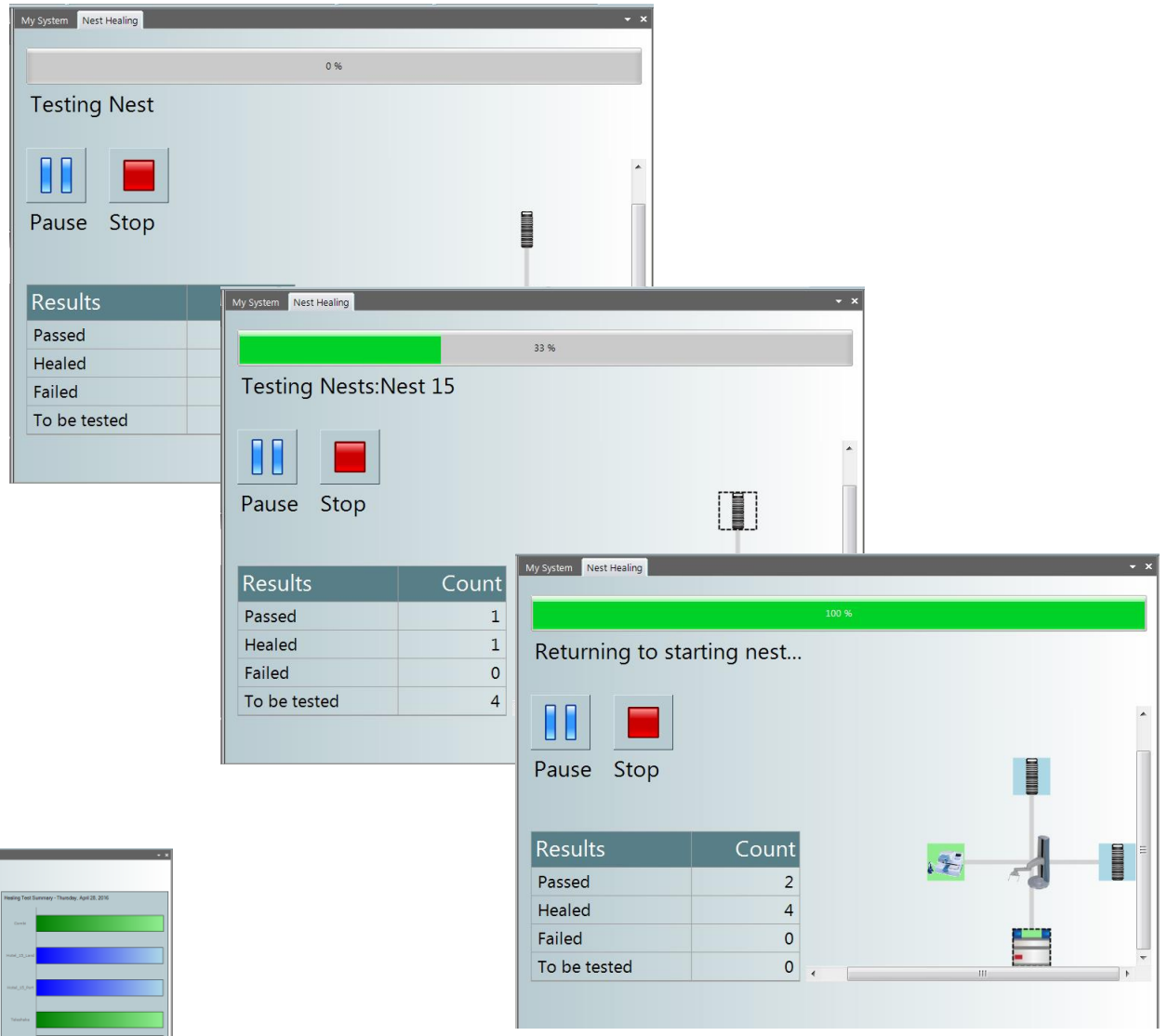
- multiple nests can be checked
- multiple devices
- starting time can be selected
- can be run during ‘down’ times

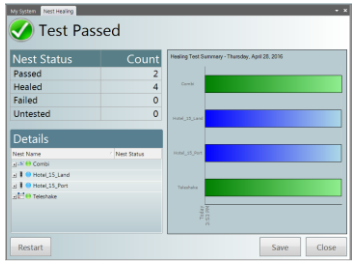


ThermoFisher SCIENTIFIC

Heal – Pass/Heal/Fail

- Action
  - Smart jig moved to nest
  - takes image
  - calculates position
  - compares current to existing location
- Result
  - passed – no change
  - healed – new position taught
  - failed – cannot determine, retry
- Summary
  - displayed
  - can be saved





ThermoFisher SCIENTIFIC

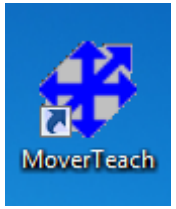
Section 4: MoverTeach

MoverTeach Overview

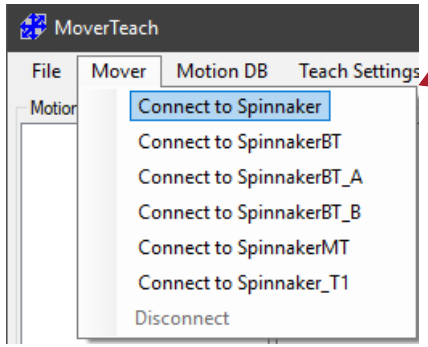
- Requires the user to interact directly with the motion database
- Powerful in making small controlled changes
  - can control movement in one coordinate at a time
- Can teach locations that are complex (obstructed path to nest) and require multiple transit locations
- Can teach a nest that is in open space (waste bin)
- Error recovery
  - you or Momentum pause the system
  - you intervene on the on the mover to correct the situation
  - retrieve a container still in mover gripper
- A new device has been added to the system

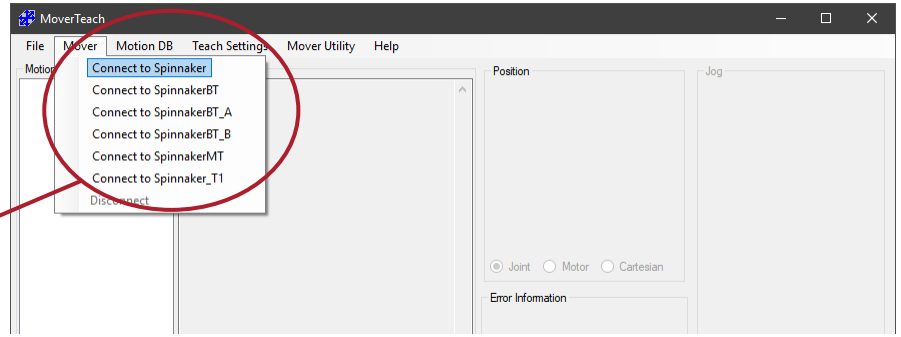
MoverTeach – Start

- Start MoverTeach program

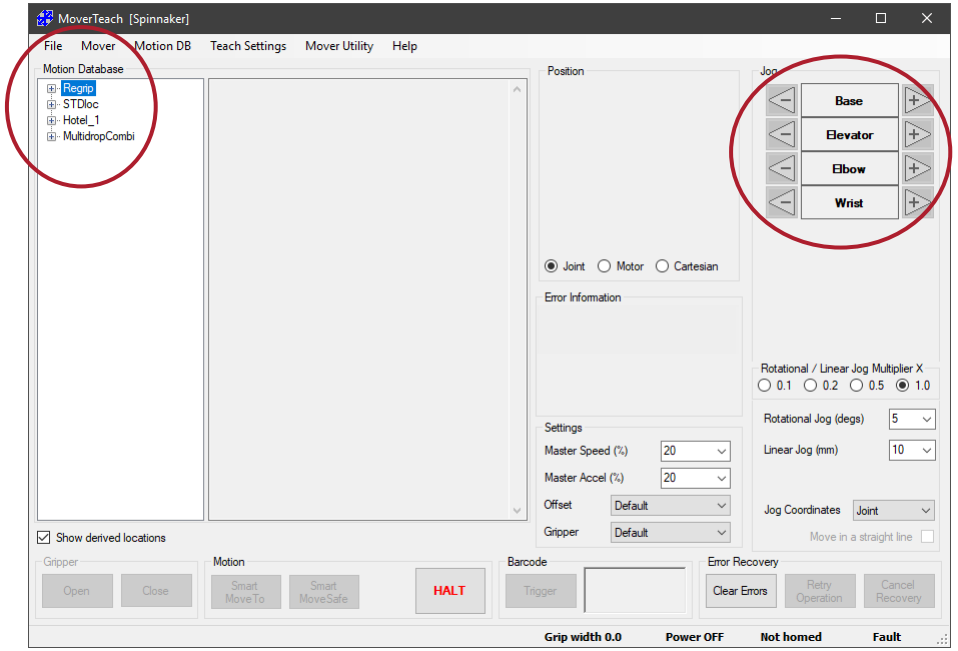


- Connect to your mover

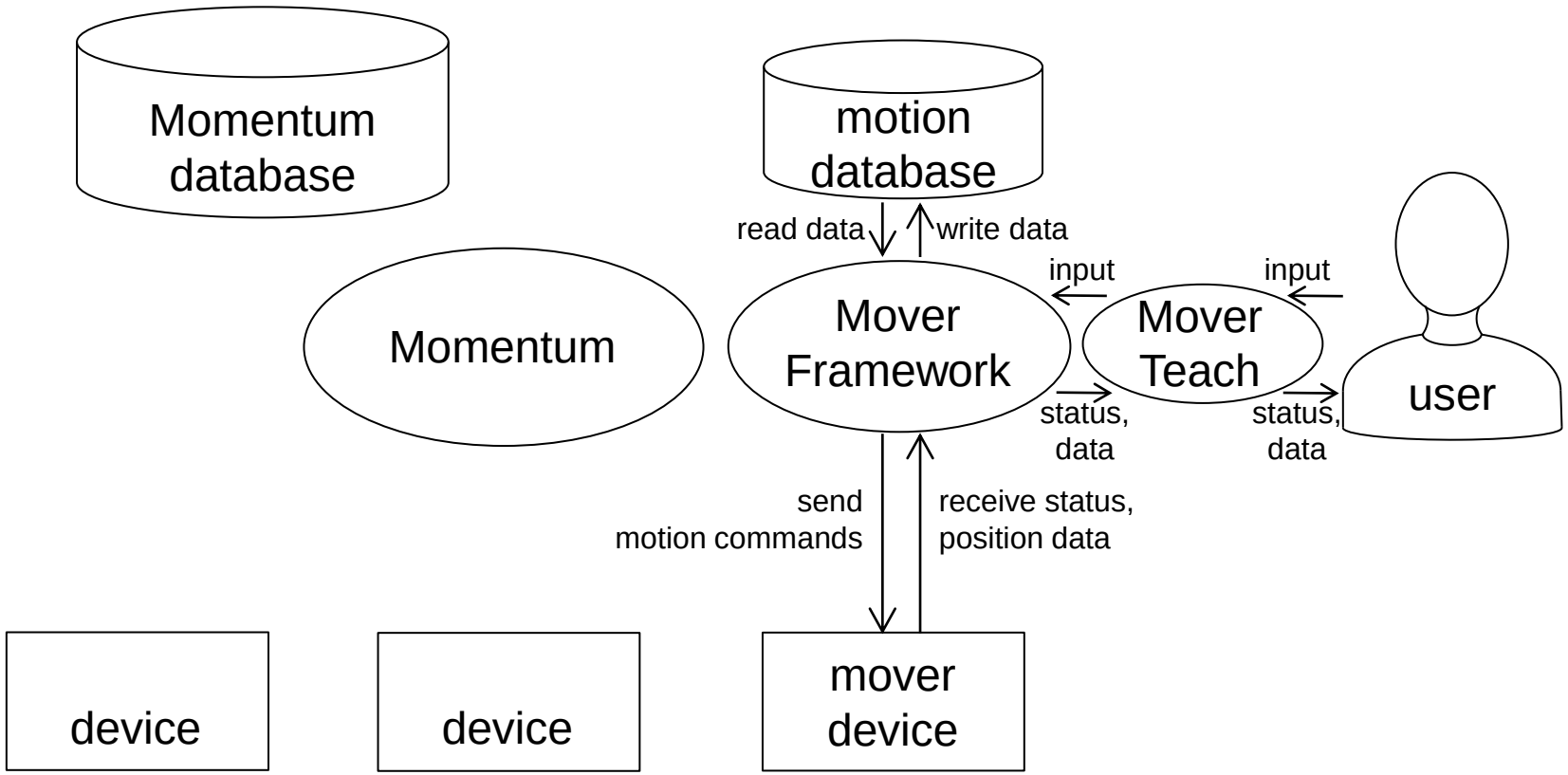




- MoverTeach displays your mover's database of locations (nests) and position controls

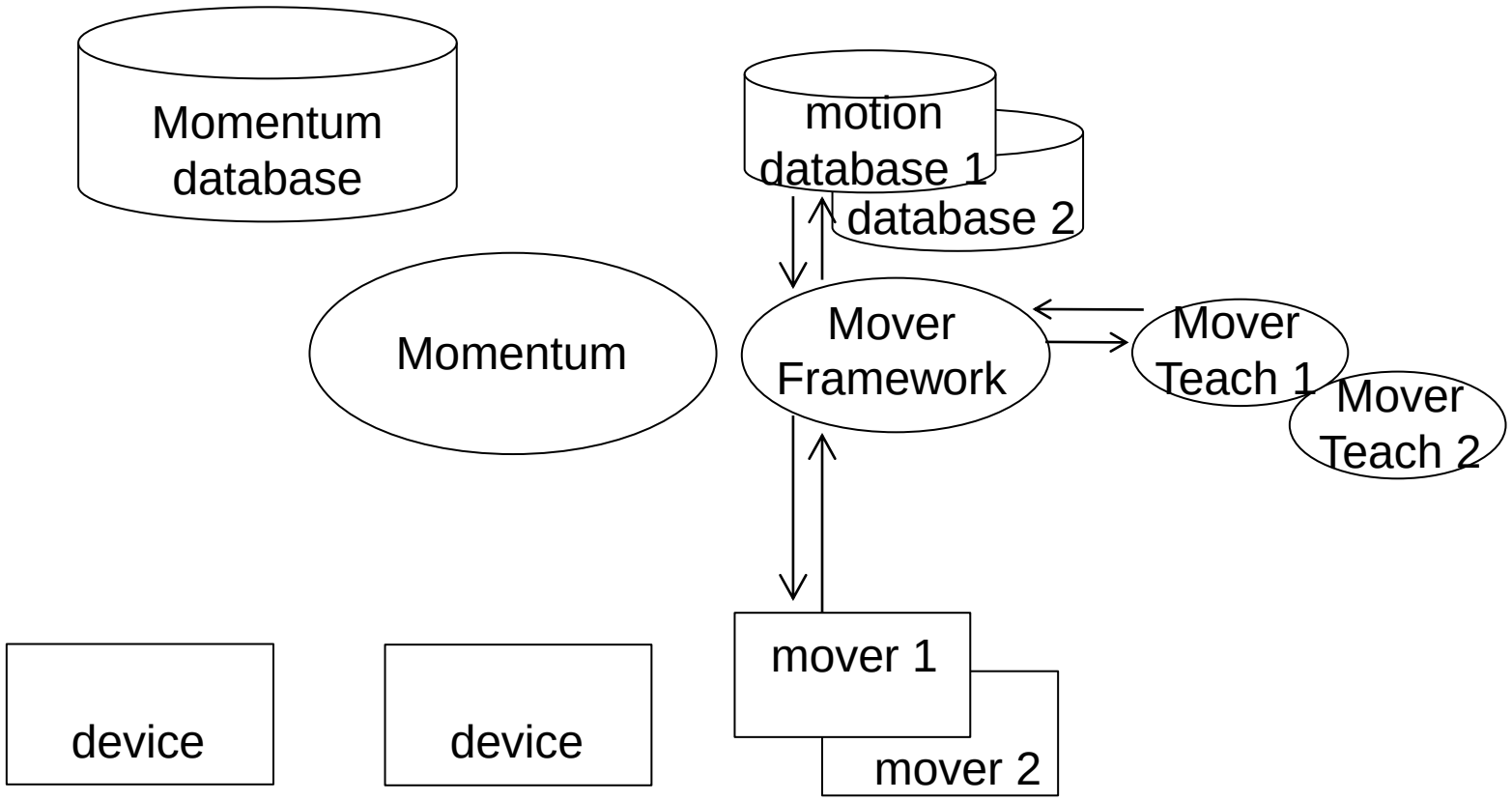


Single Mover



- MoverTeach, interface for the user, takes input, displays status and database data
- MoverFramework, behind the scenes, does the major work
- Motion database, stores all positions for that mover, different from the Momentum database

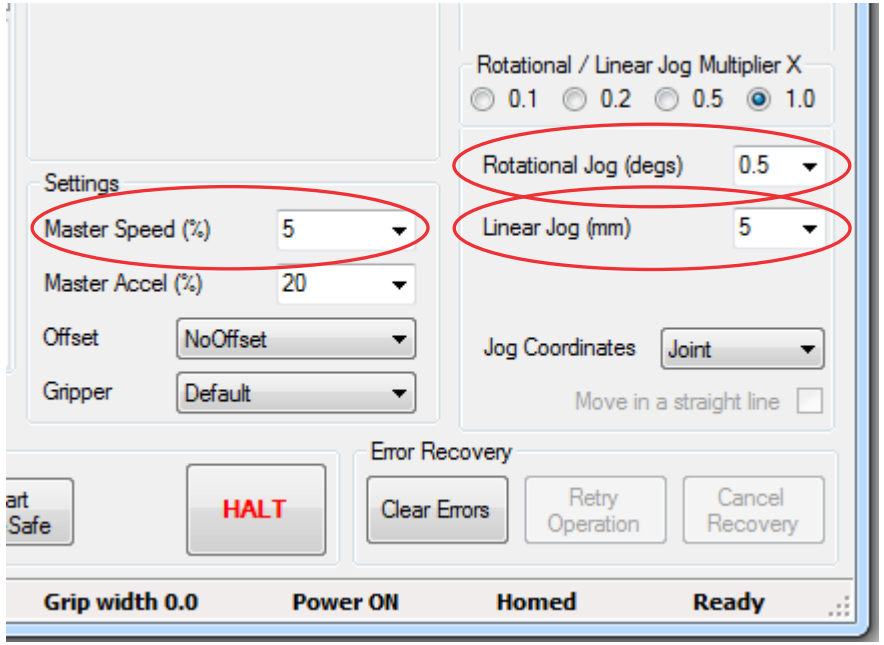
Multiple Movers



- Multiple movers: each mover has a database for its positions, has a connection, can be controlled by MoverTeach
- Only one instance of MoverFramework manages all: all databases, all connections, all instances of MoverTeach

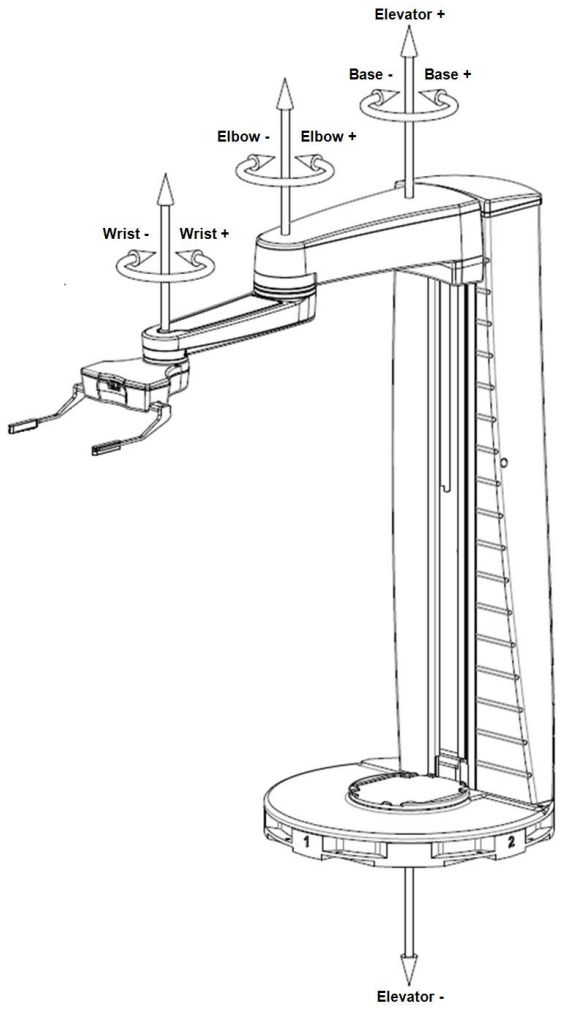
Check Motion Settings

- Safe operation settings
- Speed
  - how slow or how fast the mover travels
  - determines how much or how little time you have to reach the emergency stop and press it
  - 5 % good for learning, 10 % or 20% OK when familiar
- Jog
  - amount of motion each time you click for motion
  - linear jog
    - in millimeters, 0.5 when near nest of device
  - rotational jog
    - in degrees, 0.5 or less when near device
- Jog coordinates
  - each jog control type allows a mover to be moved in a slightly different way
  - each control type is based on a different set of coordinates

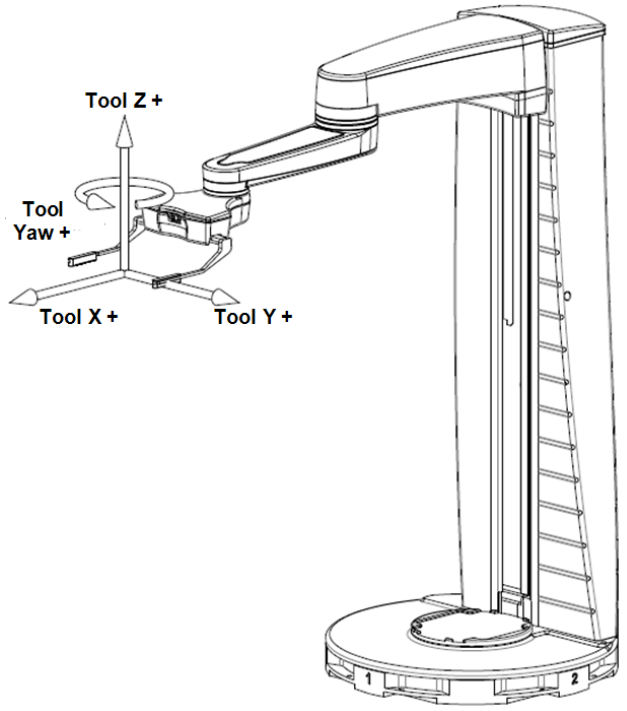


Spinnaker Jog Control Types

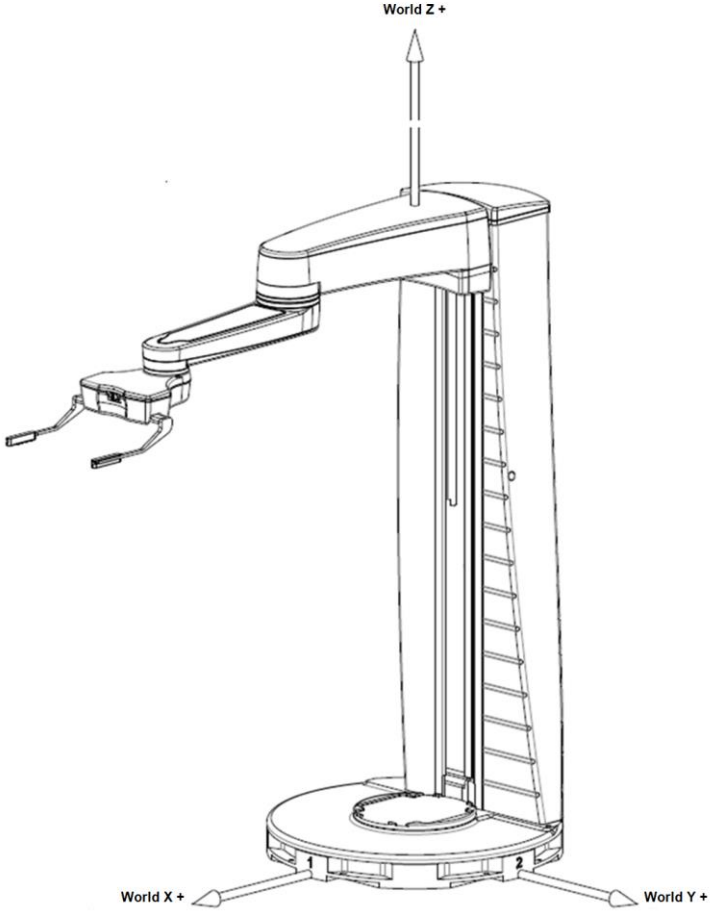
Joint



Tool

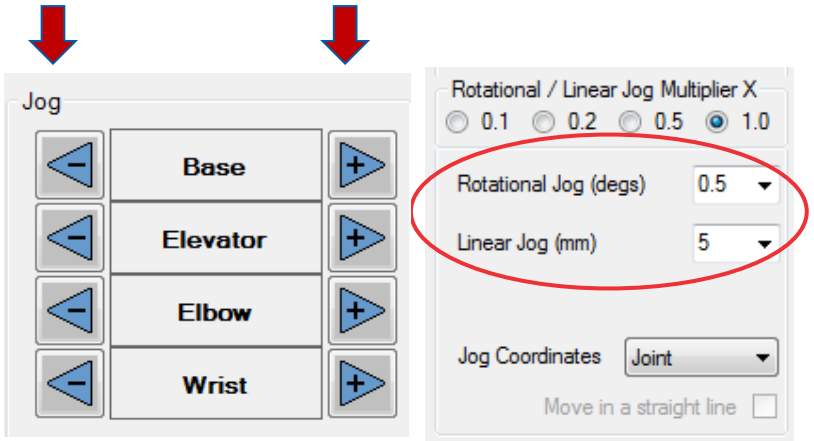


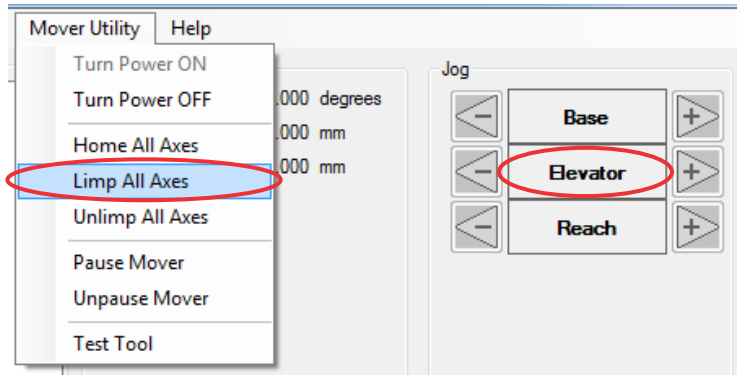
Cartesian

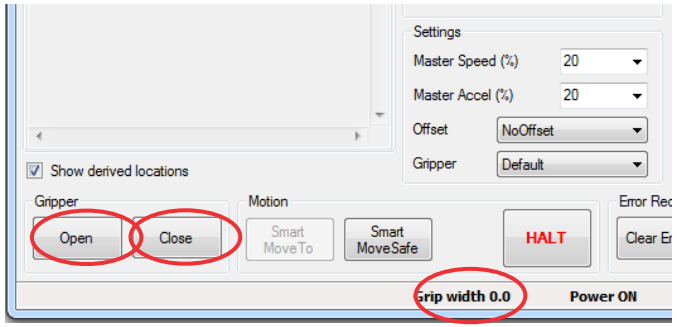


Controlling the Mover by Jogging

- Move under motor control
  - click negative (–) or positive (+)
  - one click is one jog of increment
- Move by limping (remove motor control)
  - limp all axes at once with drop-down menu
  - limp one axis at a time with right-click on axis control
  - manually push arm
  - unlimp when finished
- Open or close the gripper
  - to put or get a plate



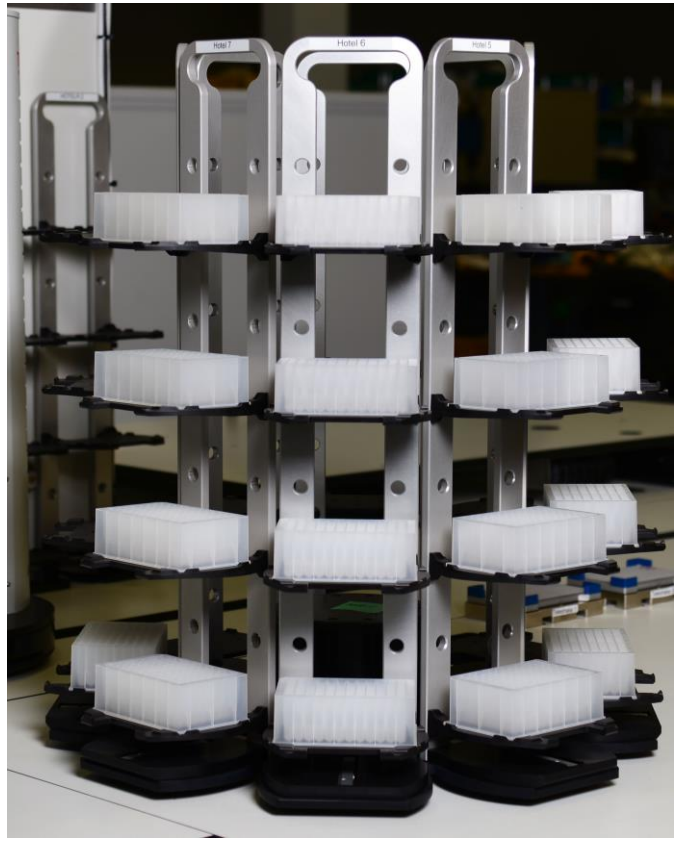




ThermoFisher SCIENTIFIC

Carousel Motion Settings

- Carousel – same motor as rotational base of some movers
  - rotor rotational, around base

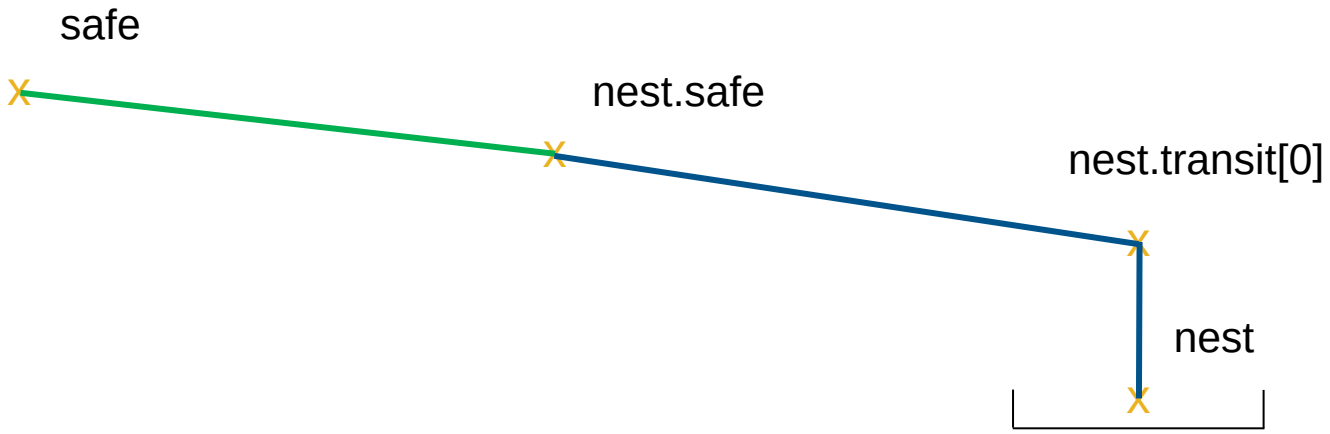


Controlling the Mover with Commands

- Takes knowledge of the motion database.
- Under motor power
  - slow speed, small increments, specific direction (+ or -)
- Using a pre-determined method
- SmartMoveTo – an efficient path from current location to a destination
  - Avoids objects
  - produces an error message if the current/destination location is not on a path (mover collision pushed it off path)
  - can plan a motion by joining paths and selects the quickest path
- SmartMoveSafe – finds a path from the current location to a safe location
- MoveTo – takes the shortest route to destination
  - does not consider possible obstructions
- Get plate into gripper – opens gripper, SmartMoveTo location, close gripper, move to nearest safe location
- Put plate into nest – SmartMoveTo location, open gripper, move to nearest safe location

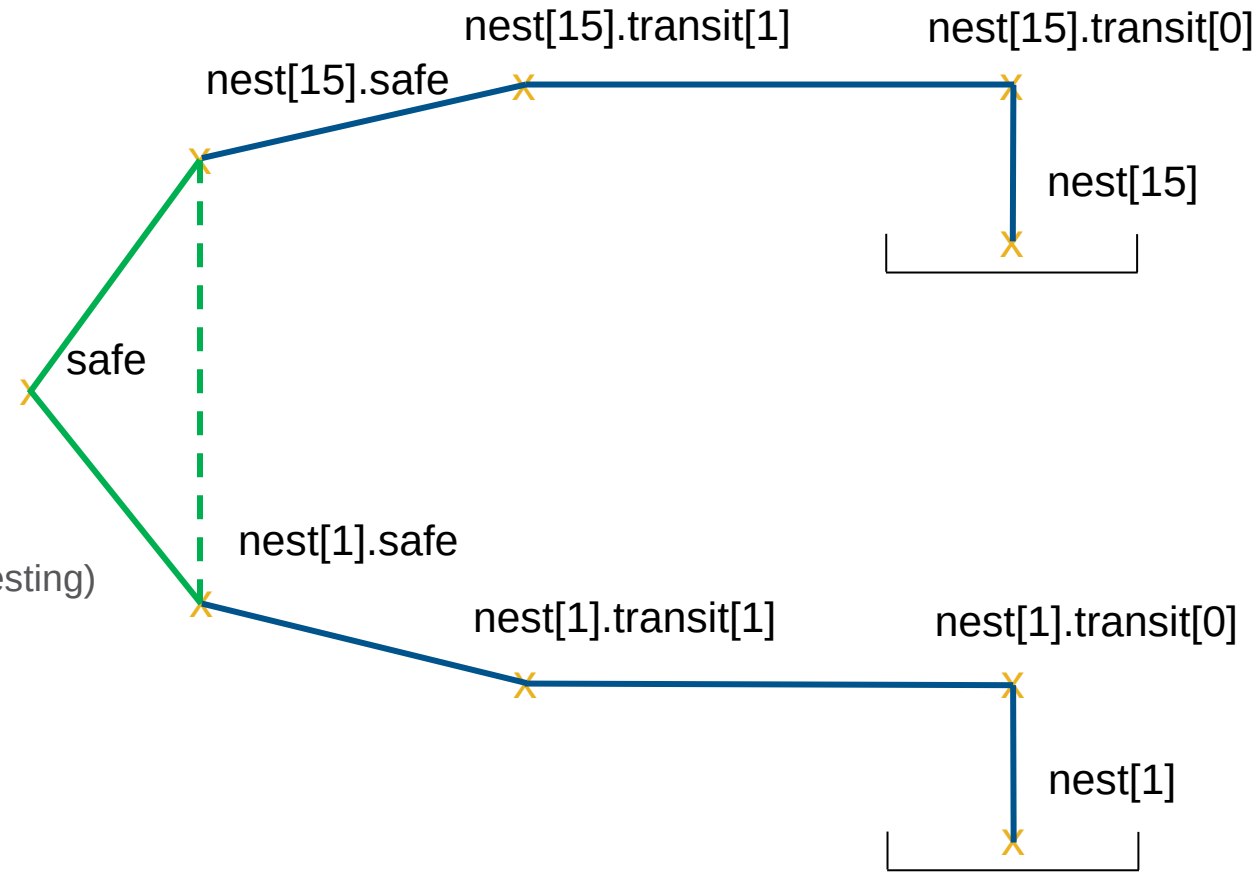
Motion Database Locations – Single Nest

- nest
  - a place for the plate
- nest.transit[0]
  - a location in transit from the nest to the safe
- transit[0] is vertical from the nest
- nest.safe
  - the end of the nest's path,
  - a safe distance from the nest
  - calculated using interpolation
    - from nest to nest.transit, 50 mm up (Tool Z+)
    - from nest.transit to nest.safe, 150 mm back (Tool X-)
- safe
  - the device's safe location
  - motion is safe from here to any other device or from any other device to here



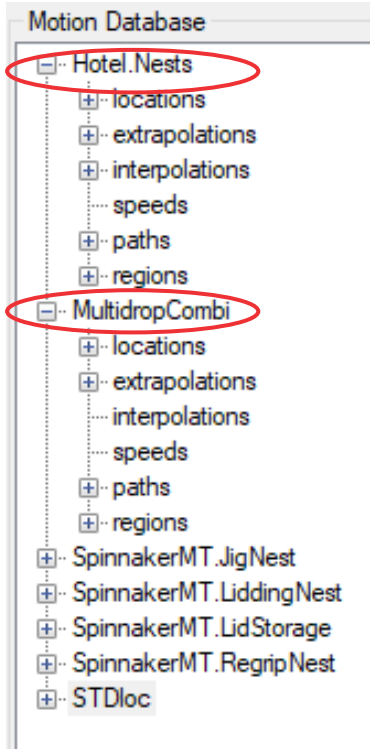
Motion Database Locations – Multiple Nests

- nest has index
  - nest[1], nest[2], …, nest[15]
- more than one transit possible
  - nest[#].transit[0],
    nest[#].transit[1],
    nest[#].transit[2]
- path
  - connects nest[#] through transits to nest[#].safe
- region
  - connects all nest[#].safe (ends of paths)
    to device's safe
  - also connects all nest[#].safe to each other (useful for faster testing)



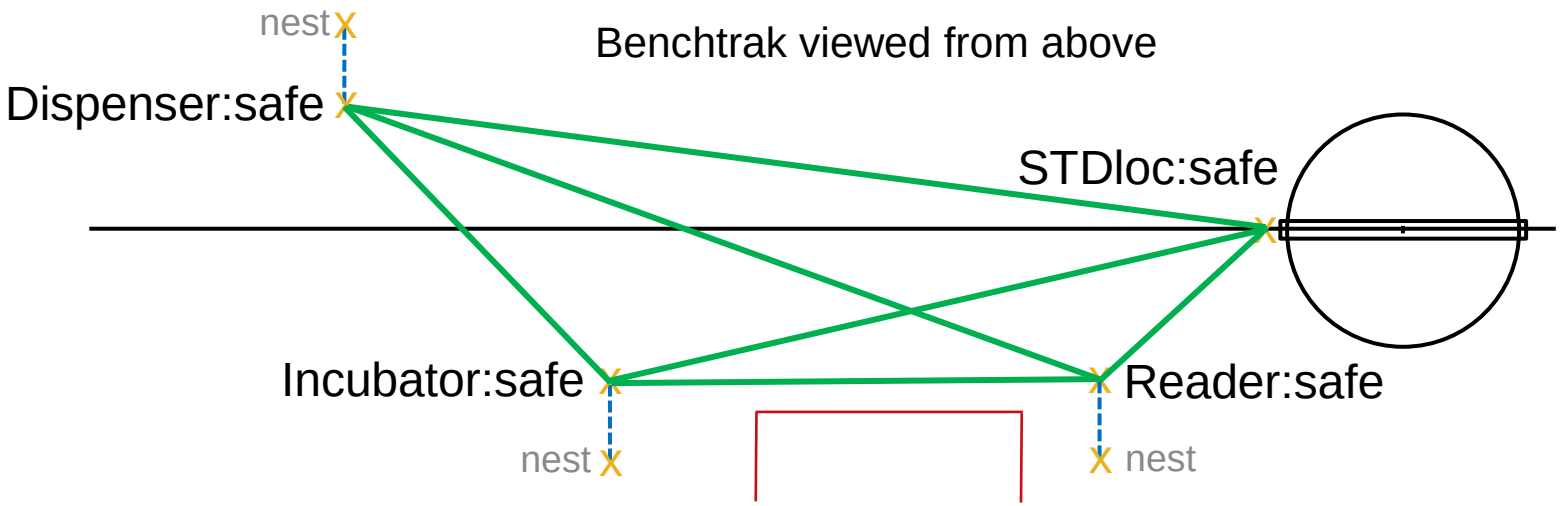
Motion Database and Its Sections

- motion database
  - mover's data about devices and their locations
- one section for each device
  - identical name as in Momentum
    (usually identical but can be mapped in Momentum)
- one section for general system-wide data
  - STDloc (STanDard locations)



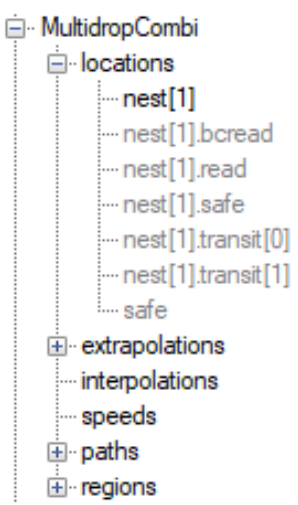
Motion Database – STDloc

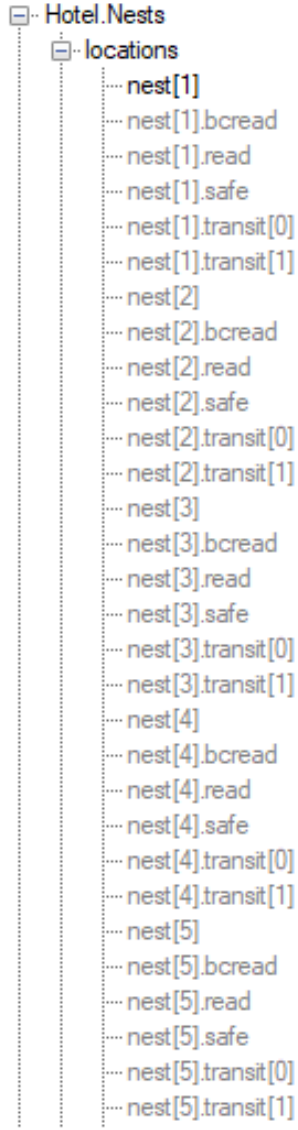
- STDloc (STanDard locations)
  - one section for general, system-wide data
- safe
  - this section's general safe, likely in the middle away from all others
- region
  - connects this section's safe and all safes of all other sections
  - it is safe to move from any one to any other



Motion Database Subsections

- All locations that have been taught appear black
- Locations that have been extrapolated or interpolated appear gray





MoverTeach – Extrapolation and Interpolation

- extrapolation
  - a mathematical rule, start with one location, calculate another location
  - example: an unobstructed device, teach the nest, from this nest extrapolate the nest.transit [0]
  - possibly have many extrapolation rules: from nest extrapolate nest.transit[0], from nest.transit[0] extrapolate nest.safe, etc.
- interpolation
  - a mathematical rule, start with two locations, calculate many in between
  - example: a hotel with nests in a straight line, teach the bottom (1), teach the top (8), calculate all nest in between (2, 3, 4, …, 7)
  - possible have many interpolation rules: interpolate nests, interpolate transits, interpolate safes, etc.
- reduce work
  - teach two nests: nest[1] and nest[15] (Spinnaker)
  - extrapolate and interpolate for all other locations

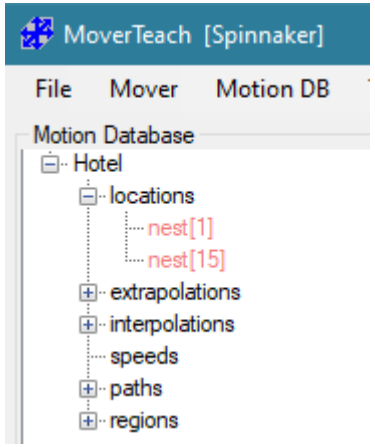
Error Recovery Steps

- Use SmartMoveTo whenever possible
- If not possible, for example, after collision and mover is away from all paths.
  - Slowly, carefully MoveTo nearby location. From here, SmartMoveTo central safe location (STDloc).
  - Slowly, carefully retract mover using small increments, specific direction (+ or -). From here MoveTo central safe location.
  - If plate needs to be recovered from gripper, SmartMoveTo a location where the Open Gripper command can be used to release plate

Section 5: Teaching or Re-Teaching a Nest with MoverTeach

Teaching the New Device Locations

- Teach the locations in red
  - the locations remain red until taught
  - taught locations appear black
  - extrapolated or interpolated locations appear grey



Moving and Teaching Steps

1. Select location
   - in device section, under locations, highlight the location or add new
2. Get plate into gripper from a known good nest in the correct orientation as the nest to be taught (i.e. portrait or landscape)
   - can use Regrip nest
   - use the Smart jig
   - fits into gripper fingers
   - smooth side down, indentation side up, small round indent towards mover
3. Bring mover close to location
   - SmartMoveTo nest.transit[0] (if re-teaching nest)
   - limp mover and manually adjust position or make small controlled moves
4. Fit Smart jig into nest
   - Visually inspect jig in nest for equal spaces around sides
   - Slide, tap jig down against floor of nest, metal jig rings if too high
5. Make sure that the jig rests in the nest without pressure on the fingers

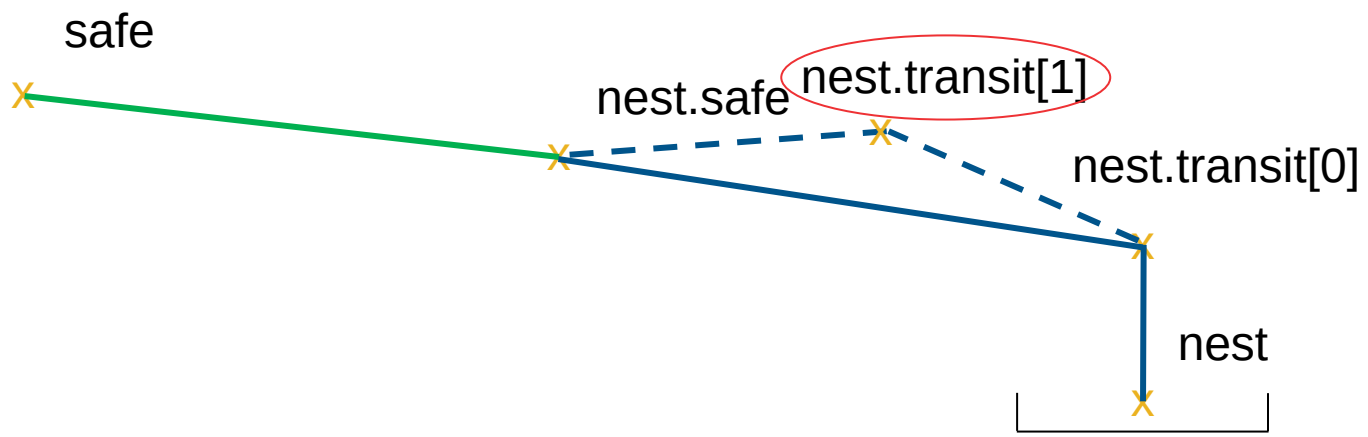
Finalizing Teaching – Saving Taught Location

1. Right-click menu, select Teach … Location
   - Teach Cartesian Location
     - nest, nest.transit, nest.safe
2. Right-click on device, Recalculate derived locations
3. Save changes
   - taught/re-taught location is in MoverTeach, not yet saved to database
   - Motion DB drop-down menu, select Save Motion Database
4. Save changes
5. Refresh database display

Changing an Existing Path in Motion Database

Changing an Existing Path of a Mover

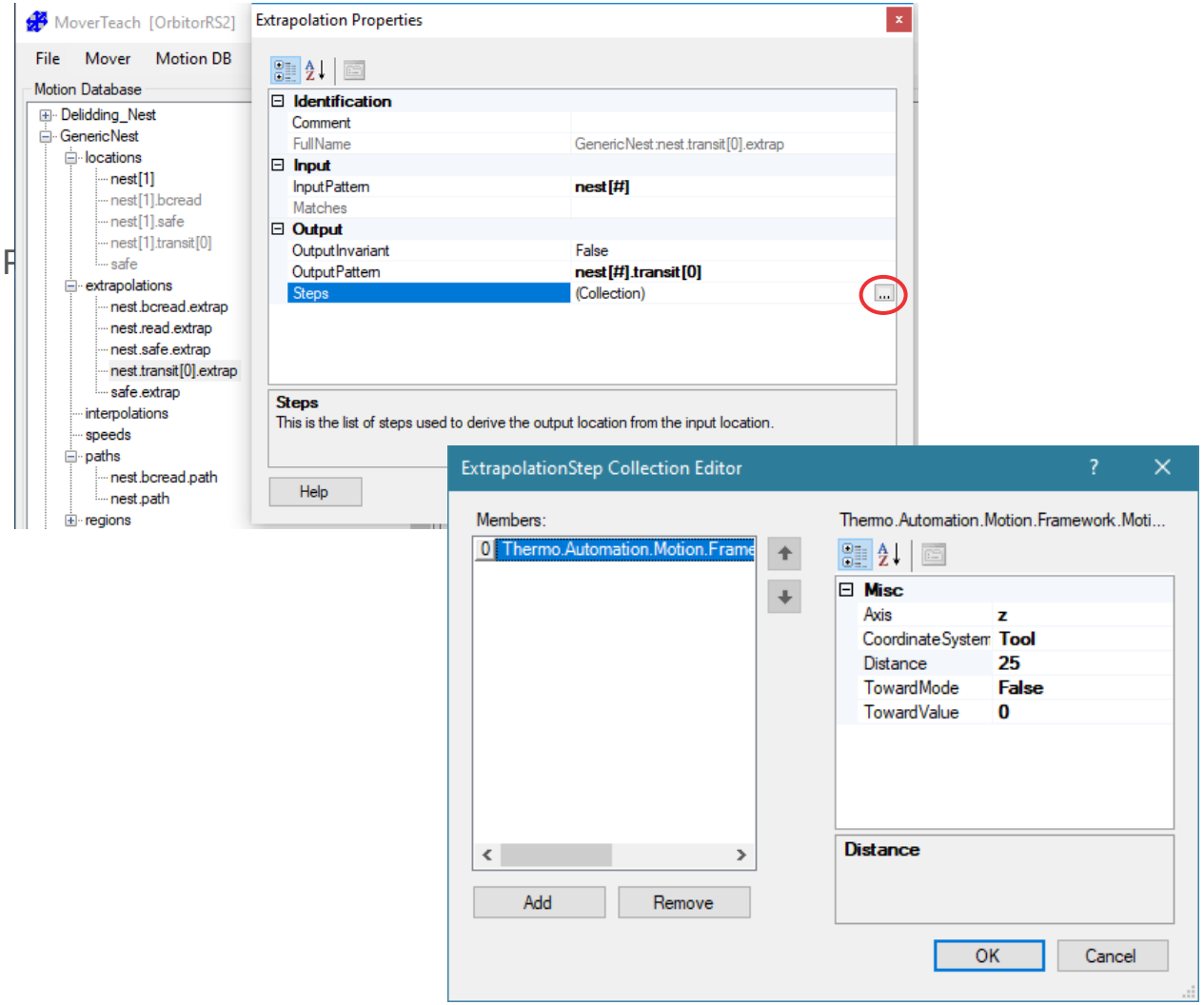
1. Changing the height of nest.transit[0]
   - to enter a restricted nest
   - to decrease height if outside upper limit of the mover
2. Adding a new location to an existing path to go around an obstacle



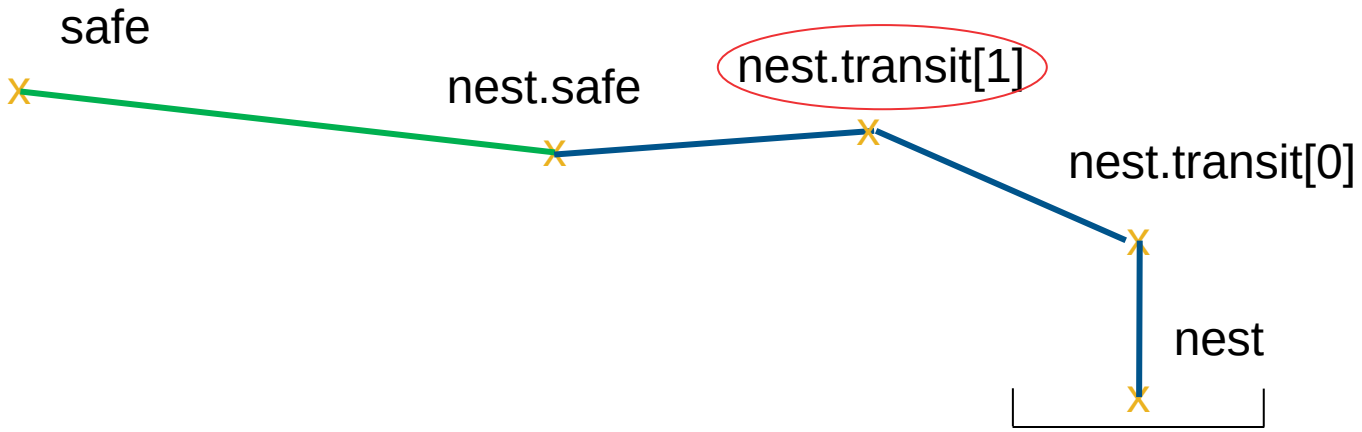
1. Steps to Changing the Height of nest.transit[0]

- Must change the Extrapolation Properties

1. Expand the MD for the device
2. Expand the extrapolations section
3. Double-click nest.transit[0].etrap to open Extrapolation P
4. Select Steps
5. Click on the ellipsis to open Collection Editor
   - Axis Z – change 25 mm to 18 mm
6. Save Motion Database



2. Adding a New Location to an Existing Path



- To go around an obstacle, it may be necessary to add another location than what MoverTeach sets as default
  - safe, nest.safe, nest.transit[0], nest

- Must add nest.transit[1] by changing the extrapolation and interpolation properties
  - if the new location is only taught, it does not automatically add the extrapolations and interpolations important for multi-nest devices

Steps to Add New Location to an Existing Path

single nest device

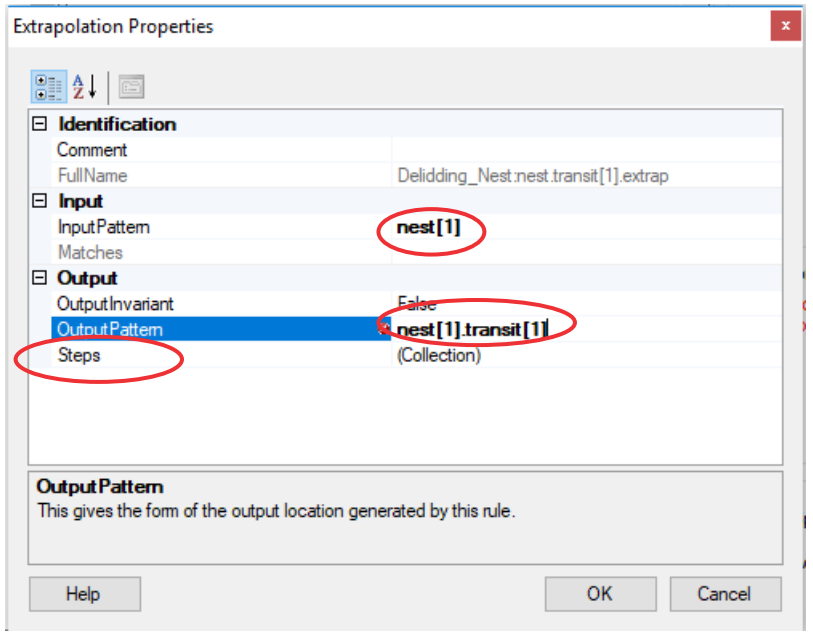
1. add new location by Extrapolation
2. add Extrapolation rules
3. add new location to existing path

multi-nest device

1. add new location by Extrapolation
2. add Extrapolation rules
3. add new location to existing path
4. add New Interpolation

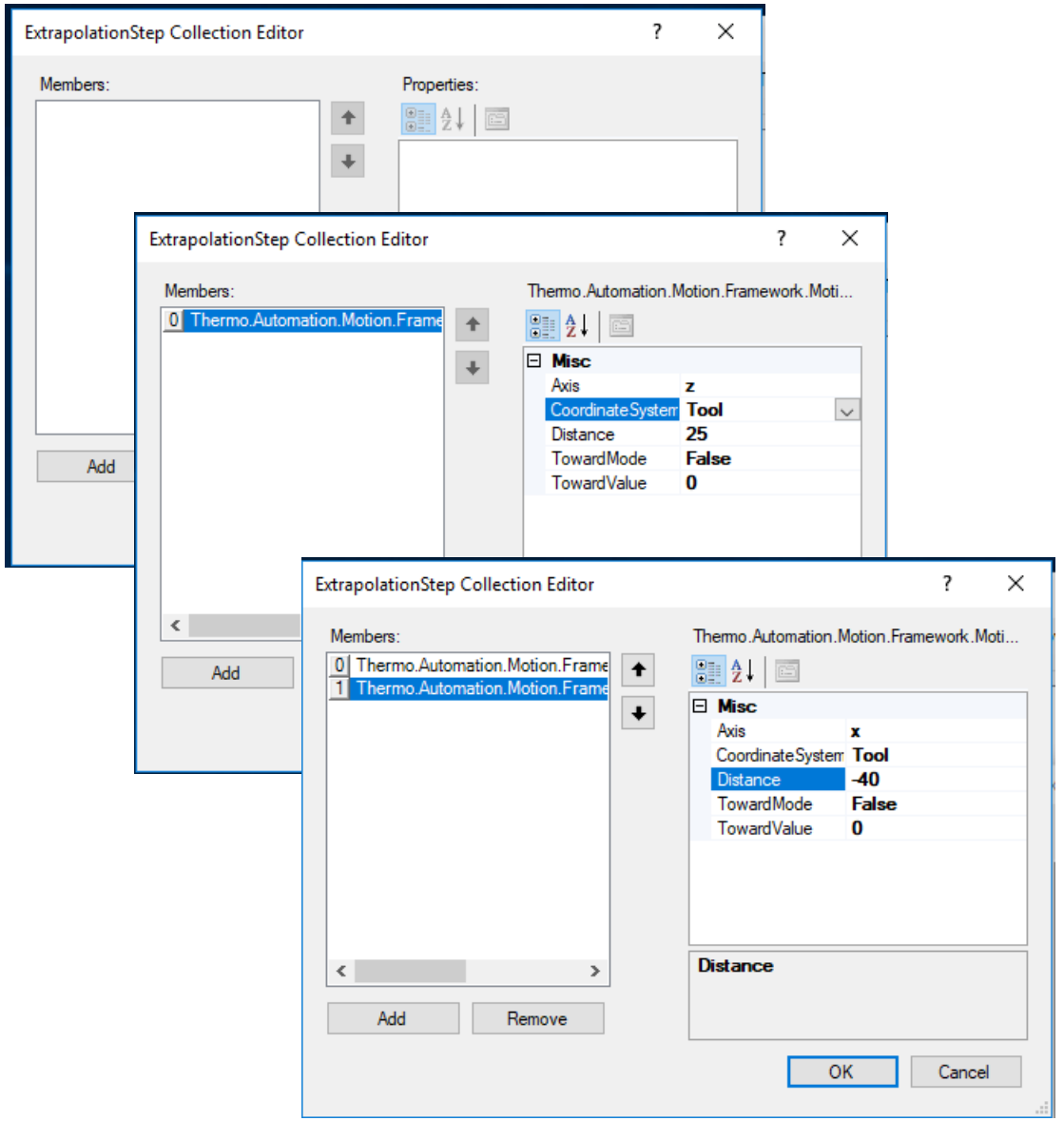
1. Add New Location by Extrapolation

- Add New Extrapolation
- Name extrapolation (follow naming conventions)
  - nest.transit[1].extrap
- Must state what to base the extrapolation on – Input Pattern
- Must state where we want the location – Output Pattern
- Steps must be changed to reflect the newly added location



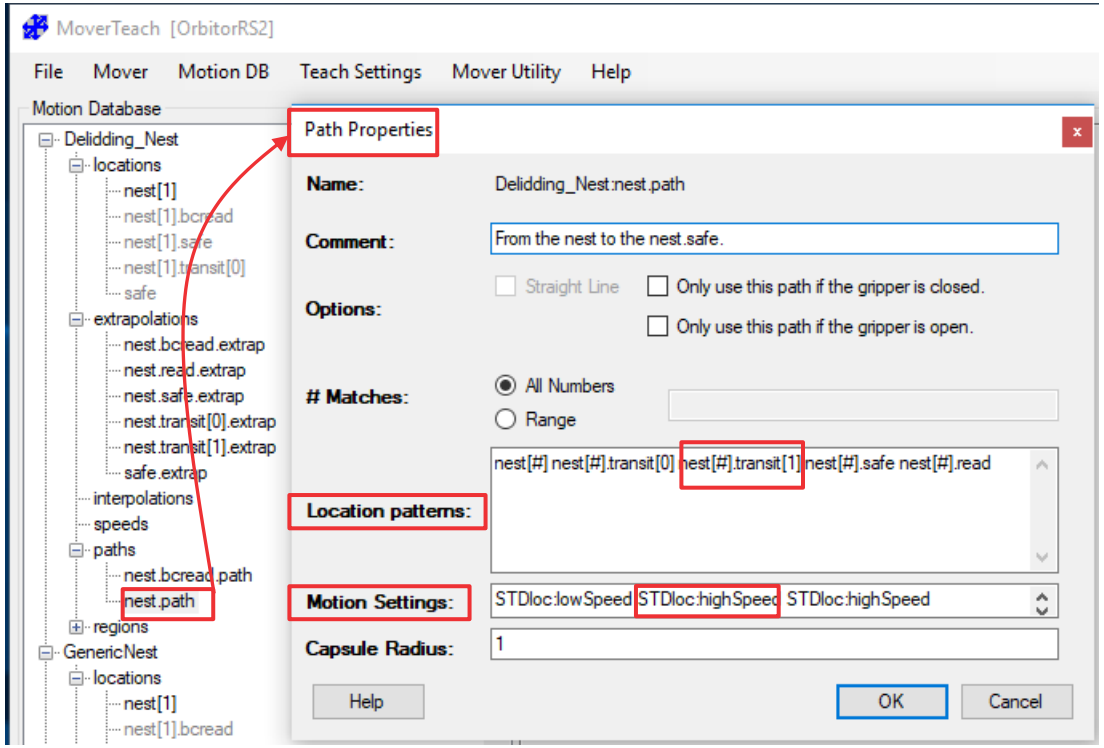
2. Add Extrapolation Rules

- Steps must be changed to reflect the newly added location
- Collection – add a rule
- Rules state the relative change in direction
  - in the ‘z’ axis 25 mm
  - in the ‘x’ axis – 40 mm



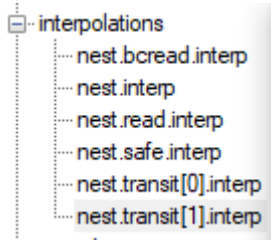
3. Add New Location to Existing Path

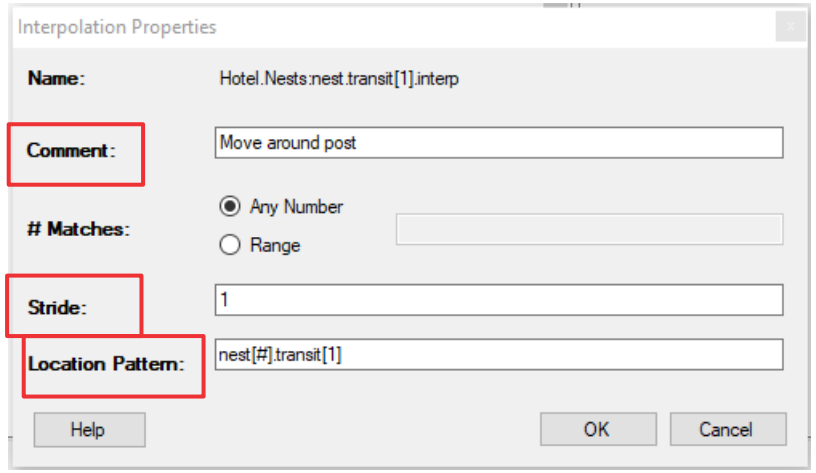
- Must create the location on the path
  - Location patterns
- Must add the speed to take on that portion of the path
  - Motion Settings
- Save Motion Database



4. Add Interpolation for Multi-nest Device

- Add New Interpolation
- Name interpolation (follow naming conventions)
  - nest.transit[1].interp
- Add Comment
- Indicate Stride (how to count nest1, 2, 3…or nest2, 4, 6, 8)
- When giving Location Pattern, use # to represent multiple numbers of nests





Summary

- Momentum Teach Wizard guides users through process to teach or re-teach nest locations
- Spinnaker can use camera in conjunction with a Smart Jig to – Teach, Test, and Heal nest locations
  - all three functions can be accessed on the Devices tab of the system Profile
- for all other movers, Momentum guides users through a Manual Teach
  - accessed through the Devices tab of the system Profile
- mover locations, paths and regions are stored in the Motion Database and accessed by Momentum