

Calibre 2024.1 Release

Highlights

Calibre Semiconductor Manufacturing Solutions

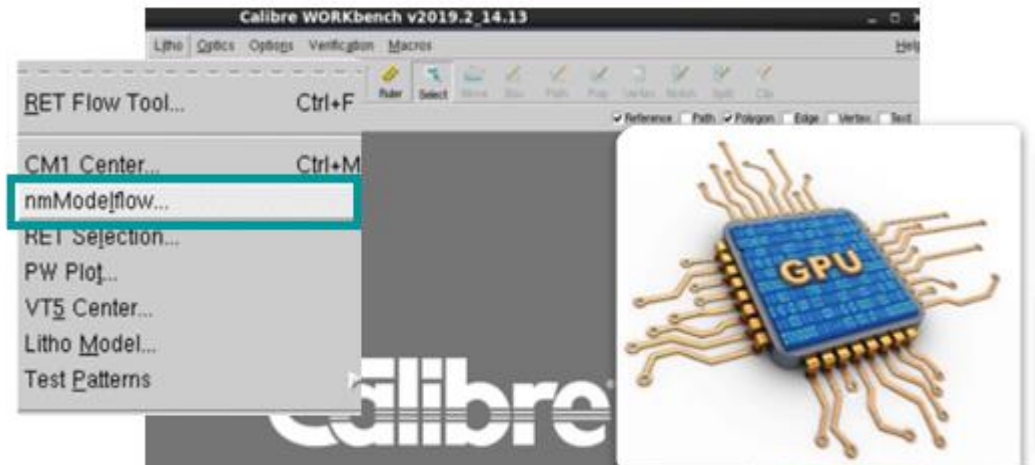
February 2024

Table of Contents

Topics	Page	Topics	Page
Extended GPU Support for Calibre RET Modeling	P.3	Updated Curvilinear SRAF Template and New Keywords for Configuring MATE	P.11
New CM1 Modelforms for EUV and Machine Learning Resist Model Training	P.4	New OPCverify Check to Detect Sharp Turns in Contours	P.12
New Commands and Options in Calibre nmModelflow	P.5	Calibre OPCverify New Features	P.13
More Calibre nmModelflow Updates	P.6	New Best Practice Recommendations for Calibre OPCverify	P.14
Calibre RET Modeling Best Practices	P.7	Updates to Machine-Learning Data Generation in Calibre ML-LFD	P.15
Calibre SEMSuite Enhancements	P.8	Calibre SONR Updates	P.16
New Features and Changes in Curvilinear OPC and Biasing Solutions	P.9	Enhanced Operations Table in CalDash to Highlight Operations with Potential Low-scaling Issues	P.17
Calibre RET MEMOPC New Defaults	P.10	New CalScope Options	P.18

Extended GPU Support for Calibre RET Modeling

- GPU acceleration can be used in conjunction with some Calibre WORKbench commands for RET modeling applications.
- ~7x TAT improvement on DDM / kernel DDM model generation with significant core FDTD calculation sped up (~80x).
- Starting from 2024.1 release, GPU acceleration can also be used to support modeling commands in Calibre nmModelflow.
- GPU acceleration now supports CM1 model calibration and machine learning resist (N2R) and etch (N2E) model training.



New CM1 Modelforms for EUV and Machine Learning Resist Model Training

- New CM1 modelforms 27, 32, 33, 34, and 98 were created for EUV modeling and machine learning resist model training (N2R).

Modelform	Descriptions
Modelform 27	This modelform extends modelform 10 by adding the slope, Laplacian, contour curvature, double dissolution, and all-mask and all-edge mask loading. Use as input for N2R calibration and training.
Modelform 32	This modelform extends modelform 22 by adding a multi-range SEM SHRINK dose and an all-mask mask loading term. This model is recommended for EUV modeling.
Modelform 33	This modelform extends modelform 22 by adding a multi-stage SEM SHIRNK dose, SEM electron absorption, and an all-mask mask loading term. This model is recommended for EUV modeling.
Modelform 34	This modelform extends modelform 22 by adding double contour curvature, triple dissolution, shrink, and allmask and all-edge mask loading. This model is recommended for EUV modeling.
Modelform 98	This modelform extends modelform 22 with doubled b-terms, quadruple polarity shrink, horizontal bias, sidewall bias, doubled contour curvature, pattern density, 10 dissolution kernels, doubled mask loading, and 72 crossterms. Use as input for N2R calibration and training.

New Commands and Options in Calibre nmModelflow

New Default!

New command to fix designs with out-of-bounds gauge coordinates

- The new `mdf gauges shift_to_32bit_zone` command shifts all gauges and associated geometries that have coordinates outside a 32-bit safety zone into it and saves the modified gauge data together with layout to the specified files.
- The new command can be used when an activated gauge object shows the following warning.

```
WARNING: Gauges with coordinates outside the 32-bit safety zone are detected.!! To be able to run simulations, you need to either disable these gauges or use the 'mdf gauges shift_to_32bit_zone' command.
```

New options and default for machine learning model optimization

- `mdf ml optimize_n2r` command has new options to specify anchor groups to assist in optimizing model selection.

```
mdf m1 optimize_n2r ..... [ -gg_group gg_group ]  
[ -ccal_group ccal_group ]
```

- Users can specify a gauge group or a site group tag to use as an anchor group.
- The `mdf ml optimize_n2e` command now has contour correction deactivated by default. Users can activate it by using `-contour_correction`.



More Calibre nmModelflow Updates

New feature to support sequential CM1 calibration

- The `mdf gui params resist` command has been modified to output the last resist model that was loaded.
- The Flow Stage Wizard Resist Calibration page has been modified to support sequential CM1 calibration.

New VEB model default version 2

- Starting with 2024.1, all new calibrated VEB models use version 2, which includes the following updates:
 - Updated `average_bias` algorithm improves VEB modeling accuracy and performance.
 - `spline` and `akima` options are added to the segmentation parameter.

`version 2`
`modelType VEB`

More nmModelflow updates

- `mdf cutline cm1_model_terms -normalize` argument has a new setting of 2, which normalizes the terms by gauge in the output files.
- The `-mlpmod` argument to the `lithomodel create` command now supports a single mask litho processing (MLP) filename and the name of a directory containing multiple MLP files.

Calibre RET Modeling Best Practices



Best practice recommendations for optical model usage with Calibre OPCpro

- Siemens EDA recommends
 - Specify optical model version 8.
 - Specify `kerngrid` and `hoodpix` values so that the `hoodpix/kerngrid` ratio is an even integer.

Best practice recommendations for High NA EUV

- Siemens EDA recommends 50 kernels for low k1 and ~30 kernels for high k1.

technology node	lithography	$k1 = (\text{min litho half-pitch})/(\lambda/\text{NA})$	# kernels
10/7nm	DUV+MP	0.27 - 0.35	50
10/7nm	EUV	0.32 - 0.40	30
5/3nm	DUV+MP	0.27 - 0.35	50
5/3nm	EUV	0.32 - 0.40	30
2/1nm	EUV+DP	0.32 - 0.40	30
2/1nm	EUV	0.27 - 0.35	40
2/1nm	high NA EUV	0.32 - 0.40	30

Calibre SEMSuite Enhancements

Contour Data Flow (CDF) Tool Enhancements

- The CDF Repeat Run Metrics table is reorganized to display addition metrics.
- The CDF Repeat Run Metrics table has new “Add filter” and “Clear filters” buttons.

Target Id	Target Name	Repeat ID
Dose	Focus	Repeat SEM Image
Measured CD	Polygons #	Min CD (Inner/Outer)
Max CD (Inner/Outer)	Avg CD (Inner/Outer)	CD Mismatch (Inner/Outer)
Missed # (Inner/Outer)	Bridged # (Inner/Outer)	Splitted # (Inner/Outer)
Confidence % (Inner/Outer)	CDF Repeat Run Metrics Table	

Raw Data Filtering (RDF) Tool Enhancements

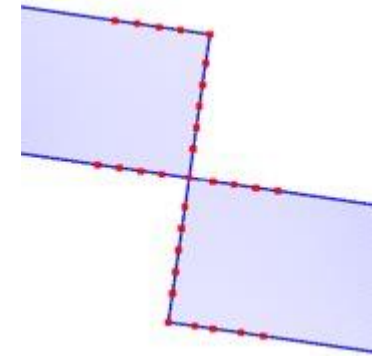
- The Generate Gauge File dialog box has new Export Target Center Type options to report the validated center or original center.
- The Generate Gauge File dialog box is also added with Generate PWA plot to produce PWA plots during gauge file generation.
- The RDF Target Repeats Images Viewer is updated with a Dose/Focus pulldown menu and is updated to display the rotation angle.

New Features and Changes in Curvilinear OPC and Biasing Solutions

New Options for Anchor Points Creation in Spline Based Curvilinear OPC and Biasing

- `anchor_point_layer`, the command used to create anchor points for spline based curvilinear OPC and biasing, has a new optional `ap_corner` argument set. New Anchor Point (AP) type `ap_corner` was generated for AR/VR design.

```
anchor_point_layer {...  
  [ap_corner {[-angle x] [-length d] [-ripplelen z] [-minjog l]} | [-off]]  
  ...}
```



AR/VR design and `ap_corner`

Changes in How Promoted Anchor Points are Classified

- The argument `promoted` now always returns an empty set. Promoted anchor points now retain the original type (curve, marker, implicit, and so on) to make it easier to tune anchor point creation.

```
POINTSET type layer promoted
```

New Command to Specify MRC Rules in Spline Based Curvilinear Biasing

- A new command, `cl_mrc_rule`, is available in nmCLBIAS Gen2 to create external and internal spacing constraints for spline based curvilinear biasing.

```
cl_mrc_rule {internal | external} layer1 [ layer2] ...
```

Calibre RET MEMOPC New Defaults



New Defaults!

- There are default changes in the `pre_processing_options` for RET MEMOPC_PARTITION.
- The default value for `maximum_wire_width` has changed to 1.0 microns.
 - `maximum_wire_width` is an optional preprocessing block parameter specifying the maximum width of rectilinear wires to decompose. When decomposing rectilinear polygons, specify `maximum_wire_width` so that RET MEMOPC_PARTITION adds cut lines that cut through wire polygons.
- The default value for `minimum_wire_length` has changed to 4.0 microns.
 - `minimum_wire_length` is an optional preprocessing block parameter specifying the minimum length of straight wires to be decomposed.
- The `wire_distribution` pre-processing option is obsoleted.

Updated Curvilinear SRAF Template and New Keywords for Configuring MATE

Updated `ringedge` Template for Curvilinear SRAF Insertion

- The `ringedge` template has a new keyword, `useoffsetlayerforcenter`, to allow offset layers to be used in the creation of centered `ringedge` SRAFs.
- This optional argument toggles the creation of centered SRAFs in very specific circumstances.

```
ringedge [{tag name}...] [ useoffsetlayerforcenter { true | false }]
```

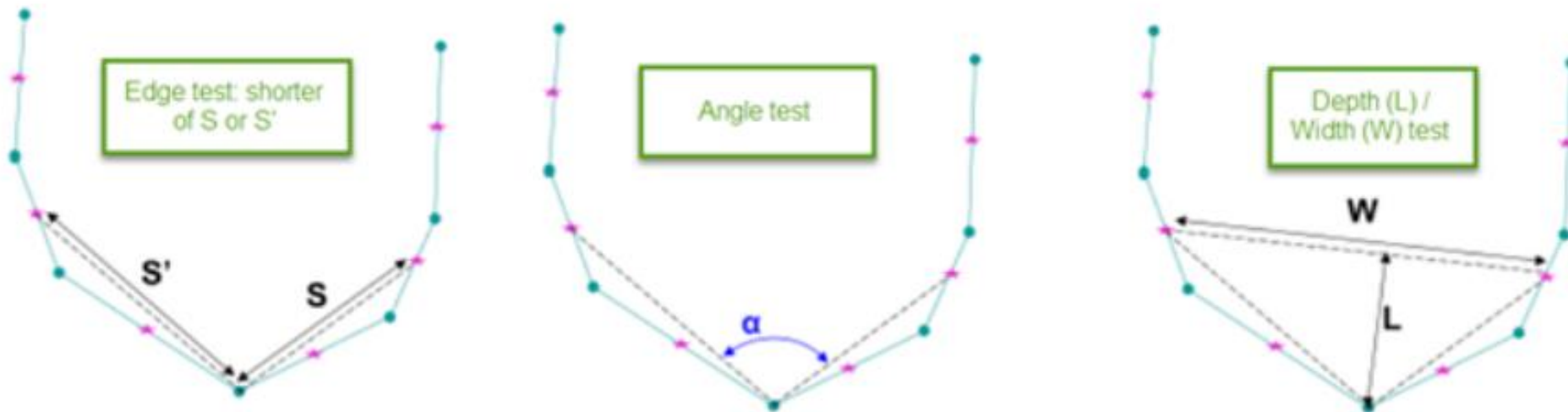
New Keywords for Configuring MATE

- Four new keywords are added to `mate_config`, the command configures Calibre MATE for subsequent processing. Users can optionally
 - Specify the use of edge length classifications suitable for contact layers.
 - Specify that MATE perform coverage checks for the local review layout comparing the ILT and MATE SRAFs.
 - Specify a model symmetry.
 - Specify the use of edge length classifications suitable for metal layers.

```
mate_config [ -contactlayer ] [ --coverage={0|1} ] [ --fsym=string ] [ --metallayer ]
```

New OPCverify Check to Detect Sharp Turns in Contours

- New `sharp_turn_check` places points of interest (POIs) on vertices and checks their angle, depth to width ratio, and distance to the centers of the second edges away from the vertex to detect sharp turns.
- Calibre OPCverify returns error markers for a POI only if all three parameters (distance, angle, and ratio) simultaneously meet the error criteria for that POI.



Calibre OPCverify New Features

New Keyword in `measure_distance` Check

- `measure_distance` check has new `separation_factor` keyword, which enhances the separation argument by adding variable separation behavior.

```
measure_distance ..... [measure_all | {separation sep [separation_factor factor]}]
```

New Keyword in `identify_corner` and `identify_edge` Commands

- New `jog_filter` argument skips processing jogs that are less than the specified length when OPCverify identifies corners or line ends, respectively.

```
identify_corner ..... jog_filter jog_length
```

New Keyword in `contour_options` Command

- New `tile_clean` argument is available to clean artifacts on contours near tile boundaries.

```
contour_options..... tile_clean { on | off }
```

New Keyword in `enclosure`, `external` and `internal` Commands

- New `exclude_shielded` argument is available to implement SVRF shielding filter checks for edges.

```
enclosure ..... exclude_shielded { 0 | 1 | 2 | 3 | 4 }
```

New Best Practice Recommendations for Calibre OPCverify

Best Practices!

New Best Practice Recommendations for `contour_options` Settings

- The best practices settings for DUV are `contour_options interp_algo lagrange interp_degree 5 max_edge_merge_error 0.0001 max_segment_length 0.003`. Users are required to define the distance constraint.
- The best practices settings for EUV are `contour_options interp_algo lagrange interp_degree 5 max_edge_merge_error 0.0001 max_segment_length 0.002`.

New Best Practice Recommendations for `optical_transform_size`

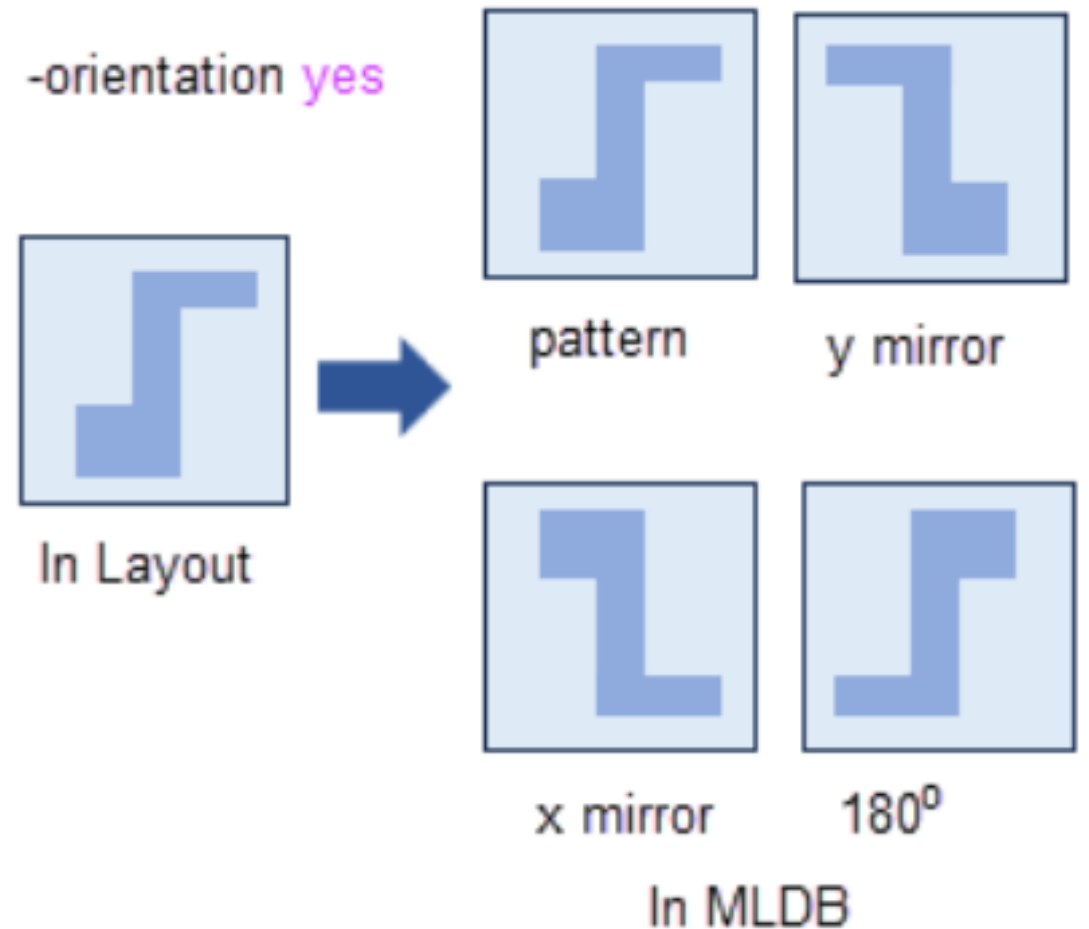
- The recommended setting for DUV is 768.
- The recommended setting for EUV is 1024.

New Best Practice Recommendations for EUV `imagegrid`

- The recommended image grid value for EUV is `imagegrid aerial 1 1`.

Updates to Machine-Learning Data Generation in Calibre ML-LFD

- The `-orientation` and the `-mergeLabelsOn` arguments are now mandatory for the `MLDataGen` command.
- The recommended settings for optimal data generation are as follows:
 - Users can use `-orientation` to enable (or not enable) reporting features of different orientations for each anchor point.
 - Users can use `-mergeLabelsOn` to specify how the labels are merged when multiple feature vectors have identical values but different labels.



Calibre SONR Updates

New Defaults!

New Default

- `SONR_COLLECT` and `SONR_PREDICT` now default `-dist` to 0.001 microns.

New Behavior of Reporting Transcripts

- SONR transcripts now report the total and available memory of the computer.

New keyword

- New `interm_prop` keyword allows to read properties from intermediate layers in a `svrf_block`.

Updated `SONR_COLLECT` command

- `-save_frequency` now includes a count of the number of times a feature vector has occurred in the output database.

New Enhancements in `svrf_block`

- Users can now export intermediate layers using rule checks.
- `Variable.. ENVIRONMENT` statements within the `svrf_block` can now read environment variables declared with `Variable.. ENVIRONMENT` in the main SVRF file.

New Options in `sonr --cluster`

- New `--optical_rotation` keyword treats feature vectors that are identical except for the order of values for certain paired CM terms as identical.
- New `--rotation` keyword identifies sets of features that can be treated as order-independent when identifying “identical” feature vectors.

Enhanced Operations Table in CalDash to Highlight Operations with Potential Low-scaling Issues

- Calibre operations with poor scaling often result in their real time being bigger than CPU time. These operations are now highlighted for attention.

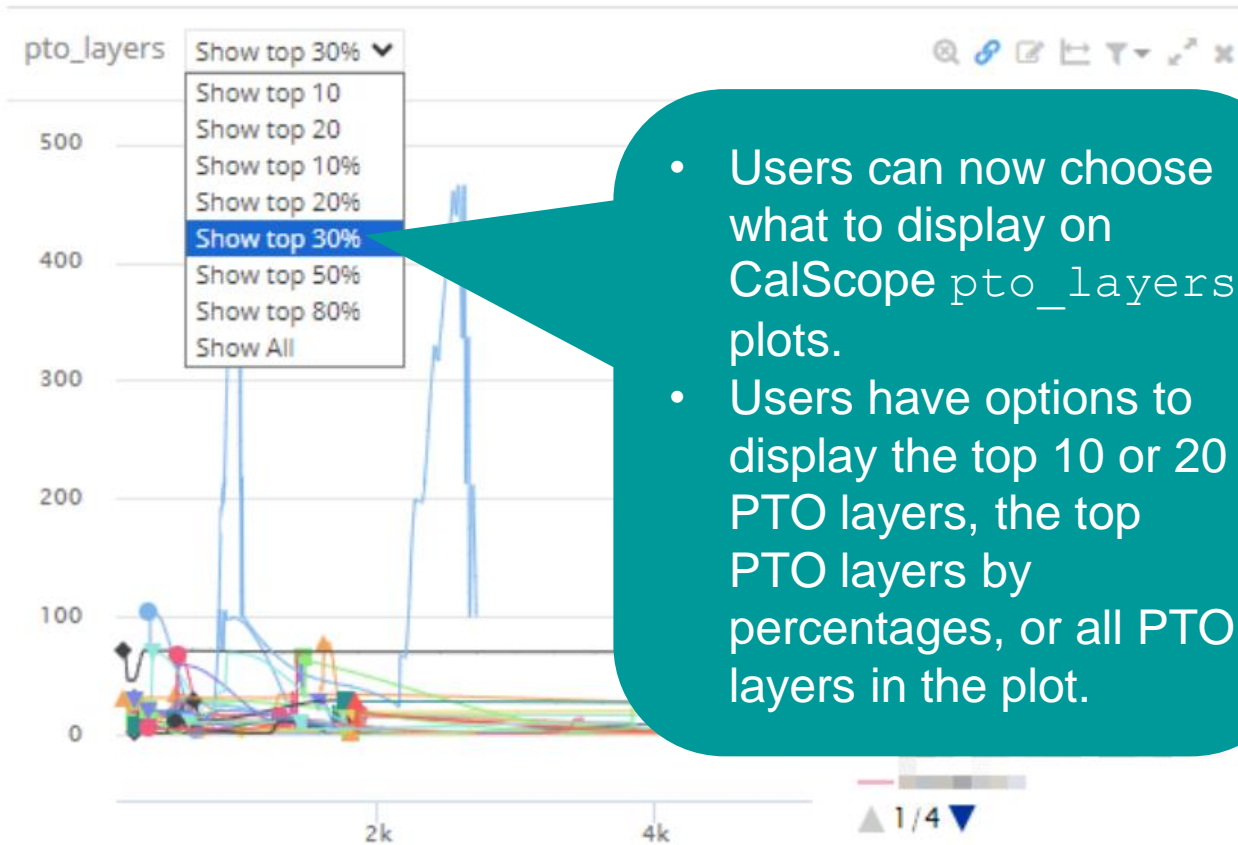
Operations

Operation	OP Name	Operator	Start Time	End Time	Real Time	CPU Total	CPU Primary	CPU Remote	LVHEAP Curr	L
181	PTO OP 107		179	2,945	2,766	392	0	392	0	
176	PTO OP 73		179	2,843	2,664	885	0	885	0	
108	PTO OP 35		179	2,726	2,547	2,442	0	2,442	0	
180	PTO OP 142		414	2,844	2,430	3	0	3	0	
179	PTO OP 143		414	2,843	2,429	3	0	3	0	
178	PTO OP 141		414	2,843	2,429	3	0	3	0	
177	PTO OP 145		414	2,843	2,429	0	0	0	0	
175	PTO OP 144		414	2,843	2,429	0	0	0	0	
94	PTO OP 51		179	2,602	2,423	40	0	40	0	
93	PTO OP 52		179	2,602	2,423	43	0	43	0	

Operations with potential low-scaling issues are highlighted.

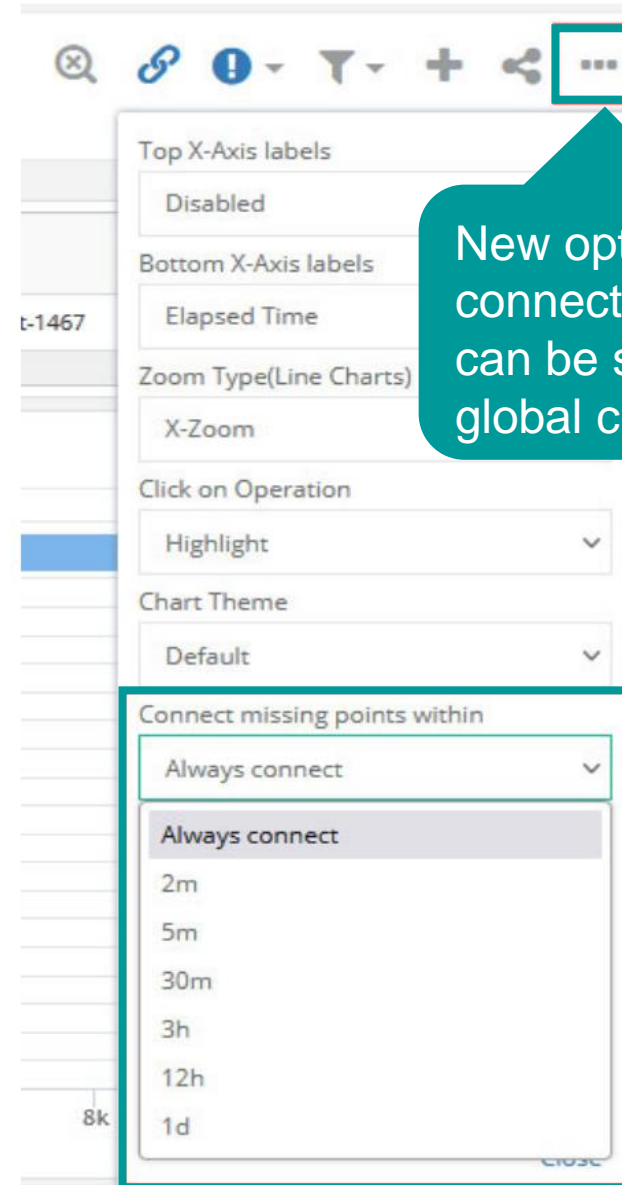
New CalScope Options

New Options to Display PTO Layers



- Users can now choose what to display on CalScope pto_layers plots.
- Users have options to display the top 10 or 20 PTO layers, the top PTO layers by percentages, or all PTO layers in the plot.

New Options to Specify Time Intervals for Missing Data Points



New options for connecting missing points can be specified in the global customize menu.

| Thank You!

Where today meets tomorrow.