Calibre 2024.2 Release Highlights
Calibre Semiconductor Manufacturing Solutions

May 2024

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Calibre LSG DRM-Mode Accelerates Process Ramp-up and Design Enablement

- Calibre LSG DRM-Mode enables quick initial set-up and fast response to design rule revisions.

- Calibre LSG DRM-Mode elevates its constraints syntax to the familiar DRM-style language of Physical Design, removing the previous time-consuming effort to translate constraints to a different constraint paradigm.

- To invoke Calibre LSG DRM-Mode from Linux, enter the command line as follows:

$MGC_HOME/bin/calibre -lsg **-DRMmode** LSG_drm_options_file
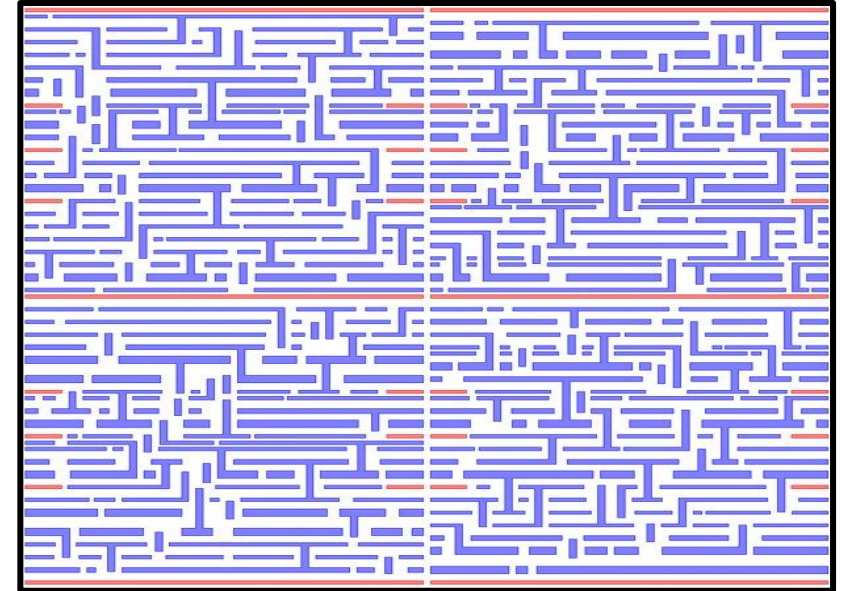
Increase User Productivity 10x
- ✓ Configuration set-up using familiar DRM-Style constraints
- ✓ Fast LSG Kit development
- ✓ Update DR/technology revision in minutes

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New Rule Creator GUI Supports Custom Rule Development for Calibre LSG DRM-Mode Flow

LSG Rule Creator

2. Write rule logic

Input Rules
```
if (D1 < C1)
then (D2 > C2)
endif
```

4. Generate rules in a file

1. Draw required polygons and dimensions in the canvas

D1
S1
D2
S2

- New Rule Creator GUI enables users to create custom rules for the Calibre LSG DRM-Mode flow.
- This streamlined GUI is invoked in a Linux command line as follows:

  $MGC_HOME/bin/lsg_rule_creator

Generation Options

Rule Name
```
Rule_1
```

■ Rule is Symmetric on X-a
■ Rule is Symmetric on Y-a

3. Enter rule name and select generation options

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Curvilinear MRC Check and SRAF Print Avoidance (SPA) Support in Calibre nmCLOPC

- The `cl_mrc_rule` command allows users to specify external and internal constraint checks between spline segments in curvilinear layers.

Example 1- sets the spacing for layer "array"

cl_mrc_rule external array {
     use 0.014
     separation 0.05
     angle_tolerance 60

}

Example 2 - defines the minimum spacing between shapes on two layers, "array" and "periphery."

cl_mrc_rule external array periphery {
     use 0.11
     angle_tolerance 60

}

- New `-curvilinear` argument enables SRAF print avoidance run on non-rectilinear SRAFs.
- The additional options provide external and internal MRC settings, and limit how much an SRAF may be shortened to control SRAF printing.

Example – The use of Tcl to create a loop to alternate between OPC and SPA adjustment.

```
OPC_ITERATION 5
for {set i 1} {$i <= 5} {incr i} {
    OPC_ITERATION 1
    sraf_print_avoidance -curvilinear -layer sraf -step 0.001 \
    -min_width 0.008 -min_space 0.011 -min_area 0.00015
}
OPC_ITERATION 5
...
```

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Enhanced Anchor Points Creation and Curvature Aware Curvilinear OPC

- All anchor points are initially given equal priority when `spline_opc` tries to achieve the best edge placement or resolve MRC conflicts. With `POINTSET_WEIGHT`, users can reduce the priority of some anchor point sets so that conflict resolution favors the non-weighted sets.

  Example - To meet the EPE specification for critical anchor points, first create an anchor point set containing them.

  POINTSET all L1.smooth -out all_points
  POINTSET topological not_inside L1.smooth L1 -out critical_points

  POINTSET_WEIGHT all_points 0.7
  POINTSET_WEIGHT -remove critical_points

- `anchor_point_layer` creates anchor points for use with the `spline_opc` and `POINTSET` commands. This command is updated with new `-inorder` option for creating implicit anchor points.

- Optional `-radius_of_curvature` argument is added in `spline_opc` to ensure the corrected mask is smoothly curved.

  Red : without Curvature check
  Green : with Curvature check

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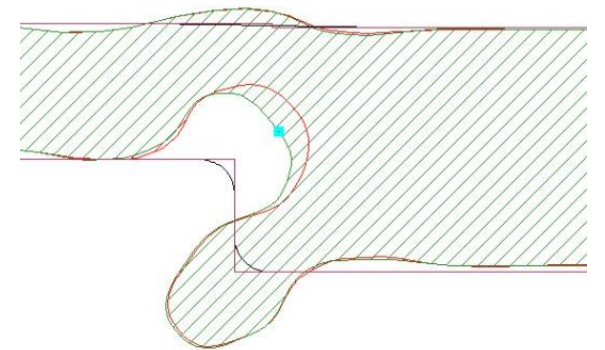
Calibre RET Flow Tool (RFT) Enhancements

- The Calibre RET Flow Tool has been updated to include a CL checkbox to allow curvilinear sessions (nmCLOPC, nmCLBIAS, CL OPCverify) to be created within the tool and SVRF files with curvilinear options to be exported.
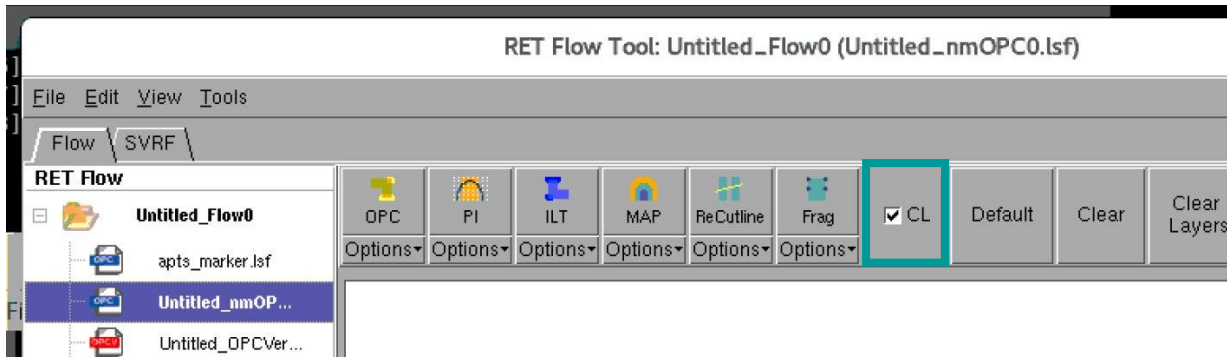
- The Calibre RET Flow Tool has been updated to include an Etch Image Grid option in the Simulation Settings panel.

- The Calibre RET Flow Tool has been updated to output debug layers for a Calibre nmOPC flow that includes SRAF Print Avoidance.
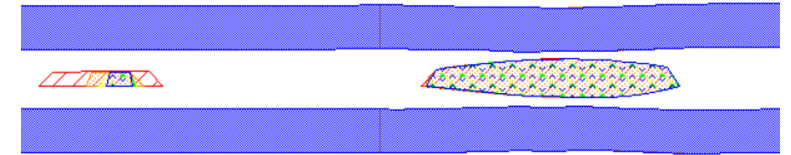
- The Calibre RET Flow Tool has been updated with a Pre-OPC checkbox to output preopc anchor points from spline-based nmCLOPC flows.

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Updated nmSRAF Template for Centered SRAFs Placement

- Calibre nmSRAF `ridgecorner` template has new arguments to allow the placement of centered SRAFs in regions between target corners.

A required argument that places centered SRAFs between target corners

An optional argument specifying a side length defining a square region to search for other corners.

An optional argument specifying the angle between a line from the corner to the middle of the centered SRAF and the line connecting the corner pair.

```
ridgecorner [{tag name}...]
    [w[idth] value]
    [center {0 | 1 | 2 | 3} [spacelimit value] {[offset value] | [angle value]} [strictcenter {0 | 1}]
    [corner key]]
    [arc_specification]
    [prior int]
```

An optional argument specifying the position of the centered SRAFs.

An optional argument specifying which corners the template creates centered SRAFs for.

An optional argument controlling which of the target corner pairs the template creates (pairs of) centered SRAFs for.

ridgecorner tag long1 w 0.01 center spacelimit 0.2 offset 0.04 corner pair

This template generates center SRAFs, with a width 0.01 um, for any tagged edge corner with another corner within the 0.2 um search box. The process of placing the center SRAFs is shown in the figure:

Placement of corner pair Center SRAFs

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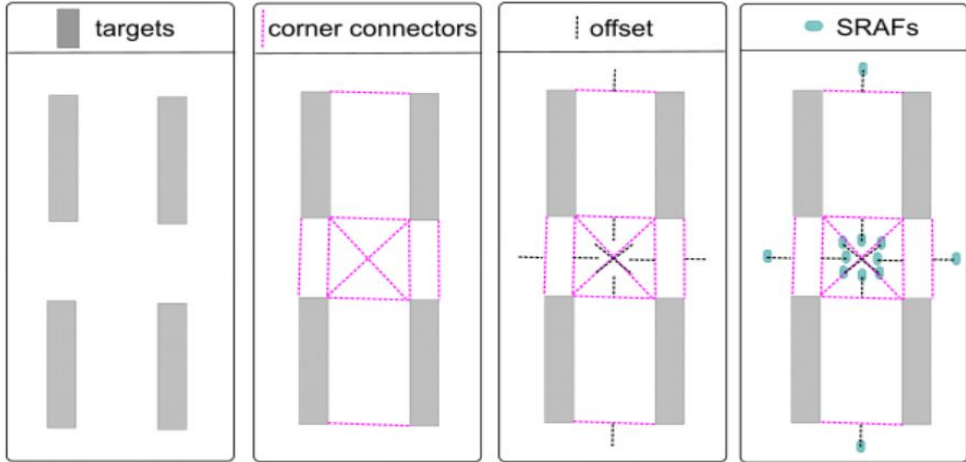
New Defaults and Updates in Calibre nmSRAF/ MATE

New Defaults in nmSRAF and MATE

- The `lineendmergeangle` keyword in Calibre nmSRAF has a new default value of 150 degrees.
- Several default MRC values used by Calibre (CL EUV) MATE have been updated:

MRC Parameter	Pre-2024.2 Value	Post-2024.2 Value
minarea	0.000225	0.000025
minlength	0.025	0.005
minsquarearea	0.000125	0.000025
minsquarelength	0.010	0.005
minwidth	0.008	0.005

Calibre MATE Updates

- Calibre CL MATE is now able to reuse test patterns for multiple extraction directions for some symmetries, reducing the size of SRAF pattern library directory.
- Calibre MATE now automatically assigns priority values at the end of template generation, preventing duplicate values from occurring.
- The `--converge` argument in `mate_config` command now also causes the coverage calculations to be written to the log file `coverage.log`

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New OPCverify Command for Eliminating Tile Boundary Contour Jogs

	Check / Cell △	Results
⊞ ✖	Check skew_jogs_tile::<2>	534
⊞ ✖	Check skew_jogs_GS::<2>	534
✔	Check skew_jogs_core::<2>	0

Skew jogs detected at tile boundary.

- Tile boundary contour jog is not a problem when the contour is checked within the same OPCverify run. However, it may be a problem for specific applications when the contour is output and used as an input for another litho run.

- A new command is implemented to clean up/smooth image contour kinks located near tile boundaries.

  clean_tile_stitching [**max_displacement** length]

- `contour_options` command has been updated with `tile_clean` argument in 2024.1 release to clean artifacts on contours near tile boundaries.

  contour_options….. **tile_clean { on | <u>off</u> }**

	Check / Cell △	Results
✔	Check skew_jogs_tile::<2>	0
✔	Check skew_jogs_GS::<2>	0
✔	Check skew_jogs_core::<2>	0

No skew jogs detected with clean_tile_stitching or tile_clean on.

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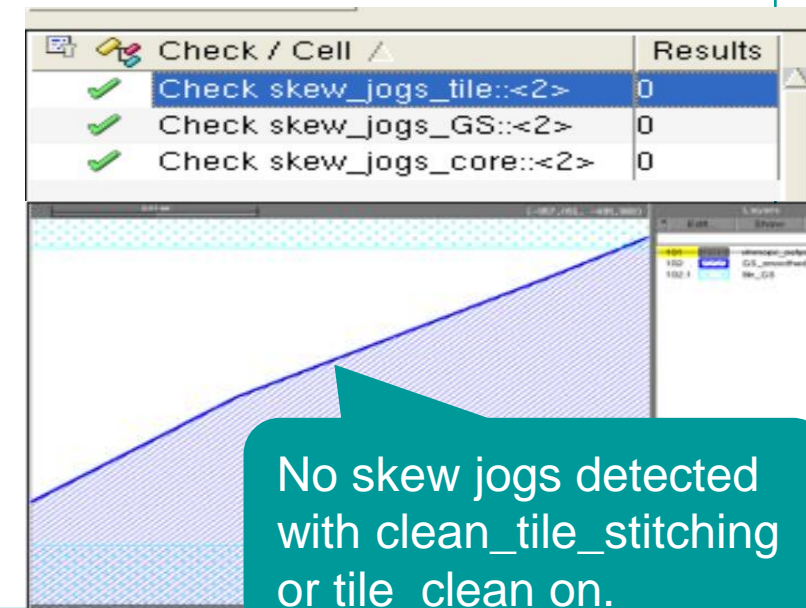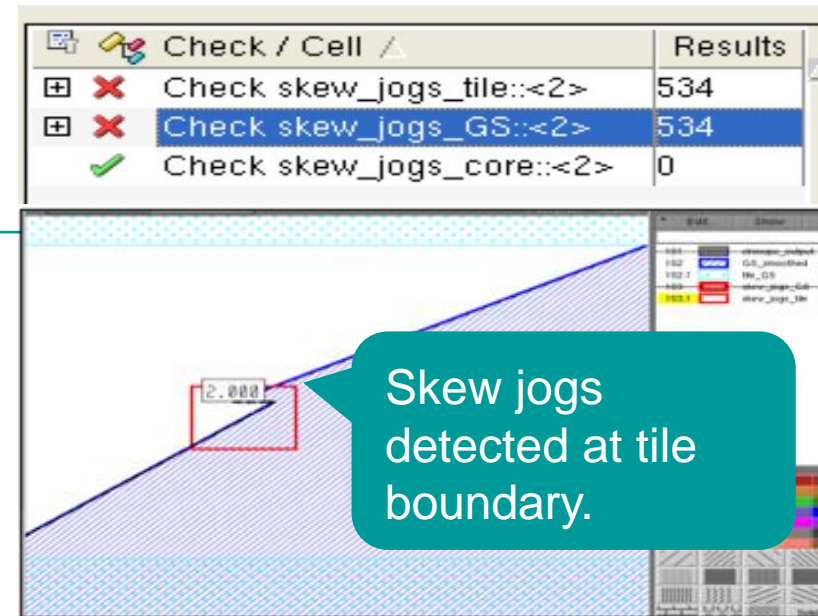
Open Frame Intensity Optimization for Throughput-Aware Obscuration in High NA EUV Source Mask Optimization

- Calibre SMO supports throughput-aware obscuration usage, which optimizes dose and minimizes amount of light blocked by the obscuration, for balancing between lithographic quality and scanner throughput.

- New commands are available to apply to EUV processes to optimize light energy losses due to obscuration.

  - `open_frame_intensity` can be used to activate open frame intensity optimization at the nominal process condition while keeping acceptable lithographic quality.

  - Users can also specify a target value for the optimization of open frame intensity by using `target_open_frame_intensity` and `target_open_frame_intensity_weight`.

Example 1- Open frame intensity maximization

```
….
job 4 polish
    pw_select nominal_1.0  pw1 pw2 pw3 pw4
    iterations 500
    open_frame_intensity_weight 300
```

Example 2 - Example - Open frame intensity optimization to a target of 0.75 with weight 300

```
….
job 4 polish
    pw_select nominal_1.0  pw1 pw2 pw3 pw4
    iterations 500
    target_open_frame_intensity 0.75
    target_open_frame_intensity_weight 300
```

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Calibre nmModelflow New Options

New argument to select the mode for plotting cm1 terms

- New `cm1term` argument is added in `mdf plot grid` to select the mode for plotting specific cm1 terms.

New argument to write the grid information to disk

- New `-savetextgrid` and `-savegrid` arguments in `mdf plot grid` write the grid information to the disk in either text or binary format.

New option to change how normalization is calculated for CM1 model analysis

- `mdf cutline cm1_model_terms` has a new option, `-normalize`, which changes how normalization is calculated for CM1 model analysis.
  - `-normalize 1` involves summation of absolute term values computed over all gauges or sites.
  - `-normalize 2` involves summation over only a specific gauge or site.

Updated `mdf param_set_and_build` command

- `mdf param_set_and_build` now accepts contours as input data; previously it only worked if gauge data was included in the inputs.

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Calibre nmModelflow GUI Updates

Updated optimization settings for CM1 length parameters

- The optimization settings for certain CM1 length parameters have been changed so the upper bound is set to "auto" instead of a fixed value in order to handle values higher than 100 for DUV and to automatically set a value of 100 for EUV.
  - This change primarily affects Modelforms 29, 50, and 99.

New Compare Layouts button in Calibration Jobs Compare dialog

- It allows users to create a new job that combines selected layers from the compared jobs into a single layout.

New default group by group plots in Calibration Job window

- For calibration jobs that contain groups, the following Group by Group plots are selected by default in the Calibration Job window > Plots > GaugesSimStats entry:
  - Weight vs SimErr, Meas vs SimErr, SimErr vs Drawn, CtrErr vs SimErr, SimErr vs. Group

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New Commands in Calibre RET Modeling

New Command to Compute Akaike Information Criterion (AIC) for an Etch Model

- Calibre nmModelflow has a new command to compute the Akaike Information Criterion (AIC) for an etch model.
  - Akaike Information Criterion (AIC) is an information-theoretic approach to model selection that seeks to minimize over-fitting risk.
- The model with the lowest AIC is output to the terminal.

mdf check aic

New Command to Split CM1 Linear Optimizer Input Data into Training and Verification Sets

- Calibre nmModelflow has a new command to split CM1 linear optimizer input data into training and verification sets.
- This is used during MOGA calibration to improve verification objectives and test for overfitting.
  - Users have options to specify the fraction of the enabled data to be used as verification data and the method used to select the verification data subset from the enabled data.
  - Users specify the seed value to be used if type is set to random. Users are allowed to switch back to unsplit data if needed.

mdf optimize verify set [**-fraction** val **-type random** | **first** | **last -seed** val] | **unset**

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More Updates in Calibre RET Modeling

New Option for Kernel DDM Training

- `kernel_ddm_train` has a new argument, `–linear_feature_size`, to select training features linearly across a size range.

Changes to the EUV-Related Model Formats

- In the Black Border Model File Format, the `dose_ring` parameter now supports negative dose values.

Changes to the VEB Model

- The default consistency value for `average_bias` has been changed to 3 to align with current best practices.

New Warnings

- As of version 2024.2, runs that load any VT5 models exit with a message "VT5 resist model not supported with GPU."

New Default for Maximum Grid Shift

- The `mdf simulate gridshift` command has a new default value for the maximum grid shift. The new default value is 1.
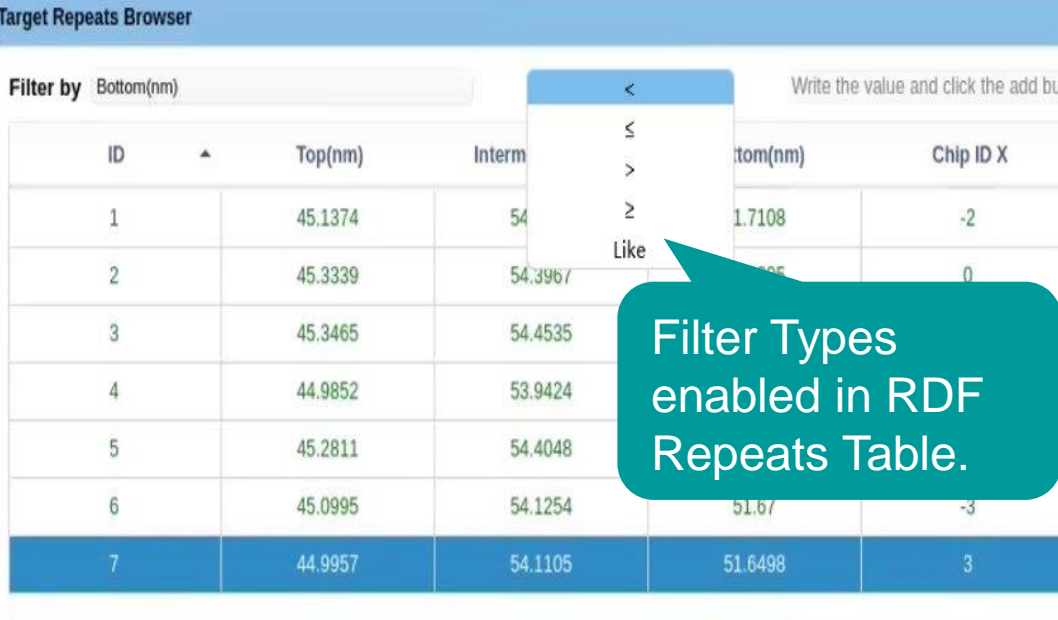
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New Features in Calibre SEMSuite

Updates in Contour Data Flow Tool

- New option in the Contour Data Flow (CDF) tool Settings Pane to activate running auto setup tuning on MTflex.

Updates in the Raw Data Filtering (RDF) Tool

- The Target Repeats Browser has enhanced filtering function in repeats table.

- Gauge file generation now uses the drawn CD value to calculate the location coordinates of the target if target validation succeeds.

- The decision results files have ImageScore and CD information columns added.

- There is a runtime improvement to the validation step.

Filter Types enabled in RDF Repeats Table.

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New Kernal Type and Automatic Chunk Size Adjustment in Calibre SONR

Non-uniform Tophat Kernel Support for Model Generation

- Users can now generate lookup table models using "tophat_gauss" kernel type which specifies to use a ring-shaped gaussian kernel.

  sonr --feature --density_file kernel name
  TYPE **tophat_gauss** outer [inner]

Automatic Chunk Size Adjustment for Low Memory Runs

- Users have a new option to adjust the chunk size automatically based on available memory in both `sonr --cluster` and `sonr --tree` commands.

  sonr --cluster **--lowmem**
  sonr --tree **--lowmem**

Density Kernel Types Supported in Calibre SONR			
1.	Circular Gaussian distribution	4.	Standard Gaussian distribution convolved with a rectangle of length and height.
2.	Tophat, or uniform, kernel	5.	Standard Gaussian distribution convolved with a tophat kernel.
3.	Elliptical Gaussian distribution with different spread along the x-axis and y-axis.		

New!

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New Features for Creating Scatterplots and Heatmaps in Calibre SONR

New argument to specify the number of bins for coverage check

- Users have a new optional argument to determine how many bins are used in calculating coverage.

- This can be useful for verifying that representative vectors have not omitted any zones of the design.

sonr --scatter --coverage **[{-b | --bin} number]**

Updated argument in `sonr --scatter` for clarity

- The "`--reference`" argument in `sonr --scatter` command is now "`--sample`" for clarity.

sonr --scatter { –s |**--sample }**

- Example below combines the input (A.db+B.db) and does two comparisons, (A.db+B.db) versus 1.db and (A.db+B.db) versus 2.db.

-i A.db -i B.db -s 1.db -s 2.db

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Updates in SONR Model Evaluator

- Users have a new "`--with_fe_after`" option in SONR model evaluator to run `sonr --fe` immediately after evaluating a model. This ranks the features in the model for relative importance to results.

  - `sonr --fe` command analyzes data to determine the features with the strongest effect on the objective and plots the Shapley values.

`--a` is an optional argument that plots the Shapley analysis in an abstract bar plot.

`--e` is an optional argument that generates a dependence plot for each feature other than the one being analyzed.

sonr --model_evaluator **–with_fe_after [--a] [--d] [--e] [--o directory]**

`--d` is an optional argument that plots the Shapley analysis as a density distribution.

`--o` directory is an optional argument that creates a new directory by the specified name.

- Users are now required to specify "--n" argument to identify the value assigned to non-hotspots.

sonr --model_evaluator **–n** number

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New Functionality in Calibre Cluster Manager (CalCM)

New command to specify include files in the job configuration file

- Users can now specify include files at the job level in the `job.conf` configuration file with the new "`JOB RUNINCLUDE filename`" command.

.

New option to submit interactive jobs

- Users can now specify `calcm_submit_job -i` to use interactive mode, which prints the Calibre log to stdout after the job is launched.

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New enhancement to share the cluster page by using the Share Page button

- By clicking the Share Page button, it copies the unique URL of the current Cluster page with its current settings to the clipboard.

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Thank You!

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