

SIEMENS EDA

# Calibre® nmModelflow™ User's and Reference Manual

Software Version 2021.2

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# Chapter 1

## Calibre nmModelflow User's Guide

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Calibre® nmModelflow™ is the next generation model calibration platform. It is accessed from the Calibre® WORKbench™ model development environment.

Calibre nmModelflow can be used in two different modes.

- The Calibre nmModelflow GUI, available from the **Litho** menu.
- Command Line Interface (CLI) mode, available from the console window or inside the Calibre nmModelflow GUI. The CLI is intended for advanced users or for customizations that are not available in the GUI.

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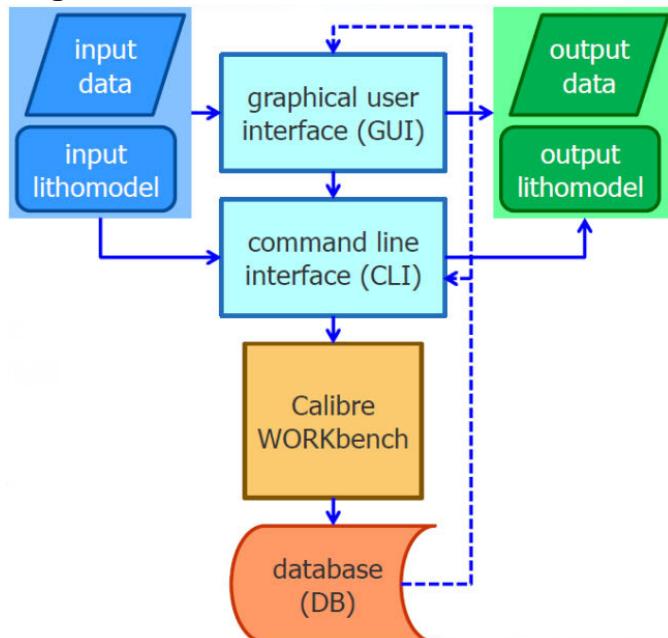
## Calibre nmModelflow Overview

Process models are used to simulate the results of lithography designs on a wafer. As design sizes shrink, more complex models are needed to accurately predict and simulate the effects of those elements.

Calibre nmModelflow improves on the Calibre WORKbench modelflow\_v2 and CM1 Center functionality by:

- Basing the modeling flow around persistent database objects
- Creating separate flow stages to calibrate models in phases
- Supporting metrics capabilities, filters, plots, and dynamic process windows

**Figure 1-1. Calibre nmModelflow Overview**



### Related Topics

[Calibre nmModelflow Database Overview](#)

[Calibre nmModelflow Workflow](#)

## Key Concepts

Calibre nmModelflow uses some key concepts related to the modeling flow experience.

- **Active Data** — The currently displayed dataset (gauges, layout, litho model, metrics, plots, filters, and so on). The GUI applies the commands to active data; items in the database must be activated before they can be used. An active data item can be added to the database.
- **CLI** — Command Line Interface. Calibre nmModelflow includes an integrated console window where you can enter commands directly.
- **Cost Objective** — The value that the optimization attempts to minimize when testing permutations of variables.
- **Database** — A collection of items managed by Calibre nmModelflow. All models, simulations, stages, and simulation results are stored in a database that persists through Calibre WORKbench sessions. You can select items from the database to reuse elements like litho models and filters.

Database items are unique, and have referential integrity; you cannot delete or modify an item without removing all references to it first.

- **GID** — Gauge ID. A GID is a numeric value that corresponds to a row in the **Gauge Analysis** tab. The GIDs are stored in the third column of a gauge or super gauge file.
- **Job** — A run of a Stage. You can have multiple jobs running, and jobs can be dependent on the results of other jobs.
- **Joint Optimization** — A calibration efficiency innovation over modelflow\_v2's serial optimization paradigm. Joint optimization simultaneously optimizes the mask and optics models with the resist models. In Calibre nmModelflow, the resist optimization subsearch can be performed jointly during a search over mask and optical model parameters.
- **Lithomodel** — A file comprising mask, optical, resist, etch, EUV, and topo models. Calibre WORKbench operates on the models contained in a litho model as a set, instead of the modelflow\_v2 method of needing to load and manage each model type separately.

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#### Note

 The litho model file is always named “*Lithomodel*”, therefore this document and the Calibre nmModelflow interface refers to the actual file as “*Lithomodel*” but to the repository of data in general as a “litho model”.

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- **Metric** — A criteria used to establish the quality of models. The metric serves as an additional way of selecting models besides the cost objective.
- **MDF** — An abbreviation for Calibre nmModelflow.
- **modelflow\_v2 and CM1 Center** — The predecessor tools to Calibre nmModelflow.
  - modelflow\_v2 is an omnibus command for optical, resist, and mask model calibration that has been a central part of Calibre WORKbench.

- CM1 Center is a GUI that generates modelflow\_v2 command scripts; Calibre nmModelflow integrates GUI and command-line functionality into a single interface.
- **Stage** — One step of the modeling process. Stages include calibration of mask model, optical model, zplanes model, resist model, TOPO model, EUV Black Border model, etch model, and CDSA model; other stages are used for simulation, focus adjustments, and building models.

Creating stages forms the building blocks of an optimization run.

## Related Topics

[Calibre nmModelflow Database Overview](#)

# Product Requirements

Calibre nmModelflow has specific requirements to run.

## Calibre WORKbench Licensing

To run any of the Calibre layout viewers, you must have the license file required by the tool. The Calibre WORKbench and Calibre nmModelflow tools each require a different license.

Refer to the [Calibre Administrator's Guide](#) for more information on licensing these products.

## Memory Requirements

The amount of memory on the primary host required to effectively run Calibre nmModelflow operations is dependent on the number of remote cores.

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### Note

 The primary host is sometimes referred to in commands, environment variables, and transcripts as a “local” or “master” host.

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- **32 remote cores or fewer** — 12 GB memory on the primary host
- **33 to 128 remote cores** — 20 GB memory on the primary host

Each remote core has a recommended memory requirement of 6 GB for optics and joint calibration, but lower memory can be used in some cases.

## Software Requirements

The Qt5 components of Calibre nmModelflow may require the Xkeyboard extension for certain Linux-based virtual machine operating systems running Xmanager. Installing Xkeyboard may resolve an issue where keyboard input does not function correctly.

# Syntax Conventions

The command descriptions use font properties and several metacharacters to document the command syntax.

**Table 1-1. Syntax Conventions**

Convention	Description
<b>Bold</b>	Bold fonts indicate a required item.
<i>Italic</i>	Italic fonts indicate a user-supplied argument.
Monospace	Monospace fonts indicate a shell command, line of code, or URL. A bold monospace font identifies text you enter.
<u>Underline</u>	Underlining indicates either the default argument or the default value of an argument.
UPPercase	For certain case-insensitive commands, uppercase indicates the minimum keyword characters. In most cases, you may omit the lowercase letters and abbreviate the keyword.
[ ]	Brackets enclose optional arguments. Do not include the brackets when entering the command unless they are quoted.
{ }	Braces enclose arguments to show grouping. Do not include the braces when entering the command unless they are quoted.
“ ”	Quotes enclose metacharacters that are to be entered literally. Do not include single quotes when entering braces or brackets in a command.
or	Vertical bars indicate a choice between items. Do not include the bars when entering the command.
...	Three dots (an ellipsis) follows an argument or group of arguments that may appear more than once. Do not include the ellipsis when entering the command.

**Example:**

```
DEvice {element_name [('model_name')]}

device_layer {pin_layer [('pin_name')] ...}

[‘<auxiliary_layer> ...]

[‘(swap_list)’ ...]

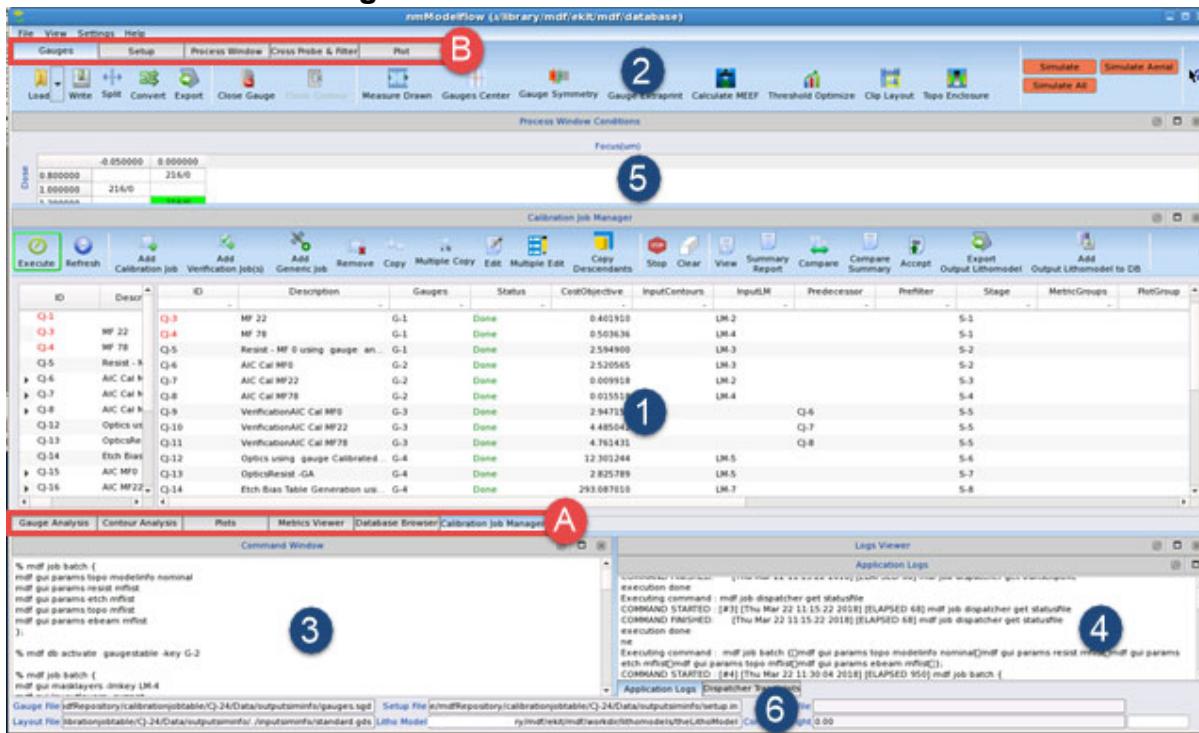
[BY NET | BY SHAPE]
```

# Calibre nmModelflow GUI Overview

To access: **Litho > nmModelflow** in the Calibre WORKbench main window

The Calibre nmModelflow GUI contains multiple tabs and sub-windows to display and interact with data.

**Figure 1-2. Calibre nmModelflow GUI**



## Description

The Calibre nmModelflow GUI is a multiple document interface (MDI) with multiple windows docked by default. The windows are labeled in the order of importance. Your GUI may be arranged differently because all windows can be moved around and undocked.

## Objects

**Table 1-2. Calibre nmModelflow GUI Main Window Contents**

Field	Description
1	<p>The display panel.</p> <p>Most of the GUI actions are performed in this window, including selecting items and displaying output data.</p> <p>The display panel contains multiple display tabs (A) that change the mode of the panel.</p> <p>The display tabs are:</p> <ul style="list-style-type: none"><li>• <b>Gauge Analysis</b> — Displays the currently active gauge object.</li><li>• <b>Contour Analysis</b> — Displays the active contours for analysis.</li><li>• <b>Plots</b> — Displays any active plots.</li><li>• <b>Metrics Viewer</b> — Displays any active metrics.</li><li>• <b>Database Browser</b> — Lists all items in the active database.</li><li>• <b>Calibration Job Manager</b> — Lists all defined jobs for calibration.</li></ul>
2	<p>The menu bar.</p> <p>The menu bar contains multiple tabs (B) that change the buttons available in the menu bar.</p> <p>The menu bar tabs are:</p> <ul style="list-style-type: none"><li>• <b>Gauges</b> — Buttons to control the gauges in the <b>Gauge Analysis</b> primary display tab.</li><li>• <b>Setup</b> — Buttons to write the current configuration as a Calibre nmModelflow setup file.</li><li>• <b>Process Window</b> — Buttons to calculate aspects of a process window gauge data set.</li><li>• <b>Cross Probe &amp; Filter</b> — Buttons to highlight and display gauges in the main Calibre WORKbench layout viewer window. The gauge analysis view will automatically scroll to the highlighted gauges when cross probing or selecting a region in the layout.</li><li>• <b>Plot</b> — Buttons to generate built-in plot functions.</li></ul> <p>The menu bar also contains simulation buttons for one-click image and CD calculation.</p>

**Table 1-2. Calibre nmModelflow GUI Main Window Contents (cont.)**

Field	Description
3	<p>The command window.</p> <p>You can enter Command Line Interface (CLI) commands directly in this panel. Some CLI commands output information to this window.</p> <p>Additionally, every command executed by the GUI is also displayed in the Command Window. You can search in the window by pressing <b>Ctrl-F</b> when the Command Window is active, or by selecting <b>Search</b> from the right mouse menu.</p> <p><b>i Tip:</b> The full CLI reference is available by selecting <b>Help</b> from the menu bar. (For more information, see “<a href="#">Calibre nmModelflow Online Help</a>” on page 20.)</p>
4	<p>The application log window.</p> <p>Calibre nmModelflow sends application status information from commands to this window.</p>
5	<p>The process window view.</p> <p>Shows a matrix of dose versus focus conditions and the number of gauges in each condition.</p>
6	<p>Active files.</p> <p>A read-only display on the bottom of the MDF window showing which gauge, setup, Lithomodel file, and layout files are currently active.</p>

## Usage Notes

Use the Calibre nmModelflow GUI by selecting a mode using the display tabs in the display panel. You interact with the data in that window using any controls in that window as well as the controls in the various menu tabs. Each display tab represents one data group in Calibre nmModelflow.

---

**Tip**  The **Settings** menu contains controls that adjust the behavior of Calibre nmModelflow, including:

- Loading a different Qt style sheet
  - Changing the font size
  - Changing the base directory for the SEM Image Viewer
- 

**Note**  If the keyboard is not working properly (typed keys do not match displayed symbols) on starting Calibre nmModelflow, you may need to set the `XKB_DEFAULT_RULES` environment variable to “base”.

---

## Related Topics

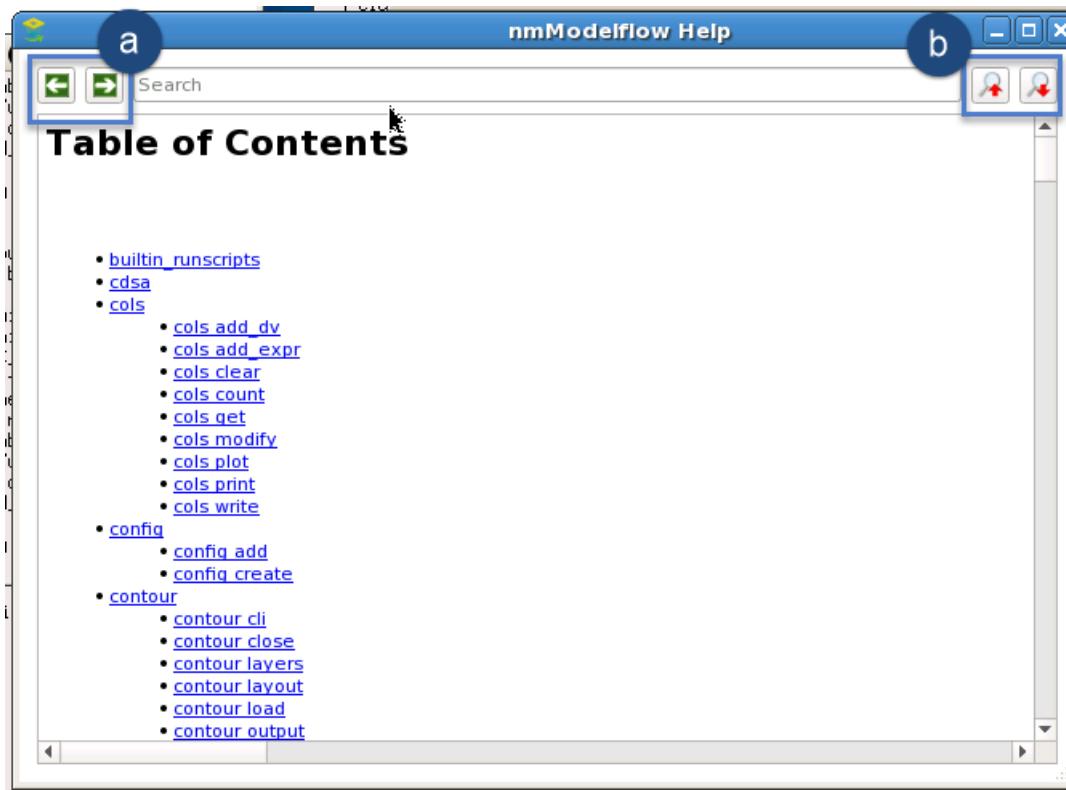
[Calibration Job Manager](#)

[Database Browser](#)

# Calibre nmModelflow Online Help

The Calibre nmModelflow Command Line Interface (CLI) dictionary is available as an online help file for better search capability within the software.

Access the Calibre nmModelflow online help file by pressing **F1** when Calibre nmModelflow is the active window.



The file is a standard HTML page with links to the CLI command dictionary. You can enter strings in the Search field at the top to find a specific command or browse using the navigational controls:

- Use the navigation buttons (a) to skip forward and back between command history views. (Note that the last page you click a link to is not saved, and scrolling actions do not get saved either.)
- Use the Previous and Next buttons (b) to go to the previous or next instance of the item in the Search field.

# Calibre nmModelflow Database Overview

Calibre nmModelflow contains powerful database functionality to assist in managing multiple items in your work environment. Understanding the most effective ways to use the database can improve your calibration efforts.

- Databases are single-user based; only one user can access a specific database at any time. However, database copies can be shared via import and export functions that work on the whole or parts of a database.
- The default database directory location (set to be *<invocation\_directory>/mdf/database*) automatically opens when you invoke Calibre nmModelflow. Your default database can be set to a fixed location with an environment variable, as described following.

---

## Tip

 Siemens EDA suggests that you use one database per calibration dataset or technology layer so all items for the database have that relationship in common.

Because the default database is located in the directory you invoked Calibre WORKbench from, you should ensure that you are in the correct directory before starting the tool.

---

The *mdfRepository* consists of a database file and data repository.

- *mdf.sqlite* contains the database information tables.
- *mdfRepository* is the directory containing the data from your calibration efforts.

## Database Environment Variables

The default database and repository location is *<invocation\_directory>/mdf/database*. If Calibre WORKbench does not find this directory when Calibre nmModelflow is first invoked, it creates the directory.

- To change the location of the database, set the environment variable `CALIBRE_MDF_DB_HOME`.

```
setenv CALIBRE_MDF_DB_HOME path
```

Calibre nmModelflow requires a directory to place automatically generated scratch data. By default, it uses the location *<current\_directory>/mdf/mdfworkdir*.

- To change the location of the working directory, set the environment variable `CALIBRE_MDF_WORKDIR_DEFAULT`.

```
setenv CALIBRE_MDF_WORKDIR_DEFAULT path
```

Calibre nmModelflow requires a dispatcher directory to track job execution. By default, it uses the location *<current\_directory>/mdf/dispatcher*. To change the location of the

dispatcher directory, set the environment variable CALIBRE\_MDF\_DISPATCHER\_DIR.

```
setenv CALIBRE_MDF_DISPATCHER_DIR path
```

## Related Topics

- [Importing a Database](#)
- [Exporting a Database](#)
- [Database Browser](#)

# Calibre nmModelflow Workflow

Calibre nmModelflow has a number of different entry points, depending on whether you are migrating from a modelflow\_v2 environment or continuing previous Calibre nmModelflow work.

## Migration from modelflow\_v2 Workflow

Although modelflow\_v2 and Calibre nmModelflow share some common items, Calibre nmModelflow may use a newer version of them. In order to use the modelflow\_v2 items, they must be converted or regenerated to fit their respective Calibre nmModelflow format.

**Table 1-3. modelflow\_v2 Migration Items**

Item	Action	Task
Gauge files (.gg) Super gauge files (.sgd)	Convert using the gauges convert command	<ul style="list-style-type: none"><li>• <a href="#">Converting modelflow_v2 Gauge Files</a></li><li>• <a href="#">Loading Gauge Files</a></li></ul>
Individual model files	Use the files to create a litho model	<ul style="list-style-type: none"><li>• <a href="#">Creating Litho Models</a></li></ul>
Lithomodel file	Import an existing litho model to the database	<ul style="list-style-type: none"><li>• <a href="#">Importing an External Litho Model</a></li></ul>

## Existing Calibre nmModelflow Source Files Workflow

The Calibre nmModelflow component files are designed to be portable on both a per-item and database basis.

**Table 1-4. Existing Calibre nmModelflow Source Items**

Action	Notes	Task
Import a database	Import exported database to the current database, adding its contents to the existing database.	<ul style="list-style-type: none"><li>• <a href="#">Importing a Database</a></li></ul>

**Table 1-4. Existing Calibre nmModelflow Source Items (cont.)**

Action	Notes	Task
Export a database	Save the whole or parts of the current database to a file for sharing purposes.	<ul style="list-style-type: none"> <li>• <a href="#">Exporting a Database</a></li> </ul>

## Calibre nmModelflow Modeling Tasks

Once you have your Calibre nmModelflow database set up, you can perform modeling tasks.

**Table 1-5. Calibre nmModelflow Modeling Tasks**

Action	Notes	Task
Load a gauge file	Gauge files are required to view, measure, simulate, and calculate information.	<ul style="list-style-type: none"> <li>• <a href="#">Loading Gauge Files</a></li> <li>• <a href="#">Manipulating Gauges in the Gauge Analysis Tab</a></li> </ul>
Set up a litho model	Whether using an existing litho model, or creating a new one, the litho model must be imported into the database.	<ul style="list-style-type: none"> <li>• <a href="#">Creating Litho Models</a></li> <li>• <a href="#">Importing an External Litho Model</a></li> </ul>
Start the Flow Wizard for stage setup	Each stage contains all the commands executed in a calibration job.	<ul style="list-style-type: none"> <li>• <a href="#">Creating a Stage With the Flow Stage Wizard</a></li> </ul>
Set up a job	A job contains all the data and commands needed to run the job.	<ul style="list-style-type: none"> <li>• <a href="#">Setting up a Calibration Job</a></li> </ul>
Set up a plot	Plots are created separately from an optimization run and can be requested on any job or on the active data.	<ul style="list-style-type: none"> <li>• <a href="#">Creating a Custom Plot</a></li> </ul>
Set up a metric	Metrics assess the quality of calibrated model compared to one or more criteria.	<ul style="list-style-type: none"> <li>• <a href="#">Creating a Custom Metric</a></li> </ul>
Set up a filter	Filters can remove gauges from the calibration candidates or filter for specific gauges that meet certain criteria after a calibration is run.	<ul style="list-style-type: none"> <li>• <a href="#">Creating a Filter</a></li> </ul>
Saving model results	Calibrated models can be exported for use with other Calibre tools.	<ul style="list-style-type: none"> <li>• <a href="#">Saving the Models After Calibration</a></li> </ul>

**Table 1-5. Calibre nmModelflow Modeling Tasks (cont.)**

Action	Notes	Task
Add process window conditions	Calibration is run across all process window configurations, and will often give different results at varying dose and defocus values.	<ul style="list-style-type: none"><li><a href="#">Adding Process Window Conditions to a Litho Model</a></li></ul>

# Gauge-Related Tasks and Concepts

Gauges contain measurement data used during calibration and simulation. Most stages operate on gauge data, or subsets of gauge data.

<b>Loading Gauge Files .....</b>	<b>25</b>
<b>Converting modelflow_v2 Gauge Files .....</b>	<b>31</b>
<b>Adjusting the Length of Gauges.....</b>	<b>33</b>
<b>Adjusting Gauge Symmetry .....</b>	<b>34</b>
<b>Centering Gauges.....</b>	<b>39</b>
<b>Methods for Filtering Gauges.....</b>	<b>41</b>
<b>Manipulating Gauges in the Gauge Analysis Tab .....</b>	<b>43</b>
<b>Adding User-Defined Columns to the Gauge Analysis Tab.....</b>	<b>51</b>
<b>Selecting Focus-Sensitive Data .....</b>	<b>53</b>
<b>Viewing Depth of Focus Data .....</b>	<b>55</b>
<b>Calculating the Process Capability Index .....</b>	<b>57</b>
<b>Testing Parameter Sensitivity Data .....</b>	<b>58</b>
<b>Checking Etch Models for BTERM and Kernel Quality.....</b>	<b>60</b>
<b>Adding MEEF Data to the Gauge Analysis Tab.....</b>	<b>60</b>
<b>Calculating the ILS for a Layer .....</b>	<b>62</b>
<b>Generating Extra Printing Information .....</b>	<b>63</b>
<b>Advanced Extra Printing Options .....</b>	<b>68</b>
<b>Finding Adjacent Gauges .....</b>	<b>69</b>
<b>Computing SRAFs Crossed By Gauges.....</b>	<b>70</b>
<b>Automatically Inserting Gauges for SRAFs .....</b>	<b>72</b>
<b>Loading Contours .....</b>	<b>73</b>
<b>Methods for Filtering Contour Blocks and Sites .....</b>	<b>74</b>

## Loading Gauge Files

A gauge file typically has a *Lithomodel* file and a design file associated with it, so that process information is kept together in the database.

### Prerequisites

- A gauge or super gauge data file in Calibre nmModelflow format
  - Gauge files that have user-defined columns must have their initial comment line start with ## instead of # to signal to Calibre nmModelflow that there are user-defined columns. They cannot use names that match existing column names. Column names

are case-insensitive. (Special characters are not allowed in column names, except for ##On and %95CI, both of which are not user defined.)

- Gauges from modelflow\_v2 gauges are converted automatically. If you want to manually convert gauges for use with Calibre nmModelflow, see the task “[Converting modelflow\\_v2 Gauge Files](#)”.

---

**Note**

---

 Sim Error values for gauges in Calibre nmModelflow use the opposite sign convention compared to Calibre WORKbench modelflow\_v2. Plots coming from Calibre nmModelflow may be flipped upside down compared to their modelflow\_v2 counterparts. To keep the sign convention consistent, set the environment variable:

`MDF_JOB_REPORT_ERROR_PLOTS_USE_MFV2_POLARITY 1`

---

- One of the following items is recommended (but not required):
  - A *Lithomodel* file.
  - A Calibre nmModelflow or Calibre® OPCverify™ setup file. Setup files from CM1 Center and the Litho File Tool will not work.
- The corresponding layout file.

## Procedure

1. Open the Calibre nmModelflow GUI (**Litho > nmModelflow**).
2. In the **Gauges** tab, click the **Load** button.

---

**Tip**

---

 You can use the dropdown menu for the **Load** button to reload your most recently-loaded gauge files.

---

The Load Data Wizard dialog box appears.

---

**Note**

---

 Alternatively, you can use the **Add Using Wizard** button from the Gauges list in the Database Browser. The Gauges Wizard that it invokes uses a similar flow.

---

3. Select the appropriate option (Gauge, Contour, or Gauge and Contour) from the list, then choose the appropriate file(s).
  - If there are custom columns in your loaded gauge file, they can be selected for inclusion from the Choose Gauge Extended Column List.
  - Activating the Fix Drawn option causes Calibre nmModelflow to check the layout when the gauges are loaded. If necessary, the Drawn column is adjusted to match the CDs measured in the layout.

- Activating the Load Hollow option causes Calibre nmModelflow to skip costly preprocessing actions (checks for uncentered gauges and clipping the layout for preparing the data for simulation) in order to load the gauges more quickly.

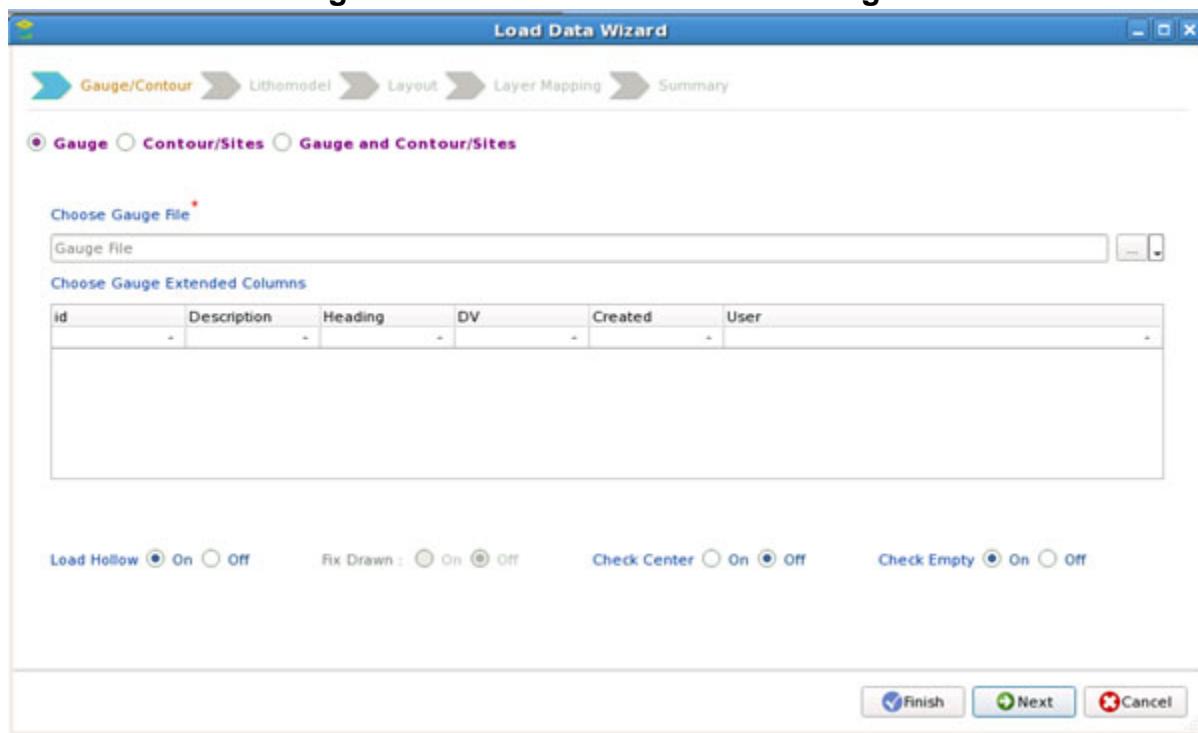
**Note**

 The mdf gauges loadhollow command is the CLI equivalent of this option.

- By default, the Check Empty option is selected. Unselecting this option allows you to load gauge files that contain empty gauges. (This option is useful for curvilinear mask gauge files.)

Click **Next** to continue.

**Figure 1-3. Load Data Wizard for Gauges**



- Select a data source using one of the radio buttons, then a layout, and then map the layout layers, clicking **Next** to proceed through each form (as shown in [Figure 1-4](#)):

- Layout only (not Lithomodel or Setup)** — Skips mask layer mapping and loads the specified layout along with the gauge file.

**Note**

 If you are using the Gauge Wizard, loading a layout is the only available option.

- Lithomodel** — Uses a previously created litho model to associate with the gauges. You must map the mask layers in the litho model to the layers in the layout.

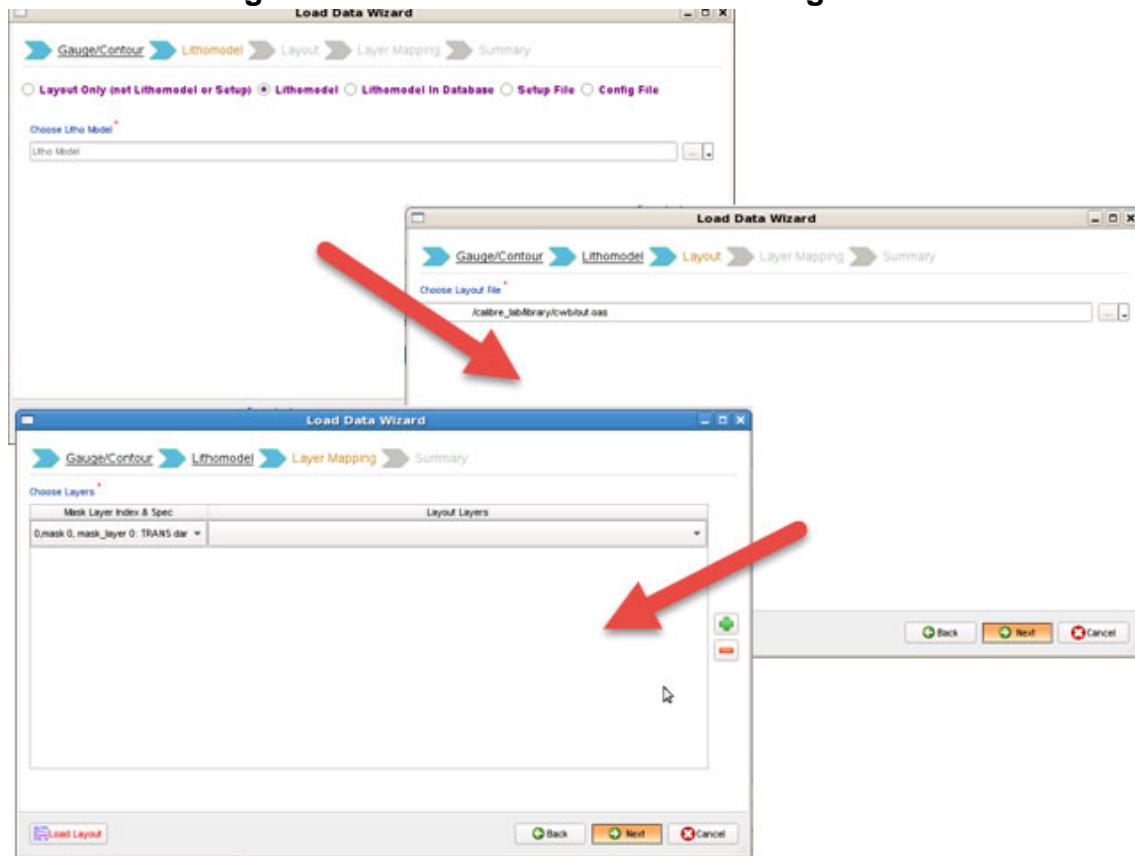
- **Lithomodel In Database** — Uses the litho model that you choose from the list of previously-saved litho models in the Calibre nmModelflow database.
- **Setup File** — Uses a Calibre nmModelflow setup file to load relevant information.
- **Config File** — Loads an MDF .in configuration file. Typically, this is used for DDM group file loading and VEB selective\_biasing\_type1 layer definition.

**Note**

The layer assignments in the Load Data Wizard are only for layers you intend to perform simulation and calibration on.

For users who have multilayer VEB files, do not map underlying layers in the Load Data Wizard. Underlying layers are mapped in the Litho Model Creation Wizard.

**Figure 1-4. Load Data Wizard Form Progression**



5. Configure the Summary screen as follows:
  - a. Review the Summary of Commands for the setup.
  - b. Set the Node, Layer, Gauge Description, and Lithomodel Description fields. These descriptions are displayed in the Gauges list on completion.

- c. (Optional) Select the Save Script checkbox to save the command summary for use from the command line.
- d. It is strongly advised that you leave the Import to Database checkbox selected, in order to reuse the imported litho model in calibration jobs.

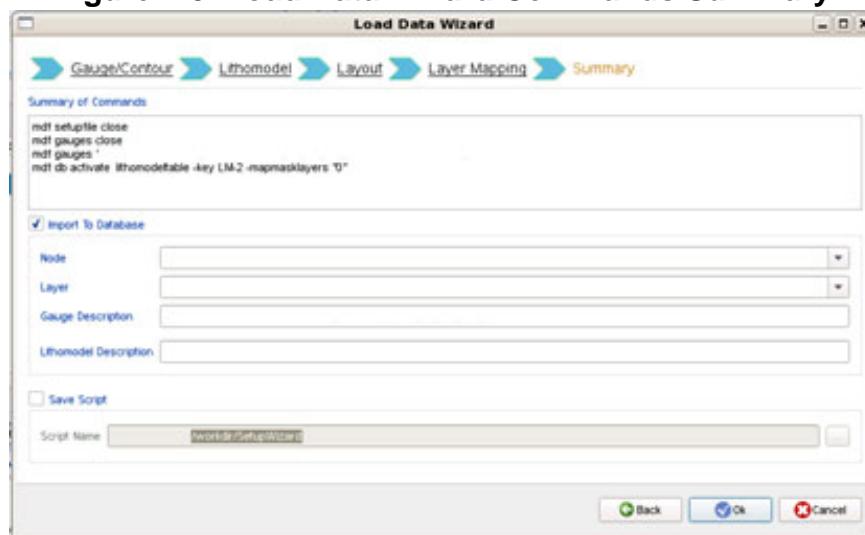
**Note**

 If you are using the Gauge Wizard from the Database Browser, this checkbox is not available, because adding the gauges to the database is assumed.

---

Click **OK** to finish importing the data.

**Figure 1-5. Load Data Wizard Commands Summary**



## Results

Calibre nmModelflow generates a setup file, runs the commands, and loads all data into the Calibre nmModelflow GUI.

- Calibre nmModelflow performs error checking for bad gauges.

Gauges that are duplicated (having identical coordinates) in a loaded gauge file are marked as “duplicate” in the ErrorInfo column, which is added to the imported gauge file.

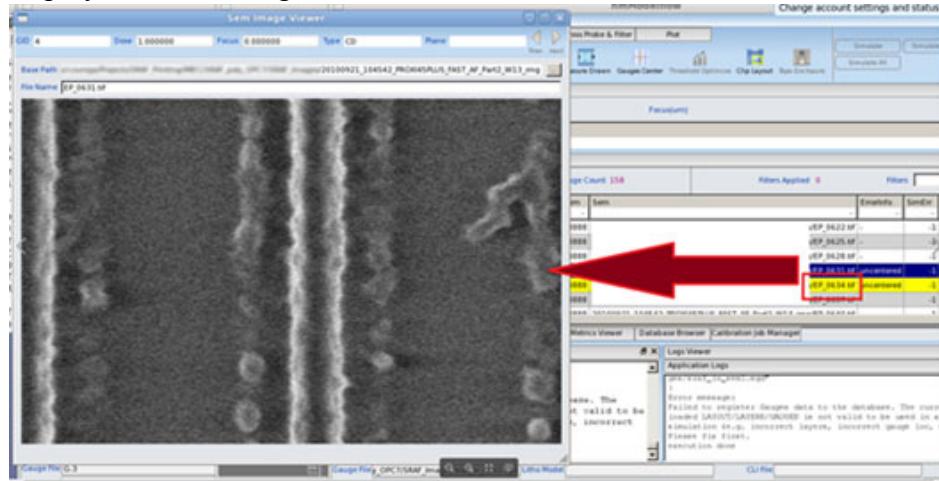
On	Struc	GID	Weight	X1	Y1	X2	Y2	Length	Drawn	Meas	Sim	ErrorInfo	SimErr	RSimErr
1	1	1	28	19012000	6306688	19012000	6309312	262.4	64	71.21	0	duplicate	-71.21	-100
2		2	32	38812000	6562688	38812000	6565312	262.4	64	74.7	0	duplicate	-74.7	-100
3		3	30.76	16042688	18228000	16045312	18228000	262.4	64	52.7	0	duplicate	-52.7	-100
4		4	32	17514688	18228000	17517312	18228000	262.4	64	55.49	0	duplicate	-55.49	-100
5		5	32	16108000	18994688	16108000	18997312	262.4	64	54.35	0	duplicate	-54.35	-100
6		6	28	17580000	18994688	17580000	18997312	262.4	64	58.06	0	duplicate	-58.06	-100
7		7	6.31	31186688	18292000	31189312	18292000	262.4	64	70.6	0	duplicate	-70.6	-100
8		8	2.77	31188000	18290688	31188000	18293312	262.4	64	68.84	0	duplicate	-68.84	-100
9		9	3.75	31186176	18356000	31189824	18356000	364.8	128	139.19	0	duplicate	-139.19	-100
10		10	9.37	31188000	18354176	31188000	18357824	364.8	128	76.86	0	duplicate	-76.86	-100
11		11	9.25	31186688	18932000	31189312	18932000	262.4	64	78.43	0	duplicate	-78.43	-100

Gauge Analysis   Contour Analysis   Plots   Metrics Viewer   Database Browser   Calibration Job Manager

### Tip

 You can remove the duplicate gauges using the “mdf gauges remove gidlist”, where *gidlist* is a list of GIDs separated by spaces.

- If the gauge file contains a SEM column, the entries in the column can be double-clicked to display the SEM image.



- If the gauge file contains Count and StDev columns with valid values, Calibre nmModelflow automatically calculates the 95% confidence interval and writes it into the 95CI column.

### Note

 If the 95CI column already contained data in your input gauge file, it is overwritten by the automatic calculations.

- On rare occasions, design files that contain SRAF gauges may detect errors while loading the gauge file if the default SRAF tolerance causes a centering error. Set a new

tolerance in the Command window using the mdf gauges sraftolerance command, then try reloading the gauges.

- If you load both gauges and contours that were derived from the same data, use the contour matching CLI command to tune the dose so that the threshold values for the gauges and contours match each other.

**mdf gauges matchcontour [-out output\_filename]**

## Related Topics

[Manipulating Gauges in the Gauge Analysis Tab](#)

# Converting modelflow\_v2 Gauge Files

Gauge files, which contain measurements of critical dimensions from a test chip, are used to calibrate the mathematical model of the process. Standard modelflow\_v2 gauge files are automatically converted to Calibre nmModelflow format.

Although conversion is automated when you use the **Load** button, manual conversion means are provided.

## Prerequisites

- A gauge file or super gauge data file from modelflow\_v2
- Calibre WORKbench invoked

## Procedure

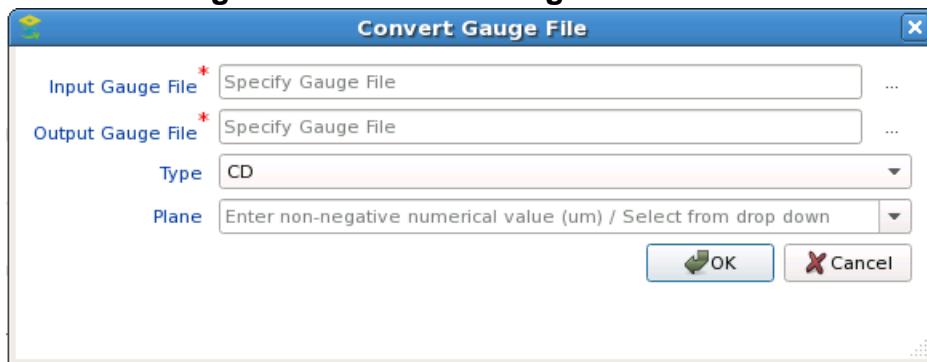
1. Open the Calibre nmModelflow GUI (**Litho > nmModelflow**).
2. Click the **Gauges** tab to raise the gauge controls.

**Figure 1-6. Gauges Tab**



3. Click the **Convert** button.
4. In the Convert Gauge File dialog box, click the Browse button (...) to the right of the Input Gauge File field and navigate to your modelflow\_v2 gauge (.gg) file or super gauge (.sgd) file.

**Figure 1-7. Convert Gauge File Wizard**



5. Set the name of the output converted gauge file (which must end in *.gg* for a gauge file or *.sgd* for a super gauge data file, as appropriate).
6. (Optional) Use the Browse button (...) to the right of the Output Gauge File field to set a destination directory; otherwise, the file is written to the directory where you started Calibre WORKbench by default.
7. In most cases, you can use the default Type field setting of CD. However, if you have a super gauge data file used with SRAF calibration (version 2), set the Type and Plane fields as follows:
  - **Set Type SRAF, Plane BOTTOM** — Use this combination for SRAF gauges near the resist bottom (where the exact plane value is a calibration parameter, initialized by the `-srafbotplane` parameter).
  - **Set Type SRAF, Plane TOP** — Use this combination for SRAF gauges near the resist top (where the exact plane value is a calibration parameter, initialized by the parameter `-raftopplane`).
  - **Set Type CD, Plane *value*** — Use this combination for CD gauges measured at a specified metrology plane (value in um measured from the bottom of resist). This supports the R3D model calibration flow using CD data measured at multiple metrology planes.

Click **OK** to convert the gauge file.

## Results

The converted gauge file is created in the specified directory and can now be loaded into the database.

## Related Topics

[Loading Gauge Files](#)

[Manipulating Gauges in the Gauge Analysis Tab](#)

# Adjusting the Length of Gauges

When you import or activate gauges, you may encounter the warning message “gauge has a length of  $x$  nm which is less than measured resist CD  $y$  nm.” Resolve this problem by lengthening the gauges in the gauge file.

## Note

 Changing the length of a gauge can have minor effects on the simulation values for gauges.

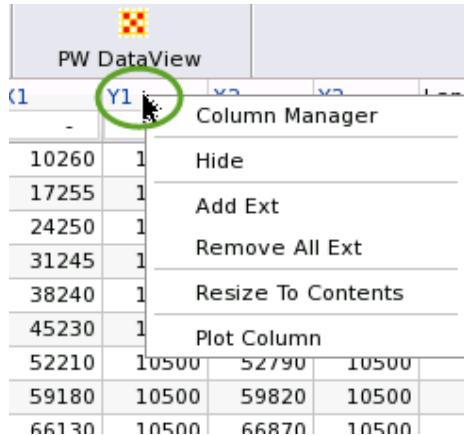
## Prerequisites

- Calibre WORKbench invoked and Calibre nmModelflow activated
- An active Calibre WORKbench compatible gauge file or super gauge file

The gauge file can be either from an initial **Load** button operation in the Gauges tab, or from an **Activate** button press in the Database Browser.

## Procedure

1. Right-click on any header to raise the context menu, then select **Column Manager**.



2. In the Column Manager, select the Coords group, and click **OK**.  
The Length column appears, along with the X1, Y1, X2, and Y2 columns.
3. Search the Length column to find the largest value in the column.
4. Add a reasonable tolerance factor to the largest value, and use that as the argument to the following command:

```
mdf gauges set_length -nm <custom_length>
```

## Results

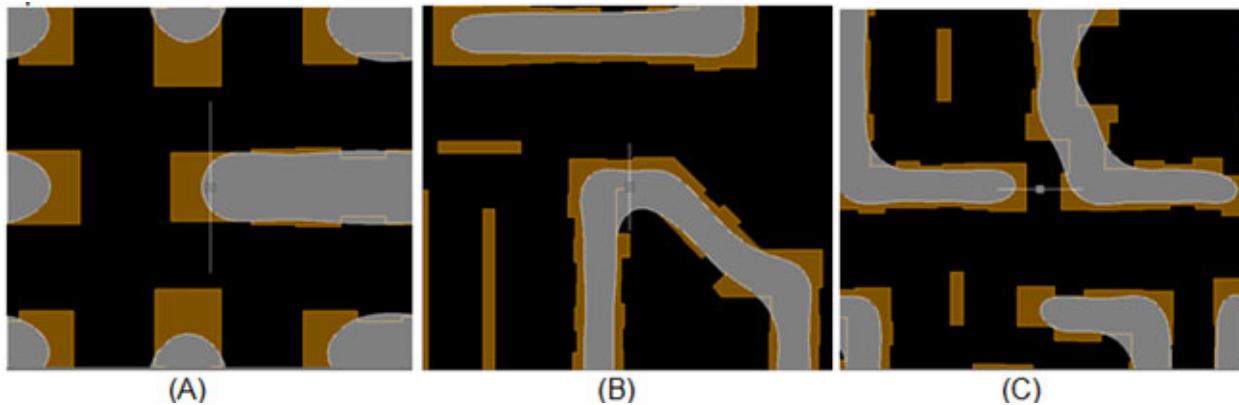
The Length field is set to the new value for all gauges, including gauges in other dose and defocus conditions in a super gauge data file. The X and Y coordinates for the gauges are modified to reflect the new length.

Clicking the **Add Active to DB** button in the Database Browser, Gauges group saves the modified gauges to a new database entry.

## Adjusting Gauge Symmetry

You may need to adjust gauge locations when gauges are not correctly placed in the position where the CDs are actually measured on the wafer. Gauges that are poorly placed near line ends (A), corners (B), and 45 degree edges of contours (C) may give unexpected EPE results.

**Figure 1-8. Gauge Misplacement Examples**



### Prerequisites

- A design file open in Calibre WORKbench

### Procedure

1. Open the design file (**File > Open Layout Files**)
2. In the Calibre nmModelflow Command Window, enter the mdf gauges checksymmetry command:

```
mdf gauges checksymmetry [-shift value] [-numpoints value]
  [[-simtype full | aerial] | {layer layernum}] [-rangingtol value] [-cdswingtol value]
  [-deltacdtol value] [-rsqtol value] [-out file]
```

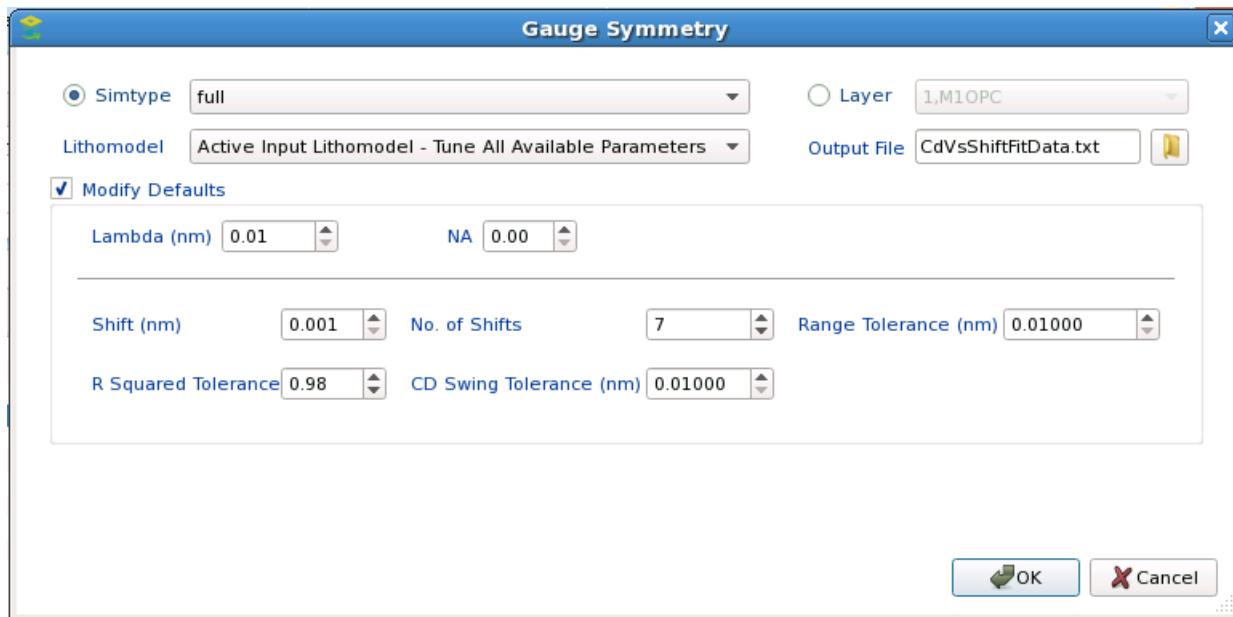
- **-shift** — Sets the width of the shift in nm on either side of a gauge. Vertical gauges are shifted horizontally, and horizontal gauges are shifted vertically. The default is 0.125\*lambda/NA (previous to 2020.2, it was 0.25\*lambda/NA).
- **-numpoints** — Specifies the number of shift values to try in an interval (-shift/+shift) with a step size of 2\*shift/(numpoints - 1). Must be a positive odd value greater than or equal to 3. The default is 7.
- **-simtype** — Sets the type of cutline used (full optical and resist simulation or aerial). The default is full (previous to 2020.2, it was aerial), unless **-layer** is specified.
- **-layer** — Specifies using edge collections from the given layer to measure drawn gauge CDs. This option is mutually exclusive with the **-simtype** argument.

- **-rangetol** — Sets the tolerance on CD range vs. shift below which the shift is not needed. Default =  $0.0035 * \text{lambda/NA}$  (recommended).
- **-cdswingtol** — Sets the tolerance parabolic CD swing vs. shift below which the shift is not needed. Default =  $0.0035 * \text{lambda/NA}$  (recommended).
- **-deltacdtol** — The tool outputs a non-zero recommended shift only if the CD impact from a gauge shift is greater than the specified value. Default = 0.1 nm.
- **-rsqtol** — Sets the tolerance for R squared fit value below which the polynomial fit of CD vs. shift is deemed poor. Default = 0.98 (recommended).
- **-out** — Specifies a CSV filename to write the command's output. Output is written to the console by default. It includes the following information:
  - GID — Gauge ID
  - Npoints — The number of valid CD versus shift points
  - CDrange — The difference between maximal and minimal shifted CDs
  - BHRecShift — The shift recommendation based on a BoxHeight fit
  - BHCD — BoxHeight approximation for simulated CD contours
  - BHDeltaCD — The CD difference based on a BoxHeight fit
  - CDswing — CD swing from the 2nd degree polynomial fit, if computed
  - RecShift2 — Shift recommendation based on poly2 fitting, if computed
  - CD2 — The poly2 approximation for the simulated CD computed at RecShift2
  - DeltaCD2 — The CD difference predicted with poly2
  - RSQ2 — The poly2 fit R squared value, if computed
  - Code2 — A numeric code associated with poly2
  - RecShift3 — Shift recommendation based on poly3 fitting, if computed
  - CD3 — The poly3 approximation for the simulated CD computed at RecShift3
  - DeltaCD3 — The CD difference predicted with poly3
  - RSQ3 — The poly3 fit R squared value, if computed
  - RecShift4 — Shift recommendation based on poly4 fitting, if computed
  - CD4 — The poly4 approximation for the simulated CD computed at RecShift4
  - DeltaCD4 — The CD difference predicted with poly4
  - RSQ4 — The poly4 fit R squared value, if computed
  - Code — The final numeric code

- DeltaCD — The final CD difference
- In addition, the numpoints columns of CD vs. shift data are also output to the file.

**Note**

 Starting with the 2019.4 release, these options are available using the **Gauge Symmetry** button in the **Gauges** tab.



Running this command computes simulated CD versus shift (or layout CD versus shift with the -layer argument) for each gauge and determines if a gauge shift is needed.

**Note**

 If the input gauge file is a super gauge data file, only the nominal process condition's shift values are used. Gauges that are not present in the nominal process condition are left unshifted, and their shift value is returned as undefined.

If the input gauge file contains a positive value in the BoxHeight column, the shift for that gauge is computed instead by averaging simulated CDs over shift values that meet the constraint:

```
-BoxHeight <= AveragedShift <= BoxHeight
```

The appropriate gauge location shift is determined by fitting the CD versus shift data using 2nd or higher order polynomials. The final shift depends on the CD versus shift range and fitting results, as well as on the quality of the polynomial fit. The output shift values produced by this command can subsequently be used to adjust gauge locations using the “mdf gauges symmetrize” command.

The result of a successful run are new results columns in the **Gauge Analysis** tab:

- Symmetrized difference output:
  - CtrSymmDiff if -simtype aerial was specified (default)
  - SymmDiff if -simtype full was specified
  - LayerSymmDiff if -layer was specified
- Gauges that have large positive values or large negative values are likely to benefit from having gauges shifted. The sign of the shift indicates the shift direction. The shift difference found by the command is reported in an additional column (CtrRecShift, RecShift, or LayerRecShift). Gauges that do not print or do not produce a reasonable shift value have this column value set as -8888, signifying an undefined value.

The “mdf gauges symmetrize” command uses the shift column to adjust the gauge position. If the gauge shift is undefined (-8888) the symmetrize command does not shift the gauge position.

- The CD difference, defined as  $|CD_{sim} - CD(\text{polynomial fit estimate})|$  and returned in the “CtrDeltaCD”, “DeltaCD”, or “LayerDeltaCD” columns.

---

**Note**

 If you want to use a different shift value than the suggested value, the RecShift and CtrRecShift columns can be edited.

---

A diagnostic code column is also added (CtrRecShiftCode, RecShiftCode, or LayerRecShiftCode) with the following meanings:

- 0 — Undefined code, which means that the appropriate polynomial could not be computed
- 10 and shift value of 0 — CD range is small
- 11 and shift value of -8888 — The gauge does not print inside the shift interval (comprised of [-BoxHeight, +BoxHeight])
- 12 and shift value of -8888 — CD data as a function of the shift exhibits no extremum value
- 13 and shift value of 0 — CD impact from BoxHeight gauge shift is small
- 14 — shift from BoxHeight fit
- 20 and shift value of 0 — CD impact from poly2 gauge shift is small
- 21 and shift value of -8888 — Not enough data for a poly2 fit
- 22 and shift value -8888 — CDswing is small
- 23 and shift value of -8888 — poly2 shift is large

- 24 and shift value of -8888 — poly2 R squared is small
- 25 and an actual value for shift — CD shift value is from the poly2 fit
- 30 and shift value of 0 — CD impact from poly3 gauge shift is small
- 31 and shift value of -8888 — Not enough data for a poly3 fit
- 32 and shift value of -8888 — poly3 fit exhibits no extremum
- 33 and shift value of -8888 — poly3 shift is large
- 34 and shift value of -8888 — poly3 R squared is small
- 35 and an actual value for shift — CD shift value is from the poly3 fit
- 40 and shift value of 0 — CD impact from poly4 gauge shift is small
- 41 and shift value of -8888 — Not enough data for poly4 fit
- 42 and shift value of -8888 — CD data for the poly4 fit exhibits no extremum
- 44 and shift value of -8888 — No shift can be found with up to a 4th order polynomial fit
- 45 and an actual value for shift — CD shift value is from the poly4 fit

3. In the Command Window, enter the mdf gauges symmetrize command:

```
mdf gauges symmetrize [-out file] [-mode disable | keep]  
[-simtype full | aerial | layer] [-addtodb]
```

- **-out file** — Saves the modified gauge data to the specified file.
- **-mode** — Sets how undefined (failed) shifts are handled:
  - **keep** — Retains undefined gauges. This is the default behavior.
  - **disable** — Disables gauges whose recommended shifts are undefined.
- **-simtype full | aerial | layer** — Optionally specifies a results column containing the value to use to move the gauge: full (RecShift DV column), aerial image (CtrRecShift DV column), or layer (LayerRecShift DV column). You must use the same value you specified for **-simtype** in Step 2. The default is aerial.
- **-addtodb** — Optionally adds symmetrized gauges to the database.

## Results

The gauges that were found to have symmetry issues are moved according to the RecShift, CtrRecShift, or LayerRecShift columns, and the modified data is saved to the file.

Starting with the 2020.2 release, the RecShift, CtrRecShift, and LayerRecShift columns are zeroed out, and new columns ShiftDone, CtrShiftDone, and LayerShiftDone are added showing the shift that was performed.

# Centering Gauges

Calibre nmModelflow has the capability to recenter gauges that may not be aligned well with the geometry of the associated target layer.

## Prerequisites

- A gauge set in the Calibre nmModelflow database

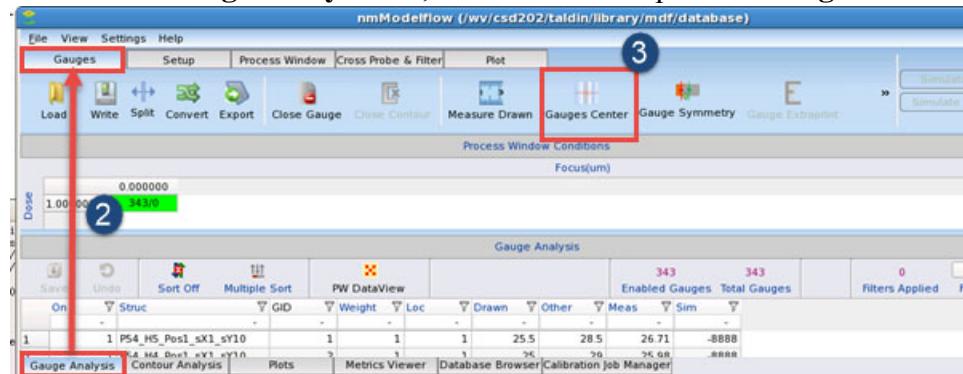
### Note

 When you initially load a gauge set using the CLI command or a Tcl script, adding the optional -checkcenter on flag to the mdf gauges command tests if centering gauges would cause them to become duplicates of other gauges.

These gauges will be marked ‘duplicate\_after\_centering’ in the gauge file.

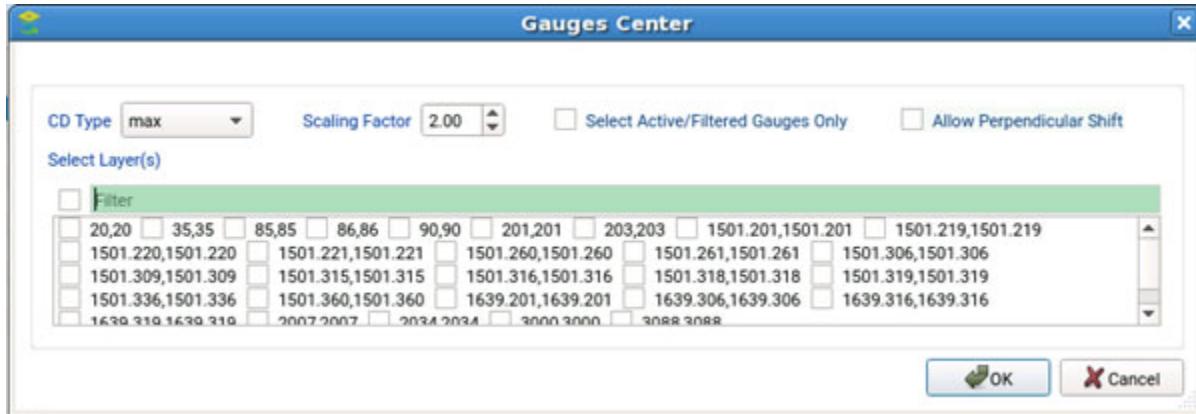
## Procedure

1. If the gauge set is not already active:
  - a. Switch to the **Database Browser** tab.
  - b. Select the **Gauges** group from the database list on the left.
  - c. Select the desired gauge from the list of gauges.
  - d. Click **Activate**.
2. Switch to the **Gauge Analysis** tab, and switch the top tab to **Gauges** mode.



3. Click **Gauges Center**.

4. In the Gauges Center dialog, select options as needed:



- **CD Type** — Sets the criteria for the centering point of the gauges.
  - **Drawn** — Use the Drawn column as the centering point.
  - **Meas** — Use the resist measurement column as the centering point.
  - **Meas\_Etch** — Use the etch measurement column as the centering point.
  - **Max** — Use the highest value of the Drawn, Meas, or Meas\_Etch columns as the centering point.
- **Scaling Factor** — Specifies the scaling factor for the gauge. The default is 2x the current size, and this value must be at least 1.0. A value of 1.0 indicates that the gauges are centered, but not resized.
- **Select Active/Filtered Gauges Only** — Sets the centering to be done on only active gauges.
- **Allow Perpendicular Shift** — Allows shifting to be performed in the perpendicular direction. This operation only shifts the gauge if the gauge crosses two edges of interest that form a rectangle with the gauge.
- **Select Layers** — Optionally specifies layers to search for centering geometries on.

Click **OK** to continue.

## Results

The gauge location (X1, X2, Y1, Y2 columns) is adjusted to center the gauge with the new scaling factor. All gauges (both enabled and disabled) are adjusted.

**Note**

 If the resulting gauges appear uncentered and your design contains SRAFs, you will need to adjust the SRAF tolerance using the “mdf gauges sraftolerance” command.

- The default value is the measured CD divided by 3, but no greater than 40nm.
  - Specify a new value based on the line width of your SRAFs compared against the measured CD.
  - After running the command, you will need to reload the gauge file again (because midpoint coordinates are stored when loading gauges, not when centering) before trying to recenter the gauges.
- 

## Methods for Filtering Gauges

Filtering gauges helps narrow your focus to only inspect gauges that are critical to your design or that may cause problems.

### Filters Available From the Command Line

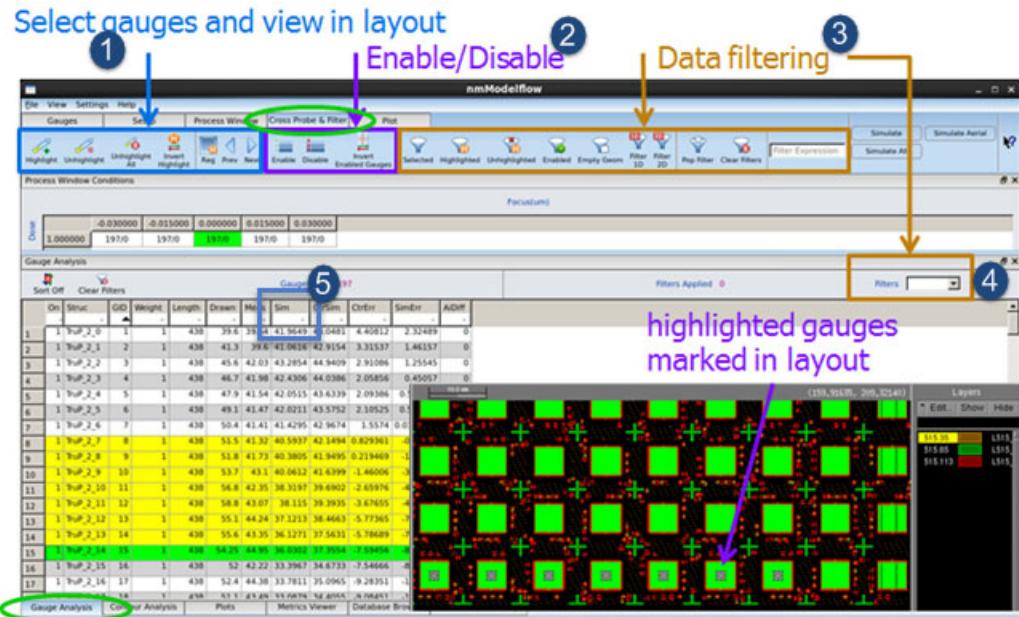
Use the mdf filter apply command to manually filter data from the visible gauges in the **Gauge Analysis** tab. Some examples:

- `mdf filter apply {sort:$SimErr top 10}`  
Filters out all gauges except the top ten highest simulation errors. (Similarly, you can specify ‘bottom’ to get the lowest values.)
- `mdf filter apply {$Meas < 160}`  
Filters out any gauges whose measured values are greater than or equal to 160nm.

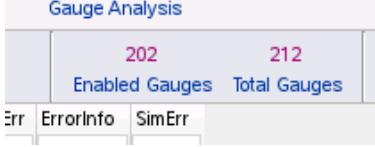
### Filter Controls Available from the GUI

Use the figure and table to learn the methods available in the interface to filter out gauges in the **Cross Probe & Filter** tab (green circle at the top of the figure).

**Figure 1-9. Cross Probe and Filter Controls**



**Table 1-6. Gauge Analysis Tab, Cross Probe and Filter Methods**

Method	Description	See Also
1 Highlighting controls	Selects gauges in the layout for further operations.	<a href="#">Manipulating Gauges in the Gauge Analysis Tab</a>
2 Enabling controls	<p>Enables or disables selected gauges. Disabled gauges are not simulated or calibrated.</p> <p>The number of enabled gauges versus total gauges is shown at the top of the <b>Gauge Analysis</b> tab.</p> 	<a href="#">Manipulating Gauges in the Gauge Analysis Tab</a>
3 Filtering controls	<p>Shows only gauges that meet filtering criteria.</p> <p>The Filter Expression entry field can contain any Tcl Boolean expression.</p> <p>Filter expressions are considered a substring match. To specify an exact match of a filter expression, specify “==” before the string.</p> <p>Right-clicking the filter icon in the column header shows a checkbox list of all items in that column for multiple selection purposes.</p>	
4 Filter pulldown	Shows only gauges that match a previously-defined filter in the Filters database.	<a href="#">Creating a Filter</a>
5 Interactive column header	Filters gauges based on a Tcl equality (==), inequality, or string match expression you enter in the text field under a column header.	<a href="#">Manipulating Gauges in the Gauge Analysis Tab</a>

## Manipulating Gauges in the Gauge Analysis Tab

Gauge data can be sorted and filtered from the **Gauge Analysis** tab. They can also be highlighted and viewed in the layout using the functions in the **Cross Probe and Filter** tab.

### Prerequisites

Gauge data loaded into Calibre nmModelflow

## Procedure

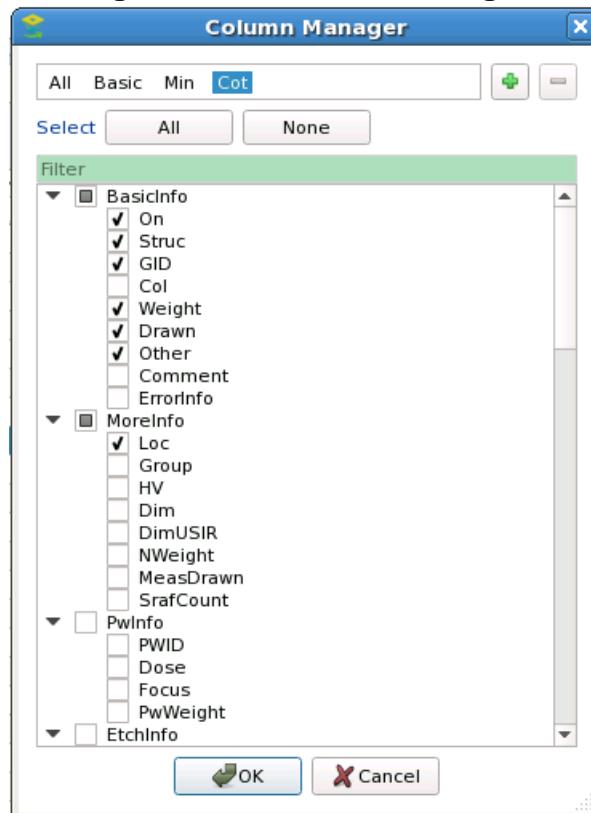
1. Raise the **Gauge Analysis** tab in Calibre nmModelflow.

The screenshot shows the 'Gauge Analysis' tab selected in the bottom navigation bar. The main area is a table with columns: On, Struc, GID, Weight, Loc, Drawn, Other, Meas, and Sim. The table contains 216 rows of data, with the last row being a summary. The top right of the table displays '216 Enabled Gauges' and '216 Total Gauges'. Below the table, there are buttons for 'Save', 'Undo', 'Sort Off', 'Multiple Sort', and 'PW DataView'. The bottom of the window has tabs for 'Gauge Analysis' (selected), 'Contour Analysis', 'Plots', 'Metrics Viewer', 'Database Browser', and 'Calibration Job Manager'.

On	Struc	GID	Weight	Loc	Drawn	Other	Meas	Sim
1	iso	1	1	0	80	0	80	78.8834
2	iso	2	1	0	90	0	90	89.773
3	iso	3	1	0	100	0	100	101.923
4	iso	4	1	0	110	0	110	114.462
5	iso	5	1	0	120	0	120	126.058
6	iso	6	1	0	140	0	140	145.521
7	iso	7	1	0	180	0	180	183.951
8	iso	8	1	0	240	0	240	243.591
9	iso	9	1	0	340	0	340	341.179
10	iso	10	1	0	500	0	500	498.699
11	iso	11	1	0	760	0	760	758.105
12	iso	12	1	0	1200	0	1200	1198.09
13	iso_pad	13	1	0	90	80	90	89.5087
14	iso_pad	14	1	0	90	90	90	90.4241
15	iso_pad	15	1	0	90	100	90	88.8355
16	iso_pad	16	1	0	90	110	90	86.4962
17	iso_pad	17	1	0	90	125	90	85.3235
18	iso_pad	18	1	0	90	145	90	88.1596
19	iso_pad	19	1	0	90	180	90	90.0485
20	iso_pad	20	1	0	90	240	90	89.3572
21	iso_pad	21	1	0	90	335	90	89.3712
22	iso_pad	22	1	0	90	405	90	89.389

2. Right click a column header and select **Column Manager** from the popup menu.

Figure 1-10. Column Manager



Four preset functional groups are available from the Column Manager. Clicking a group item at the top of the dialog box toggles the columns for that setting in the window below.

Select columns or groups of columns to show using the checkboxes. Alternatively, clicking Select All will select all columns, and clicking Select None will deselect all columns. The Filter input field allows you to search for columns by name. After your columns of interest are selected, click **OK**.

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**Note**

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 For definitions of the columns themselves, see “[Gauge Column Listing](#)” on page 293.

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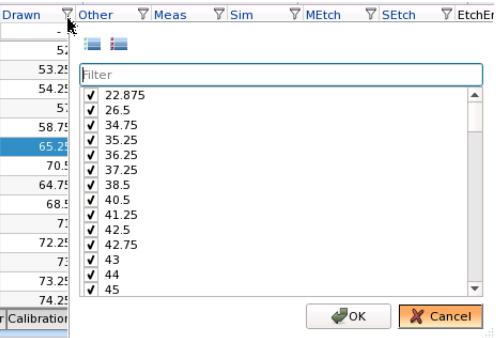
- **All** — Shows all defined gauge data columns.
- **Basic** — Limited information about the gauge, measurements, and weight.
- **Min** — Only the minimum information about the gauge structure ID and the simulation data.
- **COT** — Comprehensive Output Table. A customized output table consisting of groups of data.
  - **Basic Information** — Basic information identifying the gauge.
  - **MoreInfo** — Additional information about the gauge, such as orientation, type, group, and nominal weight.
  - **PwInfo** — Process window information on the active condition.
  - **EtchInfo** — Information relevant to etch calibration.
  - **Resist Info** — Information relevant to resist calibration.
  - **AerialInfo** — Information on the aerial image simulation at a constant threshold.
  - **Coords** — Coordinates for the gauge.
  - **FocusInfoSim, FocusInfoMeas** — Information on the through-focus data.
  - **DofInfoSim, DofInfoMeas** — Information on the depth of focus data.
  - **DoseInfoSim, DoseInfoMeas** — Information on the dose data.
  - **StatMeasInfo** — Statistical analysis items.
- **CustomCols** — User-created columns show up in this list. If there are no user-created columns, this group does not appear. See “[Adding User-Defined Columns to the Gauge Analysis Tab](#)” for instructions on creating custom columns.

**Tip**

**i** You can also use the + button to the right of the groups to create a custom group of your own, using the currently selected columns.

3. (Optional) Use any of the methods shown in [Table 1-7](#) to manipulate the data.

**Table 1-7. Methods of Manipulating Gauge Data**

Action	Notes
Right-click a column header	<p>Brings up a menu with options to show, hide, add, remove, resize, and plot columns.</p> <p><b>Note:</b> There is no undo ability for modified data. Exercise caution when using commands that modify multiple values in a column.</p>
Type an expression in a column that has a “-” button in it	<p>Filters out all gauges that do not meet the expression criteria. You can enter filter strings or expressions.</p> <ul style="list-style-type: none"> <li>Entering a string limits gauges to only gauges matching the string. You can use this to see only gauges of a certain structure type.</li> <li>Expressions filter the data. For example, entering <code>&lt; 50</code> in the Sim column filters out gauges that have Sim values greater than 50.</li> </ul>
Type a formula in a column that has a “-” button in it	<p>Entering a formula modifies the data. For example, entering <code>={abs{\$Meas-\$Sim}}</code> in the Weight column sets the weight for the whole column.</p>
Right-click the filter icon (sieve button)	 <p>Opens a checkbox selector with all distinct items in that column. Selecting one or more items filters out the gauges to only the values selected.</p>

**Table 1-7. Methods of Manipulating Gauge Data (cont.)**

Action	Notes
Click Multiple Sort	<p>Multiple sort mode uses the Drawn and Other columns as a sorting criteria. Clicking in the column “-” field adds that column to the sort priority list. Clicking the column again removes it from the sort list.</p> <p>Clicking <b>Sort Off</b> removes the sorting criteria.</p>
Shift-click to select multiple rows; Ctrl-click to add a row to the selection	<p>Perform operations on selected rows by right-clicking with rows selected. (Some operations are available as both a single process result and for all process windows, marked as “All PW”.)</p> <p>The following options are available:</p> <ul style="list-style-type: none"> <li>• Plot Cutline Aerial Intensity</li> <li>• Plot Cutline Resist Intensity</li> <li>• Plot Bossung ThruFocus</li> <li>• Plot Bossung ThruDose</li> <li>• Plot Bossung ThruPlane</li> </ul> <p> <b>Note:</b> The Plot Bossung options have a sub-menu available when multiple gauges are selected, providing a choice of a single plot containing all GIDs selected or separate plots for each GID selected.</p> <ul style="list-style-type: none"> <li>• Plot Common Process Window</li> <li>• Plot Contour, Plot Aerial Contour</li> <li>• Plot Grid</li> <li>• Enable, Disable</li> <li>• Assign Weight</li> <li>• Cross Probe</li> <li>• Highlight, Unhighlight, Unhighlight All</li> <li>• Remove Gauge(s)</li> <li>• Copy Text</li> </ul> <p> <b>Note:</b> The available options depend on the type of data that is activated. Some of these options are disabled when an active gauge has a single PW condition, and are enabled when an active gauge has multiple PW conditions.</p>

4. (Optional) Use the button controls in the various menu tabs to operate on gauges.

**Table 1-8. Methods of Operating on Gauge Data**

Menu Tab	Control	Description
<b>Gauges</b>		
	Load	Loads gauges from a gauge, super gauge, or .csv file. The <b>Load</b> button also keeps a history of previously-loaded gauge files.
	Write	Writes out gauges to a file. This button opens a prompt box to select the measurement method for gauges to be written.
	Split	Splits the gauges into a calibration set and a validation set, writing the results to two separate files.
	Convert	Converts a modelflow v2 gauge file into a Calibre nmModelflow gauge file.
	Export	Exports the entire universal spreadsheet (all columns active in the Column Manager) in the Gauge Analysis tab to a file.
	Import From Layer	Imports gauges drawn on a specified layer in the active layout into the active gauge set.
	Close Gauge	Closes the active gauge set.
	Close Contour	Closes the active contour.
	Measure Drawn	Fills a specified column with CD measurements taken from the active layout along gauge lines.  <b>Note:</b> Starting with the 2019.2 release, the dialog box can also detect SRAFs within a certain tolerance distance of the gauge.
	Gauges Center	Centers gauges at the midpoints of geometries. See “ <a href="#">Centering Gauges</a> ” on page 39 for more information.
	Gauge Symmetry	Tests for gauge symmetry in the direction perpendicular to the cutline by specifying a shift value, simulation type, and lithomodel.
	Gauge Extraprint	Tests for extra printing between CTR and resist model simulations around gauges. See “ <a href="#">Generating Extra Printing Information</a> ” on page 63 for more information.

**Table 1-8. Methods of Operating on Gauge Data (cont.)**

<b>Menu Tab</b>	<b>Control</b>	<b>Description</b>
	Calculate MEEF	<p>Runs an extra simulation to calculate the MEEF for the active gauge, using a 1 nm resize factor by default.</p> <p>You can also use the “mdf simulate meef” command to perform the following:</p> <ul style="list-style-type: none"> <li>• Show the aerial image MEEF, the default resist meef, or both (-simtype aerial   full   all). The column used for aerial image MEEF is CtrMEEF.</li> <li>• Specify a different resizing factor (-meefsizennm parameter).</li> <li>• Select a different column header name (-meefcolout parameter; the default is “MEEF”).</li> </ul>
	Threshold Optimize	Optimizes image and resist thresholds for the active litho model.
	Clip Layout	<p>Clips the layout around gauge cutlines to obtain only the layout needed for model calibration. This is used to reduce the size of the layout in order to improve GUI response time and job preparation time.</p> <p>Clipping (also available in CM1 Center) limits the areas that need to be manipulated and saved to the contours and polygons near the gauge cutlines.</p>
	Topo Enclosure	Computes topoenclosures (distances from CD sites to the nearest edge of an underlying active or poly feature). Runs the ‘mdf gauges topoenclosure’ command. Results are placed in the TopoEnclosure column.
	SRAF Count	Computes the number of SRAFS crossed by a gauge. Results are placed in the SrafCount column.
<b>Process Window</b>		
	Dof	Returns the common focus window width. Adds the “dof” and “dofcenter” columns to the <b>Gauge Analysis</b> tab.
	Doselat	Returns the common focus window width. Adds the ‘doselat’ and ‘dosecenter’ columns to the <b>Gauge Analysis</b> tab.
	Filtbossung	Filters the gauge list by specified criteria.
	Focen	Returns the mean focus center.
	Dofcen	Adjusts beamfocus by minimizing the meanfocus_shift value.

**Table 1-8. Methods of Operating on Gauge Data (cont.)**

Menu Tab	Control	Description
	Simulate	Performs simulation for optics and resist, including etch if an etch model is part of the active litho model.
	Simulate Aerial	Performs simulation for an aerial image model with a CTR resist.
	Simulate All	Performs both the Simulate and Simulate Aerial functions.
<b>Cross Probe &amp; Filter</b>		
	Highlight	Highlights selected gauges.
	Unhighlight	Clears the highlight on selected gauges.
	Unhighlight All	Clears the highlight on all gauges.
	Invert Highlight	Changes the highlighting of the currently highlighted gauges.
	Reg	Highlights gauges inside a region you select in the Calibre WORKbench main layout viewer window.
	Prev / Next	Centers the view in the main layout viewer on the current gauge (highlighted in green) in a selected set. The Prev and Next controls cycle through the set.
	Enable / Disable	Toggles the enabled/disabled property of the selected gauges.
	Invert Enabled Gauges	Changes the enabled/disabled property of all gauges to be the inverse of their current status.
	Selected	Filters out all gauges except for the selected gauges.
	Highlighted	Filters out all gauges except for gauges that you have highlighted.
	Enabled	Filters out all gauges except enabled gauges.
	Empty Geom	Filters out all gauges except for ones that have empty geometry.
	Filter 1D	Filters out all gauges that are not designated as 1D gauges.
	Filter 2D	Filters out all gauges that are not designated as 2D gauges.
	Pop Filter	Removes the last filter that was applied.
	Clear Filters	Removes all filters.
<b>Plot</b>		

**Table 1-8. Methods of Operating on Gauge Data (cont.)**

Menu Tab	Control	Description
	Gauge Data Plot	Plots columns you select in a dialog box based off of the active gauge data.
	Cutline	Reforms cutline measurements on a single gauge for one or more process window conditions.
	Thrufocus, Thrudose, Thruplane	Generates a Bossung plot for a specified gauge for one or more process window conditions through the dose, focus, or image plane.
	Contour	Plots contours for selected gauges.

## Related Topics

[Converting modelflow\\_v2 Gauge Files](#)

[Adding Process Window Conditions to a Litho Model](#)

# Adding User-Defined Columns to the Gauge Analysis Tab

You can add more columns to the **Gauge Analysis** tab in order to expand on the data results or create custom output values. Calibre nmModelflow maintains a universal gauge spreadsheet that contains all defined columns. Only a selected subset of the universal gauge spreadsheet is displayed in the **Gauge Analysis** tab.

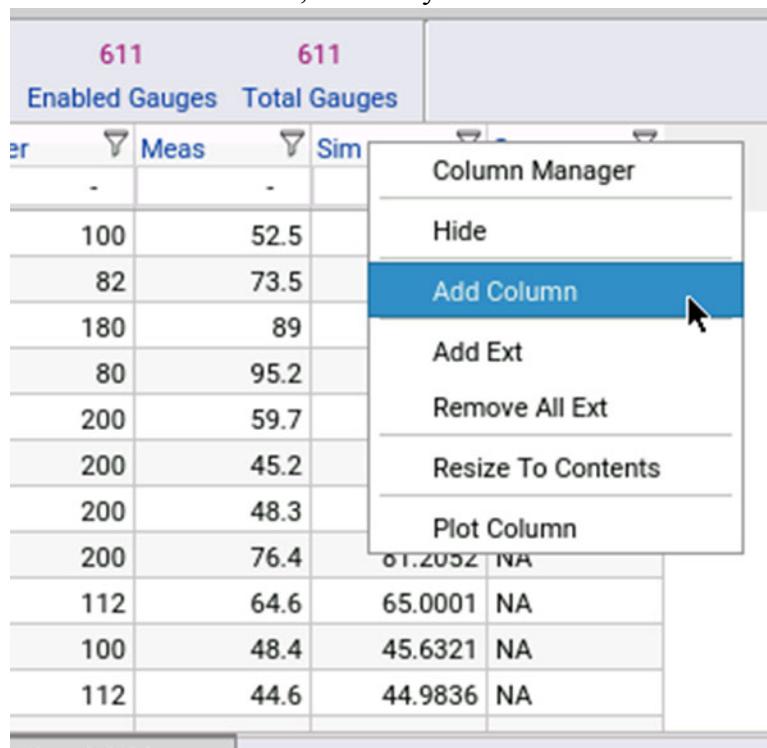
## Prerequisites

- A set of gauges loaded in the **Gauge Analysis** tab

## Procedure

1. In the **Gauge Analysis** tab, right-click the top of any gauge column, and select:
  - **Add Column** to add a variable-value column

- **Add Ext** to add a calculated, read-only column



2. In the Add User Defined Column dialog box, enter a name for the column, the displayed value (DV) for the new column, and set a data type (for variable value columns only), then click **OK**.
  - Special characters are not allowed in column names.
  - Column names are case insensitive, and cannot match the name of an existing column.
  - The Column DV field for calculated (Add Ext) columns requires a Tcl expression, usually based on existing columns. For example, specifying “abs(\$Sim-\$Meas)” displays the absolute difference between the Sim and Meas columns.
3. You can hide your new columns by right-clicking the top of any gauge column, selecting **Column Manager** from the popup menu, and disabling the new columns in the Column Manager.

#### **Note**

 You can remove custom columns by using the **Remove Ext** menu choice with a column selected, or **Remove All Ext** to remove all custom columns.

# Selecting Focus-Sensitive Data

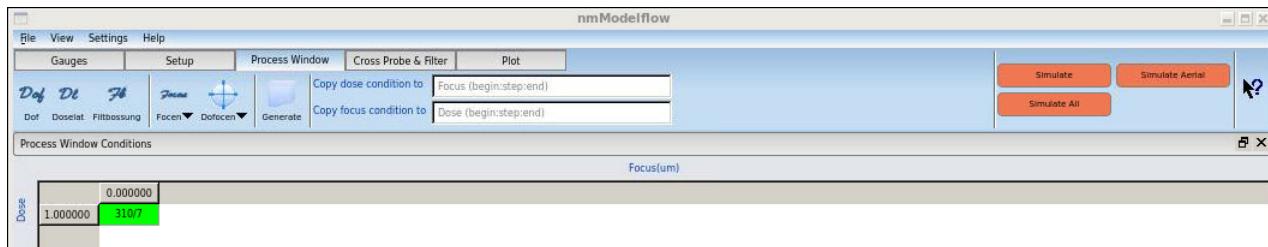
Focus-sensitive data is of particular interest in model calibration. The Calibre nmModelflow GUI has the capability to filter out test structures that meet certain criteria.

## Prerequisites

- An active super gauge data object loaded into Calibre nmModelflow and the corresponding test pattern design file loaded into Calibre WORKbench
- An active litho model to test against the gauges with generated process models (see “[Adding Process Window Conditions to a Litho Model](#)”)

## Procedure

1. Switch to the **Process Window** menu bar tab.
2. If the **Simulate All** button (located on the right side of the **Process Window** tab) is orange, click it to update the simulated CDs across the process window.



### Tip

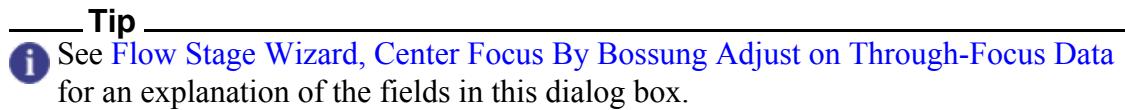
If the **Simulate All** button is transparent, it means that the simulations have not been updated for the active data set. Click the **Simulate All** button to update.

The simulation runs and updates the gauge data in the **Gauge Analysis** tab.

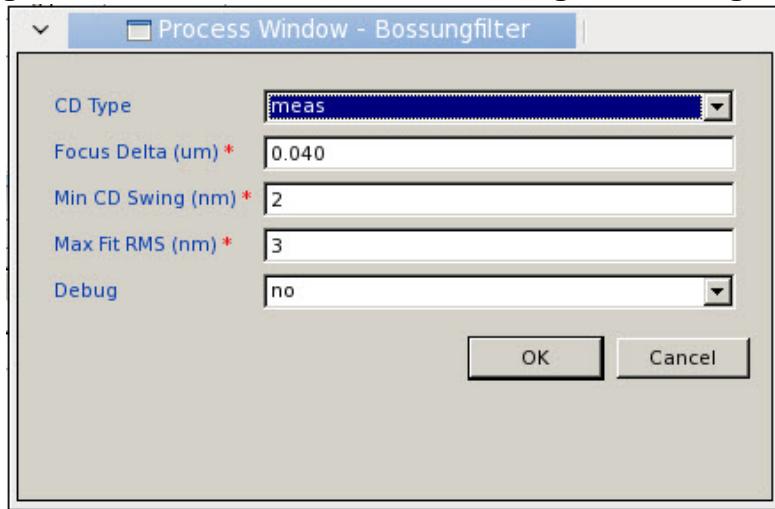
3. Click the **Filtbossung** button, located on the left side of the **Process Window** tab.



4. In the Process Window, Bossungfilter dialog box that appears, fill out the fields as appropriate and click **OK**.



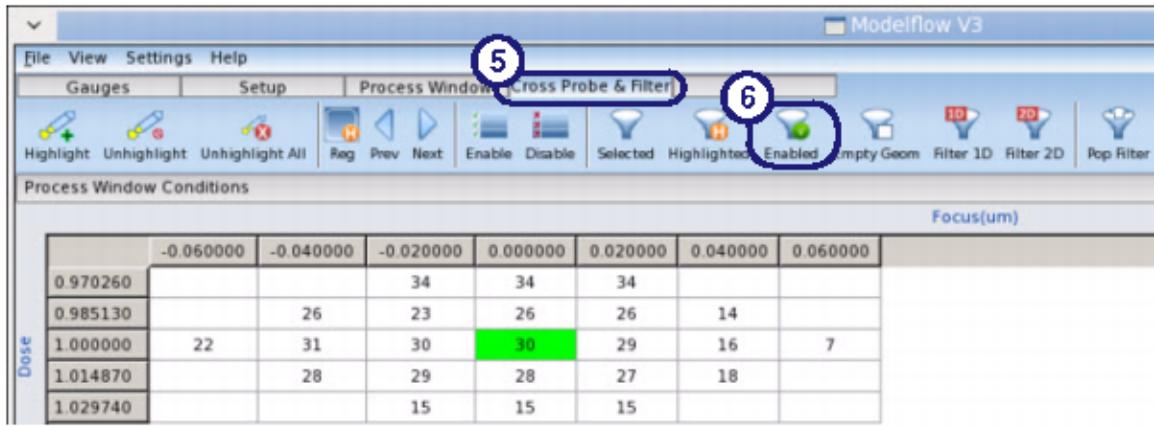
**Figure 1-11. Process Window, Bossungfilter Dialog Box**



The Bossung filter command runs. Only gauges that meet the Bossung filtering criteria remain enabled.

5. Raise the **Cross Probe & Filter** tab.
6. Click the **Enabled** button to filter the gauges so that only the enabled gauges are shown.
7. (Optional) Save the filtered data set to a file or to the database for future use.

**Figure 1-12. Cross-Probe & Filter Tab**



## Results

The filtering affects all of the process window conditions. If you switch the active process window condition (by double-clicking on its cell in the panel) you will see only the enabled gauges.

For example, double-clicking on the “7” cell at 0.06 Focus, 1.0 Dose in the matrix changes the Gauge Analysis tab contents to a view that shows only seven gauge objects with the simulation results at that dose and focus condition.

The Application Log window shows the results summary from the data filtering.

The filtered dataset can be saved to file or to the database for future use.

**Note**

To return only the most focus-sensitive gauges, a CLI-only option is available using the “mdf pw bossungfilter” CLI command with the -num option. However, note that this option is incompatible with Min CD Swing and Max Fit RMS options.

## Related Topics

[Adding Process Window Conditions to a Litho Model](#)

[Manipulating Gauges in the Gauge Analysis Tab](#)

# Viewing Depth of Focus Data

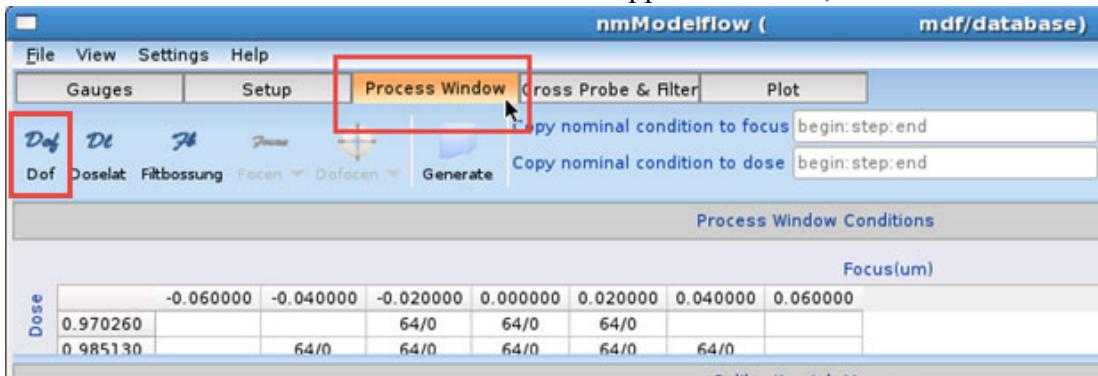
Depth of focus information can be generated for a process window in Calibre nmModelflow when there are enough process conditions available in the super gauge data object.

## Prerequisites

- Calibre nmModelflow invoked
- A super gauge data object in the **Gauge Analysis** tab

## Procedure

1. Ensure that the super gauge data is set to the nominal dose and focus condition.
2. Switch the mode to Process Window in the upper button bar, then click the **Dof** button.



3. Fill out the entries in the Process Window - Dof wizard as shown in the table.

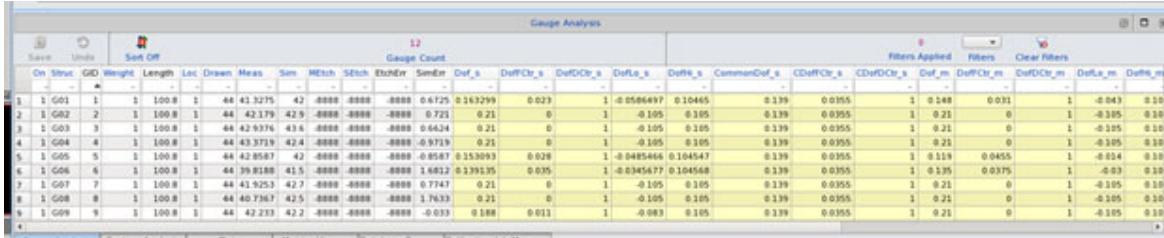
**Table 1-9. Process Window, Dof Wizard**

Field	Description
Model Form	Sets the polynomial model (eight-term, second order dose and focus or 13-term, third order dose and fourth order focus) to fit the Bossung data.  poly8 requires a minimum of 3 dose and focus conditions. poly13 requires a minimum of 4 dose conditions and 5 focus conditions.
Type	Sets the type of shape to fit inside the process window curves (elliptical or rectangle).
Target CD	Sets the target CD to either the drawn value or the nominal contour width.
Center	Sets the center point of the output shape between none (no restrictions), focus (forces the focus center to be at the nominal focus), and dose (forces the dose center to be at the nominal dose), or both (combines focus and dose options).
Nominal Dose and Focus	Sets the nominal dose and focus values for the calculation.
CD Tolerance (%)	Sets the CD tolerance range in +/- the specified value percentage to compute the process window curves. Smaller values decrease the process window size. Default is 10.
Dose Latitude (%)	Sets the fixed exposure latitude to compute the depth of focus. This value sets the height of the output ellipse or rectangle. The DOF is the width of the output shape. Default is 5 percent.

4. When you have finished configuring the wizard, click **OK**.

## Results

After the run completes, numerous columns are added to the **Gauge Analysis** tab for the active gauge and all other gauges in the process window. The new columns contain process window information relevant to the chosen fit of the depth of focus data.



The screenshot shows a software interface titled "Gauge Analysis". The main area is a grid table with approximately 20 columns and 10 rows of data. The columns are labeled with various parameters such as On, Struc, GID, Weight, Length, Loc, Drawn, Meas, Sim, Mfch, Sbm, EtchMr, SemMr, Def\_s, DefOCr\_s, DefOCr\_x, DefOCr\_y, DefOCr\_z, DefOCr\_a, CommonDef\_s, CDefOCr\_s, CDefOCr\_x, CDefOCr\_y, Def\_m, DefOCr\_m, DefOCr\_x\_m, DefOCr\_y\_m, and DefOCr\_z\_m. The data rows represent different measurement points or structures, with values ranging from -0.043 to 0.148. The interface includes standard Windows-style buttons for Save, Undo, Sort Off, and Filter controls.

# Calculating the Process Capability Index

Calibre nmModelflow can calculate the Process Capability Index (Cpk) for groups in a gauge file given upper and lower limits. Currently, this functionality is only available via a Calibre nmModelflow Tcl command.

## Prerequisites

- A standard CM1 gauge file, which must have the following columns filled in:
  - Prec — The precision for the gauge in nm, as the absolute error for the measured data.
  - Sim, SEtch, or CtrSim — The simulation data used to calculate the Cpk value, for resist, etch, and aerial images, respectively.
  - Group — Groups gauges by two or more group names. This is used to calculate group statistics.
- Calibre nmModelflow invoked.

## Procedure

1. Load the gauge file into Calibre nmModelflow and switch to the **Gauge Analysis** tab.
2. Right-click the name of any visible column to raise the shortcut menu, then select **Column Manager**.
3. In the Column Manager, type in the green Filter field to search for and select the column entries for Prec and Group if they are not already visible.
4. In the Command Window, enter the following command:

```
mdf gauges groupstat [-out filename]  
[-cdtype resist | aerial | {etch [-fit absolute | relative]}]
```

- If you do not supply an -out argument, the default filename is groupstat.csv.
- If you do not specify a -cdtype argument, “resist” is used by default, which calculates the Cpk value on the Sim column values.
- If you specify -cdtype “etch”, you can also set which method for computing the etch error statistics is used with the optional -fit option; the default is absolute error calculations.

## Results

The command runs, and an output CSV file is placed in the current working directory. The file contains a group statistics file with the following data:

**Table 1-10. Cpk Results List**

Column	Description
Group	Specifies the group name.

**Table 1-10. Cpk Results List (cont.)**

Column	Description
Total	Specifies the number of enabled gauges in the group.
InSpec	Specifies the number of gauges whose errors are within precision (automatically set to 0 if Prec was not specified).
Rate	Specifies the percentage of gauges that were in spec, $100 * \text{InSpec} / \text{Total}$ (or NA if Prec was not specified).
Cpk	Specifies the process capability index computed using UwMean and UwStDev (or NA if Prec was not specified).
Tolerance1	Specifies the weighted error-tolerance-based objective of norm 1 (or NA if Prec was not specified).
Tolerance2	Specifies the weighted error-tolerance-based objective of norm 2 (or NA if Prec was not specified).
RMS	Specifies the weighted group RMS without taking into account process window weights.
Mean	Specifies the weighted mean error.
StDev	Specifies the weighted standard deviation.
UwRMS	Specifies the unweighted group RMS.
UwMean	Specifies the unweighted mean error.
UwStDev	Specifies the unweighted standard deviation.
MinErr	Specifies the minimal error.
MaxErr	Specifies the maximal error.
Range	Specifies the error range (calculated as MaxErr - MinErr).

## Testing Parameter Sensitivity Data

Because some model parameters may be more sensitive to small changes than others, Calibre nmModelflow has the ability to test individual parameters for a given gauge data file and litho model.

### Prerequisites

- A litho model
- A gauge file and corresponding test pattern file

### Procedure

1. Invoke Calibre WORKbench and load the test pattern file.

2. Invoke Calibre nmModelflow, switch to the Database Browser, then activate the gauge file and litho model.
3. In the Command Window, issue the following command to compute one or more specialized quantities as a function of a specified parameter on each gauge. The parameter is varied in the specified range, and performs a polynomial approximation using a specified degree.

```
mdf param sensitivity -qlist "quantity_list" -pardata parname low high [-num steps] [-degree order] [-out file]
```

where:

- **-qlist “*quantity\_list*”** — Is a required argument specifying a list of one or more quantities of interest separated by spaces. Accepted quantity names are:
  - Cd — Simulated CD
  - CtrCd — Aerial simulated CD
  - Ils — Resist ILS
  - CtrlIls — Aerial image ILS
- **-pardata *parname* *low* *high*** — Is a required argument that specifies the parameter name to audit and the lower and upper bound of the interval for the parameter to be varied over.

---

#### Note

 This command does not currently support EBEAM and CDSA parameters.

---

- **-num *steps*** — Is an optional argument specifying the number of parameter values to be explored between ***low*** and ***high***. The value specified must be greater than 2; the default value for *steps* is 5.
- **-degree *order*** — Is an optional argument that specifies the degree of the approximation polynomial. The value specified must be less than the number of parameter values specified with the -num argument. The default value is 2.
- **-out *file*** — Is an optional argument specifying the name of an output file for the results. It is only used if -qlist consists of just one quantity. Otherwise, this argument is ignored and the results are output to files with default names. The default value is *<parname>\_<quantity\_name>.csv*

## Results

When the command runs successfully, the output files use the following format:

```
GID PWID {array of simulated quantity values} {array of polynomial coefficients}
```

## Checking Etch Models for BTERM and Kernel Quality

VEB etch models can occasionally be generated with terms and kernel densities that cancel each other out. Calibre nmModelflow allows you to run a test on a loaded etch model for quality purposes before you use it in calibration.

Certain conditions can lead to high risk VEB models where the calculations might not accurately match the physical behavior:

- A pair of highly correlated terms
- A pair of terms that have opposite signs
- The pair contributes a non-trivial amount of value to the model

### Prerequisites

- A litho model containing an etch model
- The set of corresponding gauges with etch measurements

### Procedure

1. In Calibre nmModelflow, switch to the Database Browser and activate the gauge file and litho model.
2. In the Command Window, enter the following command:

**mdf gauges etch\_risk\_table**

### Results

The command runs. When it completes successfully, the Application Logs window shows a table that contains the following information:

- Risk — Is the risk of the term or density kernel canceling out another.
- Related Densities / BTerms — Lists the density kernels or BTERMS that correlate with the listed item.

## Adding MEEF Data to the Gauge Analysis Tab

You can add a column to the **Gauge Analysis** tab in order to display calculated MEEF (Mask Error Enhancement Factor) values. Calibre nmModelflow maintains a universal gauge spreadsheet that contains all defined columns. Only a selected subset of the universal gauge spreadsheet is displayed in the **Gauge Analysis** tab.

### Prerequisites

- A set of gauges in the database

- An active *Lithomodel* file in the database

## Procedure

1. Activate a set of gauges so that they appear in the **Gauge Analysis** tab.
2. Issue the command “mdf simulate meef” in the Calibre nmModelflow Command Window, or click the **Calculate MEEF** button in the **Gauges** tab.

The MEEF column appears with the calculated values for the loaded gauges. The MEEF value will stay until the command is issued again.

The screenshot shows the Calibre nmModelflow software interface. At the top, there is a toolbar with various icons. Below the toolbar is a header bar with tabs: "Gauge Analysis" (which is selected), "Contour Analysis", "Plots", "Metrics Viewer", "Database Browser", and "Calibration Job Manager". To the right of the header bar is a "Filters Applied" section showing "0" filters applied. Below the header bar is a search bar with the placeholder "Filters".

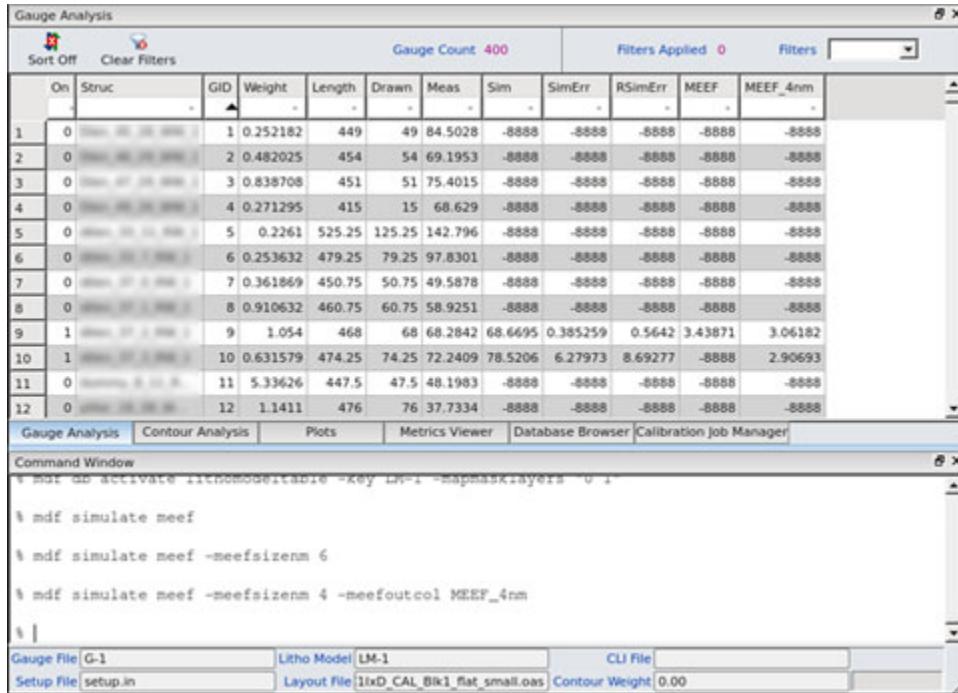
The main area contains two windows:

- Gauge Analysis Window:** A table titled "Gauge Analysis" with the following columns: On, Struc, GID, Weight, Length, Drawn, Meas, Sim, SimErr, RSimErr, and MEEF. The table lists 12 rows of gauge data. For example, row 1 has GID 1, Weight 0.252182, Length 449, Drawn 49, Meas 84.5028, Sim -8888, SimErr -8888, RSimErr -8888, and MEEF -8888.
- Command Window:** A window showing command history. It includes a red box around the command "mdf simulate meef".

At the bottom of the interface, there is a footer bar with tabs: "Gauge File" (set to "G-1"), "Litho Model" (set to "LM-1"), "CLI File" (empty), "Setup File" (set to "setup.in"), "Layout File" (set to "1lx0\_CAL\_Blk1.flat\_small.oas"), and "Contour Weight" (set to "0.00").

- Using the *-simtype* option allows you to calculate the aerial image (“aerial” option, which adds a CtrlMEEF column), resist image (adding the MEEF column, which is the default of “full”), or both (“all” option).
- As an option, you can issue the “mdf simulate meef” command and a desired size, such as “-meefsizem 4”. In the same line, specify the desired column name, such as “-meefoutcol MEEF\_4nm”.
- By default, the MEEF up-sizing calculation ( $MEEF = \delta(sim)/\delta(drawn)$ ) uses 1 nm to calculate the new MEEF values. This is a global sizing (all edges move outward by the specified value in nanometers) of the entire pattern within 1 micron area of the site of operation. You can specify a different size with the “-meefsizem *value*” argument.
- Specifying the “-meefoutcol *label*” argument creates a new, custom column with the data in it for side by side comparison. The previous MEEF values are kept in the

column labeled MEEF, and a new column with the specified name is created to store the values calculated with the new specified MEEF value.



## Results

MEEF columns are produced with the specified names and MEEF sizes (in nanometers).

## Calculating the ILS for a Layer

In some cases, measuring the Image Log Slope (ILS) and related information at a target edge is more useful than the image intensity at the simulation contour edge.

### Prerequisites

- A gauge file
- The corresponding design file
- Calibre nmModelflow invoked

### Procedure

1. Load the gauge file and design file (either using a batch file call to Calibre nmModelflow or with the Calibre nmModelflow GUI from the **Database Browser** tab).
2. Enter the following command:

**mdf gauges computeils -layer *n* [-simtype {aerial | full | both}]**

where:

- -layer *n* — Specifies a layer containing edges to be tested against the gauges.
- -simtype aerial | full | both — Sets the mode of the ILS computation for the gauge cutlines as aerial image, full resist, or both.

The command computes the following items:

- Image Log Slope (ILS) in inverse microns, calculated as:

$$(1/I) * dI/dx$$

- Normalized Image Log Slope (NILS), which is CDDrawn \* ILS.
  - Edge Placement Error (EPE), which is the difference between simulated and drawn edge locations taken at the crossing points of each gauge using the two nearest edges to the left and right of the gauge midpoint.
3. If you are working from the command line, write the gauge output to a file. If you are using the Calibre nmModelflow GUI, switch to the **Gauge Analysis** tab.
  4. Examine the resulting gauge object for the following new columns:
    - TshiftCtr and Tshift — Shift for the aerial image (Ctr) and resist image with respect to target edges.
    - (XL,YL) and (XR,YR) — Coordinates of the left and right edge crossing points in dbu.
    - IlsLCtr and IlsRCtr — Left and right edge ILS values for the aerial image.
    - IlsL and IlsR — Left and right edge ILS values for full resist.
    - NilsLCtr and NilsRCtr — Left and Right edge NILS values for the aerial image.
    - NilsL and NilsR — Left and right edge NILS values for full resist.
    - EpeLCtr and EpeRCtr — Left and right edge EPE values for the aerial image.
    - EpeL and EpeR — Left and right edge EPE values for full resist.

---

**Note**

 The aerial threshold used for the various Ctr entries is set using the mdf threshold aerial command, and defaults to the best RMS value found during optimization.

---

## Generating Extra Printing Information

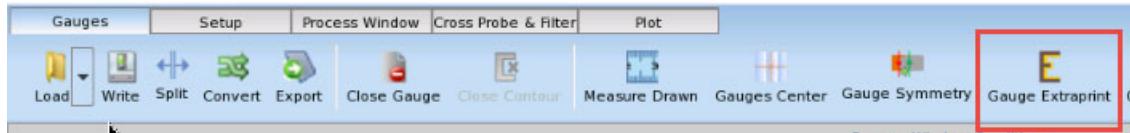
Calibre nmModelflow can generate simulation data to detect possible places where extra printing may occur in your design file. The standard comparison is between CTR and resist model simulations.

## Prerequisites

- A litho model and gauge file available in the Calibre nmModelflow database

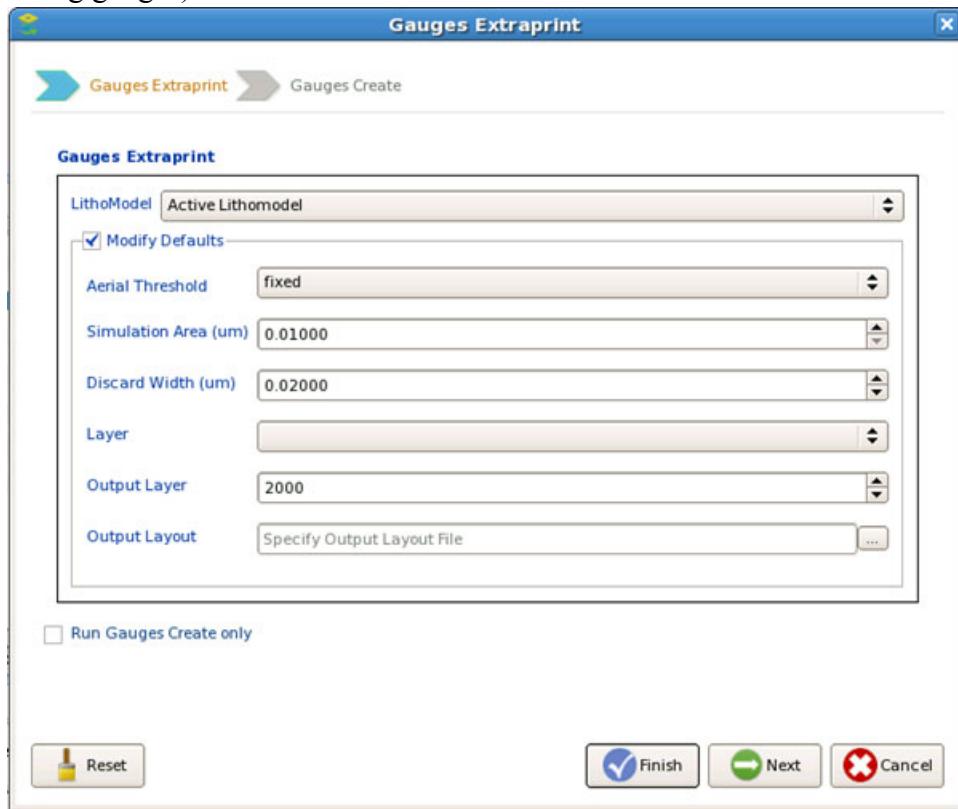
## Procedure

1. In the Database Browser, activate the relevant gauge file and litho model.
2. Switch to the Gauges tab and click the **Gauge Extrprint** button.



3. In the dialog box that appears, optionally use the LithoModel field to change the litho model to use.

Additionally, you can select Modify Defaults, then fill in the fields as follows (or select Run Gauges Create only and go to the next step if you have previously generated extra printing gauges):



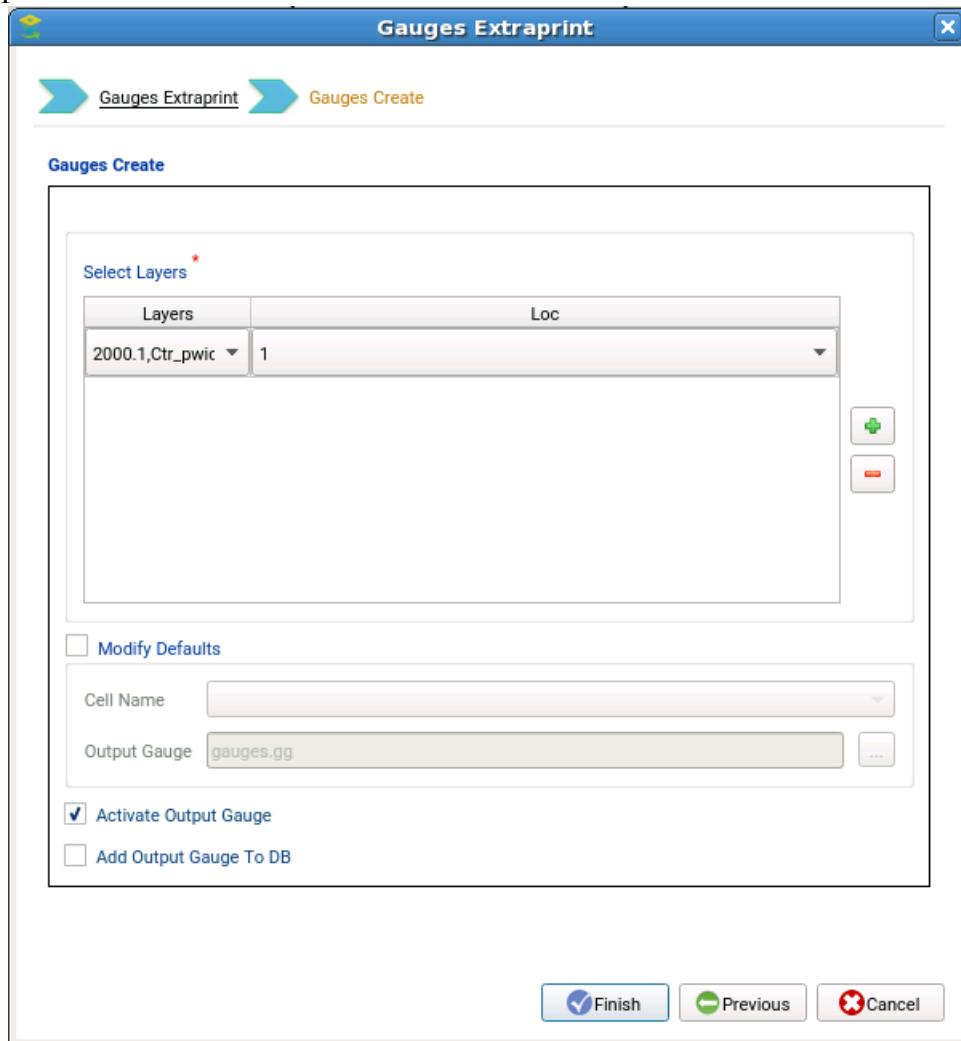
- **Aerial Threshold** — Can be one of the following:
  - **value** — A user-specified value, to test different image thresholds.
  - **fixed** — Uses the image threshold in the litho model.
  - **optimize** — Uses a 1D numerical search to find the best threshold.

- **auto** — Uses an internal search to estimate a threshold that minimizes RMS error.
- **Simulation Area** — Specifies the size of the simulation area in microns to test around each gauge. The default value is the interaction radius.
- **Discard Width** — Sets a distance in microns to use as a bounding box for extra printing checks for excluding clipped designs. The default is 0.02um.
- **Layer** — Uses edge collection information from the specified layer (instead of the CTR model contour) to report extra printing and bridging relative to drawn features. Specifying this option enables the DPrint, DHole, DPrintCtr, and DHoleCtr layers in the output.
- **Output Layer** — Sets a starting layer to write output to other than the default layer (2000).
- **Output Layout** — Specifies a layout file to write the output.

Selecting Load Output Layout replaces the current layout with the output layout of this command.

Click **Finish** to only generate extra printing data, or **Next** to continue to the Gauges Create step.

4. On the Gauges Create page, select the one of the new layers created by the extra printing operation from the list.



You can adjust the defaults to select only geometries in the specified cell, and set a different output gauge filename.

Click **Finish** to run the commands.

## Results

- For the Gauges Extralink step, the simulation is run on the active layout, and if there are results, one or more layers are generated as output.
  - By default, the layer output is layer 2000, with one or more data types attached to it. The output layout can have multiple data type layers added to it, as shown in the table. Only layers containing at least one result are output. For example, if CTR, Resist, and XHole results are generated, the layers 2000.1 (Ctr), 2000.2 (Resist), and 2000.3 (XHole) are generated.

**Note**

 Additional options are available using the CLI. A selected set of useful options are described in the online help and in the section “[Advanced Extra Printing Options](#).”

- If the gauge file is a process window gauge file, a \_pwid<n> suffix is added for each additional gauge result at a different process condition with the same relative data type number (continuing our example, 2000.2 for Resist\_pwid0, and 2000.5 for Resist\_pwid1).

**Table 1-11. Extra Printing Output Layers**

Data Type Order	Description
1 (Ctr)	CTR contours
2 (Resist)	Resist contours
3 (Xprint)	Resist sidelobes that do not interact with CTR sidelobes
4 (XPrintCtr)	CTR sidelobes that do not interact with resist sidelobes
5 (XHole)	Extra holes printed by the resist contour
6 (XHoleCtr)	Extra holes printed by the CTR contour
7 (DPrint)	Resist sidelobes that do not interact with the drawn features
8 (DPrintCtr)	CTR sidelobes that do not interact with drawn features
9 (DHole)	Extra holes printed by resist relative to drawn features
10 (DHoleCtr)	Extra holes printed by CTR relative to drawn features
11 (Dbridge)	Resist bridging relative to drawn features
12 (DBridgeCtr)	CTR bridging relative to drawn features

- For types 11 and 12 (Dbridge and DBridgeCtr), bridging is determined using the number of drawn polygons that interact with resist or CTR polygons, minus the number of resist or CTR polygons that interact with drawn ones. A zero difference means that no bridging occurs, while a positive difference means that bridging is detected.

In the case of extraholes, the difference can be negative, but the tool ignores it (reports 0 instead), because this is not considered bridging.

- If you completed the Gauges Create step, new gauges are added to the gauge object with a structure name of “gauges\_create” and a Drawn value of 0.

## Advanced Extra Printing Options

The Extra Printing feature in the Calibre nmModelflow GUI performs the most common functionality needed to check for extra printing between CTR and resist model simulations. Advanced options are only available via the console.

---

### Note

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 Standard extra printing information can be found in the section “[Generating Extra Printing Information](#).”

---

### Changing the Output Layer for Extra Printing Layers

By default, the Extra Printing feature uses layer 2000 as a base layer number when it writes to the layout. To change the layer number base, use the -outputlayer option. For example, the following command outputs the extra printing layers starting at 1000:

```
mdf gauges extraprinting other_options -outputlayer 1000
```

### Setting the Layer Used as Input for Extra Printing

By default, the CTR contour is used as the comparison to the resist simulation contour. To specify a layer instead of the CTR model contour, use the -layer option. For example, the following command uses the polygons on layer 5 to compare against the resist contour:

```
mdf gauges extraprinting other_options -layer 5
```

### Generating Isolated Line Tests for Extra Printing

An additional extraprinting command is available to inspect isolines of different sizes for extra printing potential for a loaded litho model. The command generates a separate layout file with a number of vertical and horizontal iso lines and then performs the extra printing command on the lines.

```
mdf gauges extraprintingisoline [-linewidth auto | value] [-linenum amount] [-out filename]  
[-outsgd filename] [-ctrthreshold fixed | optimize | auto | value]
```

where:

- -linewidth — Sets the maximum line width in microns. The default is “auto”, which uses the resist interaction radius.
- -linenum — Sets the number of the vertical and horizontal lines to generate. The default is 3, which generates three vertical and horizontal lines.
- -out — Sets the output OASIS<sup>1</sup> layout filename for the isoline result. The default filename is *isolineXprint.oas*.

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1. OASIS® is a registered trademark of Thomas Grebinski and licensed for use to SEMI®, San Jose. SEMI® is a registered trademark of Semiconductor Equipment and Materials International.

- **-outsgd** — Sets the output filename for the corresponding super gauge data file. The default filename is *isolineXprint.sgd*.
- **-ctrthreshold** — Specifies the threshold value to use for the CTR threshold. The default is fixed, which uses the value from the litho model file. Other options include specifying a new value, “optimize” to calculate an optimized value based on a cost function, and “auto”, which calculates the threshold to minimize RMS error.

## Adding Gauges to Extra Printing Features

Once you have detected extra printing features, you can generate gauges for them using the mdf gauges create command (or the second screen of the Gauges Extraprint dialog box):

```
mdf gauges create -loc {0 | 1} -layer input_layer [-cell cell_name] [-out filename]
```

where:

- **-loc** — A required argument that specifies the type of gauges to add (0 for polygons on the SRAFs, 1 for extra holes).
- **-layer** — A required argument that specifies the input layer to test for gauges. You should specify the appropriate layer from the extra printing output layers (for example, XPrint for 0, XHole for 1) to correctly apply the gauges to the appropriate features.
- **-cell** — An optional argument to limit the scan to the specified cell name only. The default is to use the topcell.
- **-out** — An optional argument to save the output gauge file to. The default value is *gauges.gg*.

The result of this command is a new gauge file by the specified filename (or *gauges.gg* if no filename was specified) containing the new gauges. Each gauge has the structure name “*gauges\_create*.”

You can take this gauge file and add it to the original gauge data file using the following command:

```
mdf gauge merge original_file.gg gauges.gg combined.gg
```

You can now load the combined gauge file into Calibre nmModelflow for a new calibration run that incorporates the marked SRAFs and holes as part of the calibration process.

## Finding Adjacent Gauges

For some designs, a group of gauges are used to measure a drawn shape, instead of a single gauge CD.

### Prerequisites

- An active gauge object in Calibre nmModelflow

## Procedure

Use the following command to find adjacent gauges:

```
mdf gauges findcdadjacent [-distance value] [-cdtolerance value] [-jogtolerance value]  
[-pitchcolumn name] [-out file]
```

where:

- **-distance *value*** — Is an optional argument that specifies the distance to search for an adjacent gauge in um. (Default: 0 nm.)
- **-cdtolerance *value*** — Is an optional argument that specifies the CD tolerance in nm. (Default: 3 nm.)
- **-jogtolerance *value*** — Is an optional argument that specifies the jog tolerance.
- **-pitchcolumn *name*** — Is an optional argument that specifies a name of a user-defined column to put the output in. (Default is “other”)
- **-out *file*** — Is an optional argument that specifies a filename to save group info to.

## Results

The command detects adjacent gauges with a comparable pitch or width CD and groups them together.

It then calculates the pitch for adjacent gauges, placing the result in the Other column (or the user defined column set in the -pitchcolumn argument).

- If no gauges are found on either side of the test gauge, the pitch value is set to -1.
- If only one adjacent gauge is found, the pitch is set to the sum of the CDs of the gauge and the adjacent gauge.
- If there are adjacent gauges on both sides of the test gauge, the pitch is set to the sum of the center CD plus the smaller of the left or right adjacent CDs.

When used with process window gauge sets, this command generates a table that only contains gauges that are present through all process conditions that have a CD within the specified tolerance.

# Computing SRAFs Crossed By Gauges

When working with design files that include SRAFs, it can be helpful to know when SRAFs are being crossed by user gauges.

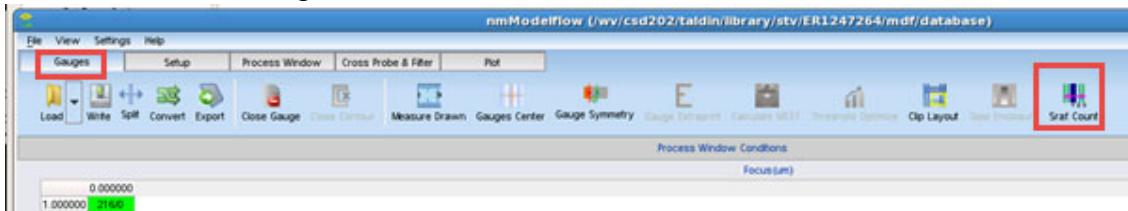
## Prerequisites

- Calibre nmModelflow running
- A design file with SRAFs

- The corresponding gauge file loaded into Calibre nmModelflow's **Gauge Analysis** tab

## Procedure

- Switch to the Gauges tab and click the **Sraf Count** button in the menu bar.



- In the dialog box that appears, set additional parameters as follows:



- Maximum Sraf Size (nm)** — Set this to the maximum size of an SRAF in nanometers.
- Maximum Distance to Look (nm)** — Set this to the maximum distance to search beyond the edge of a gauge to look for SRAFs in nm. The default is 0, which counts only SRAFs touching the gauge.
- SRAFs to Count** — The four unlabeled radio buttons at the bottom of the dialog indicate which types of SRAFs to count.
  - All** — Count all SRAFs crossed by the gauge.
  - Nearest** — Count SRAFs between the main feature and two closest polygons, one on the left/down side, and one on the right/up side.
  - Nearest Left** — Count only SRAFs between the main feature and the nearest polygon to the left or down.
  - Nearest Right** — Count only SRAFs between the main feature and the right or up side.

Click **OK** when you have finished making your selections.

## Results

Calibre nmModelflow checks each gauge (it checks disabled gauges as well) and counts the number of features crossed by the gauge (plus the specified search distance) and returns the count in a new column (SrafCount) added to the **Gauge Analysis** tab.

## Automatically Inserting Gauges for SRAFs

In some cases, calibration of test patterns with SRAFs may give false positive printing results, because standard test patterns do not include measurement entries for SRAFs. Calibre nmModelflow can detect and insert gauges for SRAFs into the gauge file.

### Prerequisites

- Calibre nmModelflow running
- A gauge or super gauge data object in the database
- The corresponding design file

### Procedure

1. Switch to the **Database Browser** tab, select the Gauges group from the list, and activate the appropriate gauge object.
2. In the Command pane, enter the following:

```
mdf gauges srafgaugesinsert -out filename -srafsiz size -layer n [-distance dist]
```

where:

- *filename* is the name of the output file to write
- *size* is the maximum size of SRAF to add a gauge to
- *n* is the layer where the test pattern and SRAFs are located on
- *dist* is the maximum search distance around the gauge in microns that Calibre nmModelflow searches for SRAFs (default is 1000nm)

If Calibre nmModelflow detects any SRAFs, it writes the modified gauge file to the specified filename. Each detected SRAF is given a unique name (*sraf\_for\_<gid>\_<id>*), and a Meas value of LT:0.

If no SRAFs were detected, no output file is written.

3. Click **Load** to import the output gauge file to the database. You can use the same design file with the SRAFs as the input design file used with the input gauges.

### Examples

The following command writes an output file given an input gauge file with SRAFs less than 15nm in size on design file layer 3.1:

```
mdf gauges srafgaugesinsert -out srafs_added.sgd -srafsiz 15 -layer 3.1
```

# Loading Contours

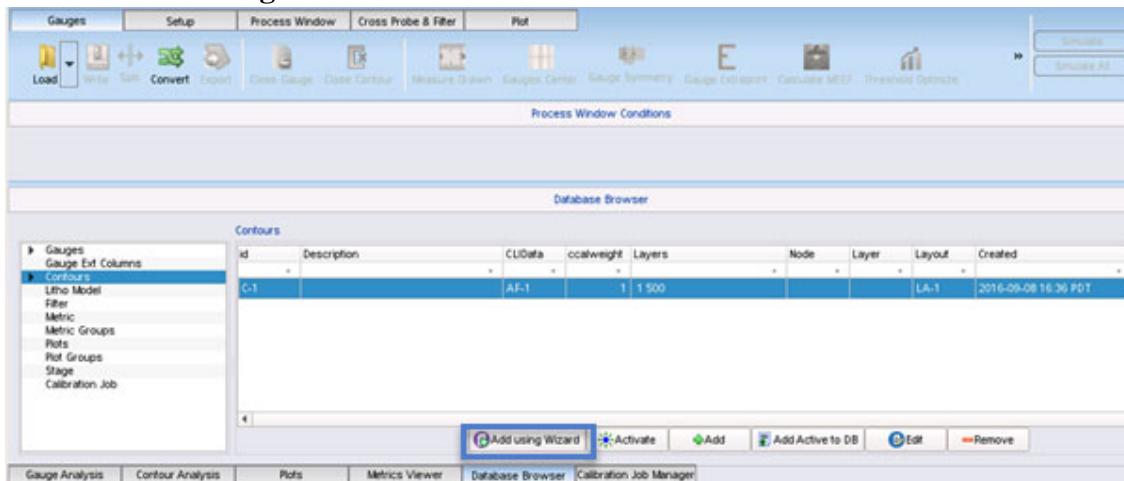
Contours can be used as an alternate calibration method for models. Simulation tests can be compared against the contours either independently or in conjunction with gauges.

## Prerequisites

- A [Contour Layer Information \(CLI\) file](#), as described in the *Calibre WORKbench User's and Reference Manual* or a contour sites CSV file. (see the section “[Sites CSV File Guidelines](#)” on page 244)
- The associated layout file, containing clip layers; each clip has a bounding box for an extracted SEM contour. The layout file should be flat.
- Calibre WORKbench invoked and Calibre nmModelflow activated.

## Procedure

1. In Calibre nmModelflow, open the Database Browser, choose the Contours list, and click **Add using Wizard**.



2. In the first Contour Wizard screen, choose Contour to just use a contour, or Gauges and Contours to associate a set of gauges with the contour.
3. Set the CLI file and the weight the contours should have on the calibration as a value between 0.0 (0%) and 1.0 (100%). If you selected Gauges and Contours, you must also select a gauge file. Click **Next** to continue.

**Tip**

 Starting with the 2020.1 release, you can change the weight for contours later from the following locations:

- **ccontweight** — By changing the ccontweight field in the Database Browser, Contours list
  - **weight and weightlayer** — By editing individual CLI file contents in the Contours list
- 

4. Select the layout file associated with the contours, set the comments for the node type, layer type, and a description of the layout file. Click **Next**.
5. In the Choose Layers screen, add all relevant layers other than the clip layer, then click **Next**. For example, for a topo modeling contour, you would add the OPC layer, the active layer, and optionally the FinFET layer and the poly layer.
6. Inspect the commands that Calibre nmModelflow will perform on the last wizard screen. If they are acceptable, click **Finish**.

## Results

A new entry for the contour is added to the Database Browser list.

## Related Topics

[Contour Analysis Tab](#)

[Methods for Filtering Contour Blocks and Sites](#)

# Methods for Filtering Contour Blocks and Sites

Filtering contour blocks and sites helps narrow the focus to sites of importance.

## Filters Available From the Command Line

Use the mdf contour sites command to enable and disable contour blocks and sites. By default, mdf contour sites applies only to the active contour block. Specifying the -thrupw argument applies the filter to all process window conditions.

**mdf contour sites {include | exclude} [-thrupw] *filtertype***

where *filtertype* is one of:

- *[cid.]sid+*

Includes or excludes the list of one or more specified sites in the active contour block (*sid*) or specific sites in the specified block (*cid.sid*).

Additional items in the list are specified using spaces.

- -filter { [-contourids {*id1,id2,...idN*} | all ] -expr *expr* } | }
- Includes or excludes the contour blocks and sites matching the filter expression.
- -contourids selects contour blocks with ids matching the comma-separated list. “all” selects all contour blocks.
  - -expr selects sites matching the specified Tcl expression.

## Examples

- mdf contour sites exclude 5 7
  - Disables sites 5 and 7 in the active contour block.
- mdf contour sites exclude 5.3 7.8
  - Disables site 3 in contour block 5 and site 8 in contour block 7. These changes are not visible unless you have contour blocks 5 or 7 currently active.
- The following two commands are equivalent:
  - mdf contour sites exclude 500.3 25.3
  - mdf contour sites exclude -filter {-contourids 500,25 -expr “\$SiteId == 3”}
- mdf contour sites exclude -filter {-contourids all -expr “\$SiteId == 3”}
  - Applies a filter that disables site 3 for all contour blocks.
- mdf contour sites exclude -filter {-expr “\$SiteId == 3”}
  - Applies a filter disabling site 3 only in the active contour block.

## Related Topics

[Loading Contours](#)

[Contour Analysis Tab](#)

# Litho Model-Related Tasks and Concepts

Litho models store information about the process. This includes all relevant model components, mask exposure polarity, the exposure conditions used, and references to one or more exposure layers to be mapped to layout geometry

<b>Creating Litho Models.</b> . . . . .	<b>76</b>
<b>Importing an External Litho Model.</b> . . . . .	<b>84</b>
<b>Adding Process Window Conditions to a Litho Model</b> . . . . .	<b>85</b>
<b>Comparing Process Window Conditions.</b> . . . . .	<b>87</b>

## Creating Litho Models

Litho models are a collection of models. You can specify one litho model instead of multiple models in commands. Litho models are a key component in Calibre nmModelflow.

### Restrictions and Limitations

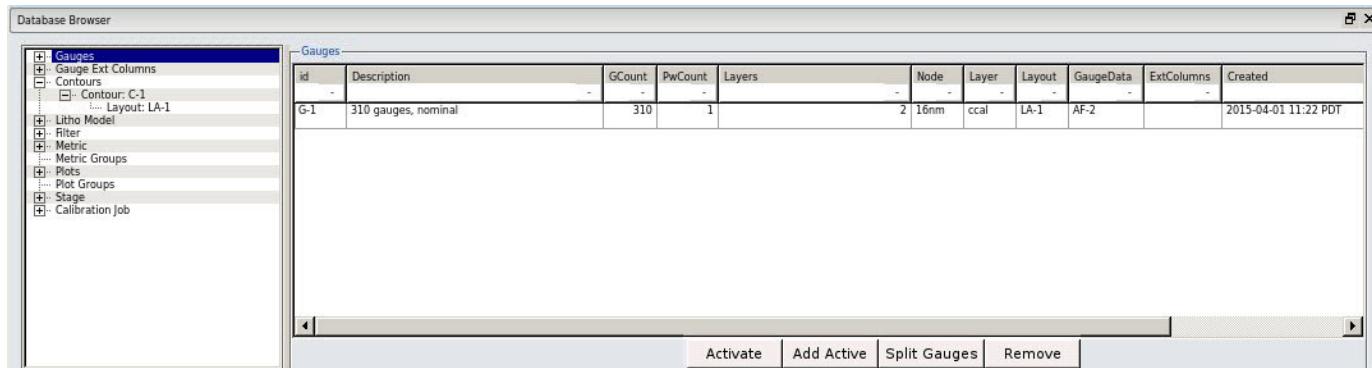
- Litho models only support a single resist model per litho model definition. Only CM1 resist models can be used in Calibre nmModelflow; Calibre nmModelflow does not accept VT5 resist models.
- Optical models must use resolvable paths for included source, Jones pupil, apodization, and laser spectrum files. Both absolute paths and relative paths (from the optical directory or current working directory) are accepted.

### Prerequisites

- Any model components needed to describe the lithographic exposure.
- Calibre WORKbench invoked and Calibre nmModelflow activated.

### Procedure

1. Raise the **Database Browser** tab in the list of primary display tabs.

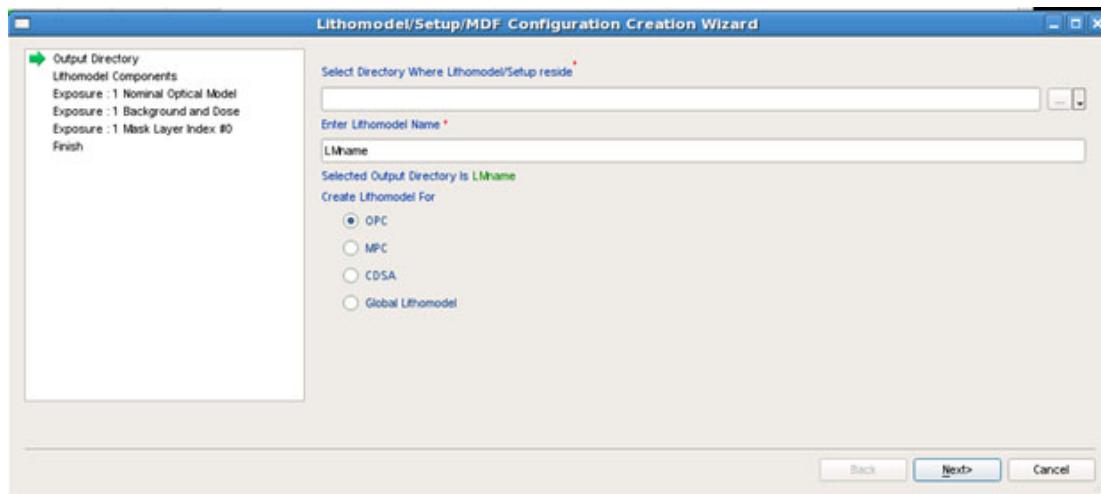


2. Select the **Litho Model** category in the browser list on the left side.

- Click **Create** to open the Lithomodel/Setup/MDF Creation Wizard for Calibre nmModelflow. The wizard lists each step that requires input (Output Directory, Lithomodel Components, Exposure, Finish).

**Tip**

The **Create Lithomodel** option is also available from the **File** menu.



- In the Output Directory page, enter or navigate to an empty working directory. The directory will contain the completed litho model. (You can create a new directory from the file chooser dialog.) Name the new litho model directory in the Enter Lithomodel Name field.

In most cases, leave the Create Lithomodel For radio button set as OPC. However, users who have MPC, CDSA, or global litho models will need to select the appropriate option.

- For the Lithomodel Components screen, fill out the fields to match your configuration and click **Next**.

**Table 1-12. Lithomodel Creation Wizard, Lithomodel Components**

Field	Notes
No. of Exposures	Required. Controls the number of exposure masks. Increasing the number of exposures adds more items to the list when you click <b>Next</b> .
Image Threshold	Sets the image threshold for the litho model. By default, 0.35 is used.

**Table 1-12. Lithomodel Creation Wizard, Lithomodel Components (cont.)**

Field	Notes
Resist Model	<p>Required. Specifies the path to the resist model for the litho model.</p> <ul style="list-style-type: none"> <li>You can alternatively select a preset modelform template using the dropdown menu.</li> </ul> <p><b>i Tip:</b> The Preview Modelform button brings up the View Modelform window, where you can see the model template definition for a selected modelform.</p> <ul style="list-style-type: none"> <li>You can also create a customized resist model by clicking the <b>Create</b> button, which opens the <a href="#">Resist Model Composition Tool</a>.</li> <li>If you select the 3D Resist checkbox, additional modelform options related to 3D modeling become available. This option becomes disabled when the modelform is an active lithomodel.</li> </ul>
Etch Model	<p>This group is used only if an etch model is part of your process.</p> <p>Specifies the path to the etch model for the litho model.</p> <ul style="list-style-type: none"> <li>You can alternatively select a preset modelform template using the dropdown menu.</li> </ul> <p><b>i Tip:</b> The Preview Modelform button brings up the View Modelform window, where you can see the model template definition for a selected modelform.</p> <ul style="list-style-type: none"> <li>You can alternatively create your own custom VEB etch model by clicking the <b>Custom</b> button (see <a href="#">Create Custom Etch Model Wizard</a>).</li> <li>If you select the selective_biasing_type1 checkbox, you must also specify the layer number where the filter shapes are located.</li> <li>If you select the Underlying VEB checkbox, you must also specify the underlying layer.</li> </ul> <p><b>Note:</b> Selecting either of the selective_biasing_type1 or Underlying VEB checkboxes changes the output, adding an extra level of hierarchy to the lithomodel setup tree. See the Results section for more information.</p>

**Table 1-12. Lithomodel Creation Wizard, Lithomodel Components (cont.)**

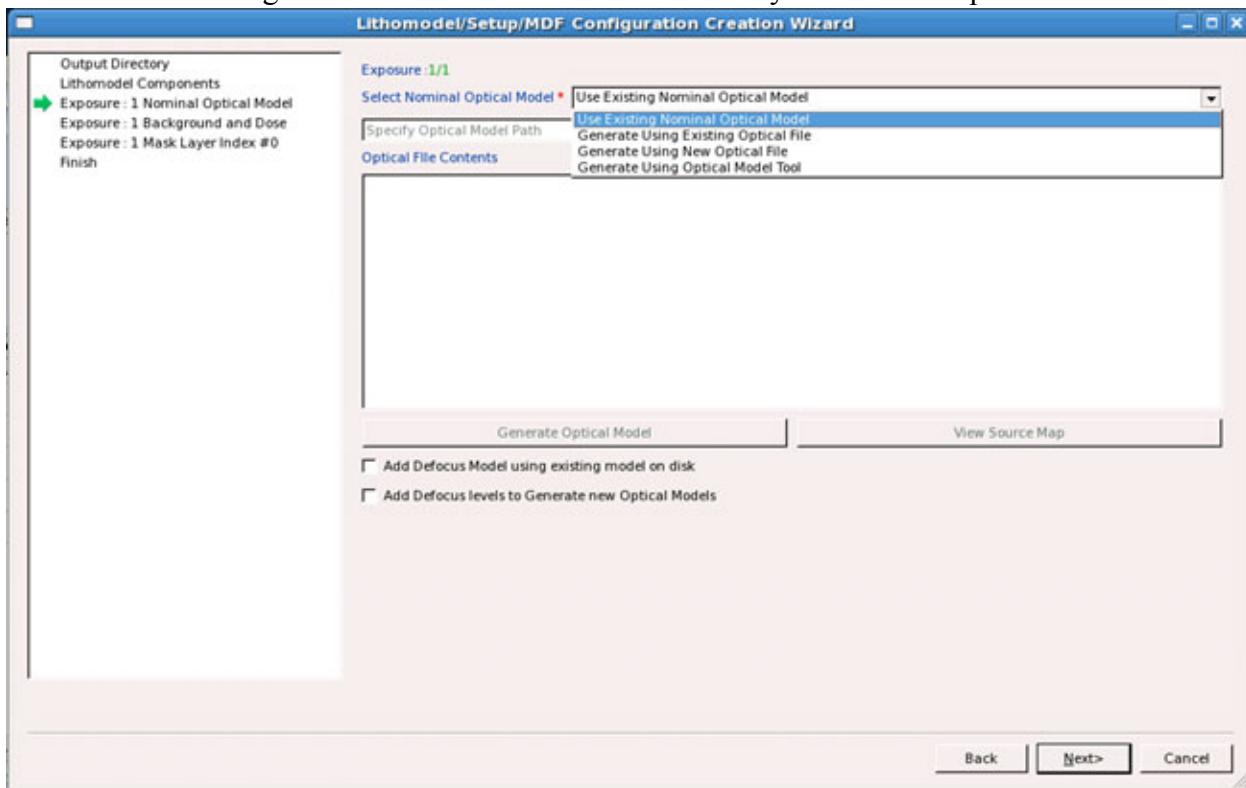
Field	Notes
Topo Model	<p>This group is used only by topography modeling processes.</p> <p>Specifies the path to the topo model for the litho model.</p> <p>You can alternatively select a preset modelform template using the dropdown menu.</p> <p> <b>Tip:</b> The Preview Modelform button brings up the View Modelform window, where you can see the model template definition for a selected modelform.</p>
 <b>Note:</b> The following four sections only appear if you select the EUV Model checkbox.	
Flare Model	<p>This group is used only by EUV modeling processes.</p> <p>Specifies the path to a flare model to be used with the litho model.</p> <p>If you specify a flare model, you can also optionally specify a constant flare value, or attach a Flare Map, which specifies the flare as a function of position in the layout.</p> <p> <b>Note:</b> The png file is loaded when the flare_model_load or flare_longrange directives are specified. The png file can be located as a file in the same directory where the setup file is located, as a file relative to the current working directory, or as a fully-qualified path.</p>
Stochastic Model	<p> <b>Note:</b> This item is intended for use by EUV modeling processes. It can be used for DUV for research purposes, but its effects are usually not significant.</p> <p>Specifies an optional stochastic model to be used as an enhancement to EUV resist modeling.</p> <p>For more information on stochastic models and how to use them, see the section “<a href="#">Stochastic Model Support in Calibre EUV</a>” in the <i>Calibre WORKbench User's and Reference Manual</i>.</p>
Black Border Model	<p>This group is used only by EUV modeling processes.</p> <p>Specifies the path to a black border model to be used with the litho model.</p> <p> <b>Note:</b> Specifying a black border model also requires you to specify a flare map file.</p>

**Table 1-12. Lithomodel Creation Wizard, Lithomodel Components (cont.)**

Field	Notes
Shadow Bias Model	This group is used only by EUV modeling processes. Specifies the path to the shadow bias model for the litho model.  If you specify a shadow bias model, you must also designate the correct value for the EUV Slit X Center value. The default value is zero.
ZPlanes	 <b>Note:</b> The following section only appears if you select the ZPlanes checkbox.  Specifies the path to the ZPlanes model for the litho model.  Selecting the ZPlanes radio button instead of loading a file allows for additional model parameters to be adjusted for models that can have a different image plane, such as for SRAF printing or TOPLOSS models.

6. For each exposure, you must fill out three screens:
  - a. **Nominal Optical Model** — Specify the nominal optical model (dose 1.0, defocus 0) in this screen. You have a choice of adding additional defocus models.
    - Nominal optical models can be loaded from the disk or generated.
      - To load an optical model directory from the disk, choose **Use Existing Optical Model**.
      - If you can copy and modify an *Optical* file, choose **Generate Using New Optical File**.
      - If you do not have an *Optical* file, choose **Generate Using Optical Model Tool**. You will fill out the Optical Model Tool and its results are used in the text field.
    - If you already have the defocus models generated, check “Add Defocus Model using existing model on disk”.
    - If you only have the nominal optical model and desire to add more defocus conditions, check “Add Defocus level to Generate new Optical Models”. The wizard will prompt you to enter the defocus range when you click **Next**.

Leaving both of the checkboxes unset uses only the nominal optical model.

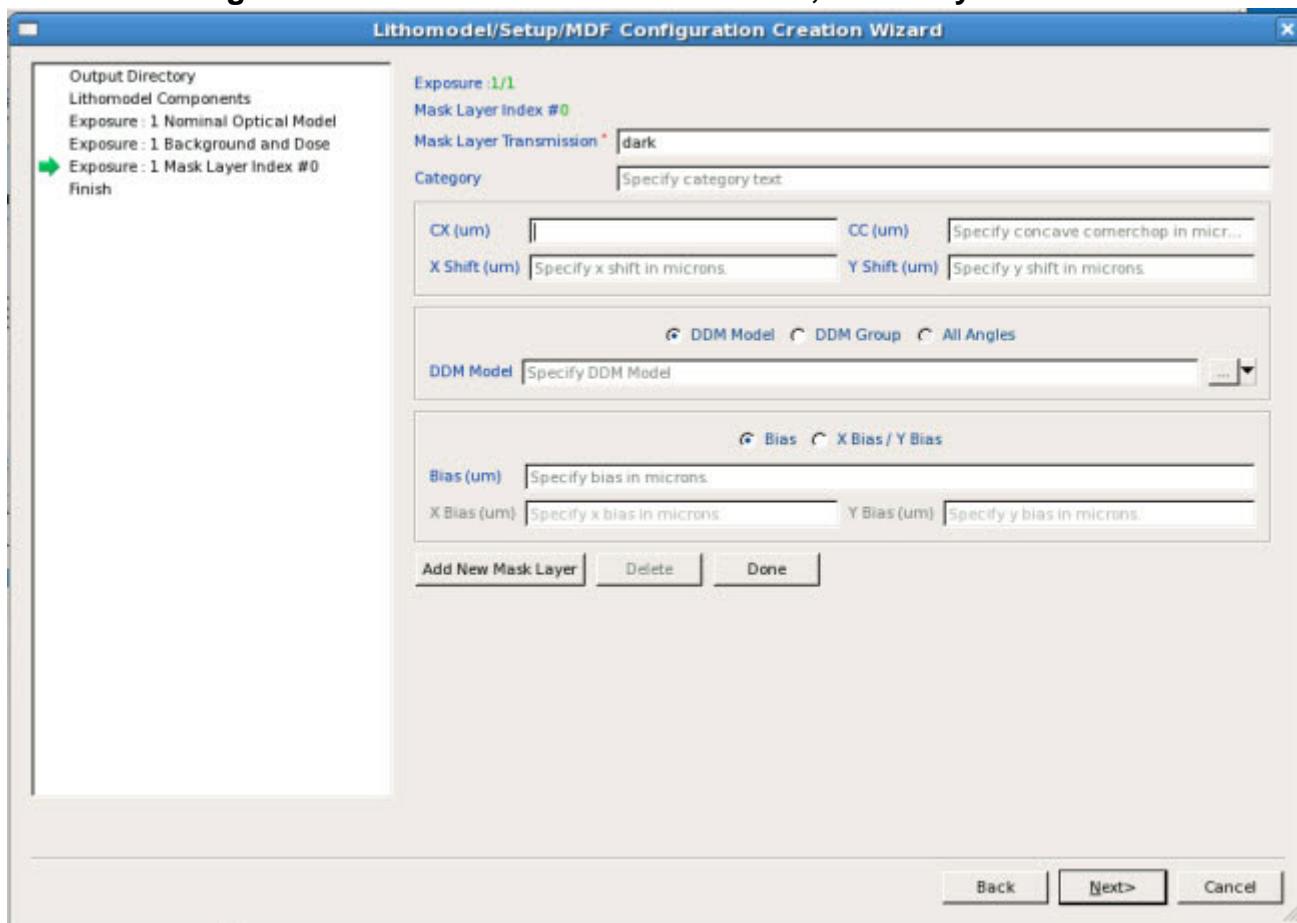


b. **Background and Dose** — Specify the background transmission type and initial dose value if it is different than 1.0 for the nominal optical model.

c. **Mask Layer Index** — Specify characteristics for one or more mask layers. All items except Mask Layer Transmission are optional.

Click **Add New Mask Layer** if you need to define multiple mask layers. Otherwise, click **Next**.

**Figure 1-13. Lithomodel Creation Wizard, Mask Layer Screen**



**Table 1-13. Lithomodel Creation Wizard, Mask Layer Index Fields**

Field	Description
Mask Layer Transmission	Specifies a required argument that specifies the transmission type of the mask_layer template. The field allows the following types: dark, clear, atten x, phase90, phase270, phase180, or a <i>real imaginary</i> pair.
Category	Specifies a notes field that you can set. Does not have any effect on the calculations.
CX (um)	Specifies a convex cornerchop value in microns. Corner chop removes a right triangle polygon with isosceles legs equal to the CX value from convex corners. Only right-angle corners are chopped.
CC (um)	Specifies concave cornerchop value in microns. Corner chop adds a right triangle polygon with legs equal to the CC value to concave corners. Only right-angle corners are filled.
X Shift (um)	Shifts all polygons in the X direction by the specified amount.

**Table 1-13. Lithomodel Creation Wizard, Mask Layer Index Fields (cont.)**

Field	Description
Y Shift (um)	Shifts all polygons in the Y direction by the specified amount.
DDM Model	Specifies a DDM model to associate with the mask layer. This option cannot be used if the All Angles option is selected.
DDM Group	Specifies a DDM group configuration. Selecting this radio button opens options to create a DDM group from multiple DDM models or use a previously created DDM group file.  <b>Note:</b> An error is produced when loading the MDF config file if the DDM group name is the same as any DDM library name in the group.
All Angles	Specifies that corner chopping should chop all-angle corners, not just right-angled ones. This option is only permitted if CX or CC is also specified.
Bias (um)	Expands or contracts all edges by the specified amount in microns. Bias values are applied to both horizontal (X) and vertical (Y) directions.
X Bias (um)	Expands or contracts only horizontal edges.
Y Bias (um)	Expands or contracts only vertical edges.

7. The Finish screen shows a summary of the commands that the Lithomodel Creation Wizard executes when you click **Finish**.

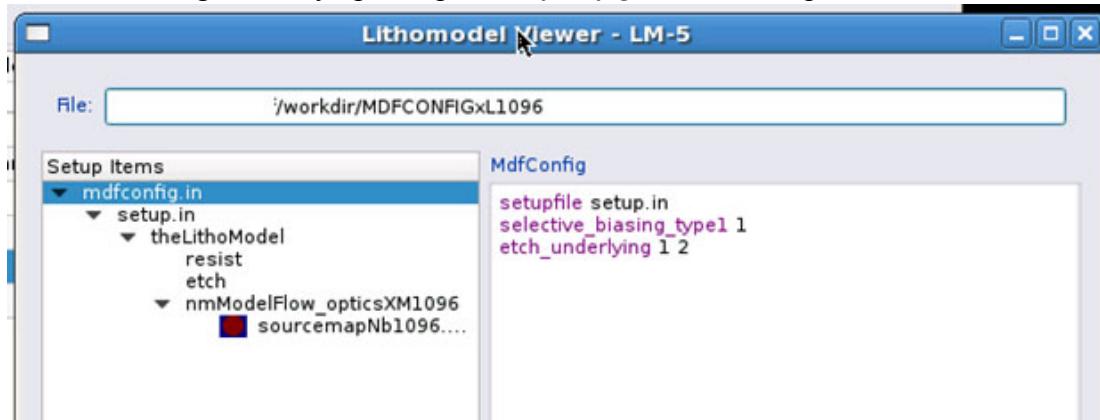
## Results

A litho model directory is created in the specified directory. Selecting the **Import Lithomodel to Database** checkbox also adds the completed *Lithomodel* file to the current database.

If you have included an etch model in the litho model and also selected one or both of the selective\_biasing\_type1 and Underlying VEB check boxes, the following additions are made to the litho model directory:

- A new key file *mdconfig.in* is added at the top level of the litho model directory, in the same directory as *setup.in*. This file contains the layer mapping for the selective\_biasing\_type1 and underlying layer numbers specified in the wizard.

- The directory entry in the Database Browser shows MDFCONFIG instead of LMSUF, and viewing the entry opens up the *mdfconfig.in* file as the parent of the litho model tree.



## Related Topics

[Importing an External Litho Model](#)

# Importing an External Litho Model

You can easily import litho models that are not in your database, even if they were created in a version of Calibre WORKbench previous to the release of Calibre nmModelflow.

## Prerequisites

- A litho model

---

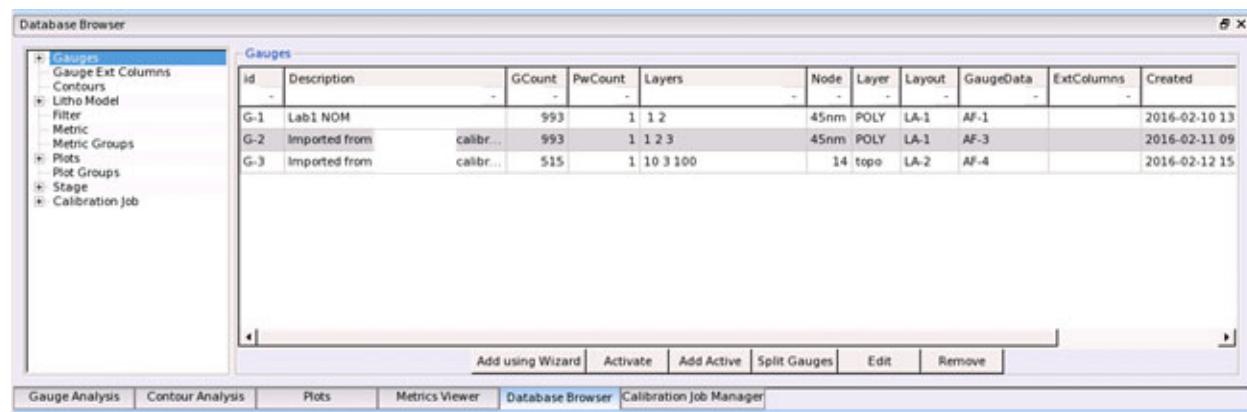
### Note

 The resist model inside the litho model must be a CM1 model. Calibre nmModelflow does not accept VT5 resist models.

---

## Procedure

- In the Calibre nmModelflow GUI, raise the **Database Browser** tab in the list of primary display tabs.



2. Select the Litho Model category in the browser list on the left side.
3. Click **Import** to bring up a file navigation box. Navigate to the directory containing the litho model (not the *Lithomodel* file) and select it. You can optionally set a Node and Layer note for the *Lithomodel* file for the database, but these options are for informational purposes only. Enter a description for the imported litho model, then click **OK** when you are finished making selections.



## Results

The *Lithomodel* file is added to the database. The node, layer, and description you specified appears in the Database Browser entry field for the new litho model.

### Note

If a resist model with a version of 8 or earlier and one of the NTD modelforms with shrink (38, 41, 42, 44, 45, 46, 47, 48, 49, 58, 78, 79, 88, 89, 90, 91, and 92) is loaded into the database or calibrated, Calibre nmModelflow automatically upgrades its version to the current version, and adds the SHRINK\_DIFFUSION term with a value of 40 to the model if it was not already present in the model. This is in order to preserve consistency.

## Related Topics

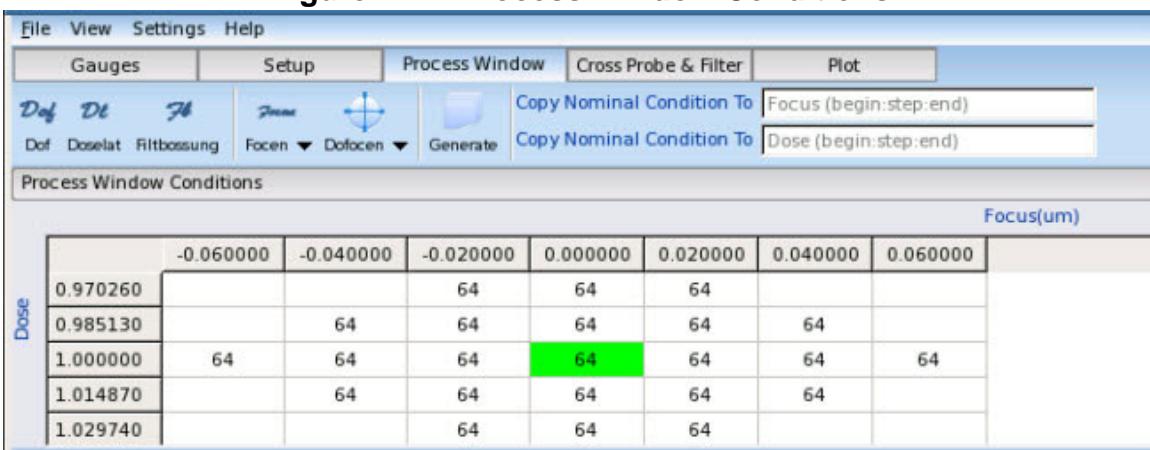
[Creating Litho Models](#)

## Adding Process Window Conditions to a Litho Model

Default litho models may sometimes only include the nominal optical model. In order to measure gauge information for a super gauge data object, you must generate all the process conditions.

When you load a super gauge data file into Calibre nmModelflow, it shows a dose and focus cross-sectional display that lists the number of gauges that exist in the active gauge set at that dose and focus value after filters have been applied.

**Figure 1-14. Process Window Conditions**



The green box indicates which set of gauges is the active gauge set. The active gauge set is displayed in the **Gauge Analysis** tab. Adding another dose and defocus entry to the table can be performed if you have access to the *Lithomodel* file that created the process window set.

## Prerequisites

- A super gauge data file in Calibre nmModelflow format
- At least three defocus conditions and at least one dose value if filtering focus sensitive data
- A litho model

## Procedure

1. Raise the **Process Window** tab in the menu bar.

2. Perform one of the following sets of actions.

To add another litho model to the process window:

- a. Click **Generate**.
- b. Supply the name of the *Lithomodel* file from which to generate a new optical model.
- c. Specify an output directory for the results.

To add a new dose and focus condition:

- a. Right-click in the Dose and Focus pane and select **Add** in the popup menu.
- b. In the dialog box that appears, specify a dose and focus value, then click **OK**.

## Results

A new process condition is created. If you added a litho model, any missing optical model directories are created as described in the *Lithomodel* key file.

## Related Topics

- [Converting modelflow\\_v2 Gauge Files](#)
- [Creating a Filter](#)
- [Selecting Focus-Sensitive Data](#)
- [Comparing Process Window Conditions](#)

# Comparing Process Window Conditions

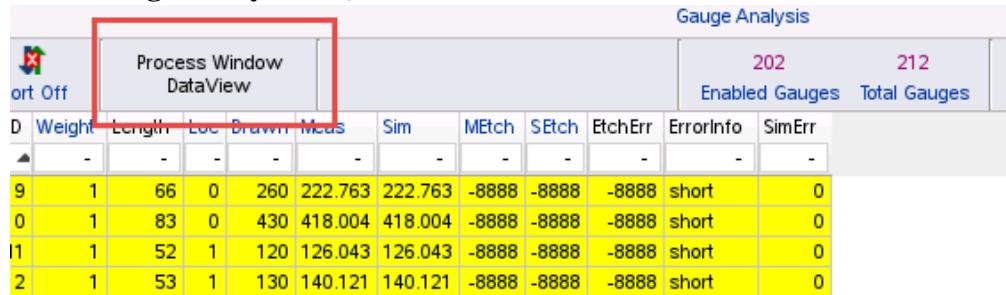
Use the Process Window Data View to compare values across multiple process window conditions.

## Prerequisites

- A super gauge data set loaded in the **Gauge Analysis** tab

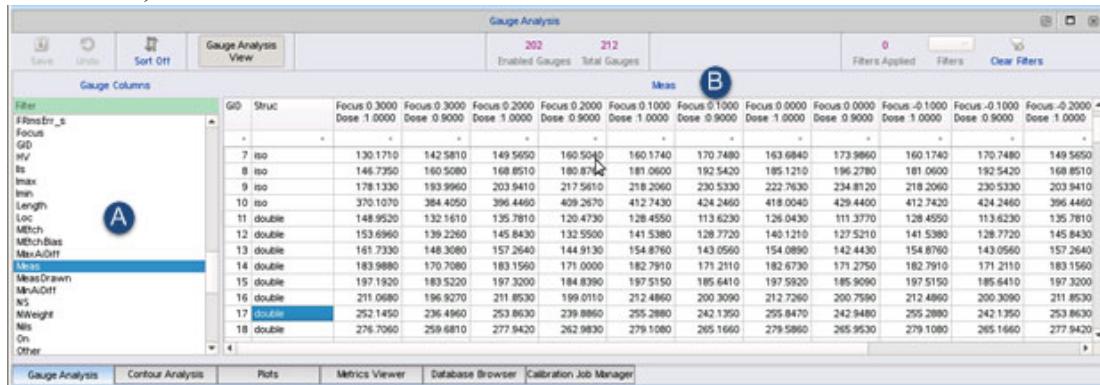
## Procedure

1. In the **Gauge Analysis** tab, click the **Process Window DataView** button.



Process Window DataView												202	212
D	Weight	Length	Loc	Drawn	Meas	Sim	MEtch	SEtch	EtchErr	ErrorInfo	SimErr	Enabled Gauges	Total Gauges
9	1	66	0	260	222.763	222.763	-8888	-8888	-8888	short	0		
0	1	83	0	430	418.004	418.004	-8888	-8888	-8888	short	0		
I1	1	52	1	120	126.043	126.043	-8888	-8888	-8888	short	0		
2	1	53	1	130	140.121	140.121	-8888	-8888	-8888	short	0		

The view switches to show the process window for a single column value (Meas is the default).



Gauge Analysis															
Gauge Analysis View				202 Enabled Gauges				212 Total Gauges				0 Filters Applied		Filters	
Gauge Columns				Meas											
Filter	Struc	Focus 0.3000 Dose 1.0000	Focus 0.3000 Dose 0.9000	Focus 0.2000 Dose 1.0000	Focus 0.2000 Dose 0.9000	Focus 0.1000 Dose 1.0000	Focus 0.1000 Dose 0.9000	Focus 0.0000 Dose 1.0000	Focus 0.0000 Dose 0.9000	Focus -0.1000 Dose 1.0000	Focus -0.1000 Dose 0.9000	Focus -0.2000 Dose 1.0000	Focus -0.2000 Dose 0.9000	Focus -0.3000 Dose 1.0000	Focus -0.3000 Dose 0.9000
A	7 iso	130.1710	142.5810	149.5650	160.5040	160.1740	170.7480	163.6840	173.9860	160.1740	170.7480	149.5650			
B	8 iso	146.7350	160.5080	168.8510	180.8740	181.0600	192.5420	185.1210	196.2780	181.0600	192.5420	168.8510			
C	9 iso	178.1330	193.9960	203.5410	217.5610	218.2060	230.5330	222.7630	234.8120	218.2060	230.5330	203.9410			
D	10 iso	370.1070	384.4050	396.4460	409.2670	412.7430	424.2460	418.0040	429.4460	412.7420	424.2460	396.4460			
E	11 double	148.9520	152.1610	135.7810	120.4730	128.4550	113.6230	126.0430	111.3770	128.4550	113.6230	135.7810			
F	12 double	153.6960	139.2260	145.8430	132.5500	141.5380	128.7720	140.1210	127.5210	141.5380	128.7720	145.8430			
G	13 double	161.7330	148.3080	157.2640	144.9130	154.8760	143.0560	154.0890	142.4430	154.8760	143.0560	157.2640			
H	14 double	183.9880	170.7080	183.1560	171.0000	182.7910	171.2110	182.6730	171.2750	182.7910	171.2110	183.1560			
I	15 double	197.1920	183.5220	197.3200	184.8390	197.5150	185.6410	197.5920	185.9690	197.5150	185.6410	197.3200			
J	16 double	211.0680	196.9270	211.8530	199.0110	212.4860	200.3090	212.7260	200.7590	212.4860	200.3090	211.8530			
K	17 double	252.1450	236.4960	253.8630	239.8860	255.2880	242.1390	255.8470	242.9480	255.2880	242.1390	253.8630			
L	18 double	276.7060	259.6810	277.9420	262.9830	279.1080	265.1660	279.5860	265.9530	279.1080	265.1660	277.9420			

2. Select any gauge column from the list at the left (A in the figure).

The selected column's value is displayed for all focus and dose combinations in the process window. The currently displayed column type is shown at the top of the pane (B).

## Related Topics

[Adding Process Window Conditions to a Litho Model](#)

# Database Input

Calibre nmModelflow operations require one or more items loaded into the database.

<b>Importing a Database</b> .....	<b>89</b>
<b>Exporting a Database</b> .....	<b>90</b>
<b>Creating a Filter</b> .....	<b>91</b>
<b>Creating a Custom Plot</b> .....	<b>92</b>
<b>Creating a Custom Metric</b> .....	<b>94</b>

## Importing a Database

Importing an existing database from another user or another session is a simple way to populate a database. Databases can also be exported and imported to migrate data from another database to a current one.

### Restrictions and Limitations

Databases must have been created with a compatible version of Calibre nmModelflow. Newer Calibre releases are able to import from older Calibre releases, but not vice versa.

### Prerequisites

A Calibre nmModelflow database in *.tar* format. (Exported databases are automatically converted to *.tar* format.)

### Procedure

1. Choose one of the following options:
  - **File > Import Db** to add to the existing database.
  - **File > Clear and Import Db** to delete all existing database items and load in the new database.
2. Navigate to the database you want to load and click **Open**.

### Results

The database file is loaded into Calibre nmModelflow, and is appended to or replaces the existing database.

### Related Topics

[Calibre nmModelflow Database Overview](#)

[Exporting a Database](#)

## Exporting a Database

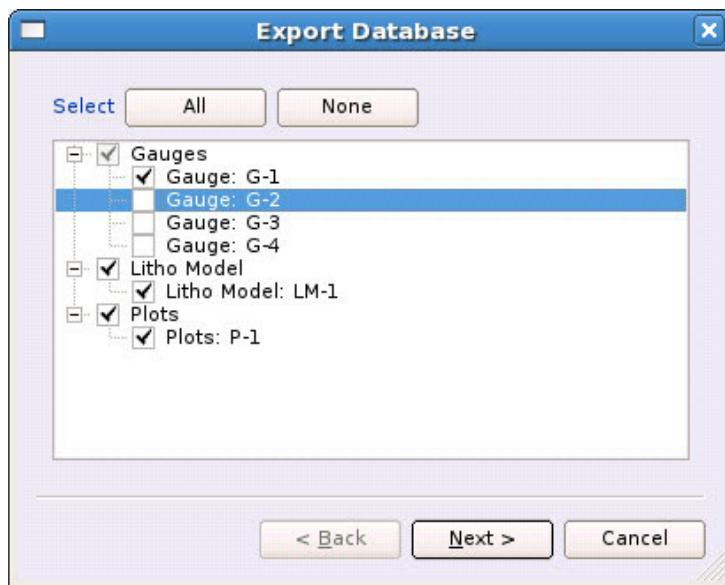
Databases are stored individually on a per-user basis. To share a database, you must export it to a file that can be imported by another Calibre nmModelflow user.

### Prerequisites

- An active database with items to be exported open in the Calibre nmModelflow GUI.

### Procedure

1. Select **File > Export Db**.
2. In the dialog box that appears, choose items to be exported and click **Next**.



3. The Export Summary screen lists the items you have selected.

Specify a filename for the new exported database and click **Finish**.

### Results

The output file is written to the disk in **.tar** format. By default, the file is written to the directory you invoked Calibre WORKbench from. Only the items you have selected and their dependencies are exported.

### Related Topics

[Calibre nmModelflow Database Overview](#)

[Importing a Database](#)

## Creating a Filter

Filters reduce the gauge data set by removing any gauges that do not meet the criteria of the filter. A typical filter might remove all the vertical features from the gauge data set in order to calibrate a model that works for horizontal features only; another filter might operate on test structures of only one type.

Filters are saved in the database for re-use on multiple data sets.

### Note

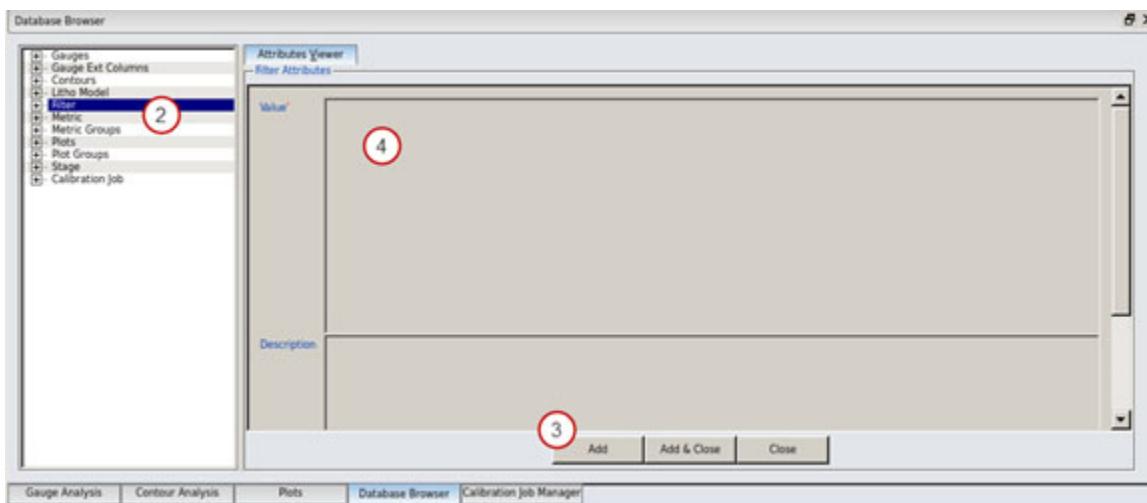
The Best Practice Database filters (see “[Loading the Best Practice Database](#)” on page 273) is a good reference for creating new filters.

## Restrictions and Limitations

- Filters must be entered as text rules and only limited syntax checking is available.

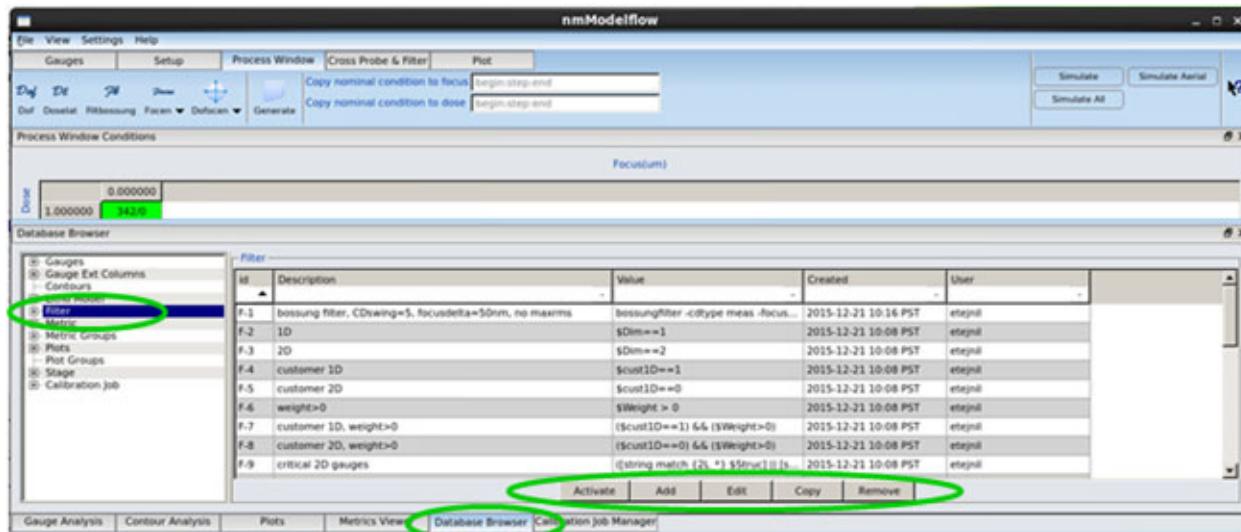
## Procedure

1. Raise the **Database Browser** tab in the list of primary display tabs.
2. Select the Filter item from the browser list on the left.
3. Click **Add** to open the filter definition pane.
4. Enter a filter definition in the Value field, a Description for the filter in the Description field, and then click **Add & Close** to save it.



## Results

The new filter is added to the Filter list in the Database Browser.



- Selecting a filter from the list and clicking **Activate** applies the filter to the active gauge data in the **Gauge Analysis** tab.
- Select a line, then click the **Edit** button, or double-click an item to open it for editing.

## Examples

Keep all gauges whose measured values are less than 160:

```
$Meas < 160
```

Filter all gauges with a simulated value greater than 180:

```
$Sim > 180
```

Keep only gauges with a dose equal to one and a focus equal to zero:

```
$Dose == 1 && $Focus == 0
```

## Related Topics

[Setting up a Calibration Job](#)

# Creating a Custom Plot

The Calibre nmModelflow GUI creates a default set of calibration plots, which are run on the active data set. However, you can create custom plots that are saved in the database.

---

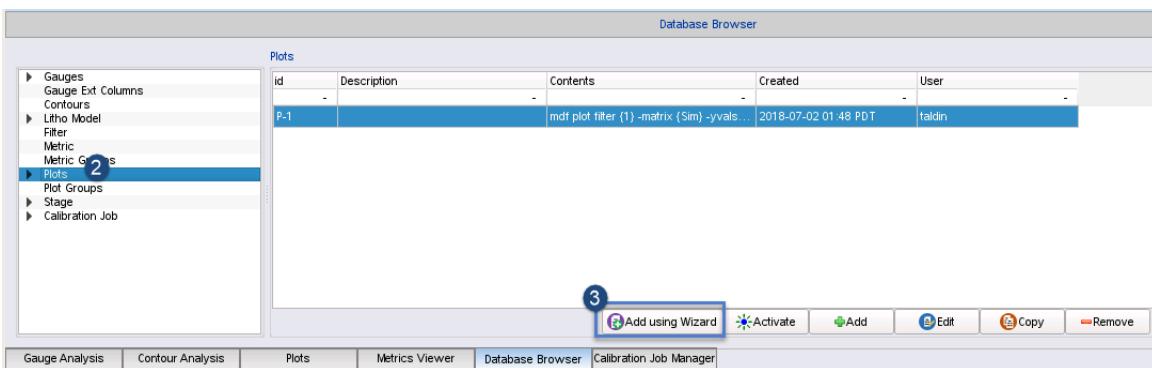
### Note

 This procedure describes defining plots in the database only.

---

## Procedure

1. Raise the **Database Browser** tab in the list of primary display tabs.
2. Select the Plots item from the browser list on the left.
3. Click the **Add Using Wizard** button.

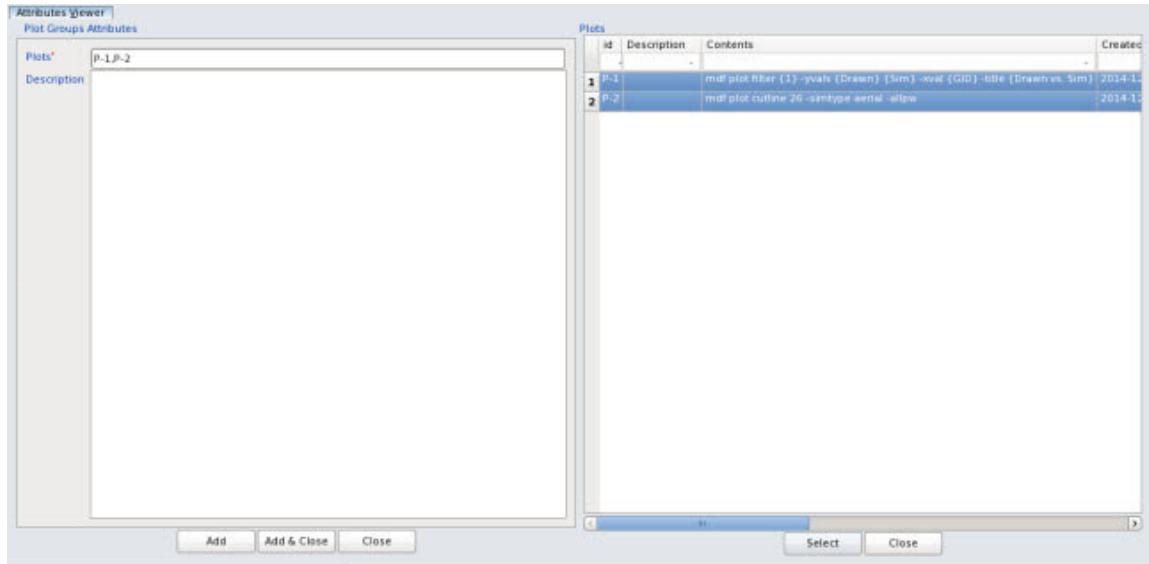


4. Select one of the listed plot types (Gauge Data, Cutline, Thrudose, ThruFocus, ThruPlane, or Contour), then click **Next**.
5. A secondary plot wizard screen appears based on your selections. Enter relevant data items and click **Next**.
  - Plot Wizard, Gauge Data
  - Plot Wizard, Contour Data Plot
  - Plot Wizard, Cutline Plot
  - Plot Wizard, Bossung-Type Plots (for Thrudose, ThruFocus, or ThruPlane)
  - Plot Wizard, Contour Plot
6. Click **Finish** when you are done making selections.

A plot listing is added to the list of plots. A single plot can be run on active data from the **Plots** tab. However, the Calibration job manager only uses Plot Groups, so you must also create a plot group in order to use the plot in a calibration run.

7. Select the Plot Groups item from the browser list on the left.
8. Click **Add**.

9. Click the Plots field. Calibre nmModelflow shows the list of defined plots from the database.



10. Hold down the **Ctrl** key and click on the plot(s) you want to include. Click **Select** to add the plots to the list.
11. Add a description. Descriptions are highly recommended for all database items, as they make it easier to understand the content and search the database.
12. Click **Add & Close** to update the Plot Groups list.

## Results

The plot and plot group are added to the respective lists in the database, and can be selected for later use. Clicking **Activate** on the Plots or Plot Groups screens plots the selected item in the main window [Plots Tab](#).

---

### Note

---

 Plots work on the active data. Ensure that simulator data is up to date by clicking the **Simulate All** button before generating a plot.

---

## Related Topics

[Setting up a Calibration Job](#)

## Creating a Custom Metric

Use metrics to measure figures of merit in gauge data. Metrics are applied to the results of simulations and calibrations. They are used to establish alternative methods to evaluate the quality of a model. Metrics can also be created in the GUI for use with the active data.

## Prerequisites

Metrics work on the active data. Ensure that simulator data is up to date by clicking the **Simulate All** button before generating a metric.

## Procedure

1. Raise the **Database Browser** tab in the list of primary display tabs.
2. Choose the Metric item from the browser list on the left.
3. Click **Add**.
4. In the screen that appears, select the metric type and the gauge column.

---

### Note

 Additional metrics (such as the OverallMean metric, which does not split gauge data into process conditions before calculating the mean) are only available through the CLI.

See the online help entry for “db add metricstable” for more information on available metrics.

---



---

### Tip

 A best practice for creating a metric is to ensure that a minimum value indicates the best result.

---

5. (Optional) Specify a previously defined filter to select a subset of the gauge data before the metric is applied.
6. Enter a description for the metric and click **Add & Close**.
7. To use the metric on a set of gauges, select it from the list of metrics and click **Activate**. Note that you must have a gauge file active in the **Gauge Analysis** tab to run the metric on.

You can optionally add a metric to a Metric Group, which runs multiple metrics at once when activated.

8. Click the Metric Groups item from the Database Browser list.

To add pre-existing metrics from a list:

- a. Click **Add**.
- b. In the screen that appears, click the Metrics field to bring up the list of defined metrics.
- c. Shift-click all the metrics you want to add to the metric group, then click **Select**.
- d. Enter notes in the Description field, then click **Add & Close**.

To add multiple new metrics as a group:

- a. Click **Add Using Wizard**.
- b. Select either Common Filters to create a combination set of filters with metrics for gauge columns or Individual Filters to create multiple metrics, of which some can have no filters at all.
- c. Set a description for the metric group, then click **OK**.

## Results

The new metric group is added to the list.

Selecting the new metric group from the list and then clicking the **Activate** button calculates the results of applying the selected metric on the active gauge data set to the **Metrics Viewer** tab.

The screenshot shows the Metrics Viewer tab with the following details:

- Metric Type: Mean
- Column: Meas
- Total: 73.2155
- Filter: [empty]
- Focus: [empty]

The table displays the following data:

	-0.060000	-0.040000	-0.020000	0.000000	0.020000	0.040000	0.060000
0.970260			73.1135	72.8089	75.4789		
0.985130		73.7447	73.2867	73.2353	74.9405	75.3352	
1.000000	74.5174	74.6343	72.8795	72.2626	74.3999	75.1617	69.9773
1.014870		72.1498	74.0422	72.1282	71.3058	70.6877	
1.029740			73.1951	75.4217	69.2487		

## Related Topics

[Setting up a Calibration Job](#)

[Creating a Verification Job](#)

[Metrics Viewer Tab](#)

[Edit Metric Group Wizard](#)

## Stage Creation

After you have litho models, gauges, and layouts in your database, you create stages to operate on them. Multiple types of stages are available in Calibre nmModelflow.

<b>Creating a Stage With the Flow Stage Wizard .....</b>	<b>98</b>
<b>Creating a Stage Experiment .....</b>	<b>106</b>
<b>Fast Rigorous Model (FRM) Considerations .....</b>	<b>107</b>
<b>Fast Rigorous Model (FRM) File Format .....</b>	<b>110</b>
<b>Model Calibration With the Genetic Algorithm.....</b>	<b>115</b>
<b>Creating an Etch Bias Rule Table .....</b>	<b>122</b>
<b>Combined and Unified Etch Bias Tables.....</b>	<b>126</b>

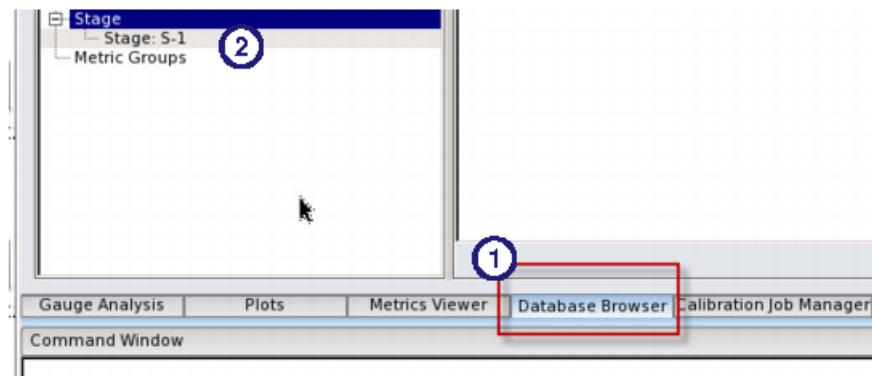
## Creating a Stage With the Flow Stage Wizard

Stages represent simulation and calibration commands in a job. When you create a stage with the Flow Stage Wizard, you define simulation commands and set parameters and optimizer settings for an optimization run. Calibration jobs can be run independently, or can be linked with the results of another calibration job.

### Procedure

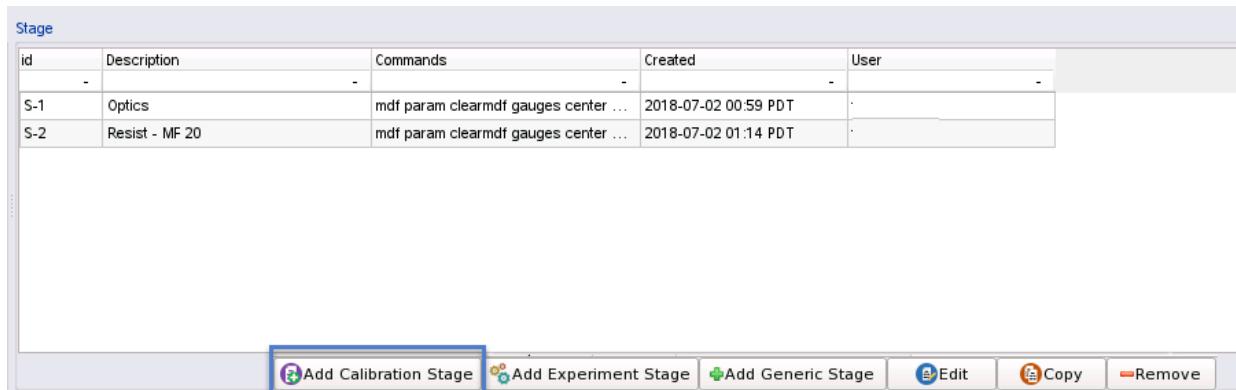
1. Raise the **Database Browser** tab in the list of primary display tabs.

**Figure 1-15. Starting the Flow Stage Wizard**



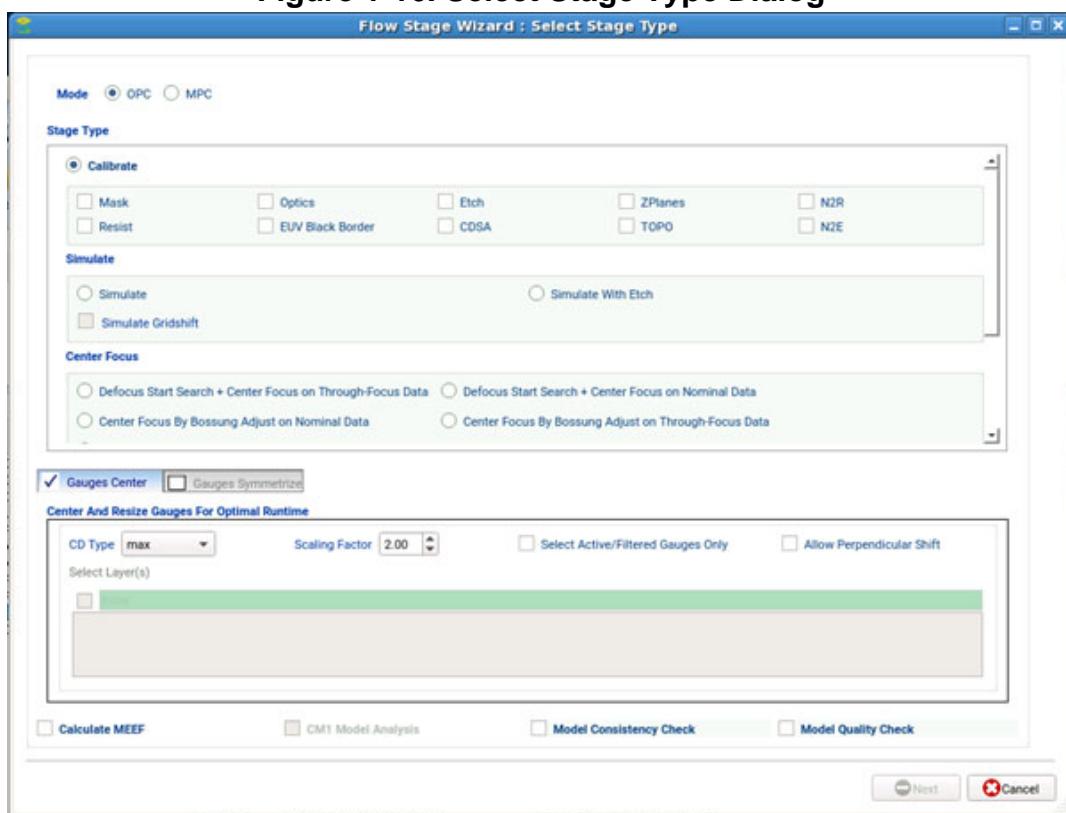
2. Click **Stage** in the left column.

3. Click the Add Calibration Stage button.



4. In the Select Stage Type wizard, choose the type of stage to create, then click Next.

**Figure 1-16. Select Stage Type Dialog**



Each type you select configures a different set of options relevant to the stage type. Some options require additional configuration choices; other options are preset options that cannot be changed.

Some stages bring up the Optimizer Settings wizard, which enables you to select optimizer options. The contents of the wizard vary depending on what you chose as the stage type.

**Table 1-14. Flow Stage Wizard Choices**

Type	Description	Notes
<b>Calibrate Group</b>		
Calibrate <ul style="list-style-type: none"> <li>• Mask</li> <li>• Optics</li> <li>• Etch</li> <li>• ZPlanes</li> <li>• Resist</li> <li>• EUV Black Border (described in the <i>Calibre WORKbench User's and Reference Manual</i>)</li> <li>• TOPO</li> <li>• N2R</li> <li>• N2E</li> </ul>	Sets up a calibration run similar to a CM1 Center run.	<ul style="list-style-type: none"> <li>• <a href="#">Flow Stage Wizard, Mask Calibration</a></li> <li>• <a href="#">Flow Stage Wizard, Optics Calibration</a></li> <li>• <a href="#">Flow Stage Wizard, ZPlanes Calibration</a></li> <li>• <a href="#">Flow Stage Wizard, Resist Calibration</a></li> <li>• <a href="#">Flow Stage Wizard, TOPO Calibration</a></li> <li>• <a href="#">Flow Stage Wizard, Etch Calibration</a></li> <li>• “<a href="#">Flow Stage Wizard, N2R/N2E Calibration</a>” on page 214</li> </ul>
CDSA	Sets up a CDSA calibration stage.	Creates additional screens to load CDSA files. See the <a href="#">Calibre Directed Self-Assembly User's and Reference Manual</a> .
<b>Simulate Group</b>		
Simulate	Sets up a simulation run.	No additional wizard screens are created.
Simulate with Etch	Sets up a simulation run with etch simulation added.	Select between absolute and relative etch simulation on the secondary wizard screen.
Simulate Gridshift	Adds calculated grid shift information to the results.	Opens a subpanel with options for the “mdf simulate gridshift” command.
<b>Center Focus Group</b>		

**Table 1-14. Flow Stage Wizard Choices (cont.)**

Type	Description	Notes
Defocus Start Search + Center Focus on Through-Focus Data	Adjusts both defocus_start and beamfocus as a single stage.	<ul style="list-style-type: none"> <li><a href="#">Flow Stage Wizard, Defocus Start Search and Center Focus on Through-Focus Data</a></li> </ul> <p>Used with process window data only.</p>
Defocus Start Search + Center Focus on Nominal Data	Similar to the Defocus Start Search + Center Focus on Through-Focus Data option, but for single focus conditions.	<ul style="list-style-type: none"> <li><a href="#">Flow Stage Wizard, Defocus Start Search and Center Focus on Nominal Data</a></li> </ul> <p>Used only with nominal condition data.</p>
Center Focus By Bossung Adjust on Nominal Data	Similar to the Center Focus By Bossung Adjust option, but allows you to specify a desired focus center.	<ul style="list-style-type: none"> <li><a href="#">Flow Stage Wizard, Center Focus By Bossung Adjust on Nominal Data</a></li> </ul> <p>Used only with nominal condition data.</p>
Center Focus By Bossung Adjust on Through-Focus Data	Adjusts the beamfocus by minimizing the mean focus shift value after running a Bossung filter on the initial data.	<ul style="list-style-type: none"> <li><a href="#">Flow Stage Wizard, Center Focus By Bossung Adjust on Through-Focus Data</a></li> </ul> <p>Used with process window data only.</p>
Beamfocus/Defocus Start Full Search + Center Focus on Through Focus Data  (Formerly <i>MGC Best Practice for Beam Focus / Defocus Calibration</i> )	<p>Sets up a beamfocus and defocus calibration run with preset commands, using best practice settings that are current for the release.</p> <p>These commands require focus-sensitive process window gauges. The stage uses a CTR model and applies Bossung adjustments after calibration.</p>	No additional wizard screens are created.
Build Group		
CTR Threshold Optimize	Sets up an optimization run for the threshold with a CTR (modelform 0) model.	No additional wizard screens are created.

**Table 1-14. Flow Stage Wizard Choices (cont.)**

Type	Description	Notes
Stochastic Optimize (described in the <i>Calibre WORKbench User's and Reference Manual</i> )	Sets up a run where the included stochastic model is calibrated for use with the associated CM1 model.	You are prompted to select which stochastic parameter to optimize and the search bounds.
Threshold Optimize	Sets up an optimization run for the default resist model.	See <a href="#">Flow Stage Wizard, Build Group</a>
Build TOPO	Sets up a run in which linear and quadratic topological model terms are tuned.	No additional wizard screens are created.
Build Resist	Sets up a run where the resist model is rebuilt by optimizing linear term coefficients and the model threshold.	No additional wizard screens are created.
Build Etch	Sets up a run where the etch model is rebuilt by optimizing linear term coefficients and a constant bias.	No additional wizard screens are created.
Pattern Specific Kernel Optimize	Builds an improved model by optimizing a subset of the gauges.	See “ <a href="#">Optimizing Results With Pattern-Specific Kernels</a> ” on page 148
<b>Etch Bias Table Generation</b>	Creates an etch bias table for use with Calibre Rule-Based OPC.	See “ <a href="#">Flow Stage Wizard, Etch Bias Table Generation</a> ” on page 238.
<b>Gauges Optimization Section</b>		
Center and Resize Gauges for Optimal Runtime  Note: Using this option is recommended.	When selected, this option adjusts gauge lengths to optimize runtime while maintaining accuracy.	See “ <a href="#">Centering Gauges</a> ” on page 39 for more information on the options activated when you select this checkbox.  No additional wizard screens are created.
Gauges Symmetrize	Adds an “mdf gauges symmetrize” command to the stage.	See “ <a href="#">Adjusting Gauge Symmetry</a> ” on page 34 for more information on this operation.

**Table 1-14. Flow Stage Wizard Choices (cont.)**

Type	Description	Notes
Calculate MEEF	When selected, this option calculates the mask error enhancement factor (MEEF).	No additional wizard screens are created.
CM1 Model Analysis	Adds CM1 resist model analysis information to the results.	Available only when <b>OPC &gt; Calibrate &gt; Resist</b> , <b>OPC &gt; Simulate</b> , or <b>OPC &gt; Build &gt; Build Resist</b> are selected.
Model Consistency Check	Activates additional consistency check functionality.	See the Results section.
Model Quality Check	Activates a post-calibration check for model quality using 95% CI values.	<ul style="list-style-type: none"> <li>• Adds a User Metrics section to the Calibration Job Report. See the Results section.</li> <li>• Also adds MEEF, CtrMEEF, MeefQ, and ErrCIQ columns to the resulting gauge object.</li> </ul>

- The final screen of the Flow Stage Wizard displays the commands that Calibre nmModelflow runs in a calibration job that uses that stage when you click **Finish**.

Optionally, you can click **Edit** before you click **Finish** and add or modify commands that might not be available as GUI choices, but can be found on the online help. Some example options are:

- **mdf optimize set\_resist metrics on** — Causes Calibre nmModelflow to generate metrics for each iteration (the default is off, which only calculates metrics on the final set of data).
- **mdf optimize set\_resist cleartodarkfieldctl off** — Deactivates the automatic generation of clear-to-dark field cutlines (they are automatically included by default in order to prevent printing of extra holes in large geometries).
- **mdf optimize set\_resist gridshiftconsistency** — Activates grid shift consistency checks for a resist model stage. Available options are:
  - **-shiftnum value** — Specifies checks at the specified number of intervals ( $S_{max}/value$ ) in both x and y directions.
  - **-xshiftnum value -yshiftnum value** — A pair of parameters that checks the specified number of intervals ( $S_{max}/value$ ) separately for X and Y directions.

- -shiftmax *mult* — The maximum gridshift value to check, using the formula  $S_{\text{max}} = \text{mult} * \text{Nyquist\_optical\_pixel\_size}$ .
- -shiftweight *value* — The weight of the grid shift simulation data in the objective function.
- -obj\_type {rms | tol | inspec} — Specifies the objective metric:
  - rms — Square root of the sum of the squares of the difference between the grid shifted CDs and average CDs across all of the shifts.
  - tol — Error tolerance based objective of norm 1. Uses the precision arguments (-prec1D and -prec2D, which must be positive values).
  - inspec — Percentage of gauges that meet the gridshift consistency criteria set using the precision arguments (-prec1D and -prec2D).
- -prec1D and -prec2D — Gridshift consistency tolerance for 1D and 2D gauges, respectively.
- **mdf optimize set\_resist mem\_report** — Adds a memory usage report to the output for resist stages that include contour calibration. Available arguments are:
  - off — Never prints memory report (default behavior).
  - on — Prints the estimated memory requirement before calibration, and continues the calibration as usual.
  - printonly — Only prints the estimated memory requirement without running the calibration.

## Results

A new entry is added to the Stage table in the database.

If you selected the Model Consistency Check option (or added the mdf optimize do\_consistency\_check on command to a script), the resulting calibration job report contains additional information in the CONSISTENCY REPORT and 1D/2D CONSISTENCY REPORT sections:

- **OPCV CS1** — Data calculated using the Calibre nmOPC simulation\_consistency 1 setting.
- **OPCV CS3** — Data calculated using the Calibre nmOPC simulation\_consistency 3 setting.
- **OPCV BP** — Data calculated using the current Calibre OPCverify 2018.4 best practices settings for DUV:
  - imagegrid aerial 3 8
  - final\_upsample 1
  - optical\_transform\_size 768

- contour\_options interp\_algo cubic
- In addition, the CD CONSISTENCY REPORT shows a comparison between each of the data values as optimized versus Try:
  - OPCV\_CS1-TRY, OPCV\_CS3-TRY, and OPCV\_BP-TRY for DUV
  - OPC EUV and OPCV EUV for EUV

If you included the mdf optimize set\_resist gridshiftconsistency command in your resist calibration stage, a separate “OPTIMIZE Gridshift consistency objective” entry is added to the final report.

DUV results can be viewed and used as filters in the **Gauge Analysis** tab as the Cs1Diff, Cs2Diff, and BpDiff columns, respectively.

EUV results are output as the OpcEuvDiff and OPCvEuvDiff columns, and use modified Calibre OPCverify settings:

- rasterizer\_upsample\_factor 2 1
- imagegrid aerial 1 1
- final\_upsample 1
- optical\_transform\_size 1024
- contour\_options interp\_algo lagrange interp\_degree 5

If you selected the Model Quality Check option, the resulting calibration job report contains additional information in the USER METRICS section:

- Mean (MeefQ) for CtrlMEEF or MEEF values larger than 0.
- Sum of any 95% CI values greater than 0.
- Sum of ErrCIQ for 95% CI values greater than 0.

## Related Topics

[Flow Stage Wizard, Mask Calibration](#)

[Flow Stage Wizard, Optics Calibration](#)

[Flow Stage Wizard, Resist Calibration](#)

[Flow Stage Wizard, Etch Calibration](#)

[Flow Stage Wizard, Center Focus By Bossung Adjust on Through-Focus Data](#)

[Flow Stage Wizard, Center Focus By Bossung Adjust on Nominal Data](#)

[Performing CM1 Model Analysis](#)

[Setting up a Calibration Job](#)

[Fast Rigorous Model \(FRM\) Considerations](#)

### Fast Rigorous Model (FRM) File Format

## Creating a Stage Experiment

As an alternative to creating stages individually, use the Experiment Stage Wizard to create multiple stages using variations of parameters and models together in a full factorial search.

### Restrictions and Limitations

- Attempting to create a full factorial search across multiple parameters can create a large number of calibration jobs. Ensure that you have enough Calibre nmModelflow licenses.

### Prerequisites

- At least one litho model in the database
- At least one set of gauges in the database
- The design file to run the calibration jobs on, loaded into Calibre WORKbench
- Calibre nmModelflow invoked

### Procedure

- In the **Database Browser** tab, select the Stage category from the list on the left. Click **Add Experiment Stage**.
- Similar to creating a single stage, pick one or more process model types to calibrate. For the current release, only Mask, Optics, Resist, ZPlanes, and Topo models can be used in experiments.
- On the stage configuration screens, set experimental parameters using the following rules:
  - Experiments can be run on:
    - Dropdowns with Experiment Mode (for optical parameters)  
If a parameter is selected as Experimental, its related Begin and End values cannot be “auto” “auto”.
    - Multiple resist modelforms (for resist calibration)
    - Fields with purple asterisks
  - An experiment parameter field must use values separated by colons: *start:end:intervals*
    - Iterations fields must use integers for *start*, *end*, and *intervals* values. For example, specifying 250:280:4 runs experiments for 250, 260, 270, and 280 iterations (250 to 280 with 4 intervals).

- Non-iteration fields that use floating point values can use numeric values as *start* and *end* values, but *intervals* must be an integer. For example, setting Thresholdtolerance to 1.5:4.5:3 runs experiments on a threshold tolerance of 1.5, 3, and 4.5 (1.5 to 4.5 with three intervals).
  - Use the information displayed at the bottom of the Optimizer settings page to correctly specify an experimentation string.
4. Create a calibration job using the new experiment stage.
- a. In the Gauge/Contour Select screen, you can shift-click to select more than one gauge set to use in the experiment.
  - b. In the Lithomodel/Predecessor screen, you can only select one litho model.
  - c. In the Stage screen, select the experimental stage.
  - d. In the Layer Mapping and Run Command screen, you must set the layer mapping for each lithomodel you selected in step 4a by clicking each text field and assigning layers to litho map layer in the expanded text field.
  - e. In the Summary screen, it is recommended that you leave the Execute Added Job(s) checkbox selected if you have a large number of experiments.

After clicking **Finish**, the full factorial combination set of the experiments and gauges is added to the Calibration Job list.

5. If you did not automatically execute the jobs at the end of the Create Calibration Job wizard, you can select one or more experiments to run in the **Calibration Job Manager** tab.

## Fast Rigorous Model (FRM) Considerations

The Fast Rigorous Model (FRM) is designed for use with CM1 resist models. It interacts with other resist model settings during the creation of a calibration stage, and may result in a different version of the active model.

### FRM Key Concepts

- FRM is a compact rigorous resist model based on a physical description of a resist exposure, post-exposure bake and shrink, development, and development shrink. FRM should be more predictive than a CM1 model.

---

#### Note

 For the current release, Siemens EDA recommends using the frontzoom search with 15000 iterations for all FRM calibrations. Do not use the fastga search with FRM, as it may lead to inaccurate results in some cases.

---

- With relatively small measurement data sets, FRM is typically more predictively accurate than CM1 for finding hotspots, because it closely models the resist process flow. It is less dependent on large amounts of measurement data.
- FRM has three usage modes, as described in the next section. If you use either of the **CM1 With FRM** modes, the input litho model must contain an FRM resist model or use the FRM modelform (365).

## FRM in the Calibre nmModelflow GUI

FRM-enabled options are found in the Flow Stage Wizard, Resist Calibration screen. Each choice opens up a subsection in the wizard with additional options for that mode.

---

### Note

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Siemens EDA recommends using **CM1 With FRM** in Sequential mode.

---

- FRM Only** — Fast Resist Model (FRM) calibration only. Used in place of the CM1 resist model. The parameters that appear are specific to directly calibrating the FRM model.
- CM1 With FRM** — Calibrates both CM1 and FRM in one of two different Integration Modes:
  - Sequential** — This mode uses the FRM model as an input to the CM1 model instead of the aerial image model. The mode is designed to calculate first principle effects in photoresists before applying the CM1 model. (If the CM1 model is a CTR model, it is the equivalent of FRM Only.)

This mode contains an option for the FRM\_sequential\_dilength (sequential diffusion length, which is either a floating point value in nm or “resolution”, which uses optical data for the computation) and a CM1 modelform selection box.

- Parallel** — Calibrates the CM1 and FRM models in parallel.

This mode can use either a CM1 term or FRM as the anchor term.

## FRM Using the Command Line Interface

In the command line interface, the mdf setupfile create -add\_rmodelform and -add\_resist options allow you to modify the currently active model using an FRM or CM1 model.

---

### Note

---



CM1 models can be combined with CM1-FRM or CM1-PEB\_SHRINK models, but not with other CM1 terms.

---

- Use -add\_rmodelform when you have an active setup file. It combines the active resist model and a second resist model created for a specified resist modelform.

- If the active resist model is CM1 (with or without FRM) and the specified modelform is one of the FRM modelforms, the combined resist model is the initial CM1 model plus the FRM options from the specified FRM modelform.
- If the active resist model is a “FRM ONLY” (CM1 with only FRM terms) or FRM->CTR (sequential FRM with CTR CM1 terms) and the specified modelform is one of the CM1 modelforms, then the combined resist model is the CM1 model created from the specified modelform and FRM options from the initial FRM model.
- If the active resist model is a CM1 model with a PEB\_SHRINK term and the specified modelform is one of CM1 modelforms, the combined resist model is the specified CM1 modelform and the active PEB\_SHRINK term.
- Use -add\_resist only when you have an active setup file. It combines an active CM1 resist model and a specified CM1 model that is read from a file name or inline model text.
  - If the active resist model is CM1 (with or without FRM) and the specified model is “FRM ONLY” (a CM1 model with FRM terms only) or FRM->CTR (sequential FRM with CTR term only), the combined resist model is the initial CM1 plus the FRM options from the specified FRM model.
  - If the active resist model is “FRM ONLY” or FRM->CTR and the specified model is CM1 (with or without FRM), the combined resist model is the specified CM1 model plus the FRM options from the initial FRM model.
  - If the active resist model is CM1 with PEB\_SHRINK terms and the specified model is a CM1 model, the combined resist model is the specified CM1 model plus the active PEB\_SHRINK term.

## Related Topics

[Fast Rigorous Model \(FRM\) File Format](#)

# Fast Rigorous Model (FRM) File Format

## Resist model file format

The Fast Rigorous Model (FRM) is a compact resist model used for full chip simulations. It can be used in place of or in conjunction with the CM1 resist model. It is not intended for 3D resist simulations.

## Format

```
modeltype CM1
[exposure_dose exp_dose_value]
[exposure_renormalization exp_renormalization_value]
[initial_quencher init_quencher_value]
[dill_c dill_c_value]
[quencher_decomposition quench_decomp_value]
[neutralization_rate neutral_rate_value]
[deblock_rate deblocking_rate_value]
[acid_diffusion acid_diffusion_value]
[quencher_diffusion quencher_diffusion_value]
[cross_diffusion cross_diffusion_value]
[peb_time peb_time_value]
[vshrink_max maximum_vertical_shrink_value]
[rate_max rate_max_value]
[rate_min rate_min_value]
[dissolution_order dissolution_order_value]
[inhibitor_threshold inhibitor_threshold_value]
[develop_time development_time_value]
[develop_tone development_tone_type]
[develop_solver development_solver_type]
[final_simulation final_simulation_type]
[frm_integration frm_integration_type]
[sequential_dlength { resolution | sequential_diff_length_nm_value }]
[resist_boundary_elasticity resist_boundary_elasticity_value]
[resist_boundary_interaction_distance
    resist_boundary_interaction_dist_value_nm]
[resist_boundary_density_ambit resist_boundary_density_ambit_value_nm]
[resist_boundary_b resist_boundary_b_value]
[resist_boundary_c resist_boundary_c_value]
[develop_deform_solver develop_deform_solver_type]
[developer_depletion developer_depletion_value]
[developer_dlength developer_dlength_value_nm]
[swelling_dlength swelling_dlength_value_nm]
[swelling_intensity swelling_intensity_value]
[swelling_model swelling_model_type]
[deformation_bias_algorithm deformation_bias_algorithm_type]
[output_type output_type]
[contrast_constraint constraint_value]
```

## Parameters

- modeltype CM1

A required parameter that specifies that this is a CM1 model. (Previous versions used FRM as the modeltype; currently FRM is part of the CM1 model format.)

- **exposure\_dose** *exp\_dose\_value*  
An optional argument that specifies the exposure dose in mJ/cm<sup>2</sup>. (Default is 20.)
- **exposure\_renormalization** *exp\_renormalization\_value*  
An optional parameter that specifies the type of optical image normalization.
  - none — No correction is done.
  - ambient — The aerial image intensity is multiplied by the correction factor  $k_{renorm} = \text{OFI}_{\text{ambient}}/\text{OFI}_{\text{initial}}$ , where:
    - $\text{OFI}_{\text{ambient}}$  — Is the open frame intensity computed for ambient normalization.
    - $\text{OFI}_{\text{initial}}$  — Is the open frame intensity computed for normalization specified in the optical model. (Default is ‘none’.)
- **initial\_quencher** *init\_quencher\_value*  
An optional parameter that specifies the relative concentration of the initial quencher. (Default is 0.2.)
- **dill\_c** *dill\_c\_value*  
An optional parameter that specifies the 3rd Dill coefficient in cm<sup>2</sup>/mJ. (Default is 0.05.)
- **quencher\_decomposition** *quench\_decomp\_value*  
An optional parameter that specifies the quencher decomposition rate in cm<sup>2</sup>/m. (Default is 0.02.)
- **neutralization\_rate** *neutral\_rate\_value*  
An optional parameter that specifies the neutralization rate constant in 1/s. (Default is 0.2.)
- **deblock\_rate** *deblocking\_rate\_value*  
An optional parameter that specifies the deblocking rate constant in 1/s. (Default is 0.1.)
- **acid\_diffusion** *acid\_diffusion\_value*  
An optional parameter that specifies the acid diffusion coefficient in nm<sup>2</sup>/s. (Default is 3.0.)
- **quencher\_diffusion** *quencher\_diffusion\_value*  
An optional parameter that specifies the quencher diffusion coefficient in nm<sup>2</sup>/s. (Default is 3.0.)
- **cross\_diffusion** *cross\_diffusion\_value*  
An optional parameter that specifies the cross diffusion coefficient in nm<sup>2</sup>/s. (Default is 0.0.)
- **peb\_time** *peb\_time\_value*  
An optional parameter that specifies the total PEB time in seconds. (Default is 60.)

- **vshrink\_max** *maximum\_vertical\_shrink\_value*  
An optional parameter that specifies a dimensionless maximum vertical shrink value for fully deblocked resists. (Default is 0.2.)
- **rate\_max** *rate\_max\_value*  
An optional parameter that specifies the maximum development rate. (Default is 100.)
- **rate\_min** *rate\_min\_value*  
An optional parameter that specifies the minimum development rate. (Default is 0.1.)
- **dissolution\_order** *dissolution\_order\_value*  
An optional parameter that specifies the dissolution order n. (Default is 5.)
- **inhibitor\_threshold** *inhibitor\_threshold\_value*  
An optional parameter that specifies the threshold relative concentration of blocked polymer. (Default is 0.5)
- **develop\_time** *development\_time\_value*  
An optional parameter that specifies the value of development time in seconds. Default is 60.
- **develop\_tone** *development\_tone\_type*  
An optional parameter that specifies the development tone type: “positive” (default) or “negative.”
- **develop\_solver** *development\_solver\_type*  
An optional parameter that specifies the type of the development solver. Can be “fast\_analytical,” “fd\_regular,” “fd\_rate\_modulation,” or “vertical.” (Default is “fd\_regular.”)
- **final\_simulation** *final\_simulation\_type*  
Sets the type of final simulation in the sequence as one of: “exposure,” “peb,” “peb\_deformation,” “development,” or “development\_deformation.” For example, if the final simulation is defined as ‘peb’ then it means that PEB results are taken as the final resist image. In this case, the peb\_deformation, development, and development\_deformation simulations are not run.  
  
Note that if ‘exposure’ is chosen, then the output resist grid is filled with the difference between the acid and quencher concentrations. At points where the difference is negative the zero values are accepted. (Default is ‘development\_deformation’.)
- **frm\_integration** *frm\_integration\_type*  
An option that sets the place of FRM simulations relating to CM1 modeling.
  - sequential — FRM simulations are performed before CM1, and are used as CM1 input instead of the total aerial image. The resist image is computed on a resist grid and is downsampled to the aerial image simulation grid using Gaussian filtration.

- parallel — FRM is computed on resist grid as a separate GTERM inside the CM1 model. (Default is “parallel.”)
- sequential\_dlength {resolution | *sequential\_diff\_length\_nm\_value*}  
Diffusion length of the Gaussian filter that is applied to the final FRM image for FRM sequential integration, nm.
  - resolution — Computes the diffusion length as  $0.11 * \lambda / NA$ , where  $\lambda$  and NA are the wavelength and numerical aperture of the optical system, respectively. (Default is “resolution.”)
  - *sequential\_diff\_length\_nm\_value* — Uses the specified value for the diffusion length.
- resist\_boundary\_elasticity *resist\_boundary\_elasticity\_value*  
An optional parameter that specifies the value of the dimensionless resist boundary elasticity value, which is a proportionality constant between normal develop deformations bias in P4 units and dimensionless normal stress. Default is 0.

---

**Note**

 PN-units are multiples of the optical wavelength in photoresist. A P4 unit is four times the optical wavelength ( $P4 = \lambda / 4NA(1+\sigma)$ ).

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- resist\_boundary\_interaction\_distance *resist\_boundary\_interaction\_dist\_value\_nm*  
An optional parameter that specifies the value of maximum interaction distance  $\eta_{Max}$  in nm. Default is 120 nm.
- resist\_boundary\_density\_ambit *resist\_boundary\_density\_ambit\_value\_nm*  
An optional parameter that specifies the value of top-hat kernel radius S in density computation. Default is 30 nm.
- resist\_boundary\_b *resist\_boundary\_b\_value*  
An optional parameter that specifies the B component of the resist boundary calculation.
- resist\_boundary\_c *resist\_boundary\_c\_value*  
An optional parameter that specifies the C component of the resist boundary calculation.
- develop\_deform\_solver *develop\_deform\_solver\_type*  
An optional parameter that specifies the develop deformation solver. Can be either ‘const\_elasticity’ or ‘variable\_elasticity’. (Default is ‘const\_elasticity’.)
- developer\_depletion *developer\_depletion\_value*  
An optional parameter that specifies a dimensionless value characterizing developer depletion (the ability to diffuse into the resist). It is equal to the value of 1-b (the active developer). The default value is 0.7 (b = 0.3).

- **developer\_dlength** *developer\_dlength\_value\_nm*  
An optional parameter that specifies the developer diffusion length in nm. The default value is 30.
- **swelling\_dlength** *swelling\_dlength\_value\_nm*  
An optional parameter that specifies the swelling diffusion length in nm. It can be a numerical value, or ‘auto’. The default value is auto, which uses a diffusion length equal to P4/4.
- **swelling\_intensity** *swelling\_intensity\_value*  
An optional parameter that specifies the value of factor for the final image computation. The default value is 0.
- **swelling\_model** *swelling\_model\_type*  
An optional parameter that specifies the swelling model type. The only supported value is “model\_a”.
- **deformation\_bias\_algorithm** *deformation\_bias\_algorithm\_type*  
An optional parameter that specifies the deformation bias algorithm:
  - gradient — A gradient biasing algorithm.
  - interpolation\_zeroth — An interpolation biasing algorithm.
  - interpolation\_first — An advanced interpolation algorithm that takes into account image slope inside a moved (biased) pixel and the deformation of the moved pixel.
  - upwind\_first, upwind\_third, or upwind\_mccormack — Schemes based on the numerical solution of a transport equation; they are the schemes of the first and third approximation order and the McCormack scheme, respectively. (Default is “interpolation\_first.”)
- **output\_type** *output\_type*  
An optional parameter that specifies the type of FRM output:
  - height — FRM output without final mapping.
  - energy — Computes the resist image and then applies a height-to-dose (“blocked\_to\_dose”) mapping function. This mapping saves resist contours and it usually improves consistency. (This is the default.)
- **contrast\_constraint** *constraint\_value*  
An optional parameter that specifies a contrast calibration constraint that is used to reject cases of low contrast FRM models during calibration. The *constraint\_value* argument is a non-negative value that should be set to the maximum allowed difference between the ideal blocked polymer concentration for a max exposure dose and the actual blocked polymer concentration for a dose. (The default is 0.1. Specify “none” to turn off constraints).

## Related Topics

[Fast Rigorous Model \(FRM\) Considerations](#)

# Model Calibration With the Genetic Algorithm

The genetic algorithm (GA) mimics the process of natural selection in order to obtain an optimal model. This is accomplished by using previously found optimizations as well as investigating new configurations. Model calibration with the genetic algorithm is scalable on a large number of CPUs, can specify multiple starting points, and track and report on multiple model candidates.

---

### Note

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 Currently, the genetic algorithm is only recommended for negative tone development (NTD) models.

---

## Genetic Algorithm Search Options

Genetic algorithm search can produce more accurate resist models and is recommended for NTD models (resist modelforms 38 to 92). The following genetic algorithms can be selected:

- **ga** — The genetic algorithm can be selected from the Search Algorithm dropdown list (ga option) under the sections labeled “Optimization Search” in the [Flow Stage Wizard](#), [Optimizer Settings](#). The genetic algorithm runs with 201 iterations by default. You can specify the number of iterations for your search as follows:

```
mdf optimize explore 500 search ga
```

- **gazoom** — The gazoom option is also available in the Search Algorithm dropdown list. It is a combination of a global search using the genetic algorithm (ga) and local search using the zoom optimization. See the section “[Using Zoom Search with the Genetic Algorithm](#)” on page 121.

---

### Note

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 The epsilon parameter only appears in the Stage Wizard when you change the Optimizer Settings control to “Modify Defaults.”

---

- **gagradient** — Is a combination of a global search using the genetic algorithm (ga) and local search using the gradient optimization. The former is used to explore the search space and find multiple initial guesses (starting points) for the latter. The number of ga generations can be set using the explore parameter (the default is 201). The gradient search stops when an internal convergence criterion is met. The settings for numbers of levels and epsilon have no effect on the gagradient search.

- **gapgradient** — Is a combination of a global search using the genetic algorithm (ga) and local search using the pgradient optimization. It is similar to gagradient, except that it uses a fixed gradient search step and a fixed search range.
- **pgradient** — The standalone pgradient search stops when an internal convergence criterion is met. It explores a search range for a given step size, selecting the variable that leads to the biggest improvement with a given permutation. It tends to return an improved RMS result compared to the zoom search, but at a cost of higher runtime. This search method is best used with a good starting model as input with explore set to 0.
- **frontpgradient** — Is a combination of the front and pgradient search algorithms. The front part establishes an initial starting position based on a scan of the search space. The number of front iterations is determined by the explicitly specified explore or its default value. The pgradient search stops when an internal convergence criterion is met. The settings for numbers of levels have no effect on the frontpgradient search.
- **fastga** — Is a combination of a global search using the genetic algorithm (ga) for a fast convergence rate and a local step-based pgradient optimization. The ga part explores the search space and finds multiple initial guesses (starting points) for the local pgradient search.

---

**Note**

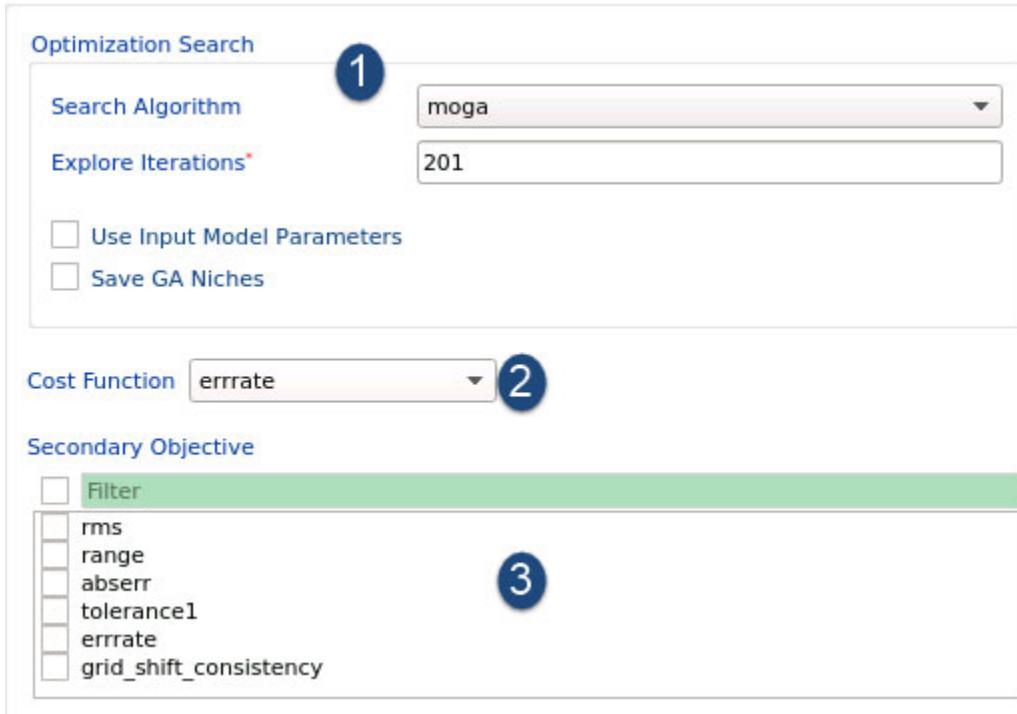


The fastga search method is the default for NTD resist model calibration.

---

- The number of ga generations is determined by the explore parameter. The default is 501.
- The pgradient search stops when an internal convergence criterion is met.
- The numbers of levels and epsilon parameters are not used in the fastga search.

- **moga** — Is a Multi-Objective Genetic Algorithm. After selecting the moga Search Algorithm (1) select the search methods with the primary objective Cost Function (2) and Secondary Objective (3) picked from the list.



When a stage using the moga search algorithm is calibrated successfully, additional entries (**Plots** category, **IterStatsPareto** subcategory and **Iterstats** category, **IterStats Pareto Table** subcategory) appear in the [Calibration Job Record Dialog Box](#). The specialized Iterstats list sorts the primary objective and secondary objective separately.

You can also use the following commands to control genetic algorithm searches:

- “mdf optimize set\_resist ga\_objective\_limit *value*” to set a specific objective limit to stop the genetic algorithm search.
- “mdf optimize set\_resist ga\_convergence\_generation\_threshold” and “mdf optimize set\_resist ga\_convergence\_objective\_tolerance” as a pair of commands to stop the search when the total objective value improvement is less than the specified tolerance for more than the specified number of generations.

## Cache Memory Size Settings

Calibre nmModelflow requires adequate cache memory in order to perform genetic algorithm calibration. Two methods are available to set the cache memory size for genetic algorithm optimizations:

- The environment variable CM1\_CALIBRATION\_CACHE\_SIZE

This environment variable accepts values in megabytes; the default value is 512.

- The “mdf optimizer set memcache” command, available in the Command pane  
This command accepts values in megabytes; the default value is 8192 (8 GB).

The two methods interact according to the following table.

**Table 1-15. CM1\_CALIBRATION\_CACHE\_SIZE and optimizer memcache Interaction**

CACHE_SIZE Environment Variable Set?	memcache command Set?	Resulting Cache Setting
No	No	8192
Yes	No	Use environment variable setting
No	Yes	Use memcache command setting
Yes	Yes	Use memcache command setting (environment variable setting is ignored)

To calculate the cache memory needed to compute all the resist model terms for all the gauges and save them to the cache in the first iteration, the following approximation can be used:

$$[500 * (\text{number of gauges}) * (\text{number of terms}) * 250 \text{ bytes}] / 2^{20}$$

The result is the required cache memory in megabytes.

---

**Note**

 If the total allocated cache size is smaller than the required size, Calibre nmModelflow issues a warning during calibration detailing the suggested cache size.

---

The number of terms required to run a calibration with the genetic algorithm for various model forms is shown in the following table:

**Table 1-16. Number of Terms for each Model Form**

Model Form	Number of Terms
mf21	7
mf22	8
mf42	9
mf43	9
mf44	10
mf48	19
mf58	20
mf78	27

**Table 1-16. Number of Terms for each Model Form (cont.)**

Model Form	Number of Terms
mf88	29

The population size varies as evolution proceeds, but will not exceed 1000. The number of models that a generation contains after the first iteration cannot be decided beforehand. The genetic algorithm will automatically load the starting model and use it in the first generation of optimizations. The genetic algorithm will generate a few models on top of the model with the best RMS fit error. They all have similar RMS fit error, but very different model parameters. These models are called niche models. If the best model is not desired, the model can be switched to one of the niche models.

## Genetic Algorithm Results Selection

The five best models are output to the last five rows in the *iterstats.csv* file with the first having the worst fitness value of the five and the last having the best RMS fitness value.

### Note

 The default behavior is to save all intermediate models to the *iterstats.csv* file. You can restrict which models are saved to the CSV file by ignoring any models with an RMS value greater than a given threshold value with this command:

---

```
mdf optimize set_resist save_iterstats_threshold value
```

---

In addition to the *iterstats.csv* file, the following output is generated:

- In the *optimizeinfo* folder in the job run directory, *index.html* contains the entry “CONSISTENCY REPORT” for all the niche models.
- In the job run directory, the *stagesiminfo* and *outputsiminfo* directories contain information for the best model, and the file *gaugesfinal.csv* that contains the final gauges from the calibration.
- Folders with names “*outputsiminfo\_<sampleID>*” contain information for the other niche models.
- If the Save GA Niches option in the Flow Stage Wizard Optimizer was selected, or if you issued the “mdf optimize set\_resist save\_ga\_niches on” command, additional files for each of the best five niche models are written to the run directory:
  - *gaugesfinal\_<niche\_ID>.csv*
  - *miscparams\_<niche\_ID>.csv*
  - *metricparams\_<niche\_ID>.csv*
  - *modelparams\_<niche\_ID>.csv*

These niche model files are not generated by default.

- Setting the environment variable

```
setenv MDF_OPTIMIZE_ITERSTAT_NICHE_COLUMN 1
```

before running Calibre nmModelflow adds the file *iterstats\_niche.csv* to the *optimizeinfo* folder. This file contains niche group IDs for all the niche models. The best model is given the ID of 0, the next best model is given the ID of 1, and so on. A model that does not fit into any niche is given an ID of -1.

The Optimize vs Try report as well as all the related information for the solution models can be generated by running the following command:

```
mdf job report -costobjectivefile costobjective
```

Note that this command is automatically generated when the job is created using the Calibration Job Wizard.

After running the genetic algorithm, the results can be viewed in the Calibration Job dialog box under the Best IterStats, Show Niche Models tree entry. Four of the five niche models are displayed, with the global best model excluded. These four niche models are highlighted in the main Iterstats table, where all five niches can be compared, as shown in [Figure 1-17](#). Each niche model can be selected and accepted by right-clicking on the highlighted row. Accepting a niche model makes the model active in the GUI.

**Figure 1-17. Accepting Niche Models in Calibration Job Dialog Box**

The screenshot shows the Calibre nmModelflow Calibration Job dialog box. On the left, a tree view shows 'IterStats' expanded, with 'Best IterStats' selected. Under 'Best IterStats', 'Show Niche Models' is also selected. The main area is a table titled 'Iterstats' with columns: ID, Model ID, 1.9998, 1.8982, 1.9998, 17.4077, 10.2995, and 6.0615. Rows 472067, 472068, 472069, and 472070 are highlighted in yellow. A red box surrounds these four rows. On the right, there are tabs for 'Gauge Symmetry Calc', 'Process Win', and 'Calibration'. Below the table, there are buttons for 'Accept', 'Save Lithomodel to Disk', 'Save Lithomodel to Database', and 'Add Verification Jobs'. A status bar at the bottom shows 'e' and 'e'.

ID	Model ID	1.9998	1.8982	1.9998	17.4077	10.2995	6.0615
472045	22151	1.9998	1.8982	1.9850	17.4852	9.9345	6.4596
472046	22151	1.9850	1.8982	1.9268	16.6691	9.3809	8.0085
472047	22151	1.9268	1.8982	1.9268	18.0737	9.8929	8.8081
472048	22151	1.9553	1.8982	1.9553	15.6513	9.4331	9.0406
472049	22151	1.9022	1.8982	1.9022	16.3510	9.2432	7.8155
472050	22151	1.9515	1.8982	1.9515	17.2341	10.2785	8.9246
472051	22151	1.9017	1.8982	1.9017	16.4447	9.2788	9.2476
472052	22151	1.9284	1.8982	1.9284	16.6218	9.4883	7.5735
472053	22151	1.9675	1.8982	1.9675	17.1329	9.4492	7.1687
472054	22151	1.9903	1.8982	1.9903	10.0667	7.1564	
472055	22151	1.9667	1.8982	1.9667	17.2517	9.9327	8.5179
472056	22151	1.9864	1.8982	1.9864	17.9934	7.2413	
472057	22151	2.0211	1.8982	2.0211	9.3628	7.7549	
472058	22151	1.9607	1.8982	1.9607	16.7457	9.6178	
472059	22151	1.8982	1.8982	1.8982	16.7743	7.7347	
472060	22151	1.9669	1.8982	1.9669	16.5732	9.5960	7.6838
472061	22151	1.9543	1.8982	1.9543	17.7580	9.8671	8.6755
472062	22151	1.8982	1.8982	1.8982	16.7743	9.6178	7.7346
472063	22151	1.9962	1.8982	1.9962	17.4998	10.1147	8.5149
472064	22151	1.9997	1.8982	1.9997	17.2154	10.1587	8.7416
472065	22151	2.0818	1.8982	2.0818	18.2733	10.8470	7.6042
472066	22151	1.9387	1.8982	1.9387	16.8453	9.2545	8.2841
472067	22309	1.9017	1.8982	1.9017	16.4447	9.2788	9.2476
472068	22379	1.9016	1.8982	1.9016	16.7854	9.6001	7.7739
472069	22391	1.9016	1.8982	1.9016	16.7854	9.6001	7.7738
472070	22394	1.8982	1.8982	1.8982	16.7743	9.6178	7.7147
472071	22397	1.8982	1.8982	1.8982	16.7743	9.6178	

## Using Zoom Search with the Genetic Algorithm

The Zoom search can be run on all five best niche models identified by the genetic algorithm by running the following command:

```
mdf optimizer explore generations search gazoom
```

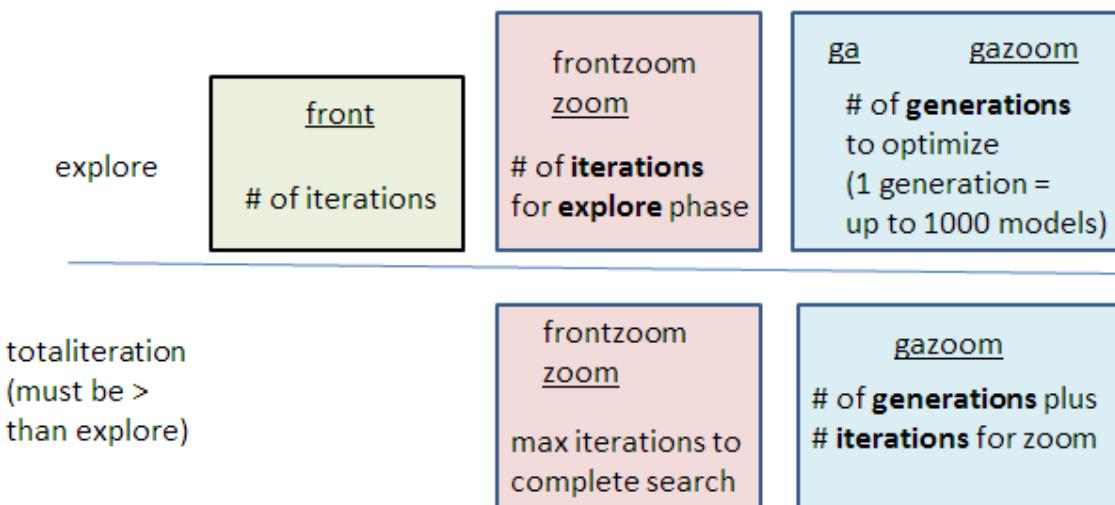
The command runs the genetic algorithm on the specified number of generations and then runs Zoom search, which evaluates all the niche models in parallel. The convergence of Zoom search is controlled by epsilon in the following command:

```
mdf optimizer set epsilon value
```

The smaller the epsilon value, the greater the number of zoom iterations required for convergence. Epsilon is automatically set to the default value of 0.001. The total run time of the Zoom search is dependent on the number of iterations required for each niche model.

## Explore and Totaliteration Setting Differences for the Genetic Algorithm

The genetic algorithm optimization search options (ga and gazoom) use the “explore” and “totaliteration” settings in Calibre nmModelflow (in the Flow Stage Wizard for a resist model on the Optimizer Settings with Resist screen) to set the number of search experiments to perform. However, these settings are also used by other search algorithms and have different meanings.



For the “explore” parameter:

- full and front use “explore” as the number of iterations to run.
- frontzoom and zoom use “explore” as the number of iterations for the exploration phase to arrive at a coarse estimate.
- ga and gazoom use “explore” as the number of generations to optimize, where one generation includes up to 1000 models.

**Note**

 In the Calibre nmModelflow interface, “explore” is set using the “Explore Iterations” field, found on the [Flow Stage Wizard, Optimizer Settings](#) page.

---

For the “totaliteration” parameter:

- frontzoom and zoom use “totaliteration” as the maximum amount of iterations allowed to complete the search.
- gazoom uses “totaliteration” to control the additional number of model evaluations used in a zoom search, where totaliteration equals the number of ga generations plus the number of zoom iterations.
- front, full, and ga do not use “totaliteration.”

The setting for “totaliteration” is optional, but if it is specified, it must be greater than the setting for “explore.”

## Creating an Etch Bias Rule Table

Etch bias rule tables are used when you have a VEB etch bias retargeting process. You use etch bias rule tables with Calibre nmBIAS to quickly adjust edges for resist target polygons.

The Calibre nmModelflow Stage Creation Wizard has an option that creates an etch bias rule table that collates collected measurement data into specific rule bins.

Two input methods are available for creating etch bias rule tables:

- **veb** — Use veb mode when you have a previously-calibrated VEB model available.
- **lsf** — Use lsf (least square fit) mode when you do not have a VEB model, but do have measured etch CD width and space data available.

### Prerequisites

- Basic simulation information (a layout, gauge file, and litho model) from your post-etch process
- A VEB model inside the litho model for VEB mode

### Procedure

1. Examine the gauge data file’s Resist CD (Meas) measurement and Etch CD (MEtch) measurement. For each value, calculate the etch bias value using the following equation:  
$$\text{Etch\_bias}/2 = (\text{Meas} - \text{MEtch})$$
2. Determine the table bin conditions using an etch bias analysis on measured data.

3. In Calibre nmModelflow, switch to the Database Browser, and select Stage from the database tree.
4. Create a new stage by clicking the **Add Using Wizard** button.
5. In the Flow Stage Wizard, select the Etch Bias Table Generation option and click **Next**.



6. In most cases, you can leave the Select VEB Fit Type, Force\_etch\_bt0, and Density Collection settings to their defaults, because these options do not influence the bias rule table generation.
  - **Select VEB Fit Type** — Sets whether the error criteria is relative (compared to the etch bias) or absolute (compared to the measured etch) for the best fit.
  - **Force\_etch\_bt0** — Sets a speed toggle; use On for higher calibration speed at the cost of calibration accuracy.
  - **Density Collection** — Adds VEB density kernel information to the output.
7. If you want to create more than one etch bias table, click “+” to add a new tab. Each tab is its own separate etch bias table definition.

---

**Note**

 You can use the Update Tab Name field to rename a tab.

---

8. Choose the method for creating the etch bias rule table. Set additional controls based on your method selection:
  - For the veb Method, set the following specific controls:
    - **Length Constraint** — Selecting this checkbox adds the ability to set length constraints in addition to space and width constraints.
    - **Dump Patterns, Dump Gauges, Dump Patterns Size** — Set these optional fields to examine the gauge file generated by Calibre nmModelflow for this etch bias rule table.
  - For the lsf Method, set the following specific controls:
    - **Extra** — Sets the search radius around each structure for gauges.

- **Order** — Sets the order of the internal equation polynomial used to fit the data.

$$a_1 * \text{space}^2 + a_2 * \text{space} * \text{width} + a_3 * \text{width}^2 + a_4 * \text{space} + a_5 * \text{width} + a_6$$

The recommended value is 2 (using just  $a_1$  and  $a_2$ ). Higher values increase fitting accuracy at the cost of speed; lower values are less accurate but calculate faster.

- **gauges\_avg, gauges\_n, gauges\_stdev** — Selecting one or more of these checkboxes adds a separate file to the output showing the gauge measurements in bins sorted by average bias (avg), numeric frequency (n), and standard deviation (stdev).
  - **Use Valid Gauges** — By default, only gauges that are in the table (have values that fall between min and max width and space ranges) are included in the output. Changing this field to “all” includes all generated gauge values.
  - **Inverse** — Optional. Changes the fitness test for width and space to be  $1/\text{width}$  and  $1/\text{space}$ .
  - **Measure From** — Sets whether the error calculations are measured from the generated layout, the gauges in the table, or the specified pitch. It changes the source of the width and space terminology for the table bins. The recommended value is ‘pitch’, which reads from the layout and measurement data (Metch).
9. Set up the bias table bins by selecting specifying up to five interval ranges in the Rule Table Parameters section for the Width and Space fields (plus Length for Method veb only). The values you set have the following effects:
- Min and Max values set the start and end ranges for width and space CDs. All bins are generated between the specified values, including the start and end values.
  - The Interval setting indicates the size of the bins as a step function. For example, the default Width value of Min\_Width 50, Max\_Width 300, Interval 10 generates bins of 50, 60, 70, 80 ... 300.
  - If additional Width, Space, or Length lines are defined, a bin is added at that value and the interval changes to the new setting. For example, if Width1 90 Interval 20 and Width2 150 Interval 30 are specified, the intervals generated are 50, 60, 70, 80, 90, 110, 130, 150, 180, 210, 240, 270, and 300.
  - For lsf mode only, you can select the Autobin radio button to cause Calibre nmModelflow to generate bins automatically based on the gauge set, with the ability to set specific boundaries if desired.
10. (Optional) Set the output options (Out Precision, Out Format, Out Unit, Out Path, and Out File) if you want to adjust the file output from the default settings.
11. (Optional) If you have defined multiple tabs, you can select Merge Table Options to open up an additional section where you can specify combined and unified outputs for the generated tables.

12. Click **Next** to continue to the results screen. Change the default description and do final command adjustments if needed, and then click **Finish**.

- **-dump\_invalid\_gauges** — Instructs Calibre nmModelflow to write all invalid gauges in an lsf file to a separate file (*invalid\_gauges.gg* is the default filename).
- **-min\_litho\_cd\_space, -min\_litho\_cd\_width** — Sets a minimum value for space or width CDs for bias values. If a bias value violates the specified limit, its cell value is updated to fit the CD.
- **-litho\_cd\_violations\_file** — Defines a file to write a list of bins where bias minimums were violated.

## Results

A new stage is created in the Stage list. When run as part of a calibration job, the output of the stage is one or more etch bias table spreadsheets using the data in the specified gauge file.

You can find the files created by this job in the following directory by default:

*mdf/database/mdfRepository/calibrationjobtable/CJ-<job#>/Data/etch\_rule\_table/*

The file name for the etch bias table is set in the Output File field. The default filename is based on the following criteria:

- **Single or first etch rule table** — *etch\_rule\_table.csv*
- **Additional rule tables (multiple tabs)** — *etch\_rule\_table\_<n>.csv*
- **Length constraint specified** — If the Length Constraint checkbox is selected for an etch bias table definition, multiple etch rule table files are generated for the given width and space definition. Each table is a width x space table, generated for a specified length. The format of the filename is modified to be:

*etch\_rule\_table\_L\_<n>\_<length>.csv*

---

### Note

 If you specify the **-out\_path** with a literal “<length>” string, the generator outputs multiple separate directories with the length string filled in as appropriate.

---

---

### Note

 Output spreadsheets separate fields with semicolons instead of commas.

---

If you selected any Merge Table options, additional files are created for the combined and unified tables. See “[Combined and Unified Etch Bias Tables](#)” for more information.

- **Combined table** — *comb\_table.csv* for the bias table and *combined.gg* as the calculated file
- **Unified table** — *uni\_table.csv*

**Note**

-  An additional directory, etch\_bias\_table\_storage, is also generated. This directory is used by the [Calibration Job Record Dialog Box](#) to generate an Etch Bias Report entry, and its contents can be ignored.
- 

## Related Topics

[Flow Stage Wizard, Etch Bias Table Generation](#)

[Setting up a Calibration Job](#)

[Combined and Unified Etch Bias Tables](#)

## Combined and Unified Etch Bias Tables

The Etch Bias Table can optionally output additional merge tables that combine multiple tables in the same generation run.

### Requirements for Merged Etch Table Output

- Output from the Etch Bias Table Generator that has at least four tables that overlap their ranges on at least six cells (a 2x3 or 3x2 intersecting shared value block).
- All tables must output an additional set of tables using the -dump\_valid\_gauges option.

### Troubleshooting Merge Table Calibration Jobs

If a merge table calibration job returns an error, you can diagnose the problem by selecting the job and clicking **View**. In the Calibration Job report, select the **Transcripts > Job** item and search for the message, “Error during building etch rule table.” The cause of the error can be found near that message:

- “Table with ID 1-gauges not found in the storage” — This is usually caused by a missing -dump\_gauges option in one or more etch rule table definition commands. All commands must dump a valid gauge file.
- “Amount of gauges with valid geometry is too small for Least Square Fit. Should be at least 6, currently X” — There are not enough overlapping cells in the combined table to form a 2x3 or 3x2 block. This can be caused by space and width definitions not being defined correctly to create an overlap.
- “WARNING: X gauges have empty layout. Possibly the passed layer sequence is wrong, first layer should contain the valid geometry.” — The first layer in the litho model file needs to be assigned to the test pattern geometry layer in the layout. Other layers are usually set to -1 (“do not map this layer”).

- “Tables for combining doesn't form a huge table.” — The tables that are passed must have a central area shared between them, requiring that each table overlaps with at least one other along a space or width range.

## Combined Tables

Combined tables output the union of the tables that are sent to the etch bias table generator. The output is a .csv (space separated) width/space table with the value ranges for all tables in a single table.

## Unified Tables

Unified tables output a CSV (semicolon separated) spreadsheet containing multiple columns of information:

**Table 1-17. Unified Table Columns (Etch Bias Table Output)**

Column	Description
Table Group	The table group ID. Each source table in the unified table has its own unique ID.
Data Type	The type of table. “table_etchbias”, “gauges_valid_LSF”, or “gauges_valid_VEB”.
Method	The method used to create the table, one of “VEB”, “LSF” or “combinedLSF”.
Length	The length bin used for the entry. This field is only used if you unified a VEB table.
LSF Order	The value of the -order parameter.
use_valid_gauges	A status flag indicating whether a gauge is in the table (intable) or not (none).
Inverse	Indicates whether the -inverse setting was “on” or “off” for a table in the unified table list.
Table Parameters	A field indicating the width and space entry (Wx_Sy) or “none” for a valid gauge entry.
Struct	The structure name for a valid gauge entry, or none for an etch bias table entry.
Loc	A field indicating the type of gauge (0 for width, 1 for space).
Drawn (nm)	The drawn value of the target's width.
Other (nm)	The drawn value of the target's space.
Meas (nm)	The measured resist value for a gauge. Empty for the etch bias table entries.
Sim (nm)	The simulated resist value for a gauge. Empty for etch bias table entries.

**Table 1-17. Unified Table Columns (Etch Bias Table Output) (cont.)**

Column	Description
Metch (nm)	The measured etch value for a gauge. For etch bias table entries, this is the same as the drawn width.
Setch	The simulated etch value for a gauge. Empty for etch bias table entries.
MEtch_Space	The measured etch value for the gauge spacing. For etch bias table entries, this is the same as the drawn space.
SimBias	A calculated simulated etch bias value: $(\text{Meas} - \text{Setch})/2$ for gauges, $(\text{Drawn} - \text{Setch})/2$ for etch bias table entries.
MeasBias	A calculated measured etch bias value: $(\text{Meas} - \text{Metch})/2$ for gauges. Empty for etch bias table entries.
Sim-MeasBias	A calculated value: $(\text{SimBias}-\text{MeasBias})$ for gauges. Empty for etch bias table entries.
Data origin	The directory location and the name of the spreadsheet the data originated from.

## Related Topics

[Creating an Etch Bias Rule Table](#)

[Flow Stage Wizard, Etch Bias Table Generation](#)

# Running a Calibration Job

Calibration jobs are created and stored in the database, and then explicitly executed later. This allows you to set up multiple experiments before running any jobs. There are several methods you can use to run a calibration job after it is set up in Calibre nmModelflow.

<b>Setting up a Calibration Job</b> .....	<b>129</b>
<b>Running a Calibration Job From the Calibre nmModelflow GUI</b> .....	<b>134</b>
<b>Running a Calibration Job in Direct Mode</b> .....	<b>136</b>
<b>Running a Calibration Job In Standalone Mode</b> .....	<b>137</b>
<b>Job Status Types</b> .....	<b>139</b>
<b>Creating HTML Summary Reports</b> .....	<b>139</b>
<b>Creating a Verification Job</b> .....	<b>142</b>
<b>Creating a Generic Job</b> .....	<b>146</b>
<b>Saving the Models After Calibration</b> .....	<b>146</b>
<b>Rebuilding a Non-Optimal Model Result</b> .....	<b>147</b>
<b>Optimizing Results With Pattern-Specific Kernels</b> .....	<b>148</b>
<b>Editing Multiple Calibration Jobs</b> .....	<b>150</b>
<b>Finding CM1 Interaction Radius-Sensitive Terms</b> .....	<b>152</b>
<b>Performing CM1 Model Analysis</b> .....	<b>154</b>
<b>Simplifying CM1 Models From Results</b> .....	<b>157</b>

## Setting up a Calibration Job

Calibration jobs are the core of optimization for Calibre nmModelflow. You must set up a calibration job in order to generate output.

### Prerequisites

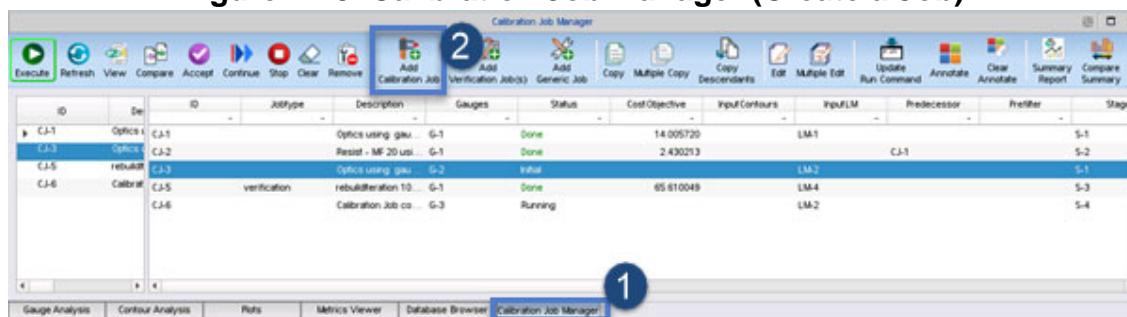
The database must contain each of the following items:

- A gauge object or contour object
- A litho model

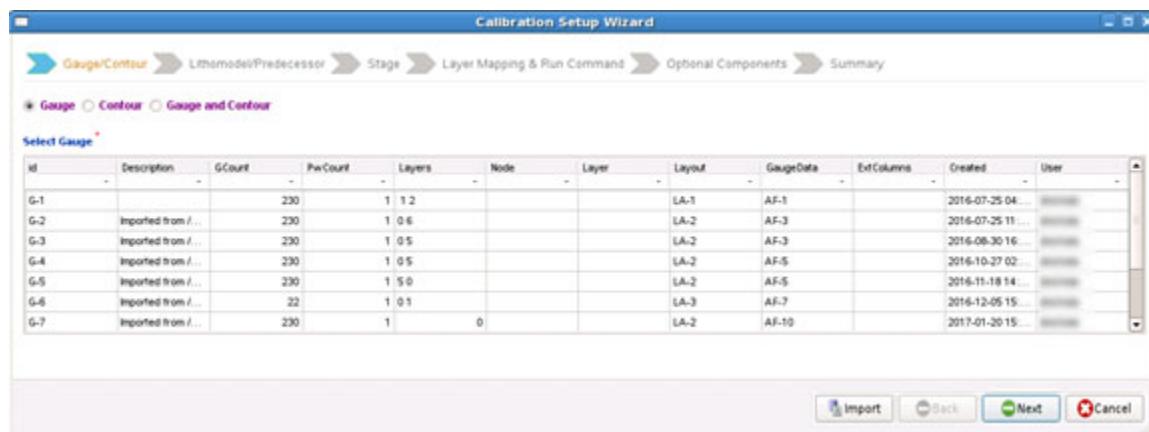
### Procedure

1. Raise the **Calibration Job Manager** tab in the main window.

**Figure 1-18. Calibration Job Manager (Create a Job)**



2. Click the **Add Calibration Job** button.
3. On the initial screen, you can choose Contour, Gauge, or Gauge and Contour (allowing you to use both gauge and contours during calibration). A corresponding list of gauges, contours, or both are populated from the database. Select a gauge and/or contour from the list(s), then click **Next** to continue.



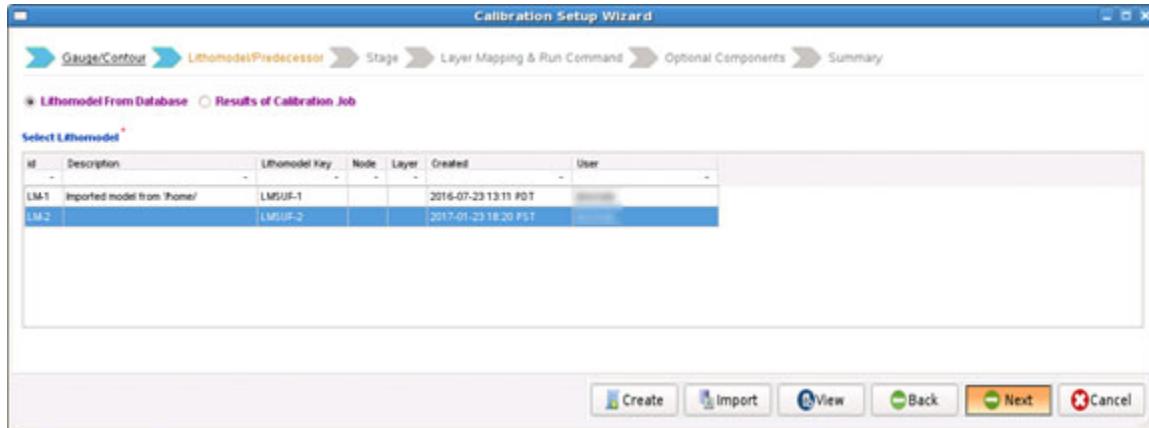
### Tip

**i** Components that are marked with a red asterisk are required. All other components are optional and you can safely click **Next** without adding any items from the list for that component.

If you have no gauges in the database, you can click the **Import** button to start the Gauges Wizard.

4. Select the “Lithomodel From Database” or “Results of Calibration Job” radio button. Based on this selection, a list of litho models or predecessors (the output of another calibration job) are populated from the database. A predecessor cannot be selected if no

other calibration jobs are defined. The contents of the litho model can be seen by clicking **View**. After selecting a litho model or predecessor, click **Next** to continue.

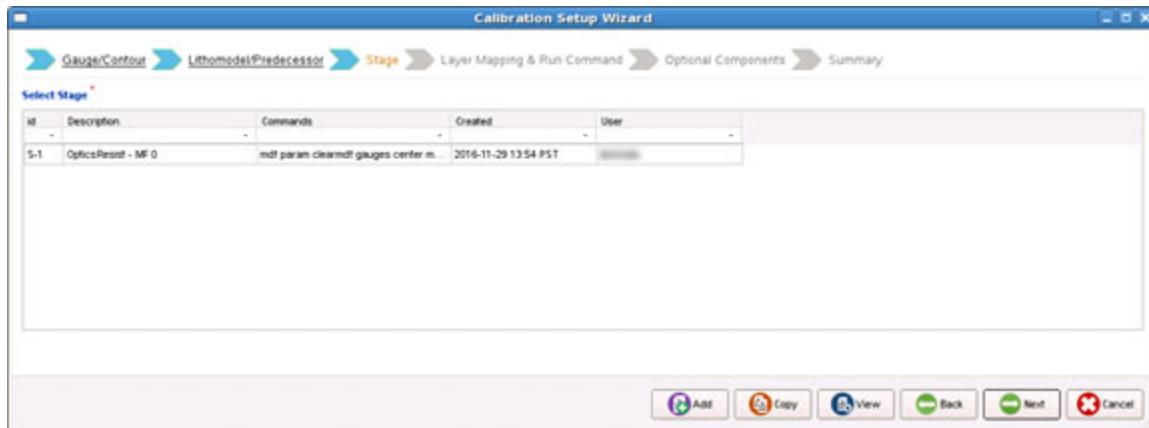


#### **Note**

If your litho model is not already in the Calibre nmModelflow database, you can create a new litho model or import a litho model using the **Create** and **Import** buttons.

If you are creating a job for a litho model that contains a topo model, do not map the FinFET layers in the design file if you are using a topo model with no FinFET signals.

5. Select a stage from the list of defined stages.



#### **Note**

For topo model contour verification purposes, choose a stage that has simulation only.

If you do not have any stages in the list, you can click **Add** to create one. Stages can be viewed or copied by clicking **View** or **Copy**, respectively.

6. In the Layer Mapping and Run Command page, complete these tasks:

- Using the dropdown list in the “Mask Layer Index & Spec” column, select the litho model layers that correspond to the respective layout layers.
- Select a runscript from the dropdown list or from a directory.

---

**Note**



The runscript dropdown list populates runscripts from the following locations, in order:

- CALIBRE\_NMMODELFLOW\_JOB\_RUNSCRIPTS\_DIR environment variable
  - \$CALIBRE\_HOME/pkgs/icmdf/pvt/runscripts
- 
- Run arguments can be edited by clicking **Edit** next to the corresponding textbox. The specified arguments are displayed in the textbox and can be modified in this location.
  - (Optional) Select a job type (jointcalmode1, verification, or jointcalmode0) for the calibration job. (The verification type is added automatically when you use the Verification Setup Wizard to create a job.)

You can Ctrl-click to add the standalone modifier to jointcalmode1, verification, or jointcalmode0 to create the job as a self-contained directory that can be copied to another machine and run from that machine.

- **jointcalmode1** — Performs outer loop (mask/optics/topo) search iterations using distribution to *hosts*, and resist calibration runs using *all* CPUs on each host.

---

**Note**



This job type is recommended for certain combinations of calibration such as mask plus resist, where the inner resist calibration is more efficient when running in MT on Remote Compute Servers (RCS) processes as child processes.

---

For jointcalmode1, each resist calibration runs on the MTflex remote using all the CPUs on that host as if it were a normal MT (not MTflex) execution on that host.

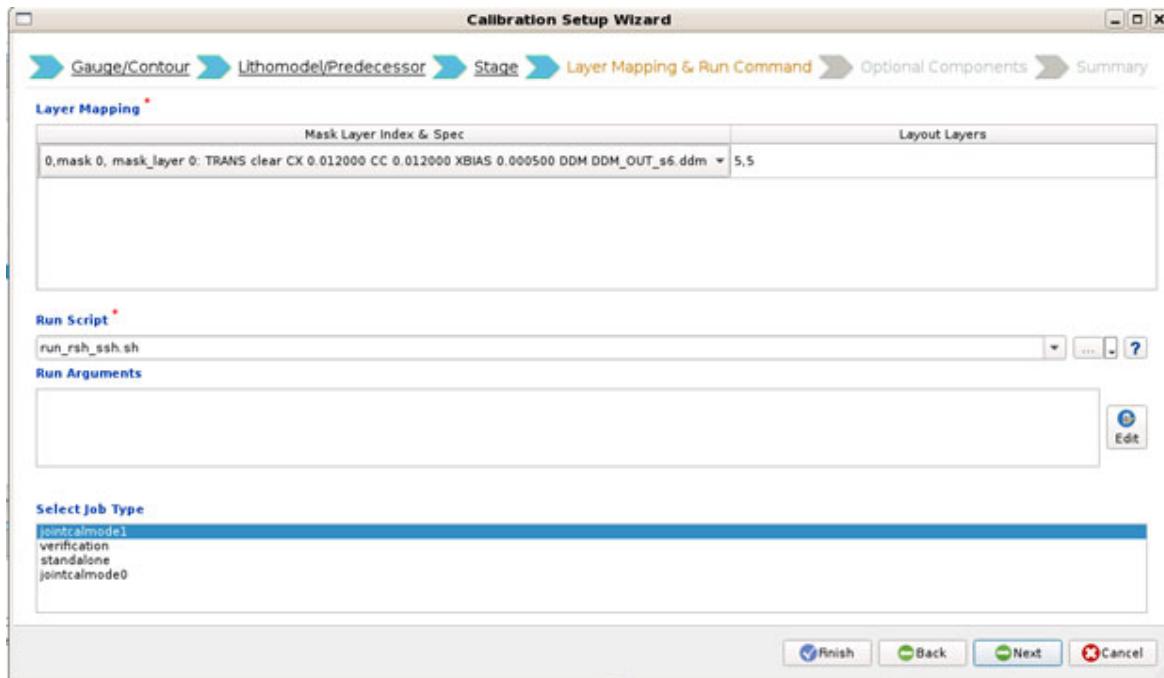
This is different than standard MTflex behavior, where remotes are guaranteed to use only a single CPU on any remote host. When the jobtype is set to jointcalmode1, some of the runscripts automatically set the number of remotes per host to 1, but it is best to inspect the runscript output before running the job. If the runscript does not recognize the jointcalmode1 job type, the job fails with an error.

When using jointcalmode1, ensure that each host is given only a single RCS process at a time, because multiple jobs running jointcalmode1 can overload a host (causing abnormal terminations from out of memory conditions) due to this behavior. You can best do this by using a user-created runscript that contains information relevant to your local hardware configuration.

**Note**

 Do not use jointcalmode1 jobs with CalCM on a grid or LSF clusters. This is because jointcalmode1 disregards the Calibre MT/MTFlex host accounting system (which assumes only a single CPU is consumed) and consumes all CPUs each time it runs an RCS.

- **jointcalmode0** — Performs outer loop search iterations using distribution to *remotes or CPUs*, and resist calibration runs *using a single CPU* on each remote.



To continue with optional components, click **Next**; otherwise, click **Finish**.

7. (Optional) Add one or more filters, metrics, or plot groups to the job.
  - Filters are added to reduce the number of gauges that need to be calibrated, limiting the gauges to test patterns of interest.
  - Metrics are added to assess the quality of the results by more than just the cost objective.
  - Plot groups are added to chart data for multiple types of data comparisons.

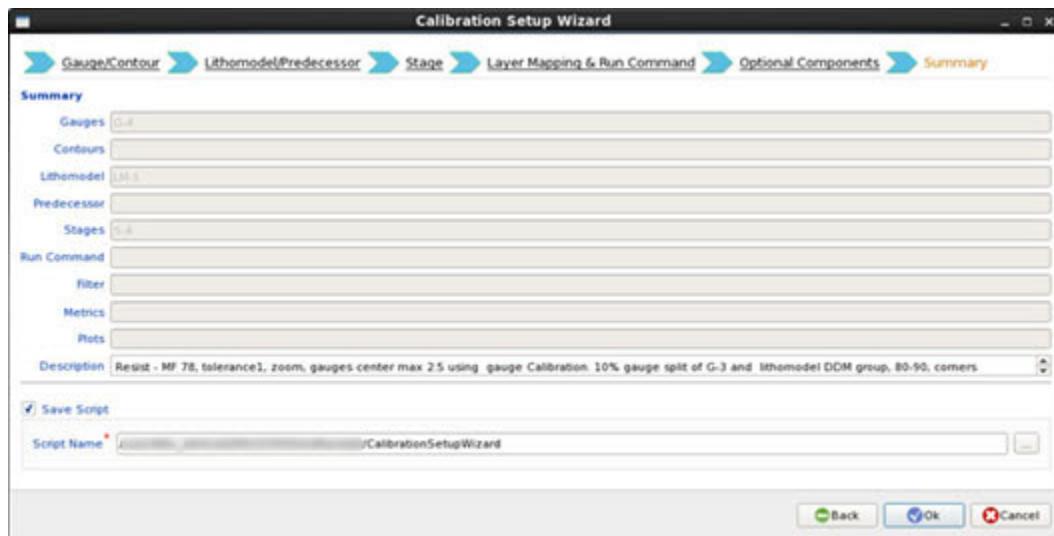
Descriptions can be added for these components. After adding the desired components, click **Next**.

**Note**

 Additional metrics can be evaluated from a completed calibration job by using the “mdf job evalmetrics” command.

---

8. On the Summary screen, you can review your calibration job and modify the description. You can save the script by selecting the Save Script checkbox. After reviewing the job, click **OK**.



## Results

The new job appears in the Calibration Job Manager list in the main window.

**Tip**

 If you need to change the parameters of a job, select the job in the Calibration Job Manager and click the **Edit** button. Only jobs in the Initial state can be edited. Clicking on a field puts the cursor there for editable text fields, or brings up a choice list for items in the database.

---

## Related Topics

[Creating a Stage With the Flow Stage Wizard](#)

[Running a Calibration Job From the Calibre nmModelflow GUI](#)

[Calibration Job Manager](#)

[Calibration Job Record Dialog Box](#)

# Running a Calibration Job From the Calibre nmModelflow GUI

This procedure describes how to run a job from the Calibre nmModelflow GUI.

### Note

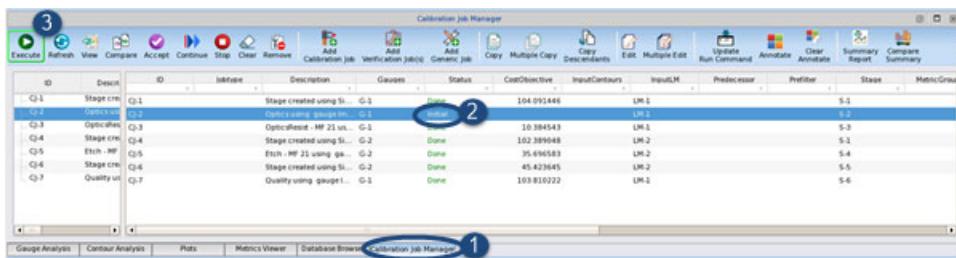
 If you are running a VEB-only calibration and do not have measured etch information, you can set the MEtch column in the gauge file to -1 to allow the calibration job to run.

## Prerequisites

- The Calibre nmModelflow GUI is running
- A calibration job in the database

## Procedure

1. Raise the **Calibration Job Manager** tab.
2. Select a job from the list. Ensure that the Status field is “Initial” or “Ready”. If the job is not in one of those two states, click **Clear** to reset the job.  
Note that any previous data for that job will be erased when you click **Clear**.
3. Click **Execute** to start the selected job(s).



## Results

The Status field for the job switches to one of the following states:

- **Running** — The job is currently active and being run.

### Note

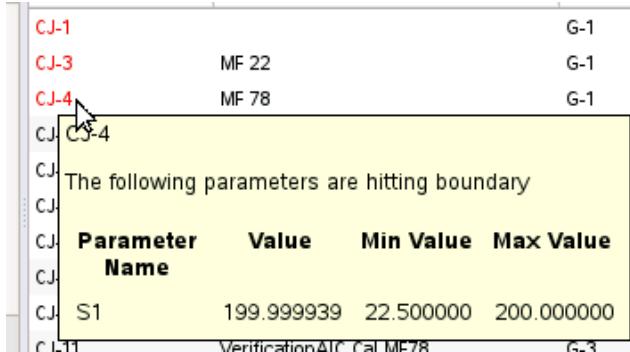
 During the run, you can click the **View** button to bring up the Calibration Job Manager, then click one of the Best IterStats sections and save models while the run is in progress.

- **Queued** — The job is waiting for the dispatcher to become available.
- **Waiting** — The job is dependent on the results of another calibration job, and will not be run until the parent job completes.

The calibration job run ends in one of the following states:

- **Done** — The cost objective for the calibration run is added to the calibration job entry. You can use the [Calibration Job Record Dialog Box](#) to view the results. Calibration jobs

with parameters that hit a bound during calibration have their ID highlighted in red. Hovering over the job number raises a tooltip to show the boundary condition.



- **Error** — An error occurred during processing. To find out what caused the error, click the **View** button in the **Calibration Job Manager**.
- **Stopped** — The job was canceled by a user.

---

#### Note

If the job completed at least one iteration, and was being performed for a Resist calibration job, you can click the **Continue** button to resume calibration as a new job.

---

- **Dead** — The Calibre WORKbench or Calibre nmModelflow process was killed.

## Related Topics

[Setting up a Calibration Job](#)

[Setting Up Dispatcher Mode](#)

[Job Execution Modes](#)

## Running a Calibration Job in Direct Mode

Direct mode runs Calibre nmModelflow without the GUI (batch mode). It is useful for debugging runscripts.

### Prerequisites

- A calibration job in the Calibre nmModelflow database
- Calibre WORKbench and Calibre nmModelflow invoked

### Procedure

1. In the Command pane, enter the following command:

**mdf job prepare CJ-x**

where *x* is the job number.

2. Close Calibre nmModelflow and Calibre WORKbench.
3. In a separate Linux command window, copy the entire job directory to a location accessible by the executing machine.

From the location of your mdf database, this is the subdirectory to copy:

*mdf/database/mdfrepository/calibrationjobtable/CJ-<x>/Data*

where <x> is the job number (such as CJ-2) containing your job of interest.

4. Navigate to the new directory and execute the *job.sh* file:

***./job.sh***

The leading “*./*” is required if the job directory is not in your \$PATH variable.

5. Periodically, check the *status* file. This is a plain text file that contains the job status. The job is complete when the contents of *status* is “Done.”

---

**Note**

 Other possible states are described in the section “[Job Status Types](#)” on page 139.

---

6. Copy the job directory back to the Calibre nmModelflow database directory.
7. Re-invoke Calibre WORKbench and Calibre nmModelflow, and raise the **Calibration Job Manager** tab.

The job status will match the result of the direct mode job.

## Related Topics

[Running a Calibration Job From the Calibre nmModelflow GUI](#)

[Running a Calibration Job In Standalone Mode](#)

[Job Status Types](#)

[Job Execution Modes](#)

## Running a Calibration Job In Standalone Mode

Standalone mode is useful where a job directory is not on the same filesystem where the job will be executed.

Standalone jobs do not rely on symbolic links that point to other files in the database, so the entire calibration job directory can be copied to another location easily.

## Prerequisites

- A Calibre nmModelflow calibration job in Initial or Ready state
- Calibre WORKbench and Calibre nmModelflow invoked

## Procedure

1. In Calibre nmModelflow, raise the **Database** tab.
2. In the database tree, select the Calibration Job list to display the existing jobs in the main pane.
3. Select the job of interest from the displayed list of jobs, then click **Edit**. Note that the job must be in an Initial or Ready state.
4. Scroll down the job definition to the Jobtype field, and add the keyword “standalone”. Click **Save**.
5. In the Command pane, enter the following command:  
**mdf job prepare CJ-x**  
where *x* is the job number.
6. Close Calibre nmModelflow and Calibre WORKbench.
7. In a separate Linux command window, copy the entire job directory to a location accessible by the executing machine.
8. Navigate to the new directory location and enter the command:

**/job.sh**

The leading “./” is required if the job directory is not in your \$PATH variable.

9. Periodically, check the *status* file. This is a plain text file that contains the job status. The job is complete when the contents of *status* is “Done.”

---

**Note**

 Other possible states are described in the section “[Job Status Types](#)” on page 139.

---

10. Copy the job directory back to the Calibre nmModelflow database directory.
11. Re-invoke Calibre WORKbench and Calibre nmModelflow, and raise the **Calibration Job Manager** tab.

The job status will match the result of the standalone job.

## Related Topics

[Running a Calibration Job From the Calibre nmModelflow GUI](#)

[Running a Calibration Job in Direct Mode](#)

[Job Status Types](#)

[Job Execution Modes](#)

## Job Status Types

The job status represents the state of a Calibre nmModelflow calibration job in the database. Because jobs are run independently of the GUI, a job's status is stored in a file in the Calibre nmModelflow database. The status is viewable either in the GUI or as a text file.

The following status types are used by Calibre nmModelflow:

**Table 1-18. Job Status List**

Status	Definition
Initial	Job directory is empty.
Ready	Job directory has been created by the “mdf job prepare” command or the GUI, but has not yet been executed.
Waiting	Job is waiting on a predecessor job to execute. Check the Predecessor field in the Calibration Job Manager to find the predecessor job.
Running	Job is currently executing.
Done	Job completed without errors.
Error	Job failed due to crashes or Tcl runtime errors.
Stopped	Job was stopped by the <b>Stop</b> button in the Calibration Job Manager, or Calibre nmModelflow found a <i>stop</i> file in the job directory.

### Related Topics

[Running a Calibration Job From the Calibre nmModelflow GUI](#)

[Running a Calibration Job in Direct Mode](#)

[Running a Calibration Job In Standalone Mode](#)

## Creating HTML Summary Reports

You can output HTML reports for completed calibration jobs. The Calibre nmModelflow GUI makes it easy to create reports with a punchlist of items to report; no coding is required.

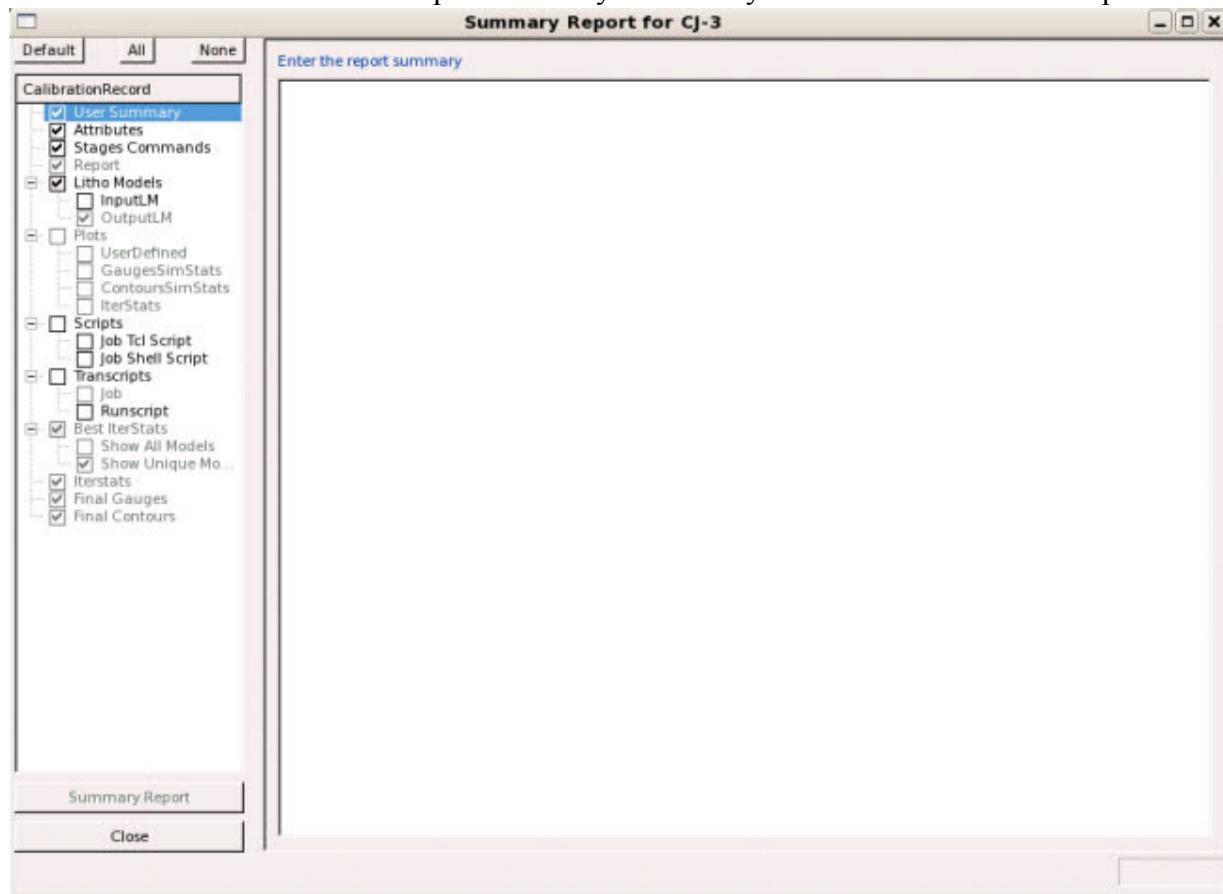
### Prerequisites

- One or more successfully completed Calibre nmModelflow calibration jobs in the currently open database.

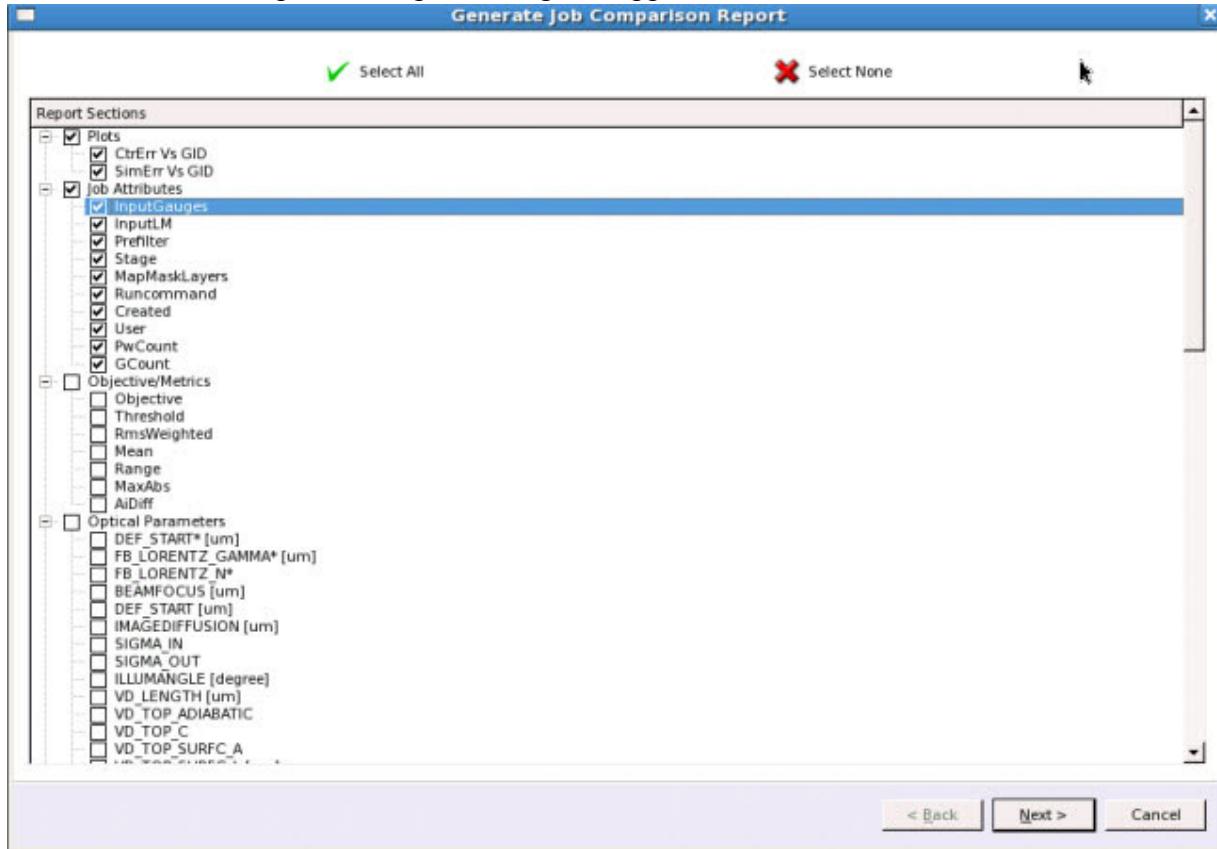
### Procedure

1. Raise the Calibration Job Manager. Select at least one calibration job from the list, then click either the **Summary Report** or **Compare Summary** button.
  - If you selected a single job, click **Summary Report**. The Summary Report dialog box appears.

Use the “Enter the report summary” field for your own notes about the report.



- If you selected multiple calibration jobs, click **Compare Summary**. The Generate Job Comparison Report dialog box appears.



2. Select calibration record types from the list.

Only items selected from the list are included in the summary report output.

3. When you have finished making selections, do one of the following actions:

- Click **Summary Report** if you selected a single calibration job.
  - Click **Next** if you selected multiple calibration jobs, then use the text field to write a description of the comparison report. Click the **Directory** button at the bottom of the dialog box.
4. Use the file browser that appears to navigate to an existing directory or create a new one, then click **Choose**.

#### **Note**

 Creating a summary report deletes the current contents of the selected directory. If the directory is not empty, Calibre nmModelflow asks you to confirm deletion.

## Results

- Calibre nmModelflow creates an HTML page containing the selected items, which can be viewed in any web browser. For multiple summary reports, each calibration job is given its own column in a comparison table.
- All summary reports contain your user notes as the front page; it is recommended that you add any important details about the comparison for later reference.
- Parameters at the upper and lower boundaries of their range in summary reports and comparison summary reports are highlighted.

nmModelflow Report			
Plots	Job Parameters		
	MASK_MODEL_LAYER1_CC [um]	0.006	0.006
	MASK_MODEL_LAYER2_CC [um]	0.006	0.006
	B0	0	0
	B1	0.0027	0.0959975
	B2	Parameter hitting lower bounds 0.1536	0.144088
	B3	0.1536	0.1536
	B4	0	0
	B5	0	0
	B6	0.3	0.3

## Creating a Verification Job

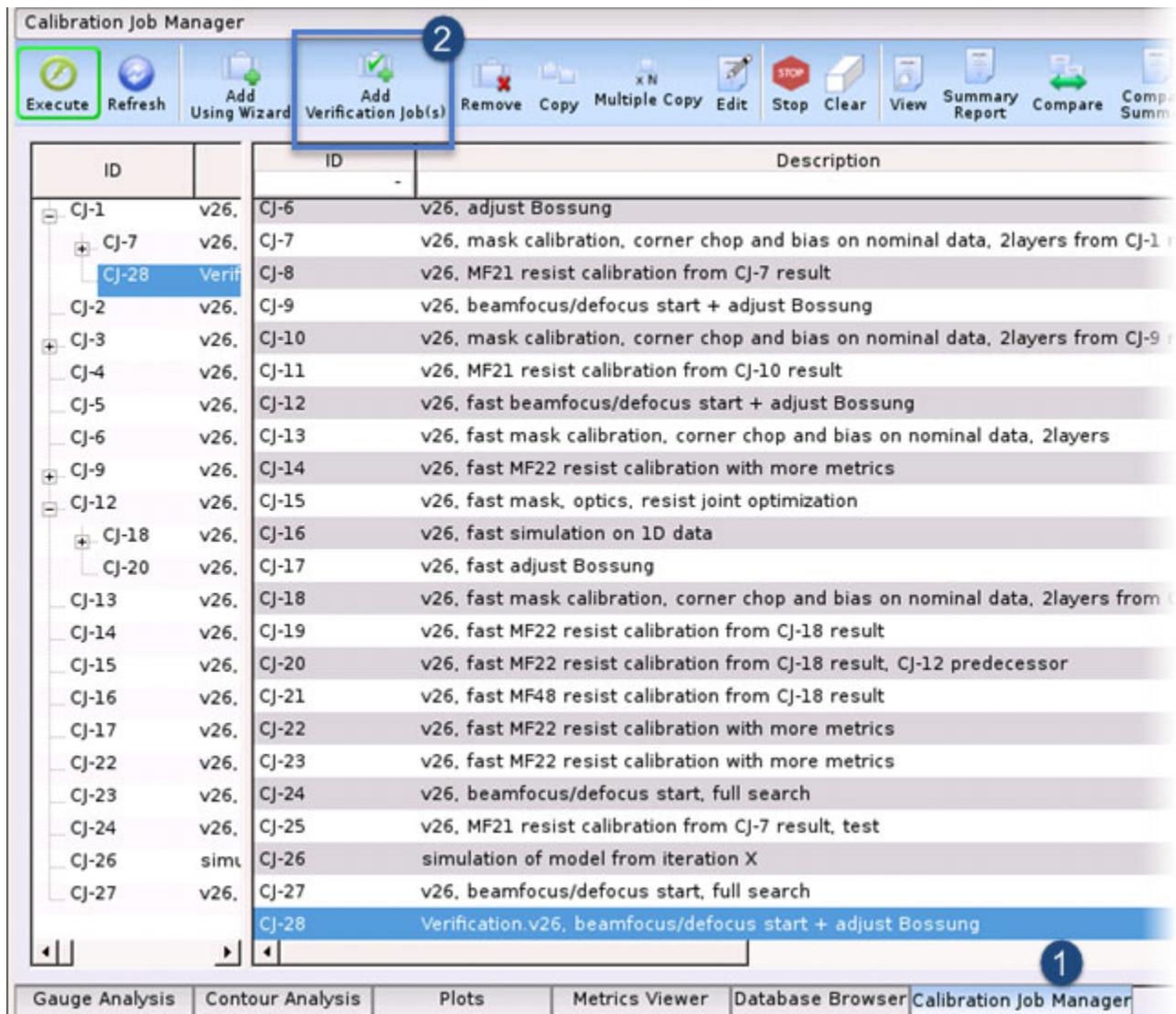
To verify a model you compare multiple calibrated models with a specific data set. You determine the metrics that matter.

### Prerequisites

- A *Lithomodel* file
- A gauge file
- One or more calibration jobs created and configured for your process

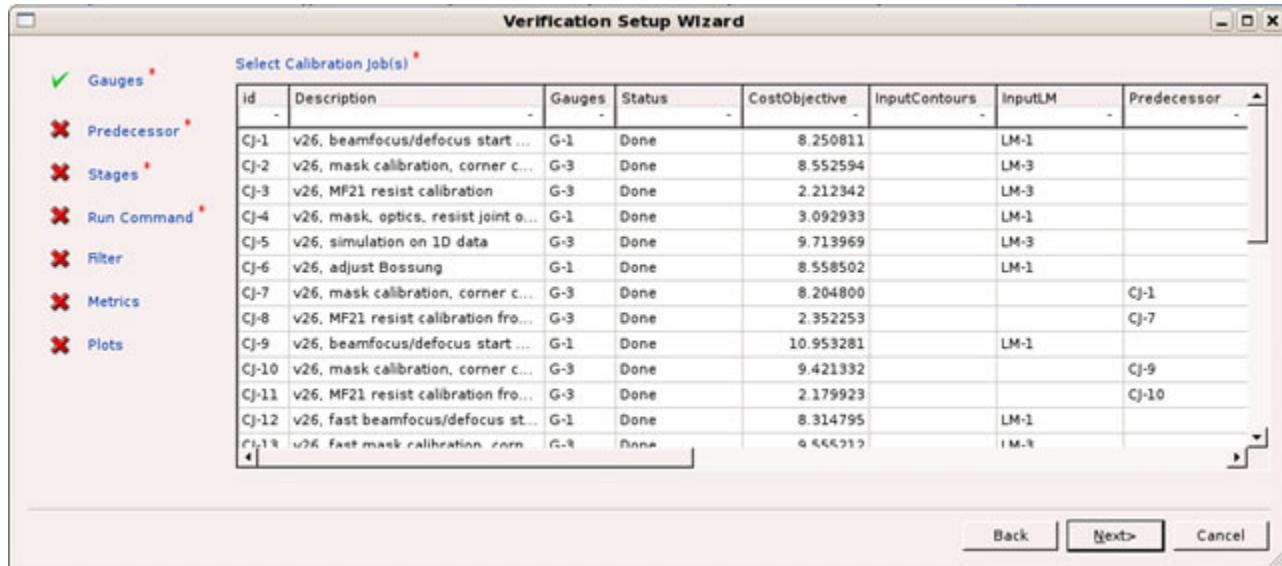
## Procedure

1. In the main window, raise the **Calibration Job Manager** tab.



2. Click **Add Verification Job(s)**. The Model Verification Wizard appears.
3. Select Gauges, Contours, or Gauges and Contours from the list.

4. In the Model Verification Wizard, select one or more calibration jobs from the list.



**Note**

To compare verification of the CTR versus the CM1 model, two calibration jobs and two verification jobs are needed, one for each model.

- The CTR calibration job requires its own independent verification stage.
- The CM1 calibration job also requires an independent verification stage, which is run on the calibrated CTR results.

5. For each calibration job you selected, specify design layers to assign to the mask layers in the litho model associated with the job.

**Note**

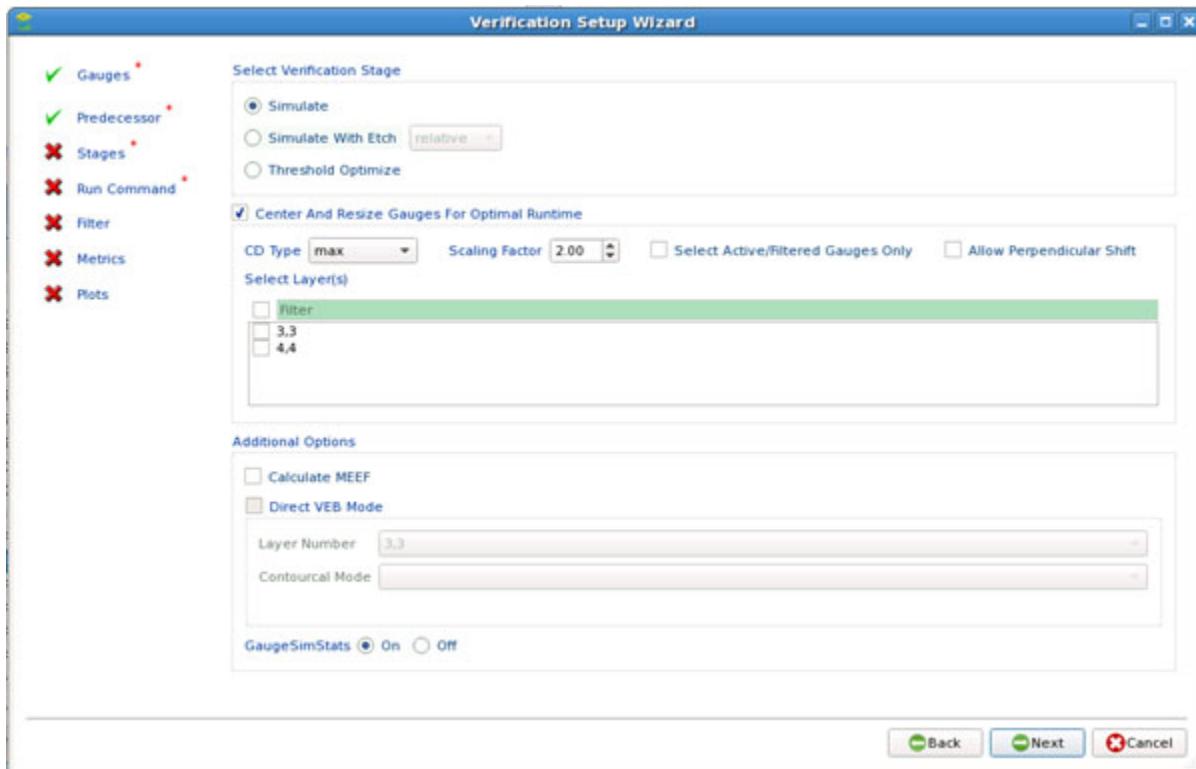
Selecting the Use Same Layer Mapping For All Jobs checkbox re-uses your layer selections for all jobs being created. This checkbox is available only if you specify calibration jobs with the same litho model. This checkbox is also accessible through the Multiple Copy wizard in the Calibration Job Manager menu after job selections have been made.

6. Choose between a simulation stage, a simulation with etch stage, and a threshold optimization stage for verification. It is recommended that you choose the “Center and Resize Gauges for Optimal Runtime” checkbox for faster verification.

If your litho model includes a VEB etch model, you can verify using Direct VEB Mode by selecting Simulate with Etch as the Verification Stage type. Direct VEB Mode allows you to use a layer with etch contours, a contour library information (.cli) file, or both to perform the verification.

**Tip**

If you are not interested in plotting the results of the verification job, select the GaugeSimStats Off radio button.



7. Set the run script command that matches your configuration.
8. (Optional) Select a filter group to use to reduce the number of gauges being verified in this job.
9. (Optional) Select a metric group to use in establishing verification criteria.
10. (Optional) Select plots to accompany the verification run.
11. Click **Finish**.

## Results

Verification jobs are created and shown in the **Calibration Job Manager** tab. The verification check runs on the litho models and returns the results of the metrics you have selected. Verification plots are added to the **Plots** tab.

## Related Topics

[Creating a Custom Metric](#)

## Creating a Generic Job

Use generic jobs to run a stage without having an associated gauge set and litho model as part of the job description. The primary purpose of a generic job is to save a set of commands that can be re-run as a job from the **Calibration Job** tab.

---

### Note

---

 Generic jobs cannot be used as a predecessor for a calibration or verification job, because they do not directly contain a litho model, even if the generic job uses a predecessor that has a litho model.

---

### Procedure

1. Switch to the Calibration Job Manager. Click the **Add Generic Job** button in the central button bar.
2. In the Add Generic Job wizard, select a stage from the list. You can also create a stage directly by clicking the **Add Stage** button and defining commands inside the mdf batch {} definition.
3. If you have a different runscript, load it using the Run Script field.
4. (Optional) Click the **Edit** button in the Run Commands section to adjust any run arguments.
5. (Optional) Use the Predecessor Job dropdown to select an existing calibration job. This job's results will be used as the input data for the stage when it is run instead of the active litho model, gauge data, and layout.
6. Enter a description for the new stage and then click **OK**.

### Results

The stage is added to the Calibration Job Manager and the database, and can be executed immediately.

## Saving the Models After Calibration

Once you have completed a successful calibration run, the calibrated models need to be exported in order to be used by other Calibre tools.

### Restrictions and Limitations

Output from Calibre nmModelflow is standardized in the collective litho model format. You cannot save individual model components separately.

## Prerequisites

A successful execution of the [Running a Calibration Job From the Calibre nmModelflow GUI](#) task (one that has the Status of “Done”). Jobs that end in the Error state do not have a model that can be output.

## Procedure

1. Raise the **Calibration Job Manager** tab in the main window.
2. Select a calibration job from the list.
3. Click the **Export Output Lithomodel** button.
4. Use the file navigator to set the location and name of the new litho model directory, then click **OK**.

## Results

A new *Lithomodel* file is written to the specified location. The exported litho model is also available from the Calibration Job window in the **Database Browser** tab.

 **Note** All source maps and pupil maps written out by Calibre nmModelflow are stored in the optical model directory that is included in the specified litho model directory.

---

## Related Topics

[Running a Calibration Job From the Calibre nmModelflow GUI](#)

# Rebuilding a Non-Optimal Model Result

The model returned from the successful calibration, known as the Final Model, is the only model that is saved to the disk. However, the other models that were tested during calibration can be rebuilt as a separate calibration job.

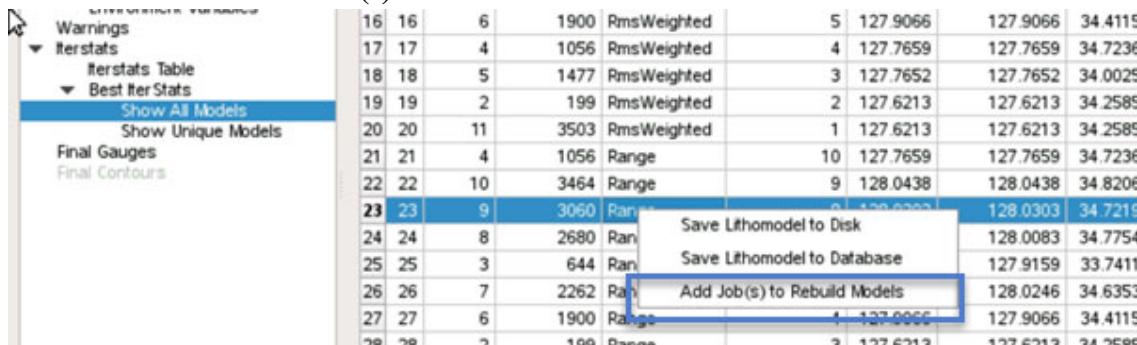
## Prerequisites

- Calibre nmModelflow running
- A completed calibration job in the database (in the Done state)

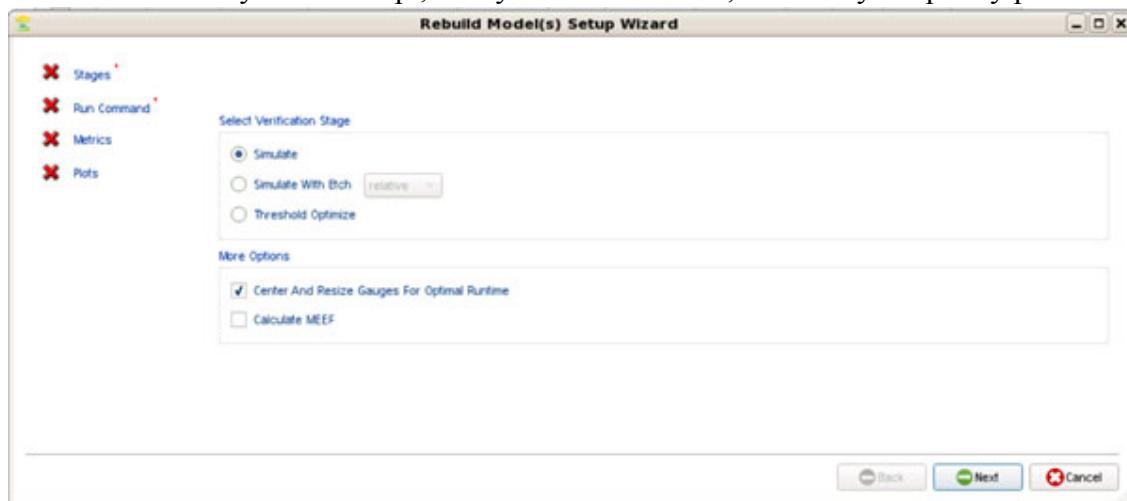
## Procedure

1. From the Calibration Job Manager tab, open the completed calibration job by selecting it and clicking **View**.
2. In the Calibration Job Record dialog box, scroll down to the **Iterstats** section. Open the **Iterstats Table**, or the **Best Iterstats > Show All Models** or **Show Unique Models** page.

3. Click on the line with the model you want to rebuild, and right click to raise the context menu. Select **Add Job(s) to Rebuild Models**.



4. The Rebuild Model(s) Setup Wizard appears. This wizard contains a subset of the functionality found in the Stages wizard. It only contains simulation-type options, a way to customize your runscript, a way to select metrics, and a way to specify plots.



Specify options as needed using the wizard, and click **Finish**.

The new rebuild job(s) appear in the Calibration Job viewer, and can be run immediately.

## Optimizing Results With Pattern-Specific Kernels

After completing a calibration run, you may have a number of features with large simulation errors. Creating Pattern Specific Kernels (PSK) allows you to fix the high simulation error gauges in a targeted fashion.

### Prerequisites

- A successful calibration run in the Calibre nmModelflow database

## Procedure

1. Activate the calibration run of interest from the **Calibration Job Manager** tab by selecting it and clicking **Accept**.
2. When the load completes, switch to the **Gauge Analysis** tab.
3. In the Command Window, enter the following command:

**mdf optimize psk mode**

where **mode** is the method (by GID, filter, positive/negative value, or absolute value) for selecting which gauges to recalibrate:

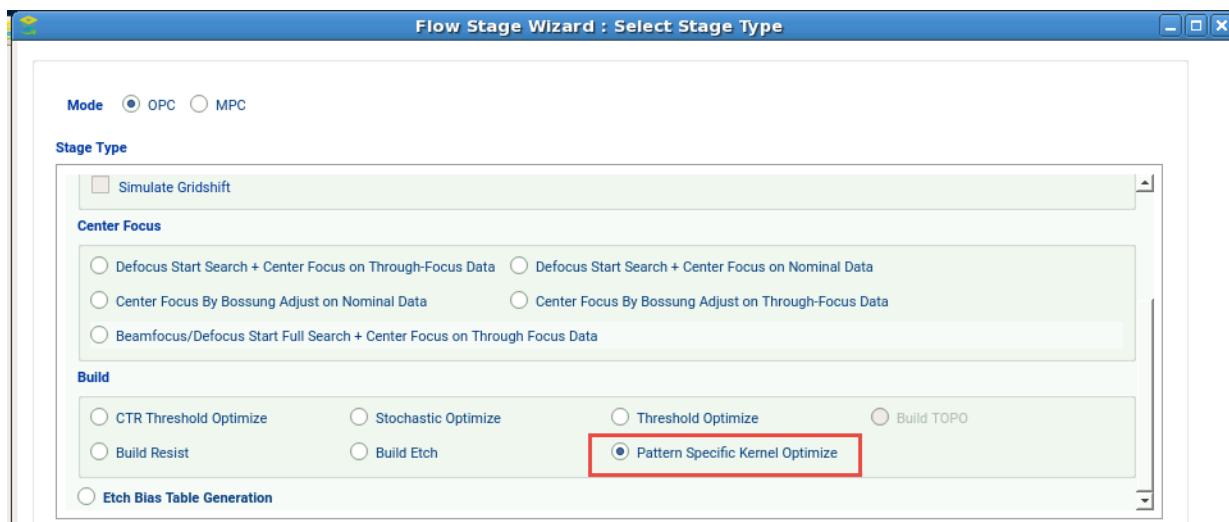
- **-gids “gid1 gid2 ...”** — Uses a user supplied list of gauge ids enclosed in quotes that are used to create the PSKs.
  - **-filter filter\_name** — Uses a previously-created mdf filter that selects gauges of interest.
  - **-pos n** — Chooses the specified number of gauges with the highest positive Sim CD error.
  - **-neg m** — Chooses the specified number of gauges with the highest negative Sim CD error.
- The -pos and -neg options can be used simultaneously or independently.
- **-top** — Selects the specified number of PSKs based on the largest absolute simulated CD errors.

---

### Note

 Starting with the 2020.3 release, you can also create a PSK command as a calibration Build Stage and save it in the database to use in a calibration job. However, note that in order to select gauges, you will need to have an active gauge object when you create the stage.

---



## Results

- New columns (PSK\_PATTERN, PSK\_BASE\_CD, PSK\_BASE\_ERR, PSK\_OPT\_CD, PSK\_OPT\_ERR) are added to the Gauge Analysis window.
- Check the Application Logs window for the results of the command. A report is generated showing which GIDs were selected, and the RMS, Mean, MaxAbs, and Range values for the PSKs, non-PSKs, and all the gauges.

## Editing Multiple Calibration Jobs

For situations where multiple calibration jobs need their components changed, use the Multiple Edit utility in Calibre nmModelflow to quickly adjust selected jobs.

---

### Note

 This wizard is also used for the **Copy Descendants** button; all descendants of the selected job(s) are added to the list of edited jobs.

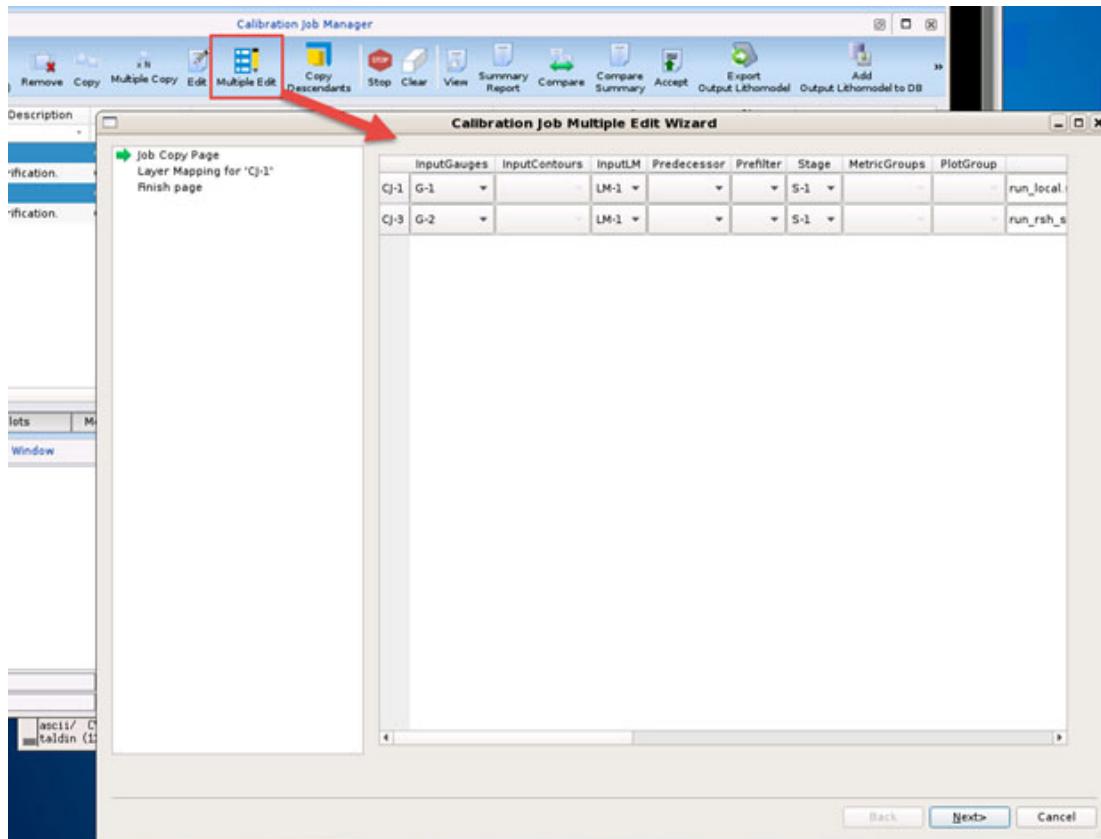
---

### Prerequisites

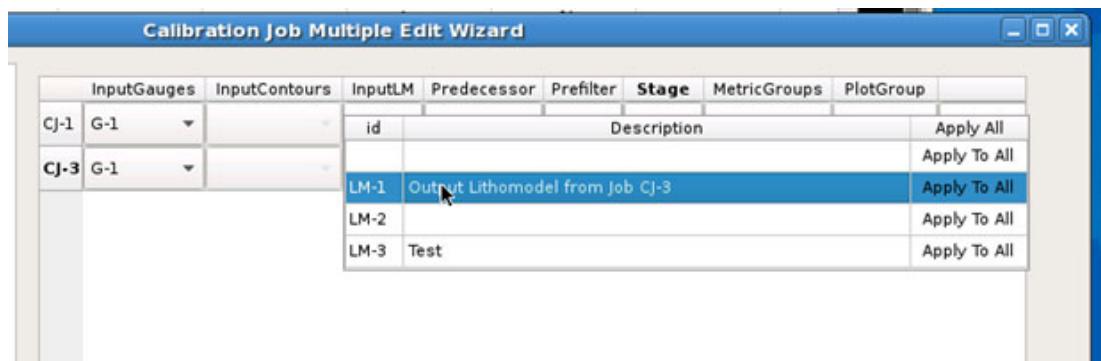
- Calibre nmModelflow invoked
- Multiple calibration jobs defined in the Calibre nmModelflow database

### Procedure

1. Switch to the **Calibration Job Manager** tab.
2. Select at least two calibration jobs and click **Multiple Edit**.



- In the Job Copy page, click any cell with a dropdown arrow to display the available choices in the database for that column.



Make a selection for the cell, or click **Apply to All** to the right of the choice to apply the change to every item in the list.

When you have finished making changes, click **Next**.

- Each job is listed as a separate Layer Mapping For CJ-x page. For each job selected, adjust the layer mapping as needed, then click **Next**.

5. On the Finish page, inspect the commands generated to make the changes, and click **Finish** to run the changes.

## Finding CM1 Interaction Radius-Sensitive Terms

For CM1 resist models, some modeling terms are more sensitive to the interaction radius (IR) than others. Calibre nmModelflow can analyze a set of calibration results and list terms that are highly sensitive.

### Prerequisites

- A successful calibration run with a non- CTR resist model

### Procedure

1. Switch to the **Database Browser** tab, select the Gauges group from the list, and activate the appropriate gauge object.
2. In the Command pane, run the following command to find problematic gauges (those that are sensitive to variations of the interaction radius):

```
mdf gauges findradiussensitive [-rmin rmin_value] [-rmax rmax_value]
[-numpoints num_points] [-cdout cd_file] [-errstat err_file]
```

where:

- *rmin\_value* — Sets the minimum radius in um to check. (Default = 0.5\*max(nominal interaction radius, 0.2 um))
- *rmax\_value* — Sets the maximum radius to check. (Default = 1.5\*max(nominal interaction radius, 0.2 um))
- *num\_points* — Specifies the number of points around the radius to check, as used in the following formula:  
Radius =  $rmin\_value + i * (rmax\_val - rmin\_value) / (num\_points - 1)$ , where  $i = 0, \dots, num\_points - 1$
- *cd\_file* — Specifies an output file for simulated CD data. The data is written in CSV format. (Default = *radiussensitiveerr\_stat.csv*)
- *err\_file* — Specifies an output file for error stat data. This data is also written in CSV format. (Default = *radiussensitivecd.csv*)

The result files contain the following information:

- The error stat data file contains a list of the interaction radii tested (Radius entry), the RMS, the range of CDs, and the absolute error at that position.
- The CD data file contains a list of GIDs per process window ID, with each interaction radii tested and the resulting CD value, along with a deltaCD column at the end. A high deltaCD value indicates a CD with potentially high sensitivity.

3. In the command pane, run the following command on potentially unstable gauges to detect CM1 terms responsible for the instability:

```
mdf cutline cm1termstat -gid gid -pwid num [-rmin rmin_val] [-rmax rmax_val]
[-numpoints num_points] [-scale on|off] [-out file]
```

where:

- ***gid*** — Is the gauge ID to get the statistics for.
- ***num*** — Is the process window ID to use for the gauge ID.
- ***rmin\_val*** — Is the minimum radius value to test in um.  
(Default =  $0.5 * \max(\text{nominal interaction radius}, 0.2 \text{ um})$ )
- ***rmax\_val*** — Is the maximum radius value to test in um.  
(Default =  $1.5 * \max(\text{nominal interaction radius}, 0.2 \text{ um})$ )
- ***num\_points*** — Is the number of points to test in the interaction radius. It also uses the formula:  
 $\text{Radius} = \text{rmin\_value} + i * (\text{rmin\_val} - \text{rmax\_val}) / (\text{num\_points} - 1)$ , where  $i = 0, \dots, \text{num\_points} - 1$
- **-scale on | off** — Toggles scaling, which multiplies term profiles by the associated linear coefficients. Scaling is off by default.
- ***file*** — Is the file to write results to. This is a CSV file. (Default = *cm1termstat\_gid<GID>-pwid<PWID>.csv*)

The resulting file from this command contains the mean and maximum standard deviation, the mean and maximum range, and the mean and max norm values. These are provided for the following data items:

- **I** — Aerial image intensity in try mode
- **F** — Full CM1 profile in try mode
- **Fbuild** — Full CM1 profile in build mode (this is a sum of individual terms multiplied by associated linear coefficients plus a constant)
- **terms** — A set of one or more terms based on the CM1 model

4. You can further visualize terms individually with the following command:

```
mdf cutline cm1term -gid gid -pwid pw_id [-name termname [-index {all |termindexlist}]] [-ir ir_value] [-scale on|off] [-out file]
```

where:

***gid*** — Is the gauge ID to report on.

***pw\_id*** — Is the process window ID to use for the gauge.

*termname* — Is the specific modeling term to report on. (Default: return all terms)

*termindexlist* — Is a space-separated list of indexes enclosed in quotes for the specified term to report on. (Default is “all”, which returns all indexes for the modeling term in the -name argument)

*ir\_value* — Is the interaction radius in nm. (Default: Use the interaction radius from the model.)

-scale on | off — Toggles scaling, which multiplies term profiles by the associated linear coefficients. Scaling is off by default.

*file* — Specifies the output file for the command as a CSV file. (Default is *cm1term\_cutline\_gid<GID>\_pwid<PWID>\_ir<IR>.csv*)

The output file for the command contains line entries indexed by increasing values of the distance in nm (L column) for:

- **I** — The aerial image intensity in try mode
- **F** — Full CM1 profile in try mode
- **Fbuild** — Full CM1 profile in build mode (this is a sum of individual terms multiplied by associated linear coefficients plus a constant)
- *terms* — A set of one or more terms based on the CM1 model, depending on the terms requested in the -name parameter.

You would use the output of this command to compare different interaction radii for consistency.

## Performing CM1 Model Analysis

Calibre nmModelflow stages that include a CM1 resist model can have additional analysis information added to the job results. This information can be used to simplify the model (by reducing the number of terms in the model) such that it simulates faster with a very similar result.

### Prerequisites

- A litho model in the Calibre nmModelflow database
- A test design and accompanying gauge data set

---

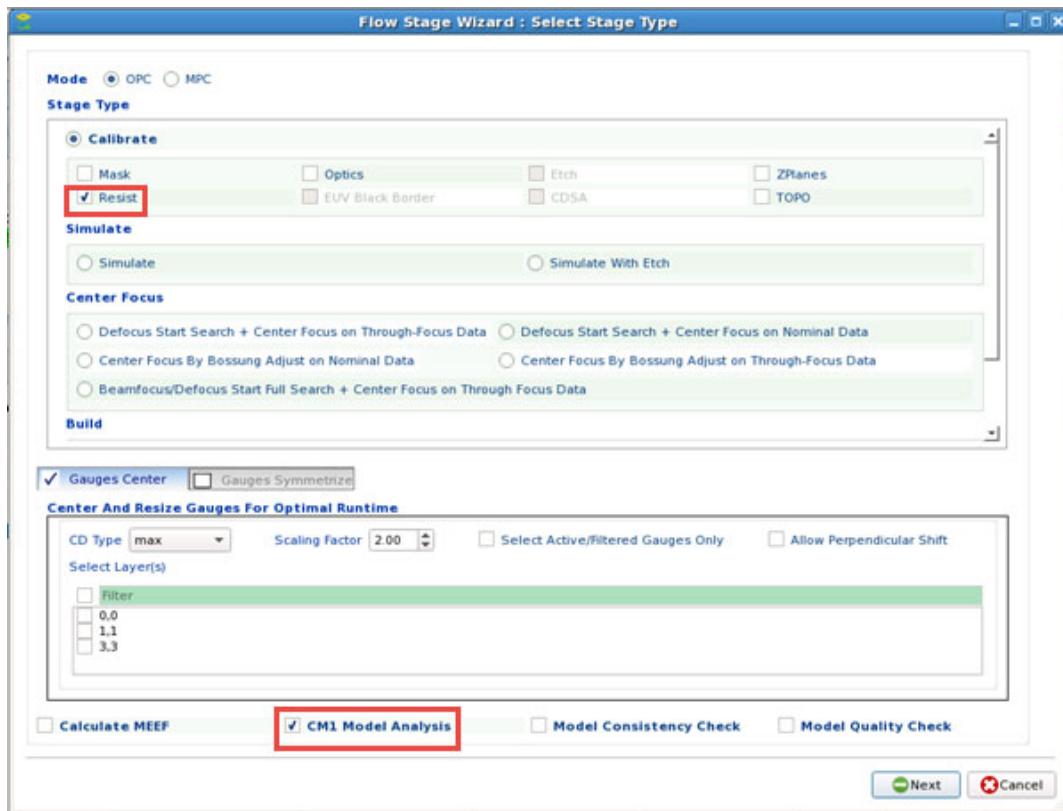
#### Note

 There are multiple methods for adding CM1 resist model analysis to the results. This method describes the stage through calibration job steps.

---

## Procedure

1. In the Database Browser, select the Stage tree and click **Add Calibration Stage**.
2. In the Select Stage Type page, select OPC, then select one of the options that enable the CM1 Model Analysis checkbox (**OPC > Calibrate > Resist**, **OPC > Simulate**, or **OPC > Build > Build Resist**).

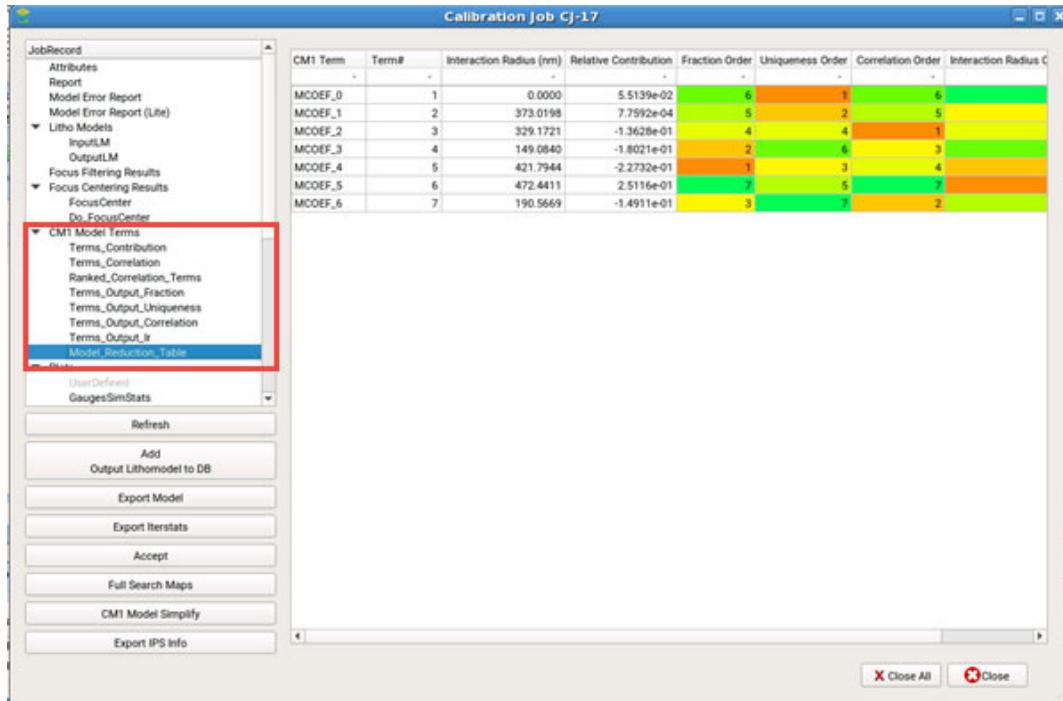


Ensure that CM1 Model Analysis is selected, then click **Next** to continue.

3. Complete defining the stage as normal. The CM1 Model Analysis checkbox only adds the mdf cutline cm1\_model\_terms command at the end of the stage creation command script.
4. Switch to the **Calibration Job Manager** tab, and define a new calibration job with the stage you defined. Run the calibration job as normal.
5. When the run completes successfully, click **View** to open the Calibration Job Report.

**Note**

 The CM1 Model Terms section only appears when you select CM1 Model Analysis or if you click the CM1 Model Simplify button. It is hidden otherwise.



6. Use the list to inspect the different sorting of the data from analyzing the CM1 model.
  - **Terms\_Contribution** — Contains the contribution of CM1 terms to gauges.
  - **Terms\_Correlation** — Contains the correlation for CM1 terms.
  - **Ranked\_Correlation\_Terms** — Contains a list of pairings of CM1 terms listed from highest to lowest frequency of correlation.
  - **Terms\_Output\_Fraction** — Contains the CM1 terms sorted by fractional contribution to the results.
  - **Terms\_Output\_Uniqueness** — Contains the CM1 terms sorted by uniqueness of the terms and their contribution to the results.
  - **Terms\_Output\_Correlation** — Contains the sorted output terms by correlation. Terms with the smallest contribution are ranked higher.
  - **Terms\_Output\_Ir** — Contains the sorted output terms by interaction radius.
  - **Model\_Reduction\_Table** — Contains a summary table of all the items above showing rankings.

A plot (CM1TermContribution) is also added to the Plots list. This plot shows contribution of the various terms in the CM1 model relative to the other terms. The labels used for the plot is as follows:

- **M** — M terms
- **SA, SP, SAP, SD** — Shrink terms
- **HB** — Horizontal bias
- **SWB** — Sidewall bias
- **D** — Dissolution
- **DV** — Density visibility
- **C** — Curvature

7. (Optional) Continue to the task, “[Simplifying CM1 Models From Results](#)” on page 157.

## Simplifying CM1 Models From Results

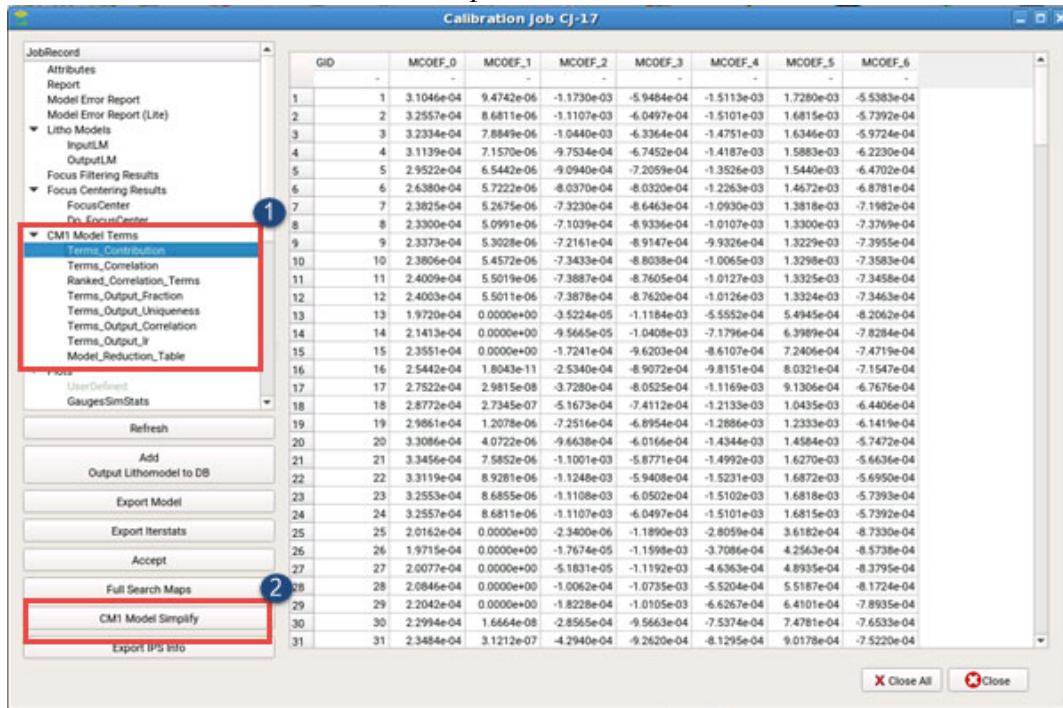
After performing CM1 model analysis, you may be able to remove less critical terms from the model. Calibre nmModelflow provides a tool that sets up calibration jobs to test the removal of one or more terms.

### Prerequisites

- Successfully completed the task, “[Performing CM1 Model Analysis](#)” on page 154.

## Procedure

- From the Calibration Job Report, open and use the CM1 Model Terms section and examine the lists to see model term contributions. The lists are ordered to show the terms to be removed first at the top of each list.



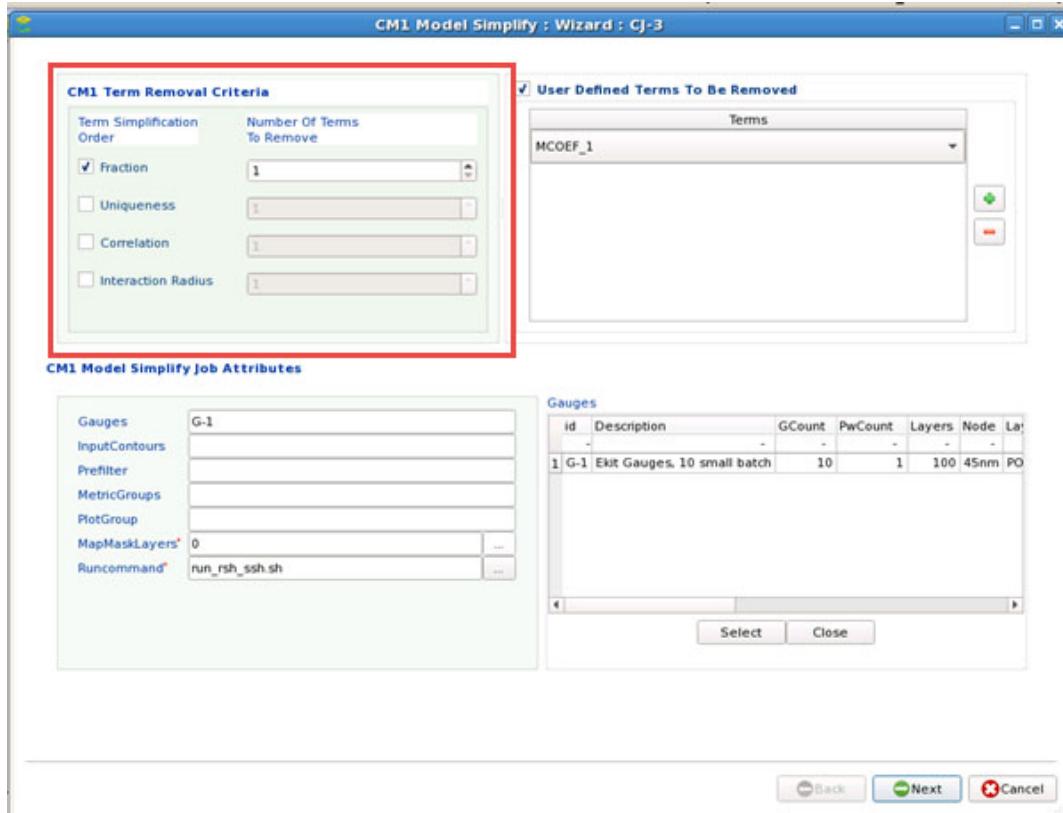
- Terms\_Output\_Fraction** — Terms are arranged by their relative contributions to the CM1 profile at model threshold in ascending order.
- Terms\_Output\_Uniqueness** — Terms are arranged such that the least uncorrelated terms are at the top of the list. The model is built from the most unique terms first.
- Terms\_Output\_Correlation** — Terms are arranged such that the pairs of most correlated terms are at the top of the list. Terms with higher correlation values with the remaining terms are arranged above terms with lower correlation values. Among the terms with the same correlation values, terms with lower contribution come ahead of terms with higher contribution value.
- Terms\_Output\_Ir** — Terms are arranged by their interaction radii in descending order. The output list contains three columns: term names, interaction radii, and relative contributions. If multiple terms have the same interaction radius, terms with smaller relative contribution to the CM1 profile are considered less significant and will be removed before ones with larger relative contributions.

### Note

You can use the Model\_Reduction\_Table entry to look at a combined summary table of all the items above showing rankings sorted by type.

2. Click **CM1 Model Simplify**. In the wizard that appears:

- Select one or more term types based on the list in Step 1 (or User Defined to select terms manually), and the number of terms to create removal jobs using that list.



- Function is recommended when you have relatively complex models and have a calibrated model.
- Fraction is used to remove a relatively small number of terms (up to 5).
- Uniqueness is used to remove a large number of terms (5 or more) while maintaining a good fit.
- Interaction radius is used to reduce runtime.

**Note**

 The item you choose uses the sorted list of that type for the order of which terms to remove, from the top of the list down. For example, choosing Uniqueness and removing three terms creates jobs that remove the first, second, and third terms from the Terms\_Output\_Uniqueness list.

If you chose Interaction Radius and removed three terms, you create jobs that may remove three different terms, because Calibre nmModelflow pulls the first three terms from the Terms\_Output\_Ir list instead.

**Note**

 SHRINK or SEM\_SHRINK terms in the CM1 model are composed of several sub-terms. Only the full SHRINK or SEM\_SHRINK term can be removed from a model and hence their sub-terms are shown with the same rank in the Model\_Reduction\_Table.

(In other words, if you remove three terms and one of them is a SHRINK term, you generate three jobs, but more than three terms are removed.) When selecting User Defined terms, selecting a SHRINK or SEM\_SHRINK term also removes all related terms automatically.

---

- b. (Optional) Modify some of the job run conditions (change the gauge set and/or contour set, add filters, metrics, or plots, and use a different run script).

Click **Next** to continue.

3. Fill out the Optimizer Settings page as usual for a resist calibration search, then click **Next**.
4. Inspect the resulting commands list, then click **Finish**.

## Results

Calibre nmModelflow creates one or more new calibration job entries for the tests with a format similar to the following:

**with Removed term1 [term2 term3 ...] from lithomodel\_name**

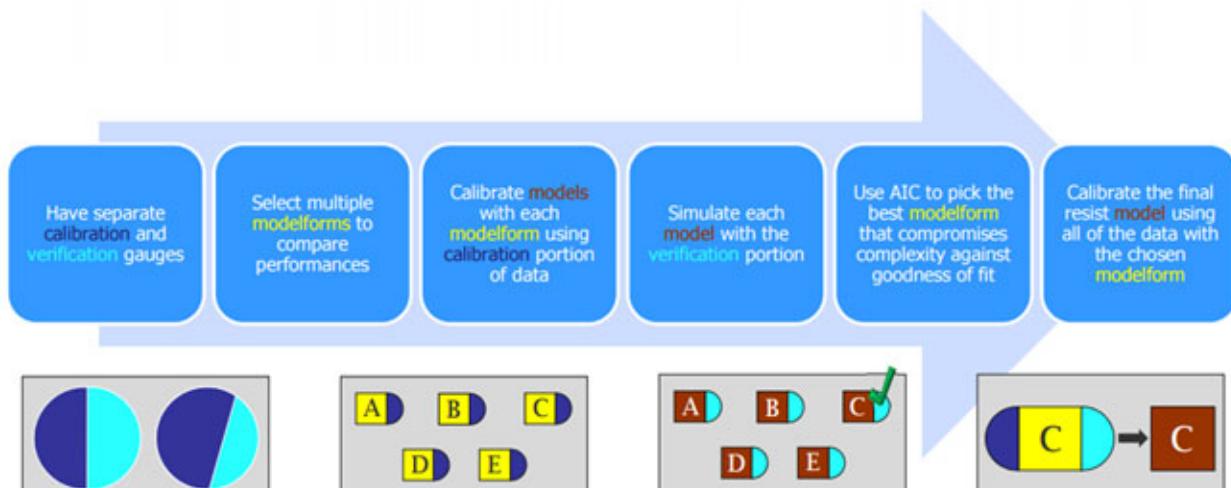
- Terms are removed in an increasing sequence, starting from the top. For example, if there are six modeling terms and three are requested to be removed, Calibre nmModelflow generates three jobs, one removing the first term, a second removing the first and second terms, and a third removing the first, second, and third terms.
- The calibration jobs created by this task are in Initial state; they have not been run and need to be run by the user (but do not have to be run separately). The reduced model always needs to be fully re-calibrated using the same method for calibrating the input model.
- You can run a CM1 Model Simplify check on a previously completed calibration job that did not have CM1 model analysis run on it by opening the Calibration Job Manager and clicking **CM1 Model Simplify**. This runs the CM1 Model Analysis command and resets the Calibration Job Manager for that job run to show CM1 Model Terms statistics. Restart this task at Step 1.

# Support for Akaike Information Criteria Computation

Use the Akaike Information Criterion (AIC) as a way to measure the quality of model results relative to other model results.

Calibre nmModelflow supports using the AIC starting with the 2015.4 release. To use the AIC features, the gauge data must be split into a calibration set and verification set. Multiple calibration runs must be performed.

**Figure 1-19. AIC Computation Flow**



50/50 is the recommended split – if there is stressed concern for over-fitting, a larger proportion can be used for verification

The process of validating modelform performance on data outside of the calibration, by itself, is a step towards mitigating over-fitting risk

Once choosing a modelform is complete, calibrate a new model with *all* of the available gauges

In Calibre nmModelflow, the following definitions are used for the AIC equations:

**Figure 1-20. AIC Equations**

<span style="font-size: 1.5em;">■</span> $RSS = \frac{\sum_{g=1}^G weight_g (sim_g - meas_g)^2}{\sum_{g=1}^G weight_g}$	$G$ is the number of gauges
<span style="font-size: 1.5em;">■</span> $\log(L) = -\frac{G}{2} \ln RSS - \frac{G}{2} \ln \pi - \frac{G}{2}$	$K$ is the number of parameters in the modelform – $K$ should ideally be derived, as users can make their own modelforms
<span style="font-size: 1.5em;">■</span> $AIC_c = -2 \log(L) + 2K + \frac{2K(K+1)}{G-K-1}$	
<span style="font-size: 1.5em;">■</span> $\Delta_i = AIC_c - \Delta_{min}$	<small>This is the <math>\epsilon</math> of <math>AIC_c</math>, it is a corrective term that goes to 0 for large <math>G</math></small>
<span style="font-size: 1.5em;">■</span> $Likelihood = e^{-0.5\Delta_i}$	
<span style="font-size: 1.5em;">■</span> $Weight = \frac{Likelihood_i}{\sum Likelihoods}$	It includes the nonlinear parameters as well as the linear parameters.

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## Splitting Gauge Information for AIC

Performing AIC calibration requires splitting a selected gauge set into two randomized sets, one for calibration and one for verification.

### Prerequisites

- A set of gauges intended for use with calibration
- Calibre WORKbench invoked and Calibre nmModelflow active

### Procedure

1. If your gauge file is not already in the database, open the gauge file that will be split (see "[Set-Up and Loading Gauge Files](#)").

2. Split gauges using one of the following methods:
    - To split the active gauges, use the **Split Gauges** button in the toolbar from the **Gauges** tab.
- 
- To split a set of gauges in the database, raise the **Database Browser** tab, switch to the Gauges group, select the gauge object from the list, then click the **Split Gauges** button.
3. In the dialog box that appears, select a mode.
    - **Random Split** — Chooses the gauges to be split semi-randomly, with control over specific gauges that must be placed in the first file.
    - **Litho Model Split** — Uses the active litho model for process information, including field tone and attenuation settings. Litho Model Split mode has three Parameterization modes:
      - **Optical Similarity Split** — Chooses the gauges based on their similarity. This option creates a special calibration job with the options you select, and runs the Calibre WORKbench `gauge_reduce` command on the gauges. It can optionally create a matrix file, which can be reused as an input for later optical similarity splits.
- 
- Note**
- Optical Similarity Split mode only works on gauge files or single process super gauge data files.
- 
- **Matrix Attribute Split** — Uses an attribute matrix algorithm instead of optical similarity for the `gauge_reduce` command.
  - **Feature Split** — Use this option to split contour sites instead of gauges. This mode requires you to specify which of the design layers contains the site markers.
4. Set the Fraction field to a fractional amount of the gauges that will be written to the first file (calibration). The remainder of the gauges are written to the second file (verification).
 

The recommended split is 50/50 (0.5) for an equal amount of calibration and verification gauges.
  5. Fill in additional fields as appropriate (such as the Calibration Gauge and Verification Gauge fields as the output filenames), then click **OK**.

## Results

When the gauges are split from the Database Browser, Calibre nmModelflow splits the gauge set to create two new gauge sets, which are saved in the database. The description written to the database is based on the fractional gauge split and the gauge set that was split (for example, “Calibration 50% gauge split of G-10” and “Verification: 50% gauge split of G-10”). Gauges that were originally disabled in the gauge set before the split remain disabled in the new gauge sets.

Use the gauge subsets for calibration with different modelforms, taking the best models for use with the task, “[Comparing Akaike Information Criterion From Calibration Jobs](#)” on page 165.

As an alternative to using the GUI for this task, a command line interface (CLI) version of the gauge splitting command is available. Enter the mdf gauges split command in the Command pane using the following syntax:

```
mdf gauges split -fraction1 value -out1 file1 -out2 file2 [-force
objective] [-explore value] [-seed value]
[-gids {gid+}]
```

where

- **-fraction1 value** specifies the percentage of the gauges to be written to the first file; the remainder of the gauges are written to the second file.
- **file1** and **file2** are the output gauge files, respectively.
- Specifying **-force objective** splits gauges so that the difference in objective between the two subsets is minimal. The objective is specified using a separate “mdf objective” command and computed using aerial simulated CDs that are generated with the “mdf optimize subsearch threshold [auto | optimize | fixed]” setting. Using the default is recommended.
- **-explore number** sets the number of random splittings explored to find the best one that meets the **-force** constraint. (Default is 1000 random splittings. Using the default is recommended.)
- **-seed** sets the seed for the random number generator. If not specified, the number of enabled gauges is used as the seed for the random number generator. Using the default is recommended.
- The option **-gids {gid+}** allows the user to specify gauges (via a list of one or more GIDs) that must be in the **-out1** file. The remaining gauges are split randomly to preserve the requested split ratio. If the list is so long that the requested ratio cannot be preserved, the data get split systematically.

# Comparing Akaike Information Criterion From Calibration Jobs

Use the Calibre nmModelflow **Calibration Job Manager** tab to generate comparative reports from an Akaike Information Criterion (AIC) run. AIC is most useful for resist and topographical modeling calibration.

## Prerequisites

- Calibre WORKbench invoked, and Calibre nmModelflow active
- A completed set of both calibration and verification job results generated from calibration gauge data that was split from sets of identical gauges

---

### Note

 A verification job used for AIC must have more gauges than the number of model parameters in order to be used for meaningful comparison purposes. Calibre nmModelflow issues a warning when you compare any jobs that have more parameters than gauges.

---

## Procedure

1. In the **Calibration Job Manager**, shift-click to select two or more completed calibration jobs from verification. Click **Compare**.
2. The Calibration Jobs Compare dialog box appears. Click the **Akaike Information Criterion** tab to raise the AIC calibration parameters page. Note that the tab is only visible if all compared jobs use the same input set.

Calibration Jobs Compare (CJ-21,CJ-22,CJ-23,CJ-24,CJ-25,CJ-26,CJ-27,CJ-28,CJ-29,CJ-30,CJ-31,CJ-32,CJ-33,CJ-34,CJ-35)								
Plots		Parameters		Parameters Plots		Akaike Information Criterion		
<input type="radio"/> Resist Model Analysis		<input checked="" type="radio"/> Topo Model Analysis		<input type="radio"/> User Defined Parameters				
Job Id	Description	Gauge Count	K (No. Of Params)	AICc	AIC Delta	Likelihood	Weight	Rms Weighted
1 CJ-21	Verification. MF11	1689	11	-6951.96	906.59	1.37001e-197	1.37001e-197	3.18367
2 CJ-22	Verification. MF21	1689	18	-7301.25	557.298	9.64808e-122	9.64808e-122	2.56714
3 CJ-23	Verification. MF22	1689	20	-7352.45	506.092	1.26947e-110	1.26947e-110	2.48445
4 CJ-24	Verification. MF38	1689	34	-7815.46	43.0868	4.40387e-10	4.40387e-10	1.85668
5 CJ-25	Verification. MF40	1689	34	-7496.87	361.679	2.9011e-79	2.9011e-79	2.24211
6 CJ-26	Verification. MF41	1689	25	-7537.9	320.644	2.36145e-70	2.36145e-70	2.2126
7 CJ-27	Verification. MF42	1689	34	-7382.8	475.744	4.93734e-104	4.93734e-104	2.39876
8 CJ-28	Verification. MF43	1689	25	-7502.41	356.138	4.63079e-78	4.63079e-78	2.25959
9 CJ-29	Verification. MF44	1689	30	-7542.01	316.533	1.84426e-69	1.84426e-69	2.19375
10 CJ-30	Verification. MF45	1689	34	-7476.12	382.425	9.06938e-84	9.06938e-84	2.26982
11 CJ-31	Verification. MF46	1689	34	-7610.01	248.531	1.07689e-54	1.07689e-54	2.09683
12 CJ-32	Verification. MF47	1689	34	-7625.41	233.133	2.37656e-51	2.37656e-51	2.0778
13 CJ-33	Verification. MF48	1689	47	-7742.55	115.997	6.47861e-26	6.47861e-26	1.90749
14 CJ-34	Verification. MF58	1689	51	-7720.25	138.298	9.31244e-31	9.31244e-31	1.92315
15 CJ-35	Verification. MF78	1689	66	-7858.54	0	1	1	1.73848

3. Choose an option from the dialog box, based on whether you used standard modelforms or not:
  - If you are comparing resist models and using standard Calibre WORKbench-provided modelforms, ensure the option is set to Resist Model Analysis. Calibre nmModelflow generates the correct parameters for your models.
  - If you are comparing VEB or topo model forms, select the User Defined Parameters option and manually enter the number of model parameters K.
  - If you are using customized modelforms, select the User Defined Parameters option. You may need to change the number of K parameters in the numeric field next to the radio button.

## Results

The AIC table is populated with the calculated values of the fitness tests.

- In the AIC table, the model with the largest weight has the best results in terms of fitness and low over-fit risk. The sum of all of the weights for a given comparison is always 1.0. If a single model has a weight of 0.99, it is the best model with the most parameters and best fit, which primarily means that the number of gauges is high enough to justify the complexity of the model.

- Weights also indicate when there is not enough information to justify the complexity of the models in a comparison. It is possible to have models that are simple but result in a larger weight than more complex models that have a lower eRMS.

## Calibrating for SRAF Print Avoidance

Calibre nmModelflow supports calibrating a CTR model for the SRAF print avoidance (SPA) model. Gauge output for SPA calibration is different from other gauge output.

### Note

 An alternate method of calibrating SRAF print avoidance using ZPlanes models is described in the section “[SRAF Calibration in Calibre nmModelflow](#)” on page 312.

---

### Prerequisites

- An optical model, optionally with vertical diffusion parameters (vertical\_diffusion in the optical model file) recommended
- A test pattern with a set of gauges intended for SRAFs loaded into the database

### Procedure

- Create a litho model (as described in “[Creating Litho Models](#)” on page 76) with the following components:
  - Resist Model Form: 0 CTR.
  - No etch model.
  - No topo model.
  - Nominal optical model: Use the optical model with the vertical diffusion parameters.
- Create a calibration stage, selecting Optics mode.

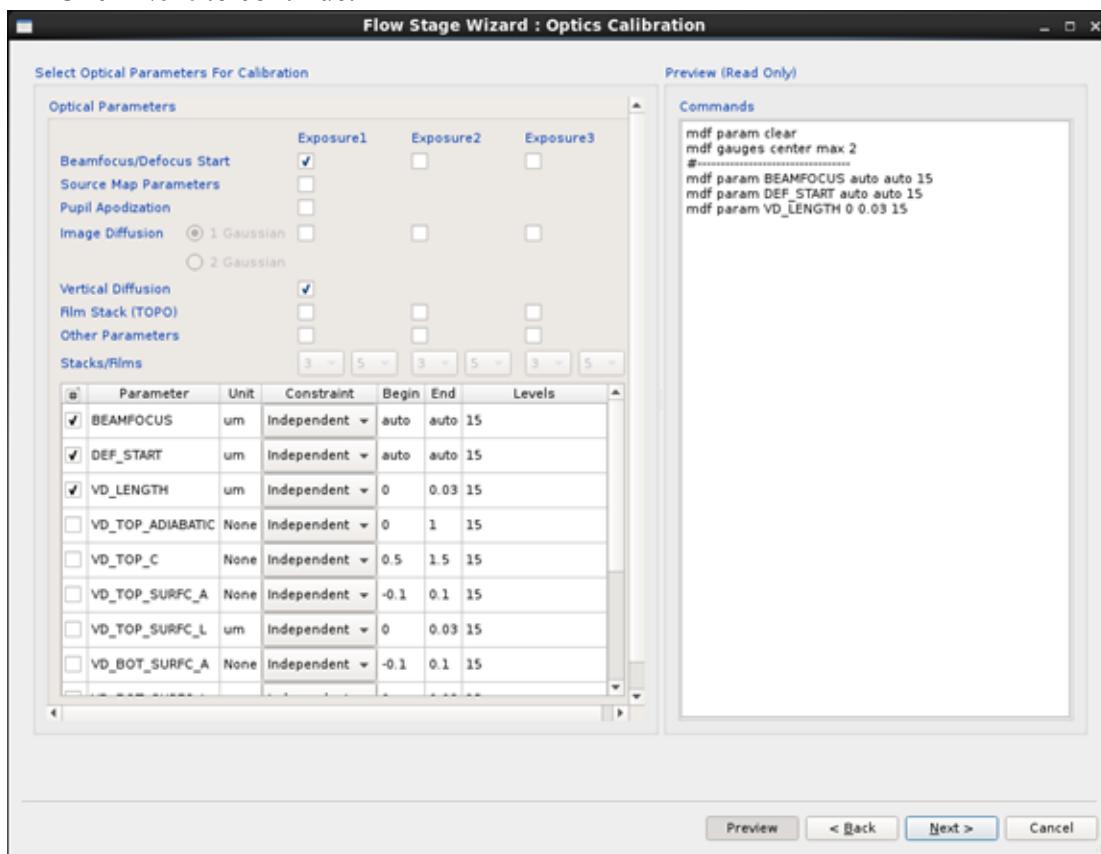
In the Select Optical Parameters for Calibration page, select:

- Exposure1 Beamfocus/Defocus Start
- Exposure1 Vertical Diffusion

This populates the parameter list with relevant options for SPA. Select only the following parameters to optimize:

- DEF\_START
- VD\_LENGTH (Optional. This may improve accuracy, but results in longer runtime)
- BEAMFOCUS (Only if through focus SRAF gauges are available)

Click **Next** to continue.



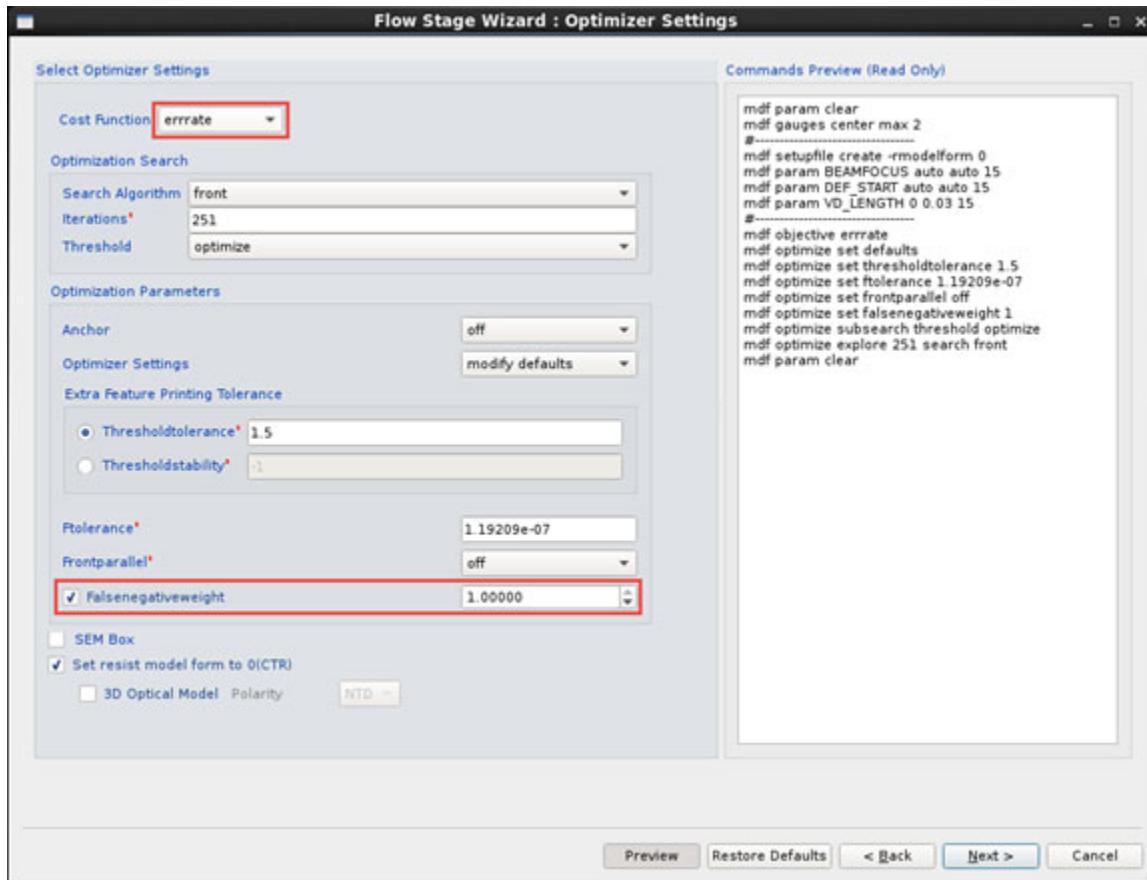
---

### Note

- If createsrafgauges is used to prepare the SRAF gauge file, the command “mdf gauges center 2” should not be used. In order to ensure that SRAF gauges are always centered on an SRAF polygon, either refrain from using the “mdf gauges center” command or use a value of “4”.
- 

3. In the Optimizer Settings page, set the Cost Function as follows:
  - a. For “Cost Function,” chose errate from the dropdown list.
  - b. For “Optimizer Settings,” choose “modify defaults” from the dropdown list.
  - c. Select the desired setting for Falsenegativeweight:
    - **Falsenegativeweight enabled** — Suppress false positives and false negative errors. Set falsenegativeweight as a value between 0 and 1.0 (the larger the value, the more false negative errors are suppressed). The default value of 1 indicates that all false negative errors are suppressed, but not false positives.
    - **Falsenegativeweight disabled** — Use the overall error rate for all SRAFs combined (both false positives and missed printing SRAFs) for the errate objective.

Click Next.



4. Create a calibration job, using the SRAF gauges and the litho model and stage you created.
5. Execute the calibration job.

## Results

When the calibration job completes, the gauges in the **Gauge Analysis** tab list inequality values in the Meas field:

- GT:X for SRAFs that printed
- LT:X for SRAFs that did not print

where X is an integer value. The Prediction field further classifies the output as TruePositive, FalsePositive, TrueNegative, and FalseNegative. This is based on the comparison versus the Sim column.

**Table 1-19. SRAF Prediction Values**

Meas Result	Sim Value	Prediction
GT:X	greater than the value of X	TruePositive

**Table 1-19. SRAF Prediction Values (cont.)**

Meas Result	Sim Value	Prediction
LT: $X$	less than the value of $X$	TrueNegative
GT: $X$	less than the value of $X$	FalseNegative
LT: $X$	greater than the value of $X$	FalsePositive

**Note**

 You may need to click the **Accept** button in the Calibration Job Summary report to see the Prediction column values. If the Prediction column does not appear, right-click any Gauge Analysis header, select Column Manager from the popup menu, and activate the Prediction column.

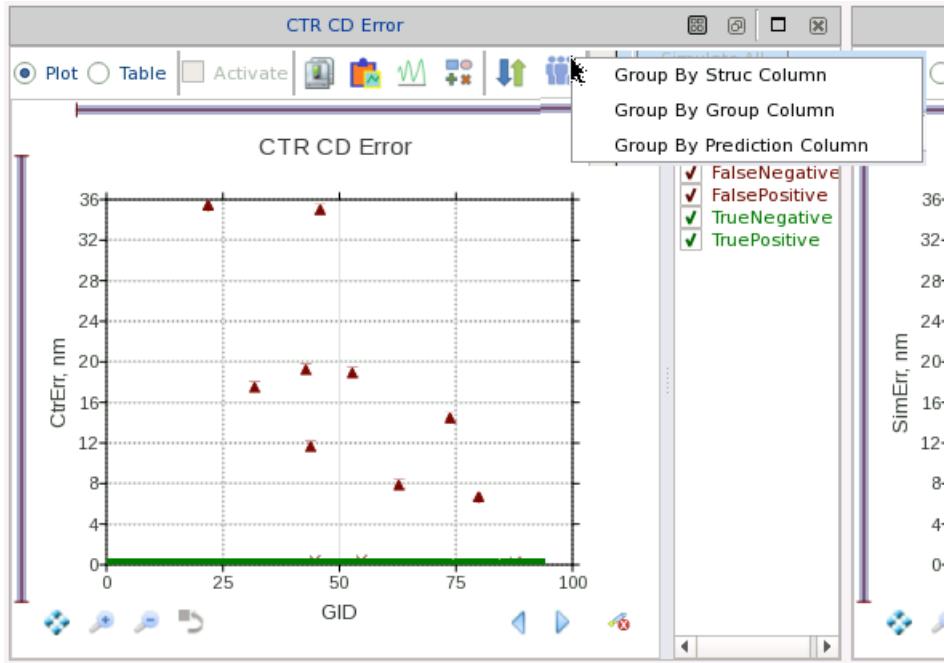
The Calibration Job Summary report also contains a section for gauge prediction statistics showing the resist printing prediction error data.

There are three main plots that are useful for analyzing SRAF calibration and verification jobs:

- Empirical Threshold
- Area\_Ratio vs. GID
- Area\_Ratio vs. EmTh (where EmTh is the empirical threshold)

**Tip**

 Results in the Calibration Job Summary report, Plots > GaugesSim Stats section can be set to show as Grouped by Prediction Column using the plot button bar controls.

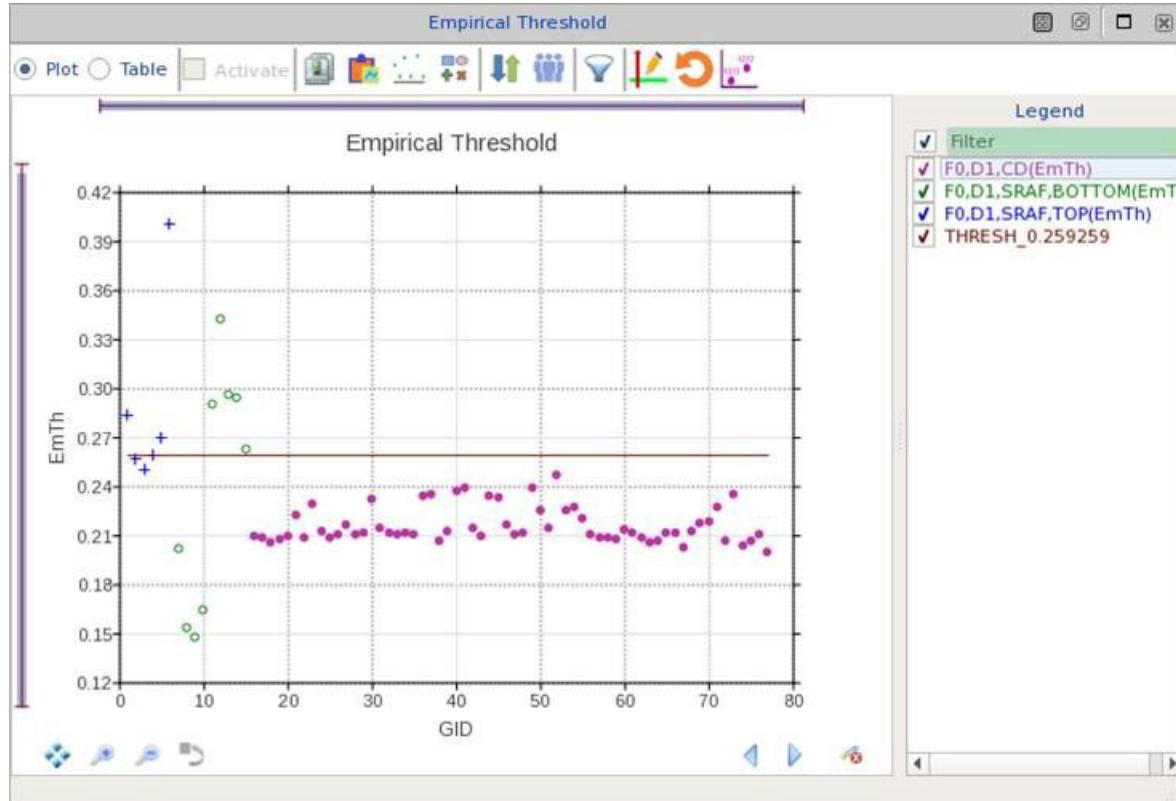


The two Area\_Ratio plots are only useful if createsrafgauges is used to prepare the input gauge file, which outputs a column Area\_Ratio in the **Gauge Analysis** tab.

The Empirical Threshold displays a distribution of the SRAF gauges. Each process window condition can be viewed separately. The Prediction gauge column Prediction can be enabled and each gauge error (falseNegative or falsePositive) can be viewed individually. The gauges can then be highlighted and shown in the plot.

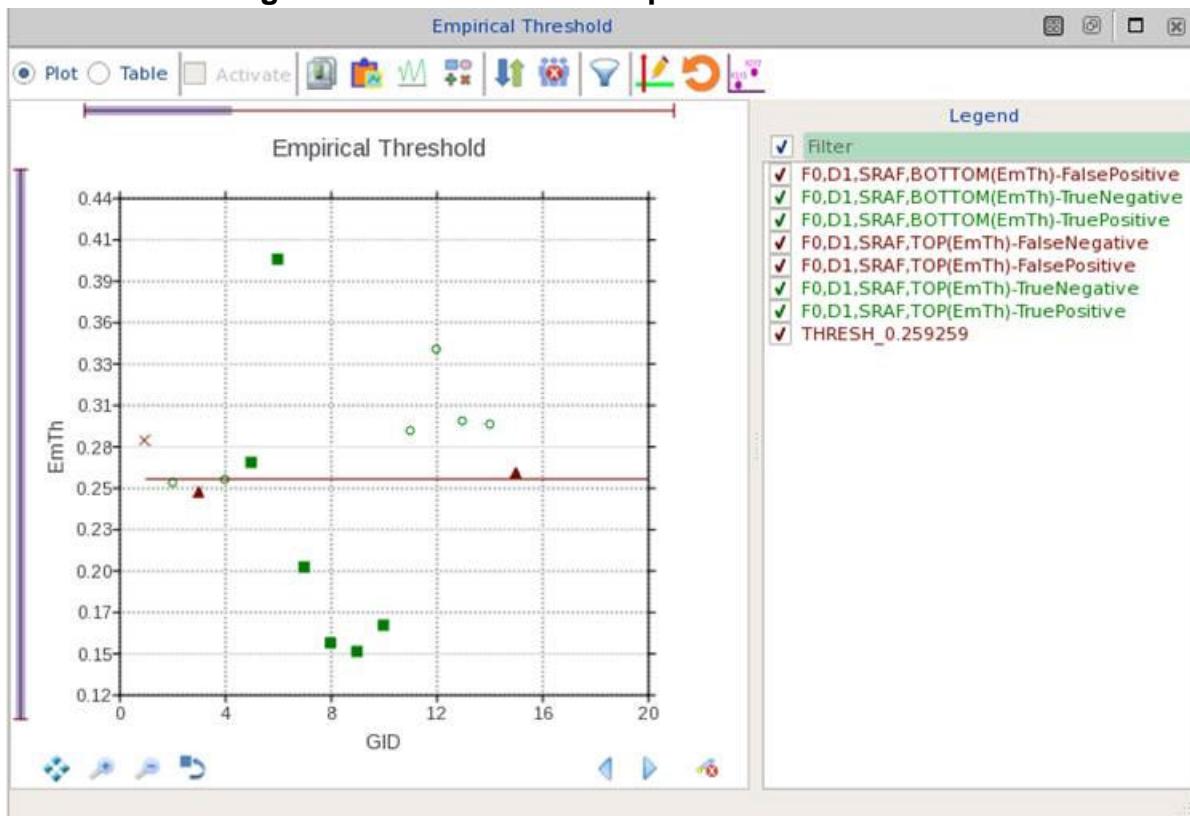
- If the SRAF gauge empirical threshold (EmTh) is very close to the threshold line, it means this SRAF is predicted to be on the borderline of printing.
- If the SRAF gauge EmTh is far from the threshold line, it means it is either predicted to be clearly printing or clearly not-printing (depending on the tone of the process).
- Any SRAF gauge can be of either case (very close or very far), depending on how this particular SRAF should print under current model.
- Gauges with an EmTh farthest from the threshold line are considered easy to fit, so they do not contribute much to tune SRAF model parameters. They can be considered for reduction, but should not be completely removed.

**Figure 1-21. Easy Fit SRAF Gauges for Empirical Threshold**



- An ideal SRAF printing model has fewer FalsePositive and FalseNegative error gauges (red-colored “x” and triangle on the second plot below). Those gauges should be close to the threshold line.

**Figure 1-22. Ideal SRAF Empirical Threshold Plot**

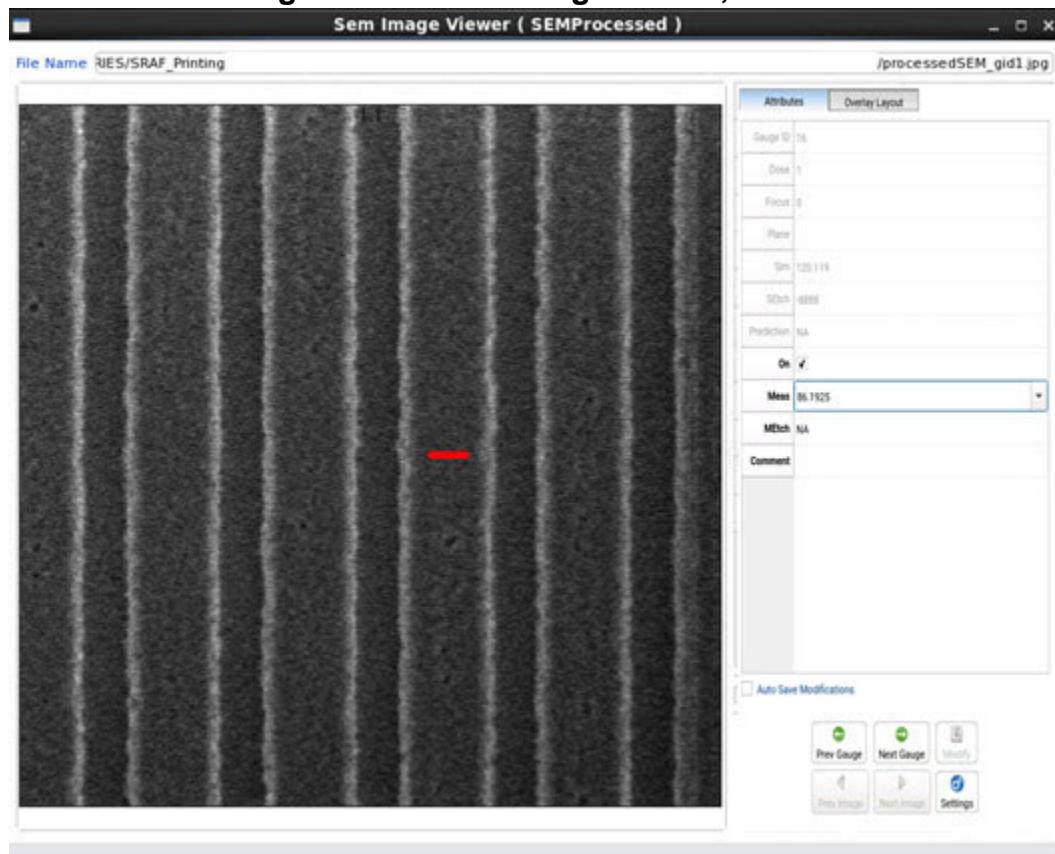


- If the FalsePositive and FalseNegative error gauges have an EmTh far away from the threshold line, it indicates that the current model fails badly in prediction. It might also indicate that the setup information is wrong, or the model is incomplete.

Additionally, the SEM Viewer can be used with createsrafgauges to view SRAF images. A gauge file prepared with createsrafgauges has two columns with links to images, one with the original SEM images and one with the processed SEM images. Clicking on the filename in the link opens the SEM Viewer.

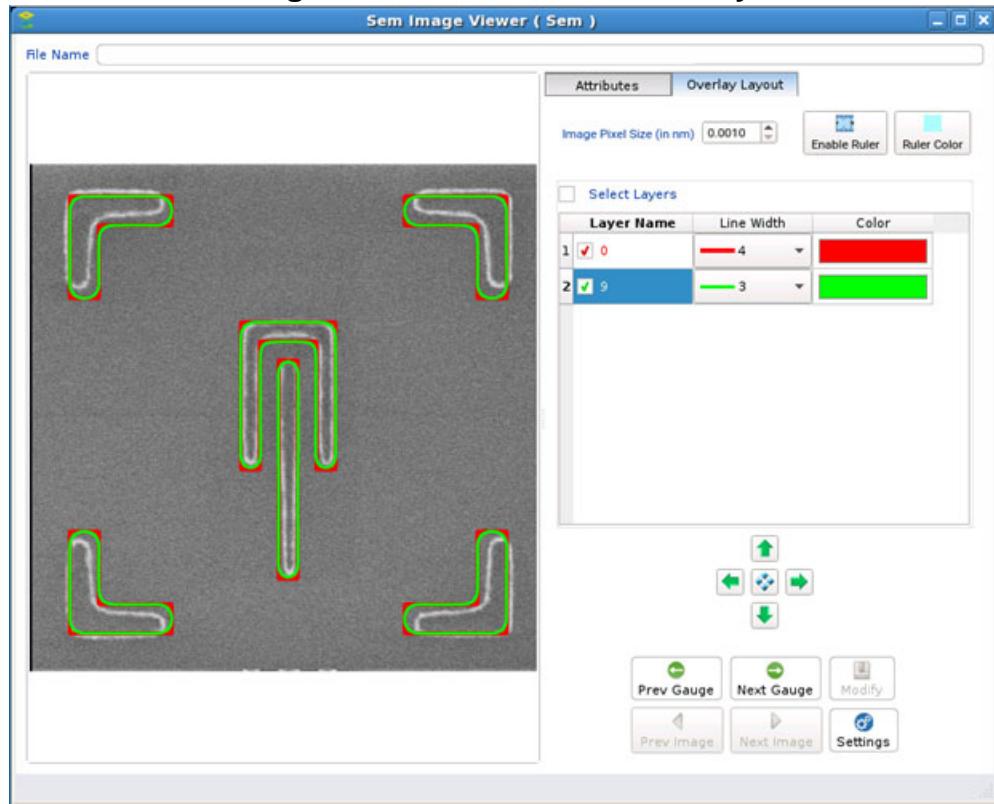
The processed images will have red contours showing where printing was detected and a red gauge corresponding to the location of the output gauge, as shown in [Figure 1-23](#). The SEM Viewer also displays additional information next to the image. You can cycle through gauges in the viewer with the provided arrow buttons.

Figure 1-23. SEM Image Viewer, SRAF



You can use the **Overlay Layout** tab to overlay the relevant layer over the SEM image to aid in visualizing the target layer versus the SEM image.

Figure 1-24. SEM Viewer Overlay



- In the layout viewer, select the area around the relevant test structure or click on its name in the **Gauge Analysis** tab.
- You may need to change the Image Pixel Size to match your design size.
- Use the Select Layers list to specify the target layer.
- Use the directional controls to move the overlay until it aligns, then click **Modify** to save the alignment.

## Training a Machine Learning Model

Training a machine learning model pairs a neural network assisted model with an existing resist or etch model. In order to do this, you must train a neural network model with gauge data.

### Prerequisites

- A calibrated litho model with a resist model (and an etch model if etch models are to be matched with a neural network).
- The corresponding gauge file.

## Procedure

1. Load the litho model and gauge data into Calibre nmModelflow, either by creating a script or using the GUI.

---

### Note

 Starting with the 2020.4 release, Calibre nmModelflow also includes a calibration stage that covers steps 2 and 3 of this procedure.

---

2. Generate the training data to go with the appropriate model (resist = n2r, etch = n2e) by entering one of the following commands in the Command Window or adding it to the script:

- mdf ml gen\_traindata\_n2r
- mdf ml gen\_traindata\_n2e

3. Optimize the training data with one of the following commands:

- For resist models:

```
mdf ml optimize_n2r -yamlfile {DUV | EUV} [-epochs integer]  
[-batch_size size] [-grid_shiftnum shiftsize]
```

where:

- -yamlfile — Sets the type of model to be trained.
- -epochs — Is the number of epochs that are used to train the model. One epoch is one full pass over the entire data set. The default for N2R is 600.
- -batch\_size — Sets the number of data samples to process before updating the model. The default value for N2R is 32.
- -grid\_shiftnum — Sets the approximation value used to help improve model consistency at the cost of more computation time. The default value is 4.

- For etch models:

```
mdf ml optimize_n2e [-mode {rel | abs}] [-epochs integer]  
[-reg_wt wt_value] [-max_norm norm_value]  
[-model_based_retargeting]
```

where:

- -mode — Changes the loss function for the optimizer to use a relative loss or absolute loss.
- -epochs — Is the number of epochs that are used to train the model. One epoch is one full pass over the entire data set. The default for N2E is 6000.
- -reg\_wt — Sets the kernel regularizer of all dense layers in the model. This value should be left as the default (0.1).

- -max\_norm — Sets the kernel constraint of all dense layers in the model. The default is NA.
- -model\_based\_retargeting — If specified, uses the etch-model only version of calibration instead, ignoring the optical and etch models in the litho model.

## Results

An optimize directory is created in your current working directory. On a successful optimization run, the directory contains:

- A modified Lithomodel file with the N2E or N2R call in it that can be used as an input litho model for Calibre tools that support machine learning
- An N2E or N2R directory containing the training data and related files

## Examples

### Example N2R Resist Script

This example is used for an EUV litho model and specifies 20 epochs for a quick test run. (Usually 20 epochs would not be enough to converge.)

```
mdf siminfo import inputsiminfo
mdf ml gen_traindata_n2r
mdf ml optimize_n2r -yamlfile EUV -epochs 20
```

### Example N2E Resist Script

The following code trains an etch (N2E) model and then optimizes it.

```
mdf siminfo import inputsiminfo
mdf ml gen_traindata_n2e
mdf ml optimize_n2e -mode abs
mdf setupfile close
mdf siminfo import optimize
mdf optimize set_etch fit absolute
mdf simulate
```

# Chapter 2

## Calibre nmModelflow GUI Reference

---

Calibre nmModelflow is strongly GUI-driven. Multiple wizards and dialog boxes guide you through tasks, and generate commands in the CLI parser that are executed using the GUI choices to correctly set the parameters.

<b>Calibration Job Manager .....</b>	<b>179</b>
<b>Calibration Job Record Dialog Box.....</b>	<b>183</b>
<b>Database Browser .....</b>	<b>190</b>
<b>Edit Lithomodel Dialog Box .....</b>	<b>193</b>
<b>Resist Model Composition Tool .....</b>	<b>195</b>
<b>Flow Stage Wizard, Optimize Group.....</b>	<b>196</b>
Flow Stage Wizard, Mask Calibration .....	197
Flow Stage Wizard, Optics Calibration .....	199
Flow Stage Wizard, ZPlanes Calibration .....	202
Flow Stage Wizard, Resist Calibration.....	204
Flow Stage Wizard, TOPO Calibration .....	209
Flow Stage Wizard, Etch Calibration .....	212
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Create Custom Etch Model Wizard .....	216
Flow Stage Wizard, Optimizer Settings .....	218
Flow Stage Wizard, Optimizer Settings With Etch .....	222
<b>Flow Stage Wizard, Simulate Group.....</b>	<b>224</b>
<b>Flow Stage Wizard, Center Focus Group .....</b>	<b>225</b>
Flow Stage Wizard, Defocus Start Search and Center Focus on Through-Focus Data .....	226
Flow Stage Wizard, Defocus Start Search and Center Focus on Nominal Data .....	229
Flow Stage Wizard, Center Focus By Bossung Adjust on Through-Focus Data.....	232
Flow Stage Wizard, Center Focus By Bossung Adjust on Nominal Data .....	235
<b>Flow Stage Wizard, Build Group.....</b>	<b>236</b>
<b>Flow Stage Wizard, Etch Bias Table Generation .....</b>	<b>238</b>
<b>Contour Analysis Tab .....</b>	<b>243</b>
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<b>Metrics Viewer Tab . . . . .</b>	<b>264</b>
<b>Edit Metric Group Wizard . . . . .</b>	<b>266</b>

# Calibration Job Manager

To access: In the Calibre nmModelflow Main window, click the **Calibration Job Manager** tab

The Calibration Job Manager is located in the primary display area. It lists and manages all jobs defined in the database. Jobs are created from stages, and incorporate litho models, gauge objects, filters, metrics, and plots.

**Figure 2-1. Calibration Job Manager**



## Objects

**Table 2-1. Calibration Job Manager Button Controls**

Field	Description
Execute	Executes the selected job(s).
Refresh	Refreshes the status of any running jobs.
View	Displays a calibration job record.
Compare	Compares the results of the selected jobs in an enhanced version of the <a href="#">Plots Tab</a> .  Note: Only jobs with the same input data should be compared. Doing so enables a job comparison report in the Model Error Report tab.
Accept	Loads the litho model, gauge data, and simulation results into the GUI.
Continue	Continues a stopped job as a separate “continuation” job. Only works for resist calibration stages.
Stop	Stops the selected calibration job if it is running.
Clear	Resets the calibration job to the “Initial” (ready-to-run) state. You must click this button after resolving a calibration job in the “Error” state.
Remove	Deletes the selected calibration job.
Add Calibration Job	Creates a new calibration job, as described in “ <a href="#">Setting up a Calibration Job</a> ” on page 129.
Add Verification Job(s)	Creates a new verification job, as described in “ <a href="#">Creating a Verification Job</a> ” on page 142. A verification job must be associated with a calibration job as its predecessor.
Add Generic Job	Creates a new generic job, as described in “ <a href="#">Creating a Generic Job</a> ” on page 146.

**Table 2-1. Calibration Job Manager Button Controls (cont.)**

Field	Description
Copy	Copies the selected calibration job to a new entry.
Multiple Copy	Creates multiple variants of an existing job. You can use the same layer mapping for all jobs that you copy.
Copy Descendants	Copies a selected job and all of its descendants.
Edit	Edits the selected calibration job.
Multiple Edit	Edits all selected calibration jobs, as described in “ <a href="#">Editing Multiple Calibration Jobs</a> ” on page 150.
Update Run Command	Edits just the runscript command for the job. Use this option to change which remote resources are used.
Annotate	Sets or unsets the color of the selected items. Used to highlight a job in the list.
Clear Annotate	
Summary Report	Provides comprehensive summaries of selected components in the Calibration Job record in an HTML format.  You can use Summary Report and Compare Summary as a way of automatically documenting results in a compact form designed for sharing with others. See “ <a href="#">Creating HTML Summary Reports</a> ” on page 139.
Compare Summary	Writes a summary HTML file for two or more selected calibration jobs.
Export Output Lithomodel	Writes the results of the selected job(s) as a litho model.
Add Output Lithomodel to DB	Imports a selected litho model to the database.
Select All	Toggles the selection status of jobs in the list.
Unselect All	

The columns in the Calibration Job Manager list brief information about a job.

**Table 2-2. Calibration Job Manager Column Information**

Column	Description
ID	The ID of the job. Calibration jobs are identified as CJ- <i>id#</i> in the window and in the logs.
Description	The description specified for the job.
InputGauges	The input gauges specified for the job.
Status	The status of the job in the database.

**Table 2-2. Calibration Job Manager Column Information (cont.)**

Column	Description
Cost Objective	The final cost function value of the calibration job. If the job has never been completed successfully, this field is blank.
InputContours	The input contour for this job.
InputLM	The input litho model for this job.
Predecessor	The calibration job that provides litho model input to this job. If a job has a predecessor, it is shown in the id column as a child of the parent.
Prefilter	A filter that is applied to the input gauges before calibration is run. Only a single filter can be specified.
Stage	The stage that is run in a calibration job.
Metric Groups	The metric group that is used to measure the results of the calibration job.
Plot Group	The plot group that is used to visualize the results of the calibration job.
Map Mask Layers	Lists reference numbers of mask layers that are being used for this calibration job.
Run Command	Shows the run script associated with a stage.
Jobtype	Shows additional information about the job type.
Errmsg	Shows an error status message.
Start	Lists the time the job was last started.
Elapsed	Lists the time taken to complete the job.
Created	Lists when the job was created.
User	Lists the UNIX username of the person that created the job.

## Usage Notes

- A calibration job must be in the Initial status in order to be run. Use the **Clear** button to delete results and reset a selected job.
- The Calibration Job Record dialog box usually has information on what caused a calibration job run to end in an error.
- Selecting one or more jobs, right-clicking on the job or list, then selecting **Export Job(s)** brings up a dialog box to create a *.tar* file with the selected calibration job(s) and related information in it, suitable for import by another user.
- The dispatcher included with Calibre nmModelflow allows you to run multiple calibrations in parallel. A calibration job that is incomplete has a status of Running.

- Double clicking a calibration job or selecting a job and clicking the **Edit** button allows you to view and edit the job. Editing operations are only allowed if the job has a status of Initial.
- If a calibration job has a predecessor (in other words, it is dependent on the results of another calibration job), the predecessor job must have a status of Done or Initial. In the latter case, the predecessor is automatically calibrated first.
- The Calibration Job Manager features a split screen view capability, which allows you to look at hierarchy on the left and sort and filter on the right side. Job selections are mirrored on both sides of the split screen.

## Related Topics

[Setting up a Calibration Job](#)

[Running a Calibration Job From the Calibre nmModelflow GUI](#)

[Saving the Models After Calibration](#)

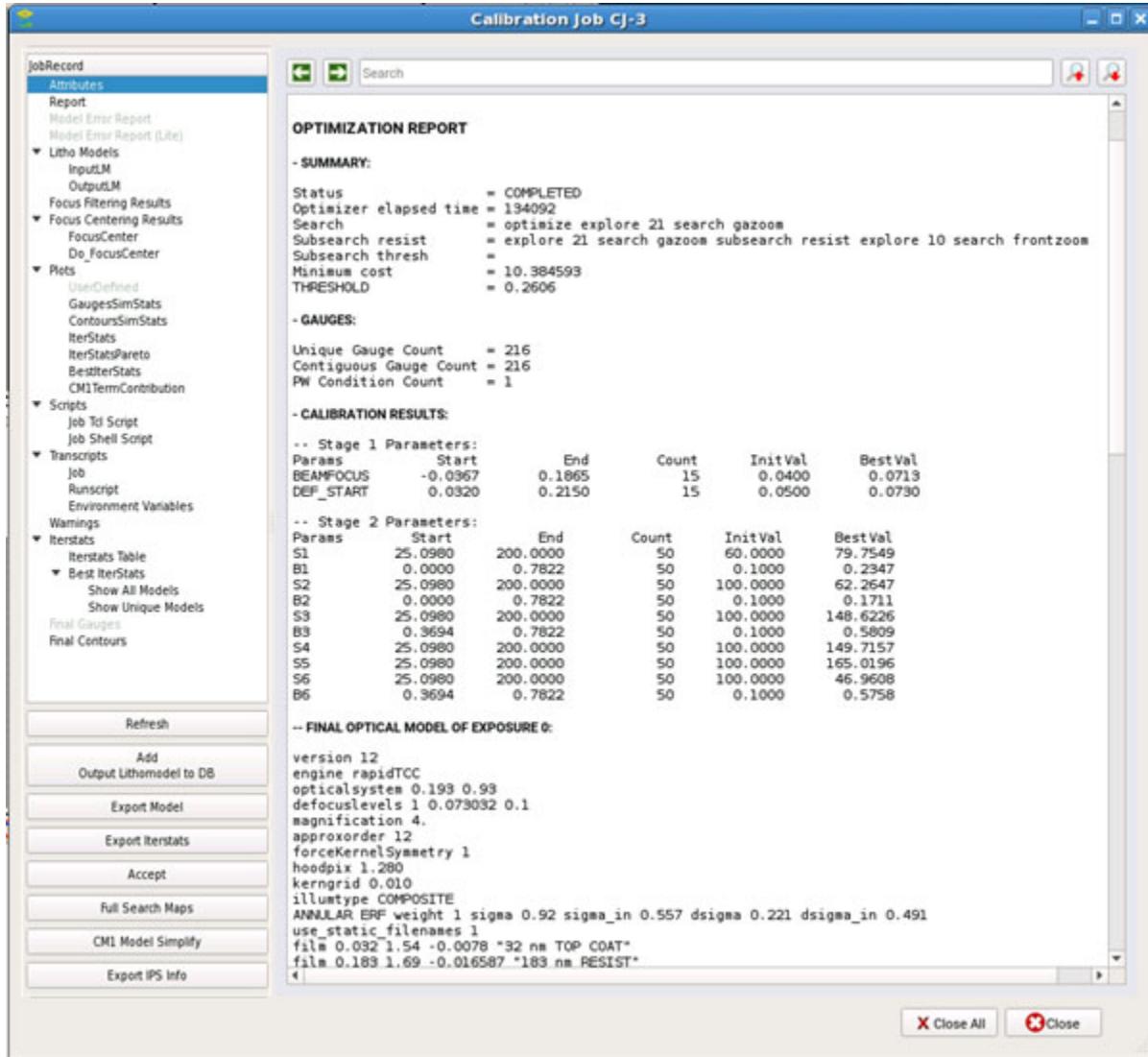
[Calibration Job Record Dialog Box](#)

# Calibration Job Record Dialog Box

Calibration Job Manager screen

The Calibration Job Record dialog box shows the results of a calibration run.

**Figure 2-2. Calibration Job Record Dialog Box**



## Description

The Calibration Job Record dialog box appears when you click **View** in the **Calibration Job Manager** tab in the main window. It shows the results of a run, both successful and unsuccessful. If a job finishes with an error, you may be able to diagnose the problem by checking the Transcripts section. Choose items from the left column to view different parts of the calibration record.

## Objects

**Table 2-3. Calibration Record Contents**

Object	Description
Attributes	Shows the input parameters for the job.
Report	Shows the results of the job in report format. A summary of fit errors and user defined metrics as well as calibrated parameter information is displayed.
Model Error Report	<p>Shows detailed statistical information from the calibration run in tabular and plot formats.</p> <ul style="list-style-type: none"> <li>Items in the list are automatically collected based on your calibration job results. If relevant data is not found for a tree item, the item is written to the report as a blank plot or empty section.</li> <li>Use the checkboxes in the tree to show or hide items in the report.</li> <li>If you have groups defined in your gauge file (using the Group column in the gauge file), the groups are also shown in the report.</li> <li>Groups in gauge files that have a precision (Prec) value specified are included in a box plot section of the report, sorted by precision and group name.</li> </ul> <p> <b>Note:</b> Click <b>Save Report</b> to save visible items to a PDF file for viewing outside Calibre nmModelflow.</p>
Model Error Report (Lite)	Shows a significantly shorter report compared to the standard Model Error report. This option is provided for users who want to quickly check reports for gauge, group and process window statistics, plus error and group summary plots.
Litho Models	<p>Shows the litho models for the calibration job.</p> <ul style="list-style-type: none"> <li><b>Input LM</b> — The litho model used as input for the job.</li> <li><b>Predecessor</b> — If this job was dependent on the output of another calibration job, this litho model is shown instead of the input litho model.</li> <li><b>Output LM</b> — The litho model from the best results of the calibration. It only appears if the run completes successfully.</li> </ul> <p> <b>Note:</b> If you have multiple DDM models, the output litho model may contain an interpolated stackslope DDM model in addition to the input DDM models. This interpolated model is indicated by the header in the model.</p>
Focus Filtering Results	Shows the results of the initial filtering process for gauges. Gauges which do not have enough valid focus conditions are removed.
Focus Centering Results	Shows the results of the focus centering calculation and dose focus centering calculations.

**Table 2-3. Calibration Record Contents (cont.)**

<b>Object</b>	<b>Description</b>
CM1 Model Terms	<p>Shows CM1 model analysis information for stages containing resist models. See “<a href="#">Performing CM1 Model Analysis</a>” on page 154 for more information.</p> <p>This section only appears after performing CM1 model analysis.</p>
Plots	<p>Shows plots generated for the calibration job. These plots only activate when the run completes successfully.</p> <ul style="list-style-type: none"> <li>• <b>User Defined</b> — If plots were selected during job creation, they appear in this window.</li> <li>• <b>SimStats</b> — The results for the output litho model are shown in this window.</li> <li>• <b>ContoursSimStats</b> — If contours were used during calibration, the calibration results for the output lithomodel are shown in this plot window.</li> <li>• <b>IterStats</b> — The results of each iteration of the calibration search are shown in this window.</li> </ul> <p><b>i Tip:</b> The Iterstats plot list allows you to create a custom plot by selecting an X-Axis item and one or more Y-Axis items. This selection is saved as a User-Defined plot for later use.</p> <ul style="list-style-type: none"> <li>• <b>IterStats Pareto</b> — Plots the Pareto front data from multi-objective (moga) calibration runs.</li> <li>• <b>CM1TermContribution</b> — The results of CM1 model analysis adds a plot of CM1 term contributions relative to other terms.</li> </ul>
Scripts	<p>Shows the scripts that were used to run the calibration job.</p> <ul style="list-style-type: none"> <li>• <b>Job Tcl Script</b> — Shows the Tcl language sent to the CLI parser.</li> <li>• <b>Job Shell Script</b> — Shows the command shell script used to run the calibration job.</li> </ul>
Transcripts	<p>Shows pertinent transcripts for the calibration job. (See also the Usage Notes after this table.)</p> <ul style="list-style-type: none"> <li>• <b>Job</b> — Shows the output logs from running the calibration job.</li> <li>• <b>Runscript</b> — Shows the messages from executing the runscript.</li> </ul> <p><b>i Tip:</b> When the run ends with an error, the transcripts usually show what caused the error. If there is no <b>Job</b> transcript, it indicates that the error was caused by the runscript.</p> <ul style="list-style-type: none"> <li>• <b>Environment Variables</b> — Lists the user’s shell environment at the time the Calibre nmModelflow job is run.</li> </ul>
Warnings	Shows a list of warnings issued by Calibre nmModelflow during the calibration job run, if any.

**Table 2-3. Calibration Record Contents (cont.)**

Object	Description
IterStats	<ul style="list-style-type: none"> <li>• <b>Iterstats Table</b> — Shows a list of iterations performed during the calibration job.</li> <li>• <b>Iterstats Pareto Table</b> — Shows the results of a multi-objective genetic algorithm (moga) calibration run. The table is sorted with the primary objective minimized.</li> <li>• <b>Best Iterstats</b> — Shows the best iteration versus various metric stats for the set of job runs. The top 15 results (smallest values) for the objective and user defined metrics are shown in the Show All Models subsection. The unique models for the objective are shown in the Show Unique Models subsection.</li> </ul>
GA Stats	Shows the results (Niches, Population, and Population Stats) of a genetic algorithm (ga) calibration job. If the ga search was not selected in the stage, this group does not appear.
Final Gauges	Shows the gauges post-simulation for the output litho model. If the genetic algorithm was selected in the stage, this section is replaced by a Gauges section showing the top five Final Gauges candidates.
Final Contours	<p>Shows the post-simulation contours for the output litho model. The section contains RMS error information for each contour.</p> <p> <b>Note:</b> The CID is mapped as a first in, last out sequence; for example, in a set of 19 contours, CID 1 corresponds to contourSet 19.</p>
Etch Bias Report	Etch Bias Table Generation stages create an additional entry showing listings for bias tables, plus combined and unified tables if they were requested. The Etch Bias Report entry also contains an Analysis entry to graph results.
<b>Refresh</b> button	Refreshes the display. Use this button while the calibration job is running for the latest updates. Note that the transcript does not refresh in real time.
<b>Add Output Lithomodel to DB</b> button	Imports the selected litho model into the Calibre nmModelflow database. You should only add models of interest from the list of resulting models.
<b>Export Model</b> button	Writes the selected litho model(s) to the disk.
<b>Export Iterstats</b> button	Exports all iterstats results to a specified directory.
<b>Accept</b> button	Loads the results of this job as the active litho model and gauge results in Calibre nmModelflow.
<b>Full Search Maps</b> button	Displays the fitness maps for the parameter search. This option is only enabled when the calibration job used the full search mode.

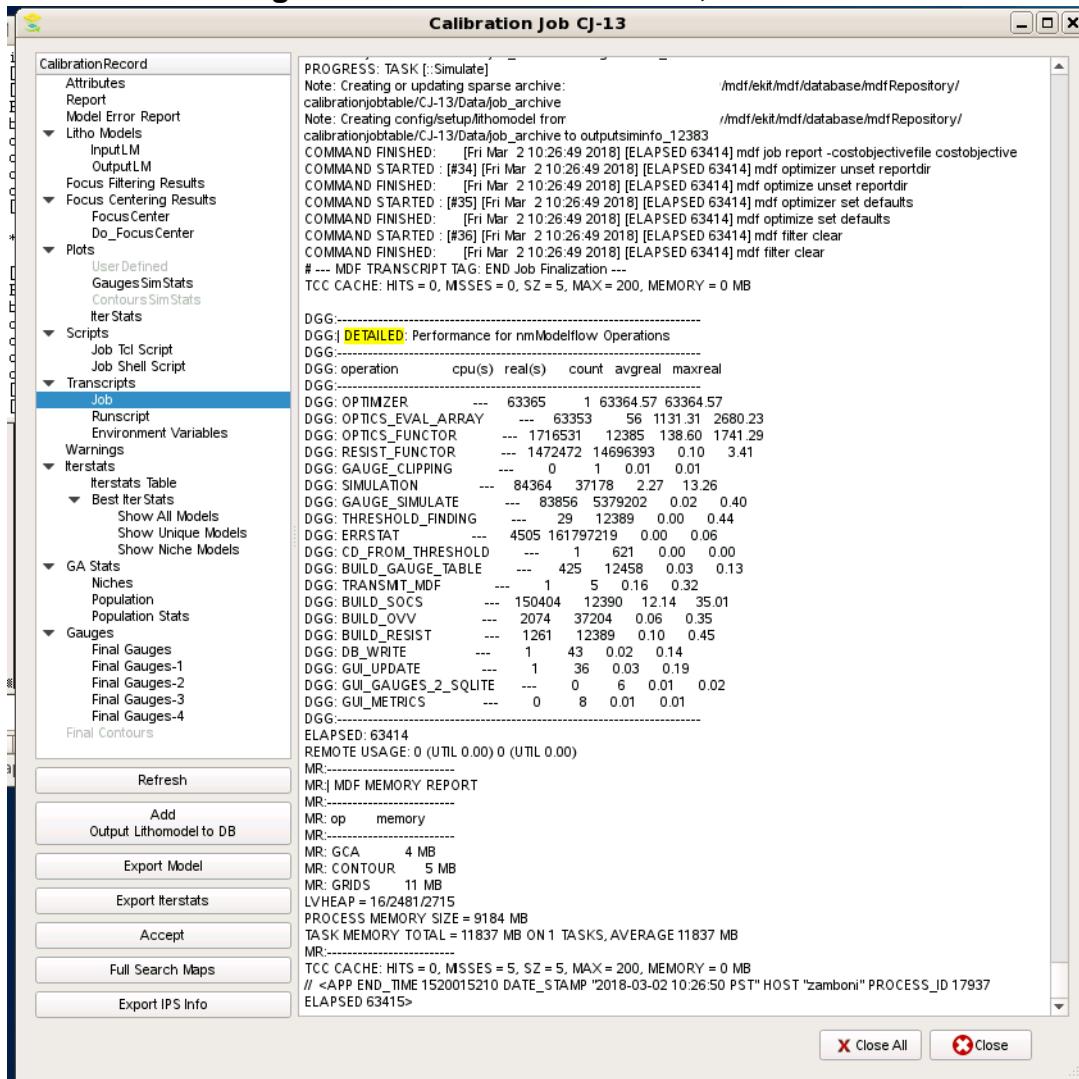
**Table 2-3. Calibration Record Contents (cont.)**

Object	Description
<b>Export IPS Info</b> button	Writes out a CSV file for use with the Calibre WORKbench Image Space Parameter Explorer tool. The CSV file is written to the directory you invoked Calibre WORKbench from, and named <i>CJ-&lt;x&gt;.csv</i> .

## Usage Notes

The transcript for a job in the Calibration Record tree can provide detailed performance information for the calibration run, as described in the following table.

**Figure 2-3. Calibration Record, Job View**



**Table 2-4. Calibration Record, Job View Columns**

Item	Description
operation	A discrete component of the optimizer (see <a href="#">Table 2-5</a> ).
cpu(s)	The amount of CPU time spent by the operation.
real(s)	The amount of real time in seconds spent by the calibration job. It may be cumulative across remotes or only on the primary host.
count	The number of times the operation was run.
avgreal	The average amount of time per operation call (calculated as real/count).
maxreal	The maximum amount of real time used on a call to that operation.
tile	The number of tiles processed by the operation.
cell	The number of cells processed by the operation.

**Note**

 The operations listed in the timer rows ([Table 2-5](#)) are not mutually exclusive. For example, the OPTIMIZER time includes the BUILD\_RESIST time. Additionally, some timers indicate time only on the primary host (OPTIMIZER), others show cumulative primary host threads and remote times (GAUGES\_SIMULATE), and others show only the primary host and remote cumulative time, but not the threads time (SIMULATION)

---

**Table 2-5. Calibration Record, Selected Job View Operations**

Operation	Description
OPTIMIZER	Time on the primary host used by the optimizer.
GAUGE_CLIPPING	Time for the gauge clipping that occurs during the gauge load phase.
BUILD_RESIST	Cumulative time on remotes, threads and primary host when solving for best fit of resist linear terms.
BUILD_OVV	Cumulative time on remotes, threads and primary host used for setting up the internal Calibre OPCverify vector.
BUILD_SOCS	Cumulative time on remotes, threads and primary host used when building optical models.
GAUGE_SIMULATE	Cumulative time on remotes, threads and primary host used when simulating gauges.

**Table 2-5. Calibration Record, Selected Job View Operations (cont.)**

Operation	Description
SIMULATION	Cumulative time on remotes (but not threads) and primary host performing simulations.

## Related Topics

[Calibration Job Manager](#)

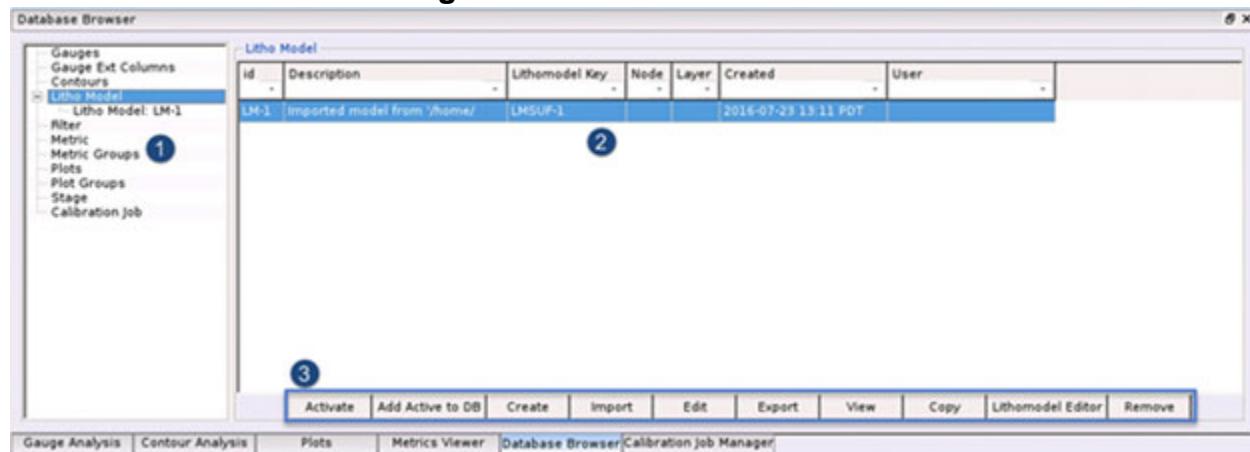
[Running a Calibration Job From the Calibre nmModelflow GUI](#)

# Database Browser

Calibre nmModelflow screen

Use the Database Browser in Calibre nmModelflow to work with components of your working environment.

**Figure 2-4. Database Browser**



## Description

The typical use model for Calibre nmModelflow involves creating individual items, storing them in the database, and then using items in the database to create a calibration job.

## Objects

**Table 2-6. Database Browser Contents**

Field	Description
1	Database list browser. If the database contains one or more items of a listed type, its type entry is shown with a + symbol, indicating that the list can be expanded to show the items.
2	Display pane. Clicking on a list entry in the list browser (area 1) shows the list of items of that type.

**Table 2-6. Database Browser Contents (cont.)**

<b>Field</b>	<b>Description</b>
3	Action buttons that apply changes to the active item. The buttons available vary depending on the selected database item type. <ul style="list-style-type: none"> <li>• <b>Add Using Wizard</b></li> <li>• <b>Activate</b></li> <li>• <b>Add Active to DB</b></li> <li>• <b>Split Gauges</b></li> <li>• <b>Create</b></li> <li>• <b>Compare</b></li> <li>• <b>Import</b></li> <li>• <b>Edit</b></li> <li>• <b>Export</b></li> <li>• <b>View</b></li> <li>• <b>Copy</b></li> <li>• <b>Lithomodel Editor</b></li> <li>• <b>Remove</b></li> </ul>

### Usage Notes

- **Activate** requires an item to be selected in the list, and loads the selected item in the appropriate tab or window. For example, activating a Plot item plots the listed items for the active gauge object.
- **Add Active to DB** takes the active item in the appropriate tab or window and adds it to the database as a new entry.
- **Split Gauges** is used for the Akaike Information Criterion functionality. It divides the selected gauge set into two new gauge sets. The split gauges are randomly divided with a specified size ratio, but you can provide a list of gauges that must be included in the first set.

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**Note**

See the section “[Support for Akaike Information Criteria Computation](#)” on page 161 for more information.

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- **Compare** is used to compare two or more selected gauge sets. The comparison appears in a plot-style format.
- **Copy** opens the appropriate editor and loads the selected lithomodel, stage, plot, or calibration job. Edit the item and make at least one change; two identical items cannot exist in the database. After editing, click **Add & Save** to add the modified copy to the database.

When copying or editing plots, the filters in the database are populated in the “Change Filters” dropdown menu.

- **Lithomodel Editor** opens a special editor that allows you directly edit the text of a litho model by selecting keywords and commands in lists related to the litho model.

---

**Note**

 Plots and Metrics can be collected into groups, allowing multiple items to be run together. Some database items require a plot group or metric group instead of an individual plot or group.

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## Related Topics

[Calibre nmModelflow Database Overview](#)

[Importing a Database](#)

[Exporting a Database](#)

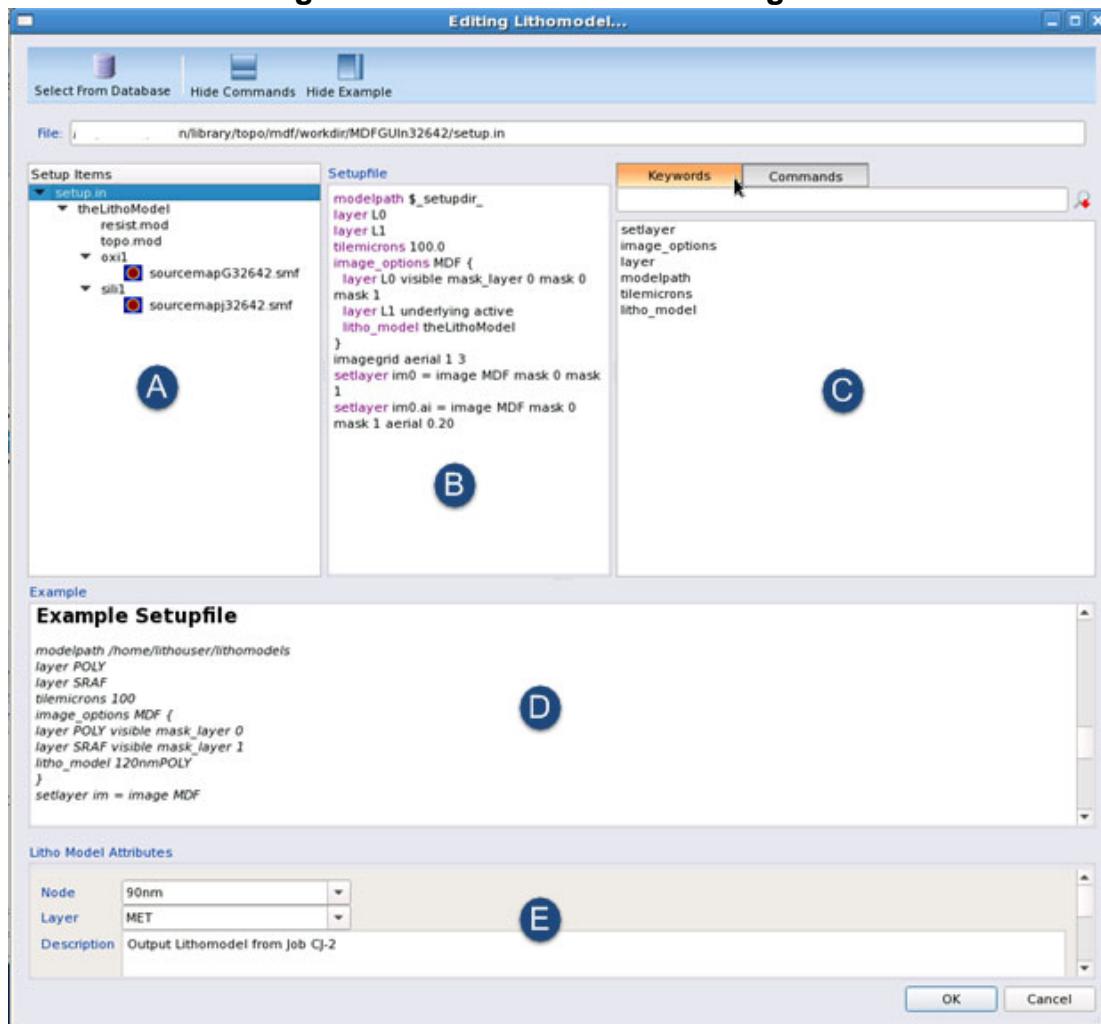
[Edit Lithomodel Dialog Box](#)

# Edit Lithomodel Dialog Box

Database browser tool

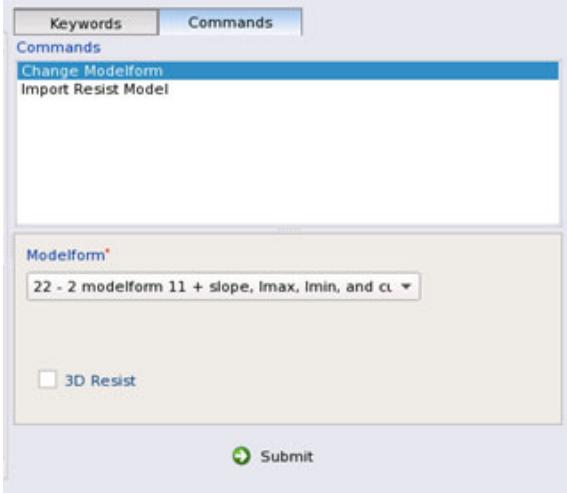
A litho model contains process information, and also contains other models with their own separate definition files. Use the Edit Lithomodel dialog box to navigate through the parts of a litho model and make changes as needed.

**Figure 2-5. Edit Lithomodel Dialog Box**



## Objects

Field	Description
A	Navigation tree. Shows the hierarchy starting with the Calibre nmMDF setup file as the parent.
B	File Viewer. Shows the contents of the selected file. <ul style="list-style-type: none"> <li>Clicking an <i>.smf</i> file brings up the Source View tool.</li> <li>Zernike files appear as <i>.xml</i> files underneath the optical model.</li> </ul>

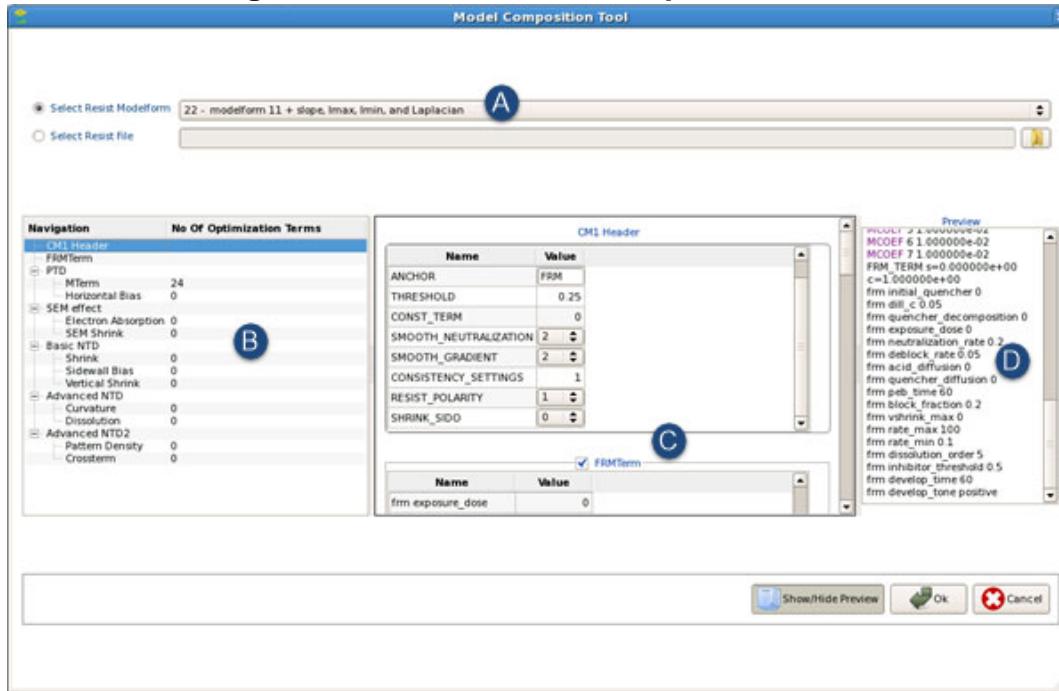
Field	Description
C	<p><b>Keywords and Commands</b> tabs.</p> <ul style="list-style-type: none"><li>The <b>Keywords</b> tab shows individual legal parameters for the currently selected file. You can type in the search field to find keywords matching the string.</li><li>The <b>Commands</b> tab shows actions that can be taken for the selected file, such as changing the modelform or loading a new model. Click <b>Submit</b> in this tab to make the change.</li></ul> 
D	Example pane. Shows the syntax of the various litho-model related files.
E	Litho Model Attributes pane. Shows the information for the selected litho model entry in the Calibre nmMDF database.

# Resist Model Composition Tool

To access: In the Lithomodel/Setup/MDF Creation Wizard, Lithomodel Components page, click the **Create** button in the Resist Model area.

Use the Resist Model Composition Tool to create a customized resist model for a litho model based on an existing resist model form.

**Figure 2-6. Resist Model Composition Tool**



## Objects

Field	Description
A	Select a starting point for the resist model, either a by selecting an item from the Resist Modelform list or loading a previously-created resist file.
B	Click a line entry from the Navigation pane to jump to the relevant term in the Term List (C).
C	Use the entries in the Term List to adjust the values of a term. Right-clicking on a row opens a shortcut menu to add a row after the selected row, or delete multiple selected rows.
D	View the resist model that is generated by your selections in the Preview pane.

## Flow Stage Wizard, Optimize Group

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Wizards in this group create stages that optimize specific types of models.

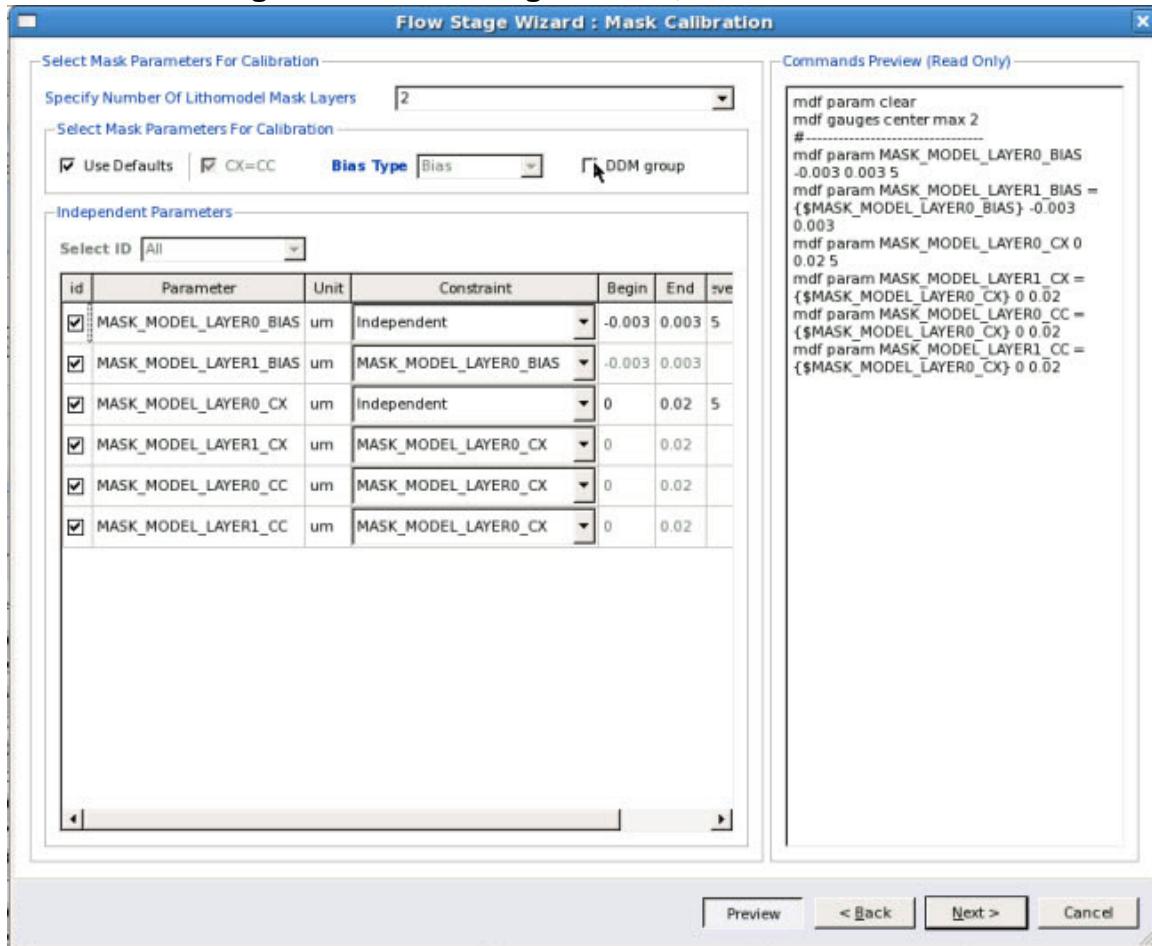
<b>Flow Stage Wizard, Mask Calibration .....</b>	<b>197</b>
<b>Flow Stage Wizard, Optics Calibration.....</b>	<b>199</b>
<b>Flow Stage Wizard, ZPlanes Calibration .....</b>	<b>202</b>
<b>Flow Stage Wizard, Resist Calibration .....</b>	<b>204</b>
<b>Flow Stage Wizard, TOPO Calibration.....</b>	<b>209</b>
<b>Flow Stage Wizard, Etch Calibration .....</b>	<b>212</b>
<b>Flow Stage Wizard, N2R/N2E Calibration .....</b>	<b>214</b>
<b>Create Custom Etch Model Wizard.....</b>	<b>216</b>
<b>Flow Stage Wizard, Optimizer Settings.....</b>	<b>218</b>
<b>Flow Stage Wizard, Optimizer Settings With Etch .....</b>	<b>222</b>

## Flow Stage Wizard, Mask Calibration

Stage Wizard dialog box

This wizard appears when you choose the Calibrate option of the Stage Wizard with the Mask check box selected.

**Figure 2-7. Flow Stage Wizard, Mask Calibration**



### Description

Use the options in the Mask Calibration screen of the Flow Stage Wizard to specify mask parameters to calibrate. Options appear in the Independent Parameters panel depending on what you choose. See “[Flow Stage Wizard, Optimizer Settings](#)” on page 218 for help with mask calibration-related optimization settings.

## Objects

**Table 2-7. Flow Stage Wizard, Mask Calibration Contents**

Field	Description
Specify Number of Lithomodel Mask Layers	<p>Increasing the number adds more sets of MASK_MODEL_LAYERx parameters to the list. Each set can be calibrated individually.</p> <p>Up to 5 layers can be used. The number of mask layers must correspond to the number of mask layers used in calibration, for which the layer properties can be set independently.</p>
Select Mask Parameters for Calibration	<ul style="list-style-type: none"><li>• <b>Use Defaults</b> — Uses current best practices for the calibration items. De-select this checkbox to enable the other options.</li><li>• <b>CX=CC</b> — Toggles whether convex (CX) and concave (CC) corners are calibrated equally. De-select this checkbox to add separate CX and CC calibration parameters to the list.</li><li>• <b>Bias Type</b> — Sets the bias calibration types between Bias (both X and Y directions have their calibration bias performed together), Bias X and Bias Y.</li><li>• <b>DDM Group</b> — Adds the DDM group calibration parameters to the list. Note that you only need to enable the DDMGROUPPARAM parameters for the number of DDM groups you have; if you only have one group, uncheck everything but DDMGROUPPARAM0.</li></ul> <p> <b>Note:</b> Not all mask parameters are selectable from the GUI. For a full list of currently supported mask calibration parameters, use the command: <code>mdf param get mask</code></p>

## Related Topics

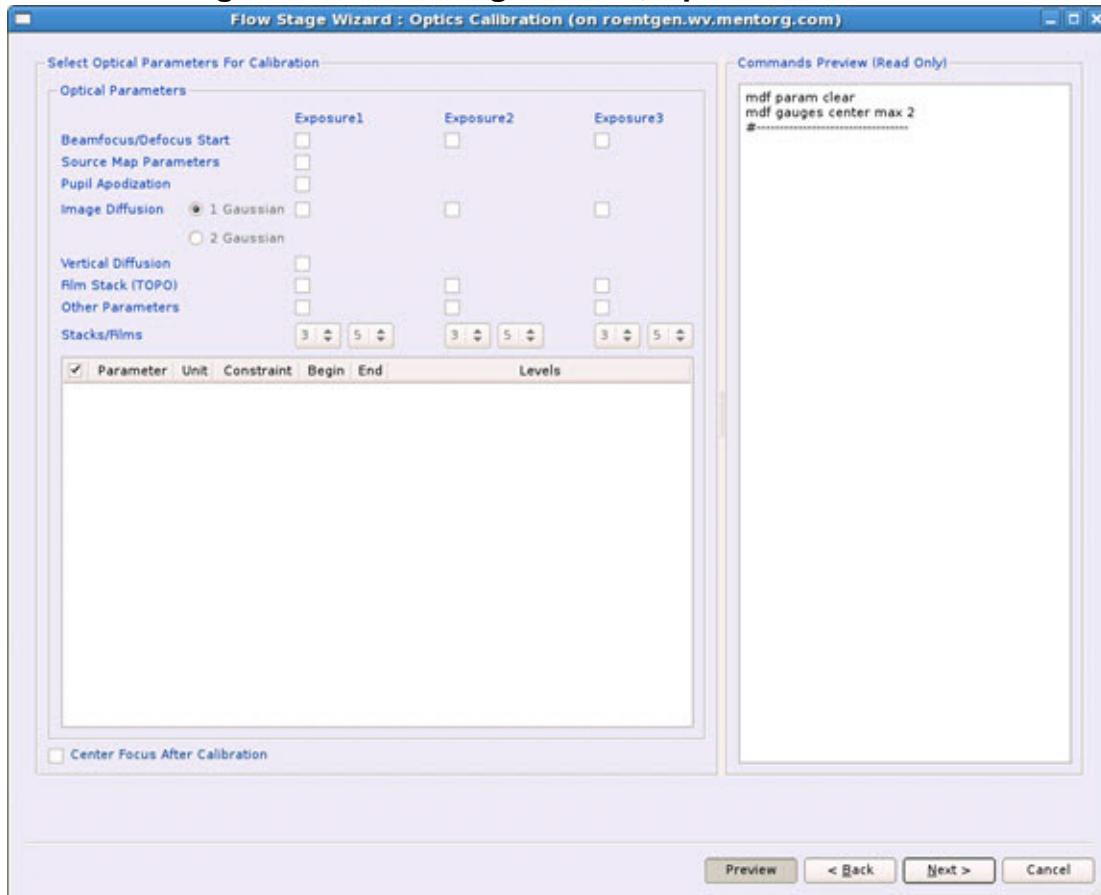
[Creating a Stage With the Flow Stage Wizard](#)

## Flow Stage Wizard, Optics Calibration

Stage Wizard dialog box

This wizard appears when you choose the Calibrate option of the Stage Wizard with the Optics check box selected. It sets the calibration parameters for the optical model.

**Figure 2-8. Flow Stage Wizard, Optics Calibration**



### Description

Use this wizard to set the parameters governing calibrating an optical model. Selecting a checkbox in the top section of the Optical Parameters pane allows you to narrow the focus down to only parameters of interest, rather than having to search through an entire list to find relevant parameters by name. See “[Flow Stage Wizard, Optimizer Settings](#)” on page 218 for help with optics-related optimization settings.

## Objects

**Table 2-8. Flow Stage Wizard, Optics Calibration Contents**

Field	Description
Select Optical Parameters for Calibration	<p>Choosing one of the check boxes adds the calibration options relevant to that choice to the list of parameters. The choices for optical modeling are:</p> <ul style="list-style-type: none"> <li>• Beamfocus / Defocus Start</li> <li>• Source Map Parameters</li> <li>• Pupil Apodization</li> <li>• Image Diffusion</li> </ul> <p> <b>Note:</b> When selected, the default value is set to 40 nm for DUV and 20nm for EUV.</p> <ul style="list-style-type: none"> <li>• Vertical Diffusion</li> <li>• Film Stack (TOPO)</li> <li>• Other Parameters — Numerous additional optical parameters that can be specified that are not part of the small subset shown in the above checkboxes.</li> <li>• Stacks/Films — The number of stacks and films per exposure that are present in an actual optical model. Only the selected number of stacks and films are displayed for calibration.</li> </ul>
Center Focus After Calibration	Selecting this check box adds Bossung adjust commands at the end of the script to be run for this stage.
Commands Preview	<p>Shows the results of your choices, translated into the CLI language.</p> <p> <b>Note:</b> Not all optics parameters are selectable from the GUI. For a full list of currently supported optical calibration parameters, use the command:</p> <pre>mdf param get optics</pre>

## Usage Notes

- The Begin, End, and Levels statements are editable and set the search range and steps (levels) explored between the Begin and End values. In most cases, leaving the default value (auto for both Begin and End) is recommended.
  - The minimal and maximal BEAMFOCUS (BF) auto values in um are calculated using the following formula:

$$BF_{min} = Fc - \Delta \text{ and } BF_{max} = Fc + \Delta, \text{ where } \Delta = \lambda / (2 * NA * NA).$$

The focus center ( $Fc$ ) is equal to 0 if the optical model does not contain a film definition. Otherwise,  $Fc$  is computed using formulas as described in the section

“Global Recommendations for Optical Models” in the *Calibre WORKbench User’s and Reference Manual*.

- The minimal and maximal DEF\_START values in um are related to the beamfocus values. The values used are BFmin and BFmax if the optical model does not contain a film definition.

If resist is the top layer of a film stack, the minimal value is set to 0. Otherwise, it is set to the sum of the layer thicknesses preceding the resist layer. The maximal value is set to the minimal value plus the resist layer thickness.

- For stages that include a mdf pw do\_focuscenter command (for example, if you check the Center Focus After Calibration checkbox or if you have non-centered process window data), the calibration run may use a different beamfocus than the final try run, resulting in a noticeable difference between the Optimize and Try results when the stage is run. Removing the mdf pw do\_focuscenter command will give more closely similar values.

## Related Topics

[Creating a Stage With the Flow Stage Wizard](#)

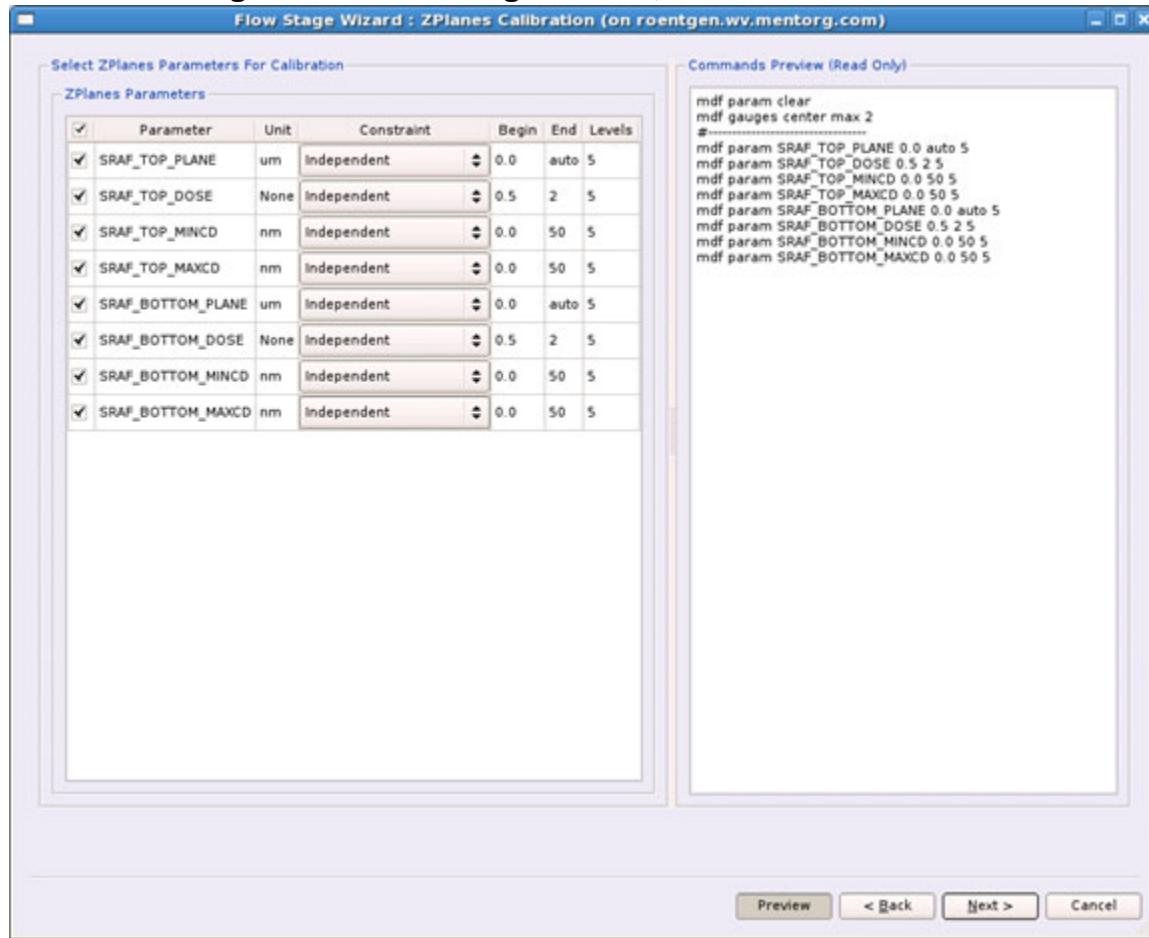
[Flow Stage Wizard, Optimizer Settings](#)

## Flow Stage Wizard, ZPlanes Calibration

Stage Wizard dialog box

This wizard appears when you choose the Calibrate option of the Stage Wizard with the ZPlanes check box selected. It sets the calibration parameters for the ZPlanes model.

**Figure 2-9. Flow Stage Wizard, ZPlanes Calibration**



### Description

Use this wizard to set the parameters governing calibrating a ZPlanes model. The ZPlanes model is used for SRAF printing models, which can have a different image plane when imaging is obtained for SRAF printing detection.

See “[Zplanes Model Format](#)” in the *Calibre OPCVerify User’s and Reference Manual* for additional information.

## Objects

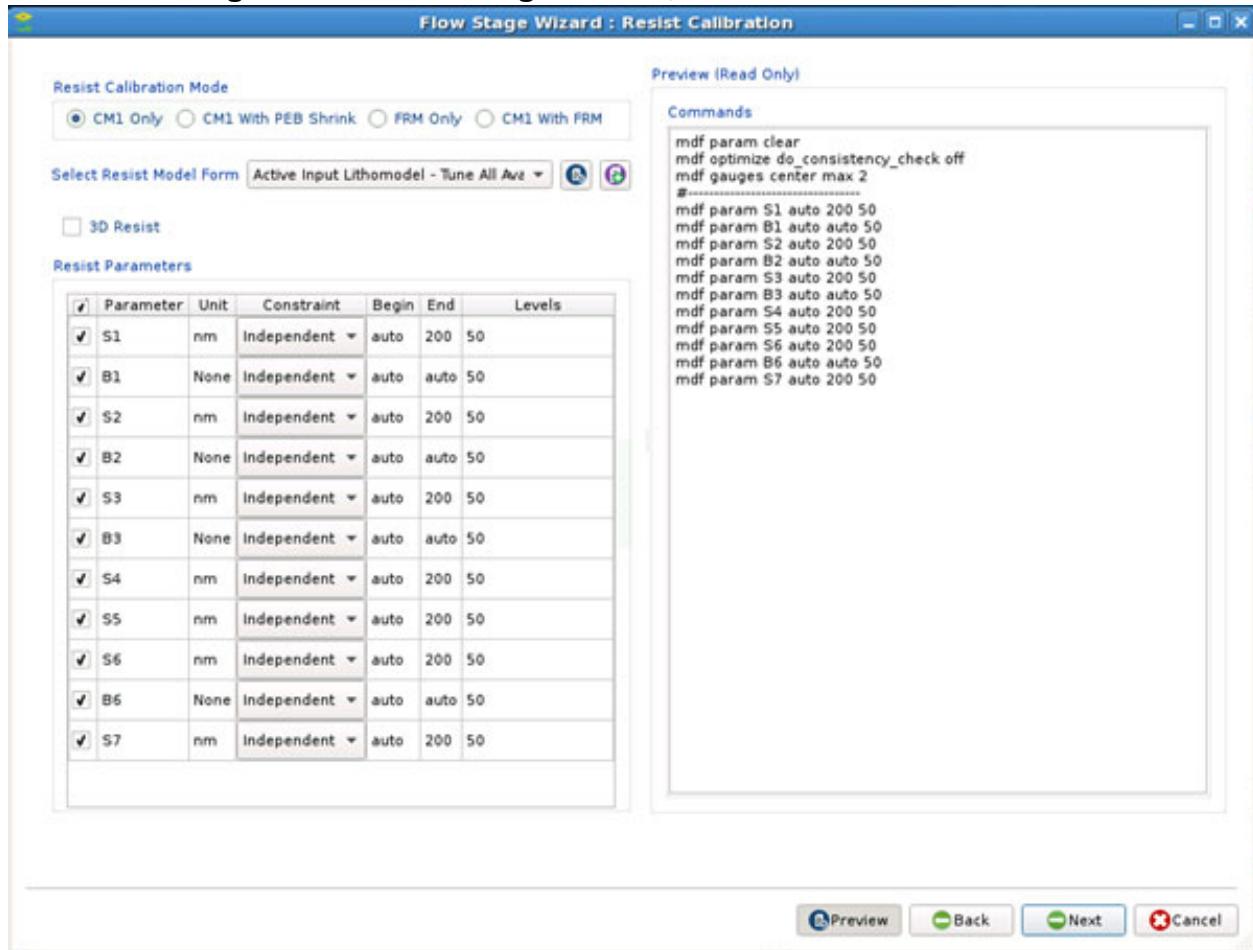
Field	Description
ZPlanes Parameters	Lists the parameters that are calibrated for the ZPlanes model.

## Flow Stage Wizard, Resist Calibration

Stage Wizard dialog box

This wizard appears when you choose the Calibrate option of the Stage Wizard with the Resist check box selected.

**Figure 2-10. Flow Stage Wizard, Resist Calibration Screen**



### Description

This wizard screen displays the resist model parameters that can be tuned. It uses the concept of modelforms, which are selectable model types based on how you would best describe your resist model function. Selecting the resist model adds only relevant parameters and relevant constraints for dependent parameters. See “[Flow Stage Wizard, Optimizer Settings](#)” on page 218 for help with resist-related optimization settings.

## Objects

**Table 2-9. Flow Stage Wizard, Resist Calibration Screen Contents**

Field	Description
Resist Calibration Mode	<p>Use this radio button to switch between modes:</p> <ul style="list-style-type: none"> <li>• <b>CM1 Resist With PEB Shrink</b> — Adds PEB-specific parameters to the wizard.</li> <li>• <b>FRM Only</b> — Fast Resist Model (FRM) calibration only. Used in place of the CM1 resist model.</li> <li>• <b>CM1 With FRM</b> — Calibrates both CM1 and FRM in one of two different Integration Modes:           <ul style="list-style-type: none"> <li>• <b>Sequential</b> — This mode uses the FRM model as an input to the CM1 model instead of the aerial image model. (If the CM1 model is a CTR model, it is the equivalent of FRM Only.)</li> <li>• <b>Parallel</b> — Calibrates the CM1 and FRM models in parallel. The FRM model is added to the CM1 model.</li> </ul> </li> </ul> <p>For more information, see the section “<a href="#">Fast Rigorous Model (FRM) Considerations</a>” on page 107</p>
Select Resist ModelForm	<p>Sets the modelform for the resist model. The modelform you choose sets the contents of the Resist Parameters list.</p> <p><b>i Tip:</b> Clicking the page button on the right of the Select ModelForm field brings up a preview viewer for available modelforms. This viewer is also available from the <b>Help</b> menu.</p>
3D Resist	Selecting this checkbox activates additional options specifically used with 3D Resist modeling. Not available in FRM Only mode.
Resist Parameters	<p>Lists the parameters that are calibrated for the selected model.</p> <p> <b>Note:</b> Not all resist parameters are selectable from the GUI. For a full list of currently supported resist calibration parameters, use the command:</p> <pre>mdf param get resist</pre>

## Usage Notes

By default, resist parameters in a selected resist model are optimized. De-selecting the checkbox uses the nominal value in the calibrated resist model. Changing the selected parameters for calibration is generally not recommended.

### Using “auto” Parameter Settings

When you optimize a resist parameter range using the “auto” setting, the following calculations are used to determine the search range:

- **S-type Parameters** — The resist diffusion length minimal value in nm for a given resist term is set to:
  - 0 — For GTERM\_U if the term is of PEB elastic shrink type, for GTERM\_S (when b=0), and for M term S (when b=0, n=1, and k=0) as long as B remains 0 (is not optimized)
  - 3 \* simpixsize — For all other combinations of M term S, GTERM\_U, and GTERM\_S, as well as for SWBIAS\_S, SWBIAS\_DVSHRINK\_S, SHRINK\_RADIUS, SEM\_SHRINK\_S, SEM\_SHRINK\_R, SHRINK\_DIFFUSION, HBIAS\_S, HBIAS\_D, DISSOLUTION\_SPAN, PATTERN\_DENSITY\_SPAN, ELECTRON\_ABSORPTION\_FOV, MASK\_LOADING\_SPAN, FRM\_TERM\_S, and the EUV resist cases CURVATURE\_D and CURVATURE\_S
  - 6 \* simpixsize — For DUV resist cases of CURVATURE\_D and CURVATURE\_S
- The resist diffusion length maximal value in nm is set to:
  - 50 - for SEM\_SHRINK\_R0, if the minimal value is less than 50, and 100 otherwise
  - 100 - for CURVATURE\_D and CURVATURE\_S, if the minimal value is less than 100, and 200 otherwise
- **B-type Parameters** — The resist dimensionless neutralization-plus (+B) minimal value is set to:
  - 0 — For direct contour-based calibration, as well as for M term B, DONUT\_B, DISSOLUTION\_THRESHOLD, PATTERN\_DENSITY\_THRESHOLD, ELECTRON\_ABSORPTION\_THRESHOLD
  - max{0.1, Bmin} — For HBIAS\_B
- The resist dimensionless neutralization-minus (-B) minimal value is set to:
  - max{0.1, Bmin} — For HBIAS\_B
  - Bmin - for M term B, DONUT\_B, DISSOLUTION\_THRESHOLD, PATTERN\_DENSITY\_THRESHOLD, and ELECTRON\_ABSORPTION\_THRESHOLD
- The resist dimensionless neutralization (both minus and plus) maximal value is set to:
  - Bmax — For M term B, DONUT\_B, DISSOLUTION\_THRESHOLD, PATTERN\_DENSITY\_THRESHOLD, and ELECTRON\_ABSORPTION\_THRESHOLD
  - 2.5 — For HBIAS\_B *value* auto

- $2.4 + \max\{0.1, B_{min}\}$  — For HBIAS\_B auto auto

where:

- $B_{min} = \max\{I_{min}\} + 0.1$ , where  $\max\{I_{min}\}$  is the maximum of the aerial image minima computed along the gauges
- $B_{max} = \max\{I_{max}\}$ , which is the maximum of the aerial image values computed along the gauges

### Useful CLI-Only Commands

Additional commands only available in the CLI dictionary are available for resist calibration:

- **mdf param limitcm1coeff** — Allows the user to limit a linear CM1 coefficient to be within a specified range. The coefficient is determined by CM1 term name and index.

**mdf param limitcm1coeff -name *term\_name* -index *term\_index* -absmax *value***

where:

- **-name *term\_name*** — Is a required argument specifying a CM1 term name. Supported names are:

MCOEF	SCOEF	SHRINK_A
SHRINK_P	SHRINK_AXP	SHRINK_SIDO
SEM_SHRINK_C	SEM_SHRINK_D	SEM_SHRINK_E
SEM_SHRINK_F	HORIZONTAL_BIAS_C	SIDEWALL_BIAS_C
VERTICAL_SHRINK_C	DONUT_KERNEL_C	CURVATURE_C
GTERM_C	DISSOLUTION_C	CROSSTERM_C

- **-index *term\_index*** — Is a required argument specifying a non-negative index of the CM1 term whose coefficient is to be limited.
- **-absmax *value*** — Is a required argument specifying the maximum absolute value of the CM1 coefficient. In order to improve the calibration result while using this command, use “mdf optimize set\_resist constrained\_optimizer on”

You can disable limitcm1coeff settings by executing the command “mdf optimize set\_resist defaults”.

- **mdf optimize set\_resist constrained\_optimizer** — Toggles optimizing CM1 coefficients by using a non-linear constrained optimizer instead of the standard aerial image difference optimizer (default is off). Using this optimizer can be more accurate at the cost of runtime.

Setting “constrained\_optimizer on” improves the calibration of the CM1 Model when CM1 coefficients are constrained by using “mdf param limitcm1coeff.”

**mdf optimize set\_resist constrained\_optimizer on | off**

- **mdf optimize set\_resist maxaidiffweightcol** — Specifies that a user-customized weight column is present in the gauge file by the specified name. This column cannot use a standard gauge column reserved name (such as Drawn, Metch, and so on) and its weight is applied for computing the resist AI difference for the corresponding gauge. You would use this weight column when you want to modify the resist-to-image difference of individual gauges during calibration.

**mdf optimize set\_resist maxaidiffweightcol *name***

#### PEB Shrink Notes

Selecting a CM1 + PEB Shrink creates six calibration jobs (and the stages needed to create them):

- Two calibration jobs (one for each neutralization type at +/- the threshold) using a CTR + PEB Shrink kernel model Calibration and a line/space gauge filter
- Two verification jobs using the above calibration jobs as predecessors with the same input gauges and litho model, but no line/space filter
- Two CM1+PEB Shrink recalibration jobs using the CTR+PEB Shrink calibration jobs as predecessors to see if CM1 improves the model

#### Related Topics

[Creating a Stage With the Flow Stage Wizard](#)

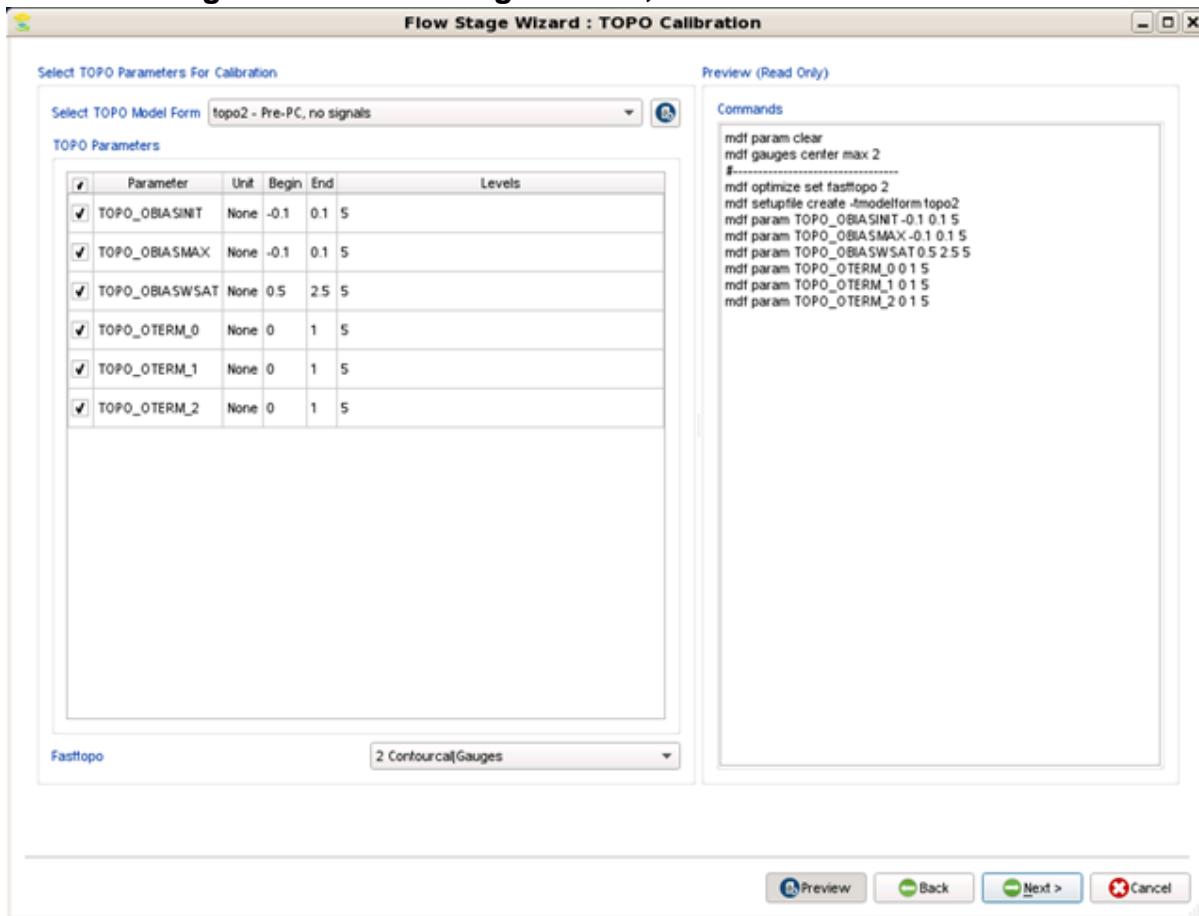
[Flow Stage Wizard, Optimizer Settings](#)

## Flow Stage Wizard, TOPO Calibration

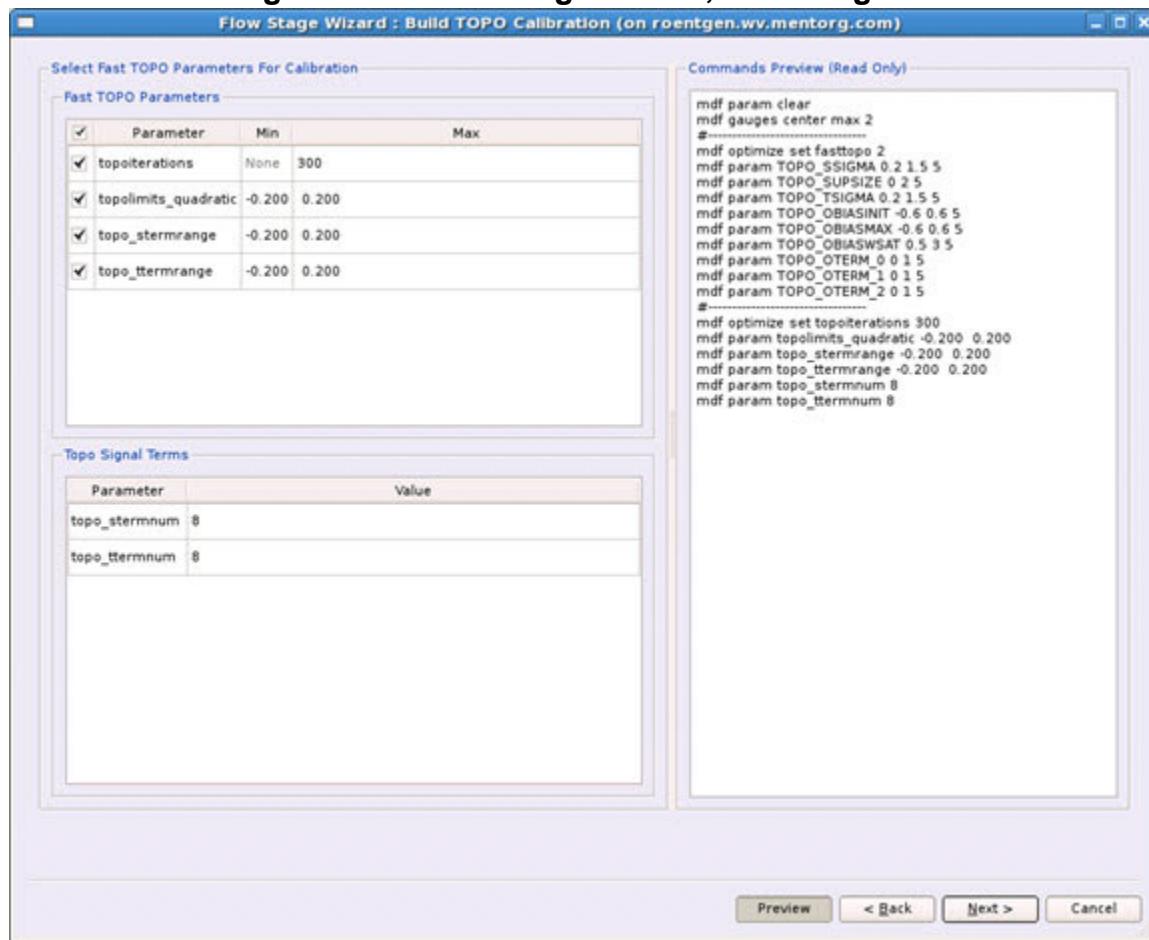
Stage Wizard dialog box

This wizard appears when you choose the Calibrate option of the Stage Wizard with the TOPO check box selected. Additionally, Topo signals terms can be set when the default Fasttopo value is set to 2 (the default).

**Figure 2-11. Flow Stage Wizard, TOPO Calibration Screen**



**Figure 2-12. Flow Stage Wizard, TOPO Signals**



## Description

This wizard screen displays the Topo model parameters that can be tuned. It uses the concept of modelforms, which are selectable model types based on how you would best describe your Topo model function. Selecting the Topo model adds only relevant parameters and relevant constraints for dependent parameters.

## Objects

**Table 2-10. Flow Stage Wizard, TOPO Calibration Screen Contents**

Field	Description
Select TOPO Model Form	Sets the modelform for the Topo model. The modelform you choose sets the contents of the Topo Parameters list.  <b>i Tip:</b> Clicking the page button on the right of the Select ModelForm field brings up a preview viewer for available modelforms. This viewer is also available from the <b>Help</b> menu.
TOPO Parameters	Lists the parameters that are calibrated for the selected model.

**Table 2-10. Flow Stage Wizard, TOPO Calibration Screen Contents (cont.)**

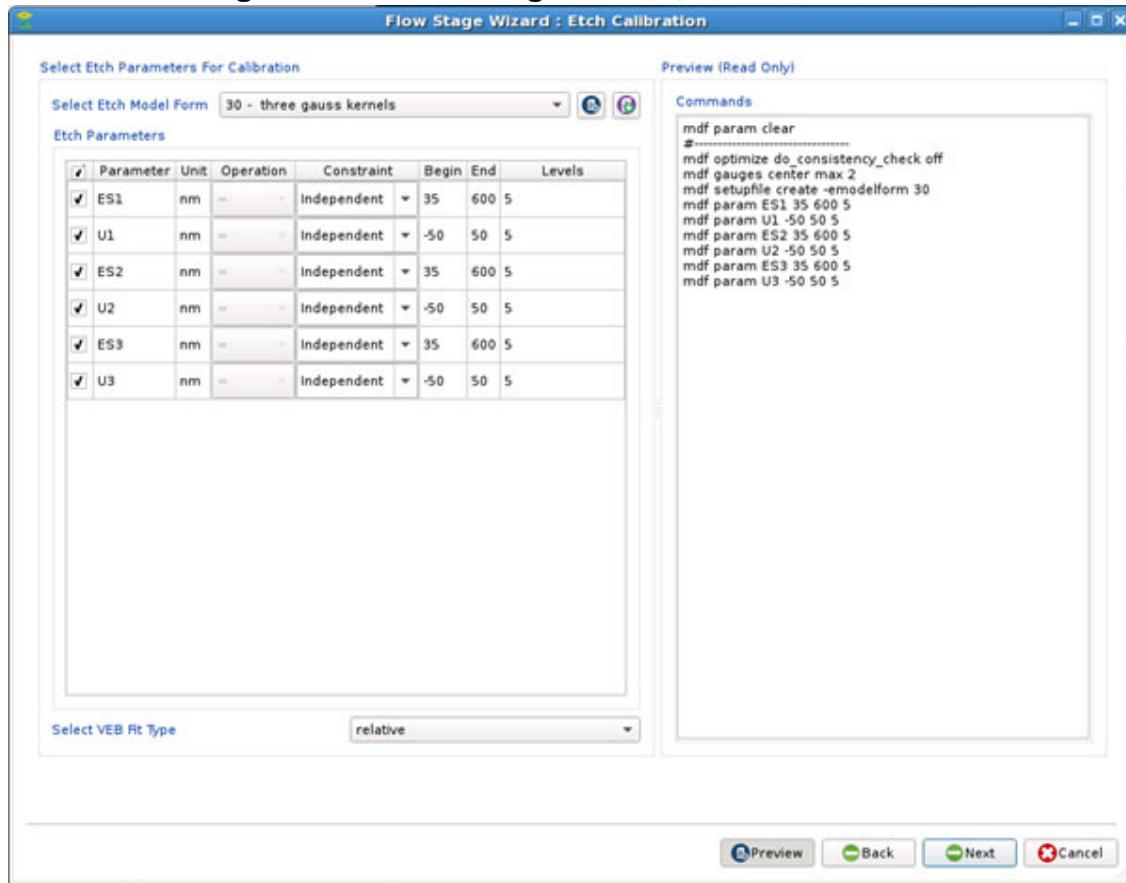
Field	Description
Fasttopo	Sets the Topo calibration algorithm for the stage. Fasttopo 0 selects the explicit Topo signals mode and can be used with gauge and/or contour data. Fasttopo 2 selects the Topo Model form selection mode and can be used only with gauge data.

## Flow Stage Wizard, Etch Calibration

Stage Wizard dialog box

This wizard appears when you choose the Calibrate option of the Stage Wizard with the Etch check box selected.

**Figure 2-13. Flow Stage Wizard, Etch Calibration**



## Objects

**Table 2-11. Flow Stage Wizard, Etch Calibration Screen Contents**

Field	Description
Select Etch Model Form	<p>Sets the modelform for the etch model. The modelform you choose sets the contents of the Etch Parameters list.</p> <ul style="list-style-type: none"> <li>If you activated a litho model prior to opening this screen, you are also given the choice to use the Active Input Lithomodel as the modelform, which tunes all available parameters.</li> <li>Clicking the <b>Preview Etch Modelform</b> button to the right of the Select Etch Model Form field brings up a preview viewer for available modelforms. This viewer is also available from the <b>Help</b> menu.</li> <li>Clicking the Launch VEB Composition button to the far right of the Select Etch Model Form field opens up the custom etch modelform wizard.</li> </ul>
Etch Parameters	<p>Lists the parameters that are calibrated for the etch model. Note that the Operation field only activates if a Constraint is specified as a value other than the default (Independent). The Operation field is used to create a constraint-type dependency between two selected parameters.</p> <p> <b>Note:</b> Not all etch parameters are selectable from the GUI. For a full list of currently supported resist etch parameters, use the command:  <code>mdf param get etch</code></p> <p> <b>Tip:</b> To set a limit on the absolute value of BTERMs during calibration, add the command:  <code>mdf optimize set_etch max_linear_coeff val</code></p>
Select VEB Fit Type	Sets the fitting type used for VEB calibration to relative or absolute.

## Related Topics

[Creating a Stage With the Flow Stage Wizard](#)

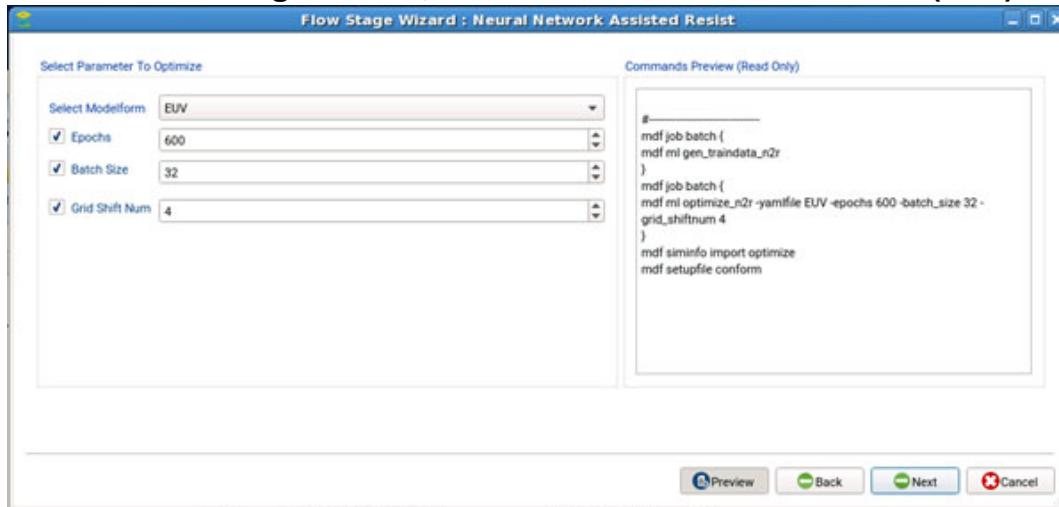
[Flow Stage Wizard, Optimizer Settings With Etch](#)

## Flow Stage Wizard, N2R/N2E Calibration

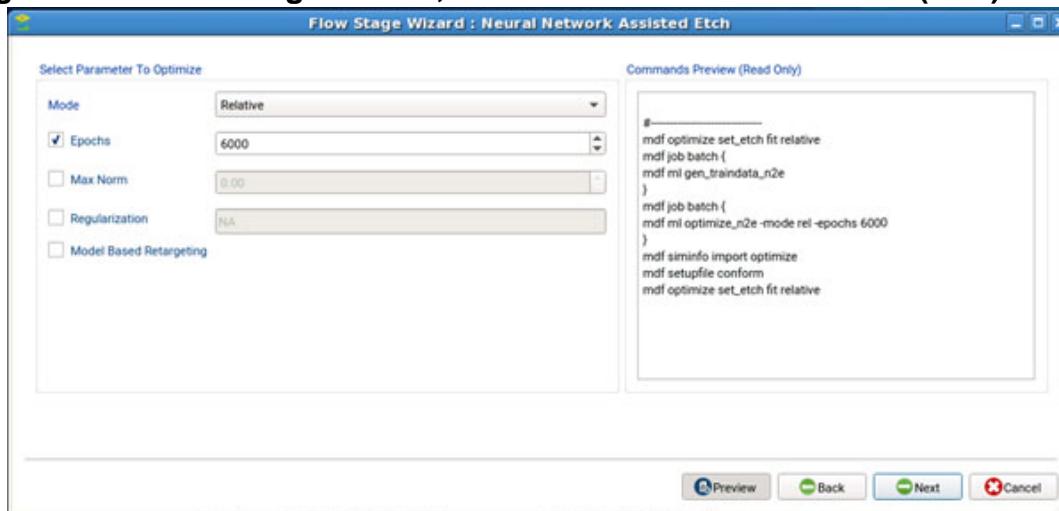
Stage Wizard dialog box

This wizard appears when you choose the N2R or N2E checkboxes in the Calibrate section of the Stage Wizard dialog.

**Figure 2-14. Flow Stage Wizard, Neural Network Assisted Resist (N2R) Screen**



**Figure 2-15. Flow Stage Wizard, Neural Network Assisted Etch (N2E) Screen**



## Objects

Field	Description
Select Modelform	Sets the type of optical model used with this stage.
Epochs	Sets the number of iterations to run. Default is 600 for N2R and 6000 for N2E.
Batch Size	Sets the number of data points before a model is updated.

Field	Description
Grid Shift Num	Sets a data consistency adjustment value.
Mode	Changes the loss function for the optimizer to use a relative loss or absolute loss.
Max Norm	Sets the kernel constraint of the dense layers in the model.
Regularization	Sets the kernel regularizer for the dense layers in the model.
Model-Based Retargeting	Calibrates the stage using the etch-only retargeting algorithm.

## Related Topics

[Training a Machine Learning Model](#)

## Create Custom Etch Model Wizard

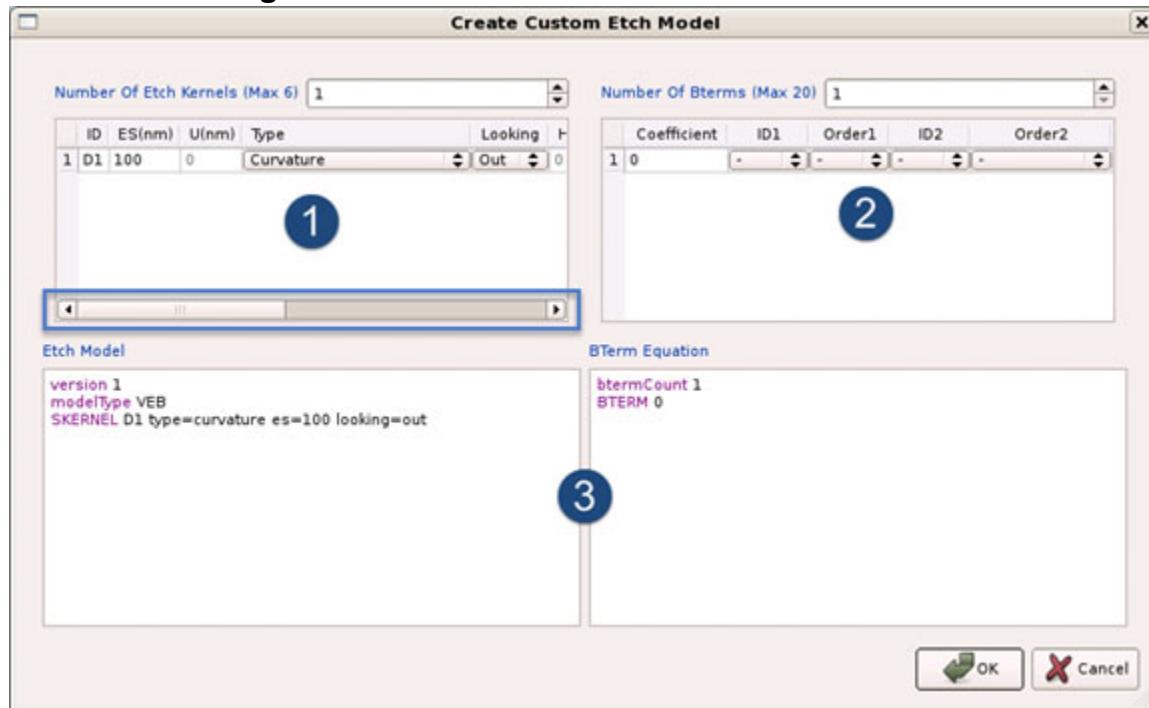
Litho Model Creation wizard

During litho model creation, you have the option to create a custom VEB etch model instead of using the VEB modelform templates.

### Note

 For more information on the VEB etch model terms, see the *Calibre WORKbench User's and Reference Manual*.

**Figure 2-16. Create Custom Etch Model Wizard**



## Objects

**Table 2-12. Create Custom Etch Model Wizard Controls**

Field	Description
1	Density kernel configuration panel.  <b>Note:</b> This text field is wider than the wizard panel. Use the marked scroll bar to see more columns.
2	Bterms configuration panel.
3	Output display panels. Each field you change dynamically modifies the output shown.

## Usage Notes

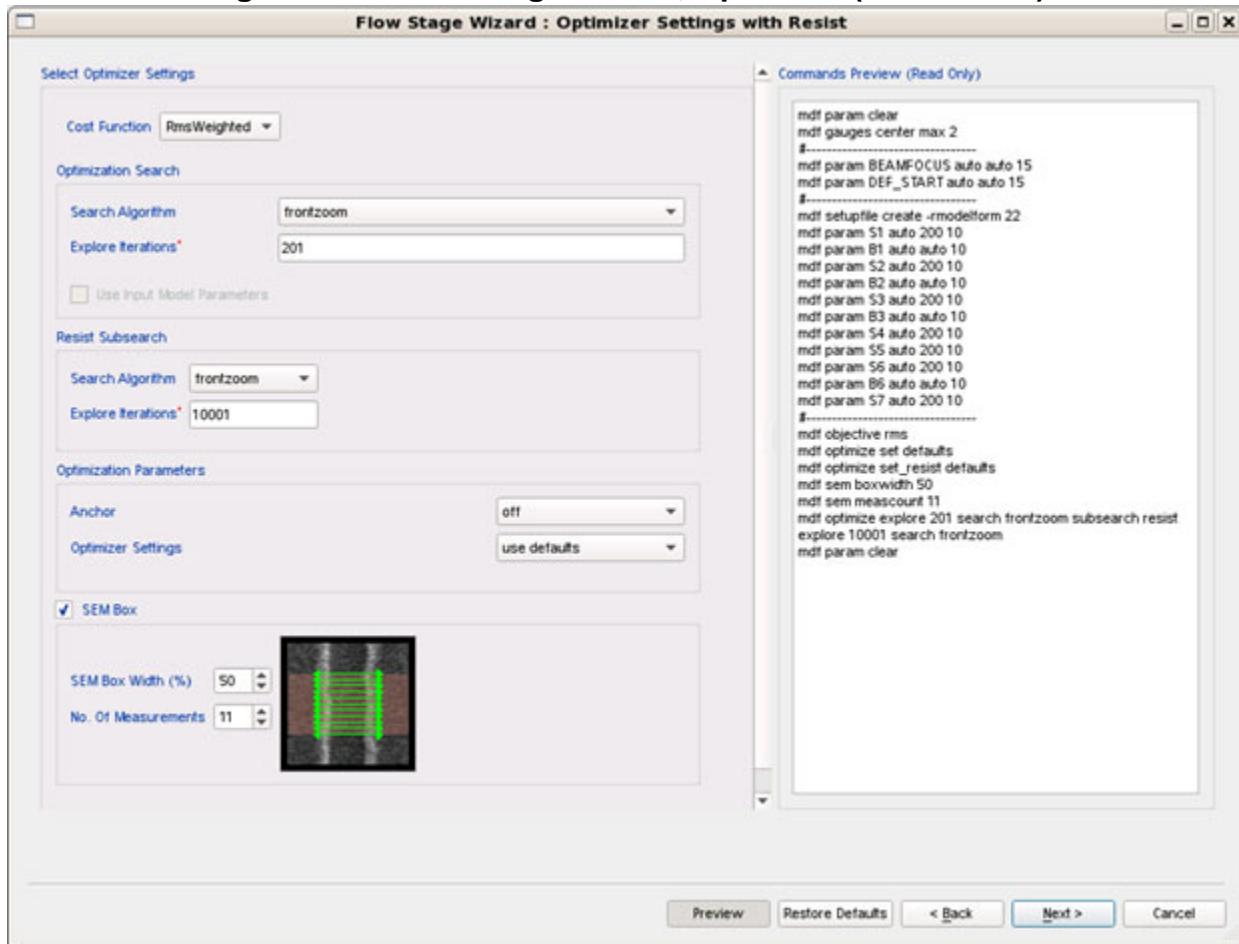
Once you have completed using this wizard, you can use the [Flow Stage Wizard, Etch Calibration](#) tool to load the new custom etch model by selecting the Active Etch Model in the Select Etch Model Form field.

## Flow Stage Wizard, Optimizer Settings

Flow Stage Wizard screen

The Flow Stage Wizard, Optimizer Settings appears as part of the wizard sequence after you select the Calibrate option. It sets the search optimization parameters for calibration.

**Figure 2-17. Flow Stage Wizard, Optimizer (With Resist)**



### Description

The Flow Stage Wizard Optimizer controls the search optimization parameters for optical, mask, and resist models, all of which have separate optimization engines.

### Objects

**Table 2-13. Flow Stage Wizard, Optimizer (With Resist) Contents**

Field	Description
Cost Function	The value that optimization attempts to minimize to find the best fit calibrated model.

**Table 2-13. Flow Stage Wizard, Optimizer (With Resist) Contents (cont.)**

Field	Description
Optimization Search	<p>Controls the type of model optimization search and iterations.</p> <ul style="list-style-type: none"> <li>Some versions of the Optimization Search area may include the Threshold field, which allows you to calibrate with a fixed threshold (the default is to use an optimized threshold).</li> <li>Some Search Algorithm selections (zoom, gradient, pgradient, newton) allow you to select Use Input Model Parameters when Explore Iterations is also set to 0. Use Input Model Parameters ignores the resist modelform selected in the Resist Calibration page and uses the input litho model's resist model for calibration.</li> <li>Selecting one of the Genetic Algorithm search types (ga, moga, gagradient, gapgradient, or pgradient) also adds the Save GA Niches control to the parameters. Deactivating this option speeds up the total elapsed time of the model calibration, but saves less data. This option is deactivated by default.</li> <li>Selecting the moga (Multi-Objective Genetic Algorithm) search type requires selecting a primary and secondary objective.</li> </ul>
Gridshift Consistency Options	<p>Controls additional search parameters when gridshift consistency is selected as a primary or secondary objective for the moga search function.</p> <p>For the gridshift cost function, simulated CDs are computed for several different grid shifts. Three types of objectives are available:</p> <ul style="list-style-type: none"> <li><b>RMS</b> — Available squares of the differences between these CDs and the average CD over all the shifts are added to the total objective</li> <li><b>Tolerance</b> — Error tolerance-based objective of norm 1. Uses the Precision1D and Precision2D settings, which must be positive.</li> <li><b>Percent In-spec</b> — Percentage-based objective. Counts the percentage of gauges that satisfy the gridshift consistency criteria specified using the Precision1D and Precision2D settings.</li> </ul> <p>Running this search adds the column ObjectiveGridShift to the gauge column information. The final report also has “OPTIMIZE total objective” and “OPTIMIZE Gridshift consistency objective” entries.</p>

**Table 2-13. Flow Stage Wizard, Optimizer (With Resist) Contents (cont.)**

Field	Description
Resist Subsearch	<p>Controls the resist model optimization parameters if optics or mask parameters are also being optimized.</p> <p> <b>Note:</b> The Resist Subsearch will not appear under Select Optimizer Settings if Optics or Mask are not selected when creating a stage.</p>
Optimization Parameters	<p>Controls general optimization parameters.</p> <p>Changing the Anchor and Optimizer Settings controls opens up additional option groups.</p> <ul style="list-style-type: none"> <li>• Activating the Anchor parameter requires you to specify an anchor gauge, whose simulated CD is to be kept equal to the measured one while calibrating or building models.</li> <li>• You can also specify which process condition to use for the anchor gauge.</li> <li>• Switching the Optimizer Settings option to “modify defaults” shows all the fields that are relevant to the type of calibration stage being created. The following parameters can be changed:           <ul style="list-style-type: none"> <li>• Resist-To-Image Constraint</li> <li> <b>Note:</b> Disabling this option deactivates the maxaidiff and maxlinear options, because those options relate to using the aerial image to constrain the resist image.</li> <li>• maxaidiff and maxlinear</li> <li>• Horizontal resist calibration</li> <li>• Inequality gauge optimization</li> <li>• thresholdtolerance and thresholdstability</li> <li>• Epsilon</li> <li>• Biasing_type (for VEB)</li> <li>• Ftolerance</li> <li>• Frontparallel</li> </ul> </li> </ul> <p> <b>Tip:</b> In most cases, using the defaults represents the best practices for the current release.</p>
SEM Box	<p>This feature outputs the average critical dimension of the measured shape. The SEM Box Width, which is a percentage of the orthogonal critical dimension listed in column “Other”, can take values from 20 to 100. The number of measurements that can be made range from 1 to 25.</p>

## Usage Notes

The options you selected to optimize for the Calibrate Stage also set how the calibration search is performed.

- **Choosing Mask, Optics, and Resist** — Optimizes the optical, mask model (if selected) and resist model.
  - The optical and mask model calibration uses the search algorithm specified in the Optimization Search area.
  - The resist model calibration uses the objective specified in the Resist Subsearch area.
- **Choosing Optics and Mask Only** — Optimizes the optical model and mask model, and uses the resist model specified in the input lithomodel. The optical and mask model calibration uses the search algorithm specified in the Optimization Search area. The Resist Subsearch area does not appear.

The resist threshold is tuned using the ‘optimize’ setting, but can be changed if you create a threshold stage using the [Flow Stage Wizard, Build Group](#), Threshold Optimize wizard.

- **Choosing Resist Only** — Optimizes the resist model only. The resist model calibration uses the search algorithm specified in the Optimization Search area (instead of the Resist Subsearch area, which does not appear).

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**Note**

 If you create a stage using Resist only calibration, the Explore Iterations field should not be set to a value greater than or equal to 80001 when you select a zoom or frontzoom search algorithm.

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## Related Topics

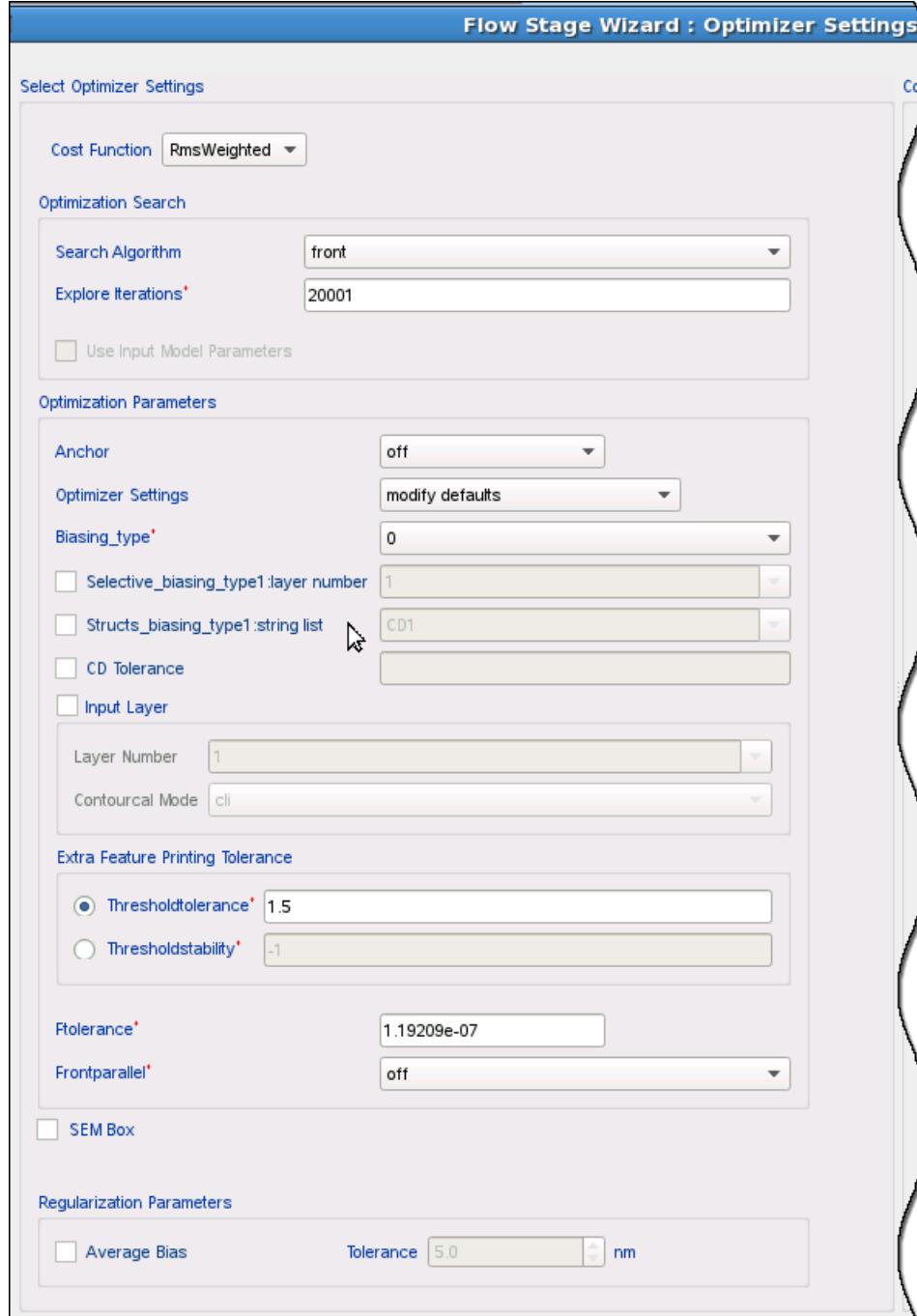
[Creating a Stage With the Flow Stage Wizard](#)

## Flow Stage Wizard, Optimizer Settings With Etch

Flow Stage Wizard screen

This wizard appears as part of the wizard sequence when you have selected the Calibrate Etch option for a stage. It sets the optimization search algorithm for the etch model.

**Figure 2-18. Flow Stage Wizard, Optimizer Settings with Etch**



## Objects

**Table 2-14. Flow Stage Wizard, Optimizer Settings With Etch Contents**

Field	Description
Cost Function	Sets the objective function for the etch optimization. It is handled separately from optics and resist calibration.
Optimization Parameters	<p>Controls general optimization parameters.</p> <p>Changing the Anchor and Optimizer Settings opens up additional option groups.</p> <ul style="list-style-type: none"> <li>Activating the Anchor parameter requires you to specify an anchor gauge, whose simulated etch CD is to be kept equal to the measured one while calibrating or building models.</li> <li>You can also specify which process condition to use for the anchor gauge.</li> <li>Switching the Optimizer Settings option to “modify defaults” allows you to change any of the following values:</li> <li>Biassing_Type — Select 0 for speedier, less accurate calibration, 1 for more accurate calculation, “auto” to detect gauges that need special attention, and “auto active_model” to run auto mode with the active VEB model.</li> </ul> <p><b>i Tip:</b> If you run with Biassing_Type “auto”, gauges that need further inspection are listed in the Job transcript as being set for biassing_type 1. Search for the string “BT1” to find the relevant section.</p> <ul style="list-style-type: none"> <li>Selective_biasing_type1:layer number — Used with Biassing_type 0 to filter certain gauges as biasing_type_1 (more accurate calculations).</li> <li>Structs_biasing_type1:string list — Used with Biassing_type 0 to include specific structures in more accurate calculations. When this option is active, you can select multiple structures using the checkboxes in the list, filter by name using the Filter field at the top, and add specific names using the text field at the bottom of the list.</li> <li>CD Tolerance — Used to set the tolerance threshold in nm for gauges that require additional calibration time.</li> <li>Inputlayer and its related fields (Layer Number and Contourcal Mode) — Used for Direct VEB optimization.</li> <li>Thresholdtolerance and Thresholdstability — Two mutually exclusive tuning parameters, used to set threshold where gauges are considered resolved (by a tolerance distance and range percent, respectively).</li> <li>Ftolerance — Optionally limits the front algorithm tolerance.</li> <li>Frontparallel — Optionally toggles parallel processing for front search mode when activated.</li> </ul> <p><b>i Tip:</b> In most cases, using the defaults represents the best practices for the current release.</p>

**Table 2-14. Flow Stage Wizard, Optimizer Settings With Etch Contents (cont.)**

Field	Description
SEM Box	Selecting SEM Box opens a subsection where you can set the box width and measurements used if you are using a SEM CD measurement algorithm to compute simulated CD values.
Regularization Parameters	Selecting Average Bias and setting a Tolerance causes the calibrated VEB model to use a computed average bias before selecting a final VEB model.

## Usage Notes

In most cases, the “use defaults” option Optimizer Settings should suffice, because it represents the best practices for the current release.

## Related Topics

[Creating a Stage With the Flow Stage Wizard](#)

[Flow Stage Wizard, Etch Calibration](#)

# Flow Stage Wizard, Simulate Group

Wizards in this group simulate CD values for gauges and an associated litho model.

The options in this group only run simulations; they do not do optimization. Use the **Optimize** group to set up optimization operations on associated gauges and litho models.

- **Simulate** — Computes the simulated values for the post-resist gauges.
- **Simulate With Etch** — Computes the simulated values for the post-etch gauges.

Selecting Simulate Gridshift enables additional options to calculate gridshift consistency during the simulation.

- Shiftnum — Enables the -shiftnum optional switch, which sets the number of grid\_shift values uniformly distributed from 0 to shiftmax. The default runs three cases: 0, optical pixel/4, and resist pixel/2.
- Shiftmax — Enables the -shiftmax optional switch, which sets the max range of grid\_shift values in the unit of optical pixel (Nyquist). The default value is 0.5.
- ShiftCM1 — Enables the -shiftcm1 optional switch. It sets resist pixels as the shift unit rather than optical pixels.
- -cm1term — An optional switch that is added on the Finish page for the stage. It calculates gridshift results for the CM1 terms as well as the default.
- -imagegrid *n d* — An optional switch that is added on the Finish page for the stage. It computes gridshift data using the imagegrid aerial settings specified. The switch accepts *n* values of 1, 2, or 3, and *d* values of 1, 2, 3, 4, or 8.

## Flow Stage Wizard, Center Focus Group

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Wizards in this group adjust the beamfocus and defocus start parameters to find the best focus values for one or more process window conditions.

<b>Flow Stage Wizard, Defocus Start Search and Center Focus on Through-Focus Data</b>	<b>226</b>
<b>Flow Stage Wizard, Defocus Start Search and Center Focus on Nominal Data .....</b>	<b>229</b>
<b>Flow Stage Wizard, Center Focus By Bossung Adjust on Through-Focus Data.....</b>	<b>232</b>
<b>Flow Stage Wizard, Center Focus By Bossung Adjust on Nominal Data .....</b>	<b>235</b>

# Flow Stage Wizard, Defocus Start Search and Center Focus on Through-Focus Data

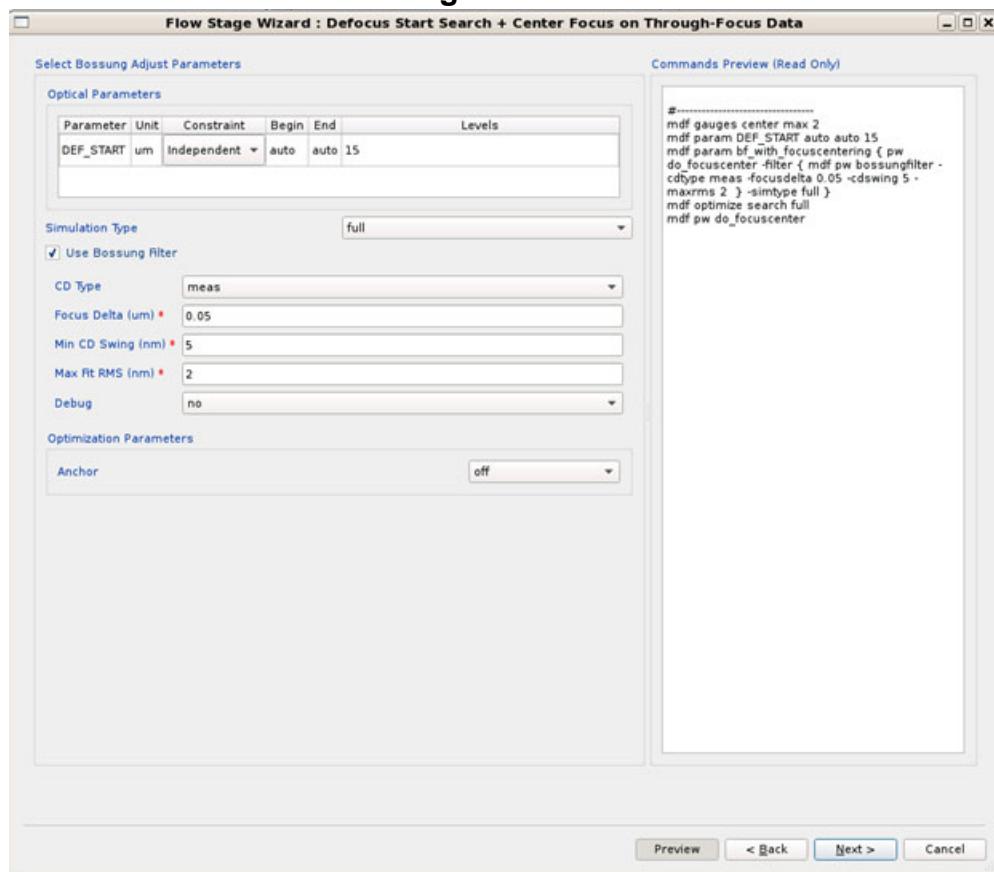
Stage Wizard dialog box

This stage optimizes beamfocus by optimizing defocus\_start independently and then minimizing the mean focus shift. This option is used for process window configurations where the focus center is determined as the parabolic fit to the through-focus CD at each dose.

## Note

 This stage requires input data with at least three defocus conditions. If you do not have sufficient defocus conditions, use the Defocus Start + Center Focus on Nominal Data stage instead.

**Figure 2-19. Flow Stage Wizard, Defocus Start Search and Center Focus on Through-Focus Data**



## Objects

Field	Description
Parameter DEF_START	Sets the defocus parameter (DEF_START) calibration search parameters for the beamfocus subsearch.

Field	Description
Simulation Type	Specifies the simulation type for computing CD values as either the aerial image or full (resist) model. The default is full.
Use Bossung Filter	Unselecting this checkbox instructs the tool to use a simulated mean focus equal to the measured one for all CDs without filtering. Checking the box limits gauges that are simulated to only gauges meeting the filter constraints. The default is to use the filter.
CD Type	Sets which gauge column is used for the focus filtering. <ul style="list-style-type: none"> <li>• meas — Measured resist CDs with full lithomodel. This option also requires a Simulation Type setting of “full”.</li> <li>• sim — Simulated resist CDs with full lithomodel. This option also requires a Simulation Type setting of “full”.</li> <li>• aerial — Uses a CTR image CD. This option also requires a Simulation Type setting of “aerial”.</li> </ul>
Focus Delta (um)	Sets the <i>CD_focus_delta</i> value.
Min CD Swing (nm)	Sets the minimum <i>CD.swing</i> value required to keep the gauge.
Max Fit RMS (nm)	Sets the maximum RMS fitting error to keep the gauge.
Debug	Toggles additional debug columns in the user spreadsheet to provide information about the filtering. It adds the following columns: <code>struc GID Col cd_center f_center maxerr RMS CDswing npoints</code>
Anchor	Optionally allows you to set an anchor gauge, which is a gauge that has its simulated CD kept equal to the measured CD when calibrating and building models. You can select the anchor gauge by its GID or name.

## Usage Notes

This stage includes a Select Optimizer Settings page that appears when you click **Next**. This second page sets the search optimization values for the Defocus Start component of this stage, specifically the following items:

- **Cost Function** — The objective for minimizing the defocus value.
- **Search Algorithm** — The algorithm used to search the gauge data.
- **Explore Iterations** — The maximum number of iterations to perform for the search.

## Related Topics

[Creating a Stage With the Flow Stage Wizard](#)

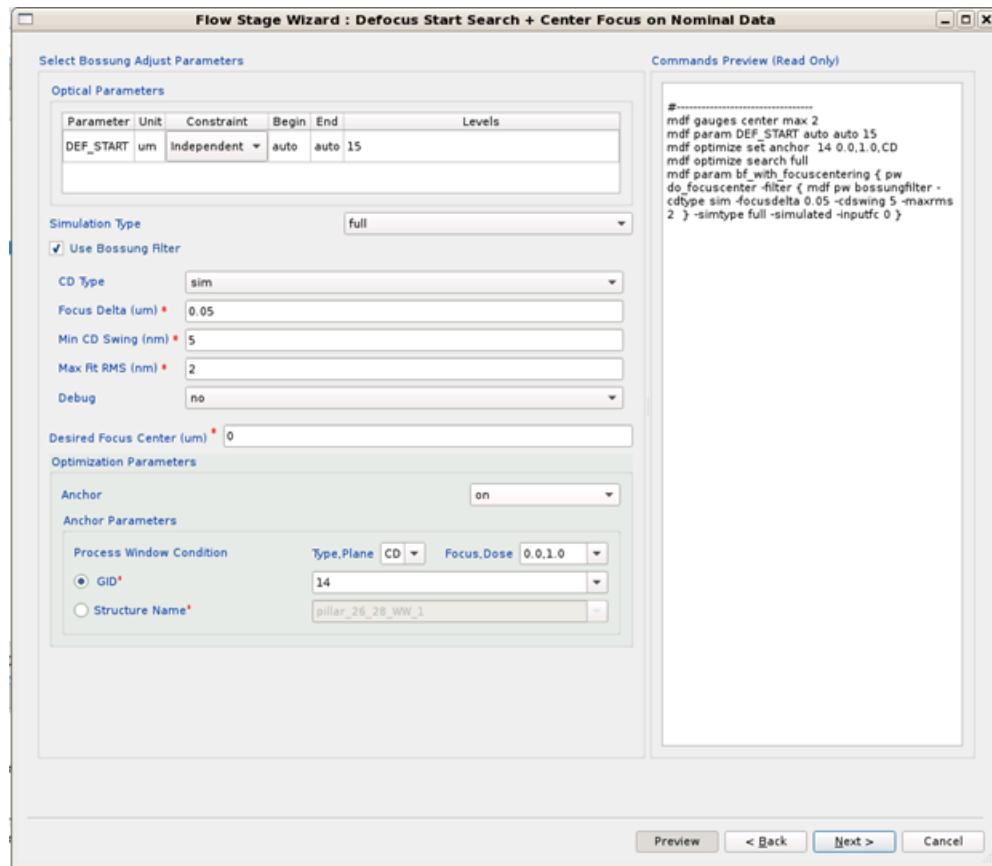
[Flow Stage Wizard, Defocus Start Search and Center Focus on Nominal Data](#)

## Flow Stage Wizard, Defocus Start Search and Center Focus on Nominal Data

Stage Wizard dialog box

This stage optimizes beamfocus by optimizing defocus\_start independently and then minimizing the mean focus shift. This option is used for a single focus condition.

**Figure 2-20. Flow Stage Wizard, Defocus Start Search and Center Focus on Nominal Data**



### Objects

Field	Object
Parameter DEF_START	Sets the defocus parameter (DEF_START) calibration search parameters for the beamfocus subsearch.
Simulation Type	Specifies the simulation type for computing CD values as either the aerial image or full (resist) model. The default is full.

Field	Object
Use Bossung Filter	Unselecting this checkbox instructs the tool to use a simulated mean focus equal to the measured one for all CDs without filtering. Checking the box limits gauges that are simulated to only gauges meeting the filter constraints. The default is to use the filter.
CD Type	Sets which gauge column is used for the focus filtering. <ul style="list-style-type: none"> <li>• sim — Simulated resist CDs with full lithomodel. This option also requires the Simulation Type setting to be “full”.</li> <li>• aerial — Uses a CTR image CD. This option also requires the Simulation Type setting to be “aerial”.</li> </ul>
Focus Delta (um)	Sets the <i>CD_focus_delta</i> value.
Min CD Swing (nm)	Sets the minimum <i>CD.swing</i> value required to keep the gauge.
Max Fit RMS (nm)	Sets the maximum RMS fitting error to keep the gauge.
Debug	Toggles additional debug columns in the user spreadsheet to provide information about the filtering. It adds the following columns:  <pre>struc GID Col cd_center f_center maxerr RMS CDswing npoints</pre>
Desired Focus Center (um)	Sets the desired focus center mean for the stage. By default, defocus 0 is used, but you can use this field to specify an off-focus center.  This setting is needed since there are no measured data outside the nominal focus.
Anchor	Optionally allows you to set an anchor gauge, which is a gauge that has its simulated CD kept equal to the measured CD when calibrating and building models. You can select the anchor gauge by its GID or name.

## Usage Notes

This stage includes a Select Optimizer Settings page that appears when you click Next. This second page sets the search optimization values for the Defocus Start component of this stage, specifically the following items:

- **Cost Function** — The objective to minimize the defocus value for.
- **Search Algorithm** — The algorithm used to search the gauge data.
- **Explore Iterations** — The maximum number of iterations to perform for the search.

## Related Topics

[Creating a Stage With the Flow Stage Wizard](#)

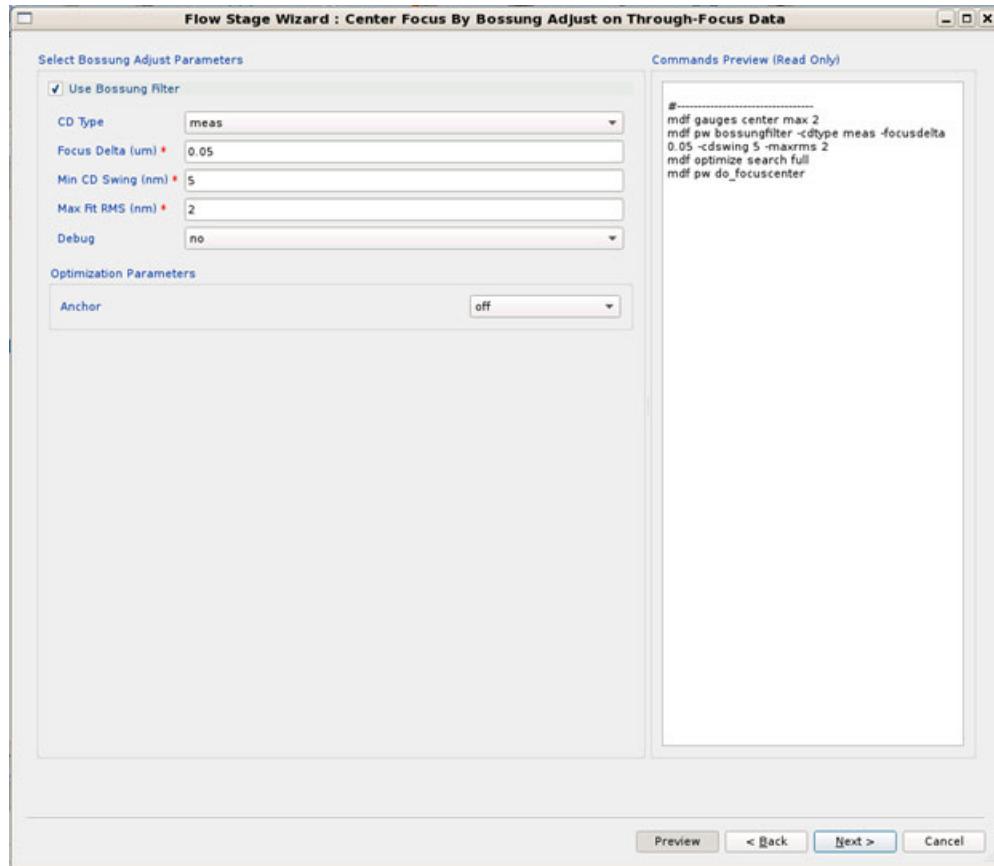
[Flow Stage Wizard, Defocus Start Search and Center Focus on Through-Focus Data](#)

## Flow Stage Wizard, Center Focus By Bossung Adjust on Through-Focus Data

Stage Wizard dialog box

This wizard appears when you choose either the Center Focus By Bossung Adjust on Through-Focus Data option in the Stage Wizard.

**Figure 2-21. Flow Stage Wizard, Center Focus By Bossung Adjust on Through-Focus Data**



### Description

This stage is used with process window data to match the focus center of measured and simulated CD data. If Use Bossung Filter is selected, this stage first reduces the number of gauges according to the Bossung filter conditions you specify to obtain only focus sensitive data.

At least three additional focus conditions with a CD value greater than 0 must exist in the process window data set for this stage to function. In order for a gauge to be retained, it must pass both the following criteria:

- $|CD\_center - CD\_focus\_delta| > Min\ CD\ Swing$

where

- $CD\_focus\_delta$  is the CD value from the parabola fitted to the data, calculated at Focus = focuscenter + focusdelta
- $CD\_center$  is the CD from the parabola fitted to the data, calculated at Focus = focuscenter
- $Min\ CD\ Swing$  is the user-defined input criteria for the filter.
- $curRMS < Max\ Fit\ RMS$

$curRMS$  uses the formula  $\sqrt{\sum (CD - CDfit)^2 / N}$

where

- $N$  is the number of CD values through focus
- $CD$  is the CD value (using the CD Type) at the given focus
- $CDfit$  is the CD from the parabola fitted to the data at the given focus
- $Max\ Fit\ RMS$  is the user-defined input criteria for the filter.

## Objects

**Table 2-15. Flow Stage Wizard, Center Focus By Bossung Adjust on Through Focus Data Contents**

Field	Description
Use Bossung Filter	Unselecting this checkbox just uses the averaged focus center for all CDs without filtering.
CD Type	Sets which gauge column is used for the focus filtering. <ul style="list-style-type: none"> <li>● meas — Measured resist CDs with a litho model.</li> <li>● sim — Simulated resist CDs with a litho model.</li> <li>● aerial — Uses a CTR image CD.</li> </ul>
Focus Delta (um)	Sets the defocus range over which the filtering is performed.
Min CD Swing (nm)	Sets the minimum $CD\_swing$ value required to keep the gauge.
Max Fit RMS (nm)	Sets the maximum RMS fitting error to keep the gauge.
Debug	Toggles additional debug columns in the user spreadsheet to provide information about the filtering. It adds the following columns: <pre>struc GID Col cd_center f_center maxerr RMS CDswing npoints</pre>
Anchor	Optionally allows you to set an anchor gauge, which is a gauge that has its simulated CD kept equal to the measured CD when calibrating and building models. You can select the anchor gauge by its GID or name.

## Related Topics

[Creating a Stage With the Flow Stage Wizard](#)

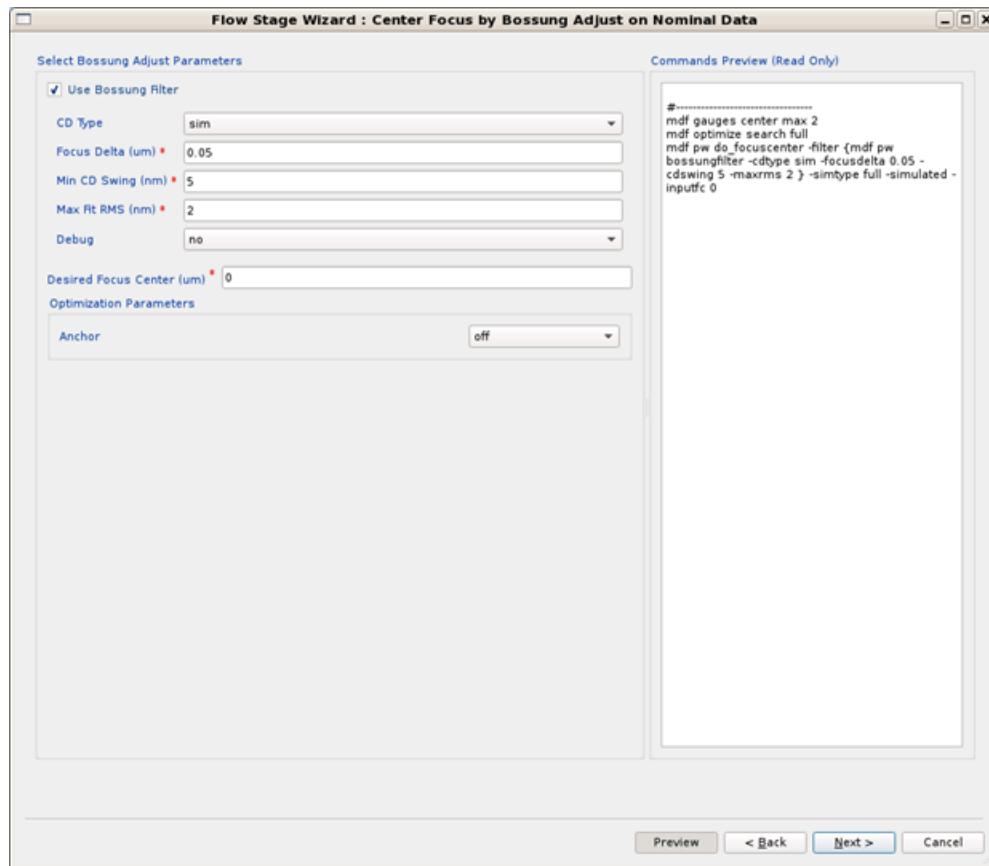
[Flow Stage Wizard, Center Focus By Bossung Adjust on Nominal Data](#)

## Flow Stage Wizard, Center Focus By Bossung Adjust on Nominal Data

Stage Wizard dialog box

This wizard appears when you choose the Center Focus By Bossung Adjust on Nominal Data option of the Stage Wizard.

**Figure 2-22. Flow Stage Wizard, Center Focus By Bossung Adjust on Nominal Data**



### Description

This stage is used with nominal data to match the focus center of simulated CD data to a user-specified defocus. If Use Bossung Filter is selected, this stage first reduces the number of gauges according to the Bossung filtering conditions you specify to obtain focus-sensitive data.

## Objects

**Table 2-16. Flow Stage Wizard, Center Focus - Bossung Adjust on Nominal Data**

Field	Description
Use Bossung Filter	Unselecting this checkbox just uses the averaged focus center for all CDs without filtering.
CD Type	Sets which gauge column is used for the focus filtering. <ul style="list-style-type: none"><li>• meas — Measured resist CDs with full lithomodel.</li><li>• sim — Simulated resist CDs with full lithomodel.</li><li>• aerial — Uses a CTR image CD.</li></ul>
Focus Delta (um)	Sets the <i>CD_focus_delta</i> value.
Min CD Swing (nm)	Sets the minimum <i>CD.swing</i> value required to keep the gauge.
Max Fit RMS (nm)	Sets the maximum RMS fitting error to keep the gauge.
Debug	Toggles additional debug columns in the user spreadsheet to provide information about the filtering. It adds the following columns: <code>struc GID Col cd_center f_center maxerr RMS CDswing npoints</code>
Desired Focus Center (um)	Sets the desired focus center mean for the stage. By default, defocus 0 is used, but you can use this field to specify an off-focus center. This setting is needed since there are no measured data outside the nominal focus.
Anchor	Optionally allows you to set an anchor gauge, which is a gauge that has its simulated CD kept equal to the measured CD when calibrating and building models. You can select the anchor gauge by its GID or name.

## Related Topics

[Creating a Stage With the Flow Stage Wizard](#)

[Flow Stage Wizard, Center Focus By Bossung Adjust on Through-Focus Data](#)

# Flow Stage Wizard, Build Group

Wizard stages in this group optimize and build results using the litho model specified for the stage.

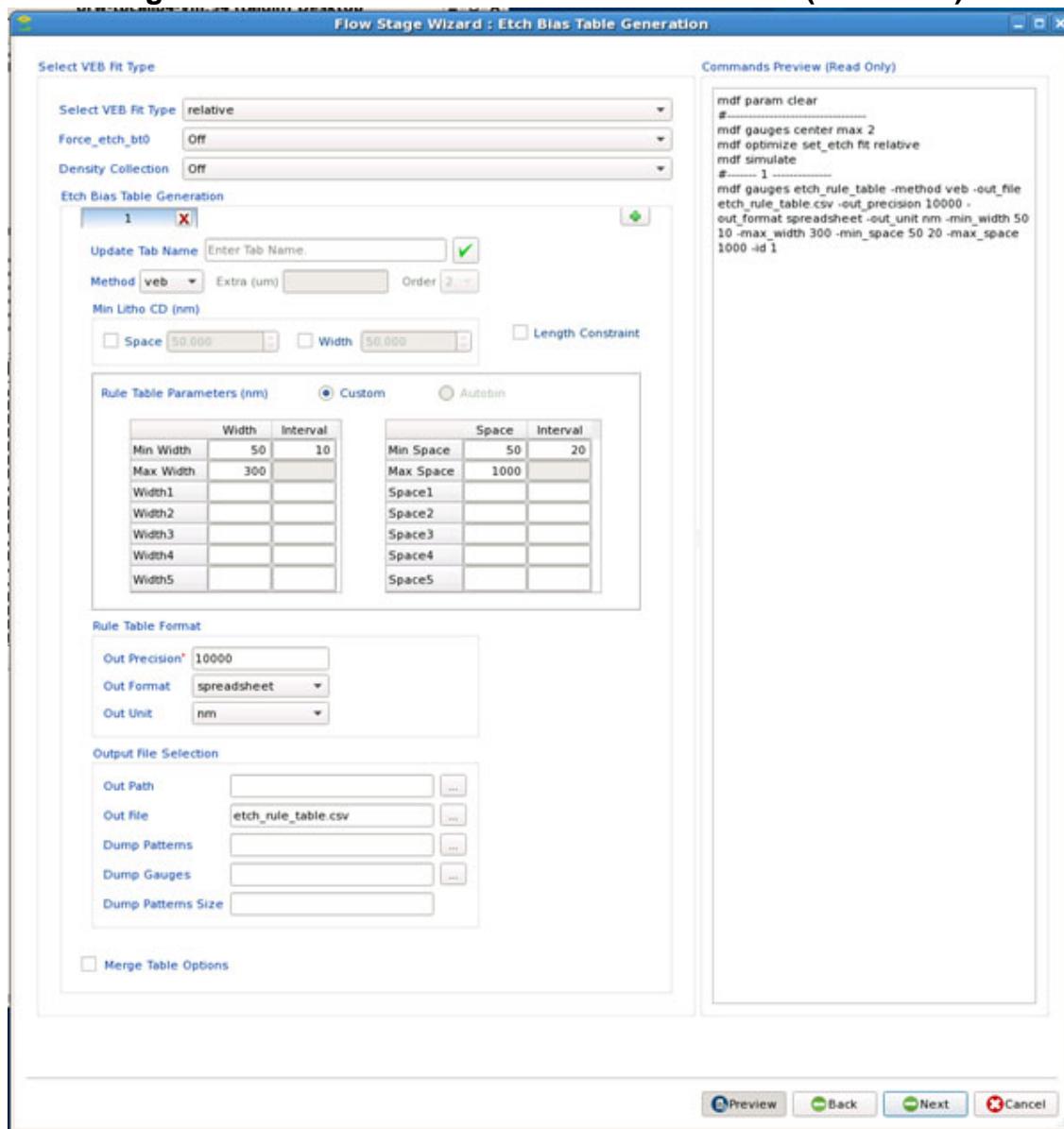
CTR Threshold Optimize — Optimizes the resist threshold for a constant threshold resist (CTR) model.

- **Threshold Optimize** — Optimizes the resist threshold for the resist model. Two options are available:
  - **Optimize** — Uses a 1D search to find the best threshold.
  - **Auto** — Uses an internal optimization search to find the minimum RMS error value.
- **Build Resist** — Tunes the linear coefficients and threshold for the resist model.
- **Build Etch** — Tunes the linear coefficients of the etch model. You can choose between a relative (difference between simulated and measured etch versus resist) or absolute (difference between simulated and measured etch CD) fitting analysis.
- **Stochastic Optimize** — Optimizes a stochastic parameter (Physical Dose, Resist Efficiency, or Diffusion Length) for the resist model.

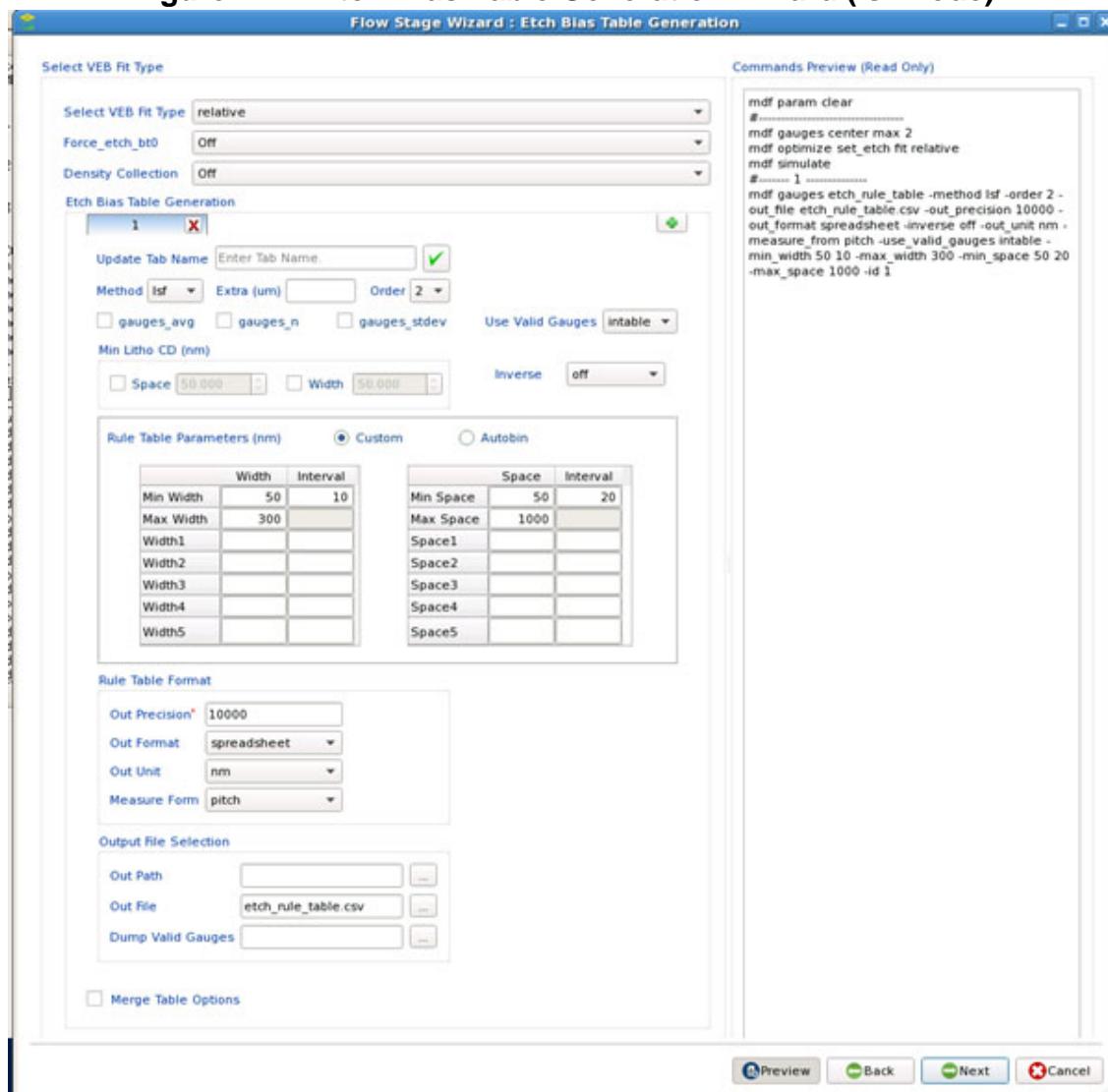
## Flow Stage Wizard, Etch Bias Table Generation

An etch bias table is used by the Calibre nmBIAS BIASRULE command to move edge fragments based on their critical dimension measurement during OPC. Calibre nmModelflow uses the Etch Bias Table Generation wizard to create tables based on your input.

**Figure 2-23. Etch Bias Table Generation Wizard (veb Mode)**



**Figure 2-24. Etch Bias Table Generation Wizard (lsf Mode)**



## Description

Two types of etch bias tables can be generated by the Etch Bias Table Generation Wizard. The mode is specified using the Method option.

## Objects

Field	Description	Available in Method
Select VEB Fit Type	Sets the error statistic computation method as <u>relative</u> (difference between simulated and etch bias, the default) or absolute (difference between simulated and measured etch CD).	both

<b>Field</b>	<b>Description</b>	<b>Available in Method</b>
Force_etch_bt0	Sets the speed toggle for VEB calibration to be <u>off</u> or on.	both
Density Collection	Generates a VEB model density spreadsheet.	both
Update Tab Name	Changes the auto-generated tab name for the active tab.	both
Method	Choose veb or lsf to set the mode for the GUI.	both
Extra	Sets the extra search radius for gauges.	lsf
Order	Sets the equation polynomial order. The recommended value is 2.	lsf
Length Constraint	Adds a Length constraint parameter table to the interface.	veb
gauges_avg	Output cell values in the bias table contain the average bias value of gauges in the space and width bins.	lsf
gauges_n	Output cell values in the bias table contain the number of gauges that are in the space and width bins.	lsf
gauges_stdev	Output cell values contain the standard deviation bias of gauges in the space and width bins.	lsf
Use Valid Gauges	Setting this to “intable” causes the generator to use only gauges with a computed width between the min and max width and space ranges.  A setting of “all” includes all computed table values in the output.	lsf
Inverse	Uses the inverse value for fitness checks: (1/width and 1/space)  Intended for use with ISO lines.	lsf
Min Litho CD (nm)	Selecting Space and Width checkboxes sets the minimum allowed litho CD for the space and width of the table, respectively.	both
<b>Rule Table Parameters</b>		

Field	Description	Available in Method
Custom / Autobin	Selecting Autobin instructs the generator to automatically create the bins based on the input gauges. Enabling Set Boundary Limits lets you set the width and space to values smaller than the boundaries of the gauge set.	lsf
Min Width	Specifying Width and Interval values for this field sets the starting value and default step interval for width bins.	both
Max Width	Setting Width values for this field sets the ending value for width bins.	both
Width1 - Width 5	Setting Width and Interval values for this field defines differently-sized width bins for ranges within Min to Max values.	both
Min Space	Setting Space and Interval values for this field sets the starting value for space bins and the default interval for bins.	both
Max Space	Setting Space values for this field sets the ending value for space bins.	both
Space1- Space5	Setting Space and Interval values for this field defines differently-sized space bins for ranges within Min to Max values.	both
Min Length	Setting Length and Interval values for this field sets the starting value for length bins and the default interval for the bins.	veb
Max Length	Setting Length values for this field sets the ending value for length bins.	veb
Length1 - Length5	Setting Length and Interval values for this field defines differently-sized length bins for ranges within Min to Max values.	veb
<b>Rule Table Format</b>		
Out Precision	Sets the bias value to match with the design precision on correction.	both
Out Format	Sets the output format as spreadsheet (for use with external programs) or nmbias and biasrule (for use with Calibre nmBIAS).	both
Out Unit	Sets the units for the table cells as nm or um.	both

Field	Description	Available in Method
Biasrule Metric	Sets the metric type for the biasrule output format option.	both, requires Out Format setting of “biasrule”
Measure From	Specifies where the measurements for the gauges should be taken from (layout, pitch, or gaugetable).	lsf
Out Path	Sets the output path for the file. The default is the directory from which Calibre nmModelflow was invoked.	both
Out File	Sets the output filename. The default is “ <i>etch_rule_table.csv</i> ”.	both
Dump Patterns	Writes the generated patterns for the etch table to an OASIS file.	veb
Dump Gauges	Writes the related gauge file for the dumped pattern file to the specified filename.	veb
Dump Patterns Size	Specifies the dumped pattern test structure size in nm. The default is 6 um.	veb
Dump Valid Gauges	Specifies that only valid gauges sorted from 1D structures are output to the rule table.	lsf
Merge Table Options	Opens an additional section to handle the output of multiple tabs.	both

## Related Topics

[Creating a Stage With the Flow Stage Wizard](#)

[Creating an Etch Bias Rule Table](#)

[Combined and Unified Etch Bias Tables](#)

# Contour Analysis Tab

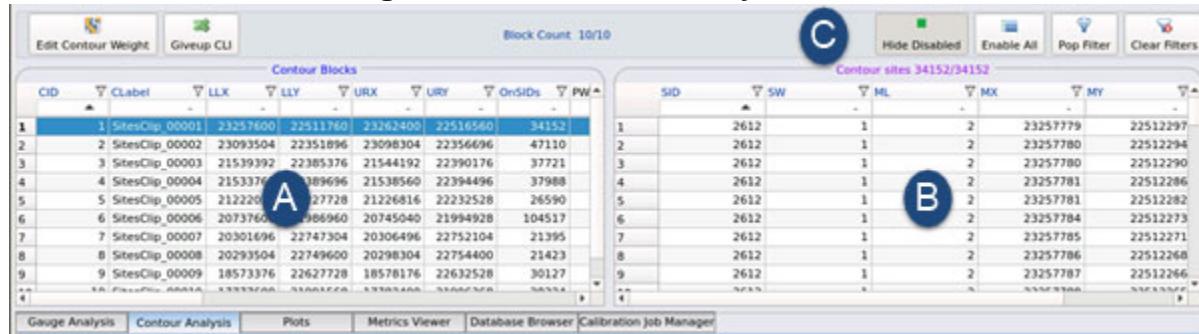
Calibre nmModelflow Main window primary display tab

The **Contour Analysis** tab displays and allows you to manipulate the active contour object.

## Description

Contours differ from gauges in that a contour object is based off of a file in [Contour Layer Info \(CLI\) File Format](#) or a CSV file for contour sites (described in the “[Sites CSV File Guidelines](#)” section).

**Figure 2-25. Contour Analysis Tab**



## Objects

**Table 2-17. Contour Analysis Controls**

Field	Description
A	<p>Contour Blocks list for the active dose and focus. Each block in the Contour Layer Info file is tracked independently and can be enabled or disabled as needed.</p> <p>The context menu contains the following options:</p> <ul style="list-style-type: none"> <li>• <b>Delete / Delete All From Pw</b></li> <li>• <b>Enable / Enable All PW</b></li> <li>• <b>Disable / Disable All PW</b></li> <li>• <b>Cross Probe</b></li> <li>• <b>Highlight / Unhighlight / Unhighlight All</b></li> </ul>
B	Sites list for the selected block. Individual sites can be enabled or disabled as needed.
C	<ul style="list-style-type: none"> <li>• Controls that hide or enable sites.</li> <li>• Controls that remove filters applied with the “mdf filter apply” CLI command.</li> </ul>

## Usage Notes

- Clicking **Giveup CLI** instructs Calibre nmModelflow to forget the loaded CLI definitions and renumber the SID list in order.

- The columns in the **Contour Analysis** tab have the following definitions:
  - CID — The block ID (a block or a clip, typically corresponding to a SEM field of view)
  - CLabel — A block label (in the CSV, this is a text string without a comma or semi-colon in between)
  - LLX — The block's lower-left X coordinate in layout dbu
  - LLY — The block's lower-left Y coordinate in layout dbu
  - URX — The block's upper-right X coordinate in layout dbu
  - URY — The block's upper-right Y coordinate in layout dbu
  - Focus — The process condition's focus
  - Dose — The process condition's dose
  - SID — The site's ID
  - SW — The site's weight
  - ML — The site's measurement type: 2 for resist, 3 for etch
  - MX — The measurement site X in layout dbu
  - MY — The measurement site Y in layout dbu
  - OnSIDs — The number of “live” SIDs, defined as sites with positive weight

#### Sites CSV File Guidelines

- The Sites CSV file is an alternative to the Contour Layer Information file. It is a CSV format file. It uses semicolons or commas as separators, is case sensitive, cannot have empty cells, and starts comment lines with #.
- The first non-comment line specifies the column definitions. It can contain items from the list above in any order. This first row specifies the order for the data in the file.
- The simplest input CSV only requires two data columns (MX and MY).

Use this format to describe a single SEM image for a resist measurement at the nominal dose and focus. Internally, Calibre nmModelflow automatically generates the rest of the columns listed above (SID, and so on) when you load the file.

- Additional columns can be used to describe one or more blocks, sites at one or more dose and focus conditions, or sites for etch measurement. This is referred to as the “extended format.”
  - The CID, Clabel, LLX, LLY, URX, and URY items are optional. Add these data columns only when you define additional blocks. If you do not define the coordinates of a block (using the LLX, LLY, URX, and URY fields), Calibre nmModelflow generates it using the sites in the given CID plus a 50 dbu halo.

- Similarly, the PWID, PW, Focus, and Dose items are optional if you only have a nominal dose and focus condition.
- Add the ML column if you have measurement data for etch or if you have both resist and etch data. Acceptable values for ML columns are 2 (resist) and 3 (etch).

## Related Topics

[Loading Contours](#)

## Plot-Related GUIs

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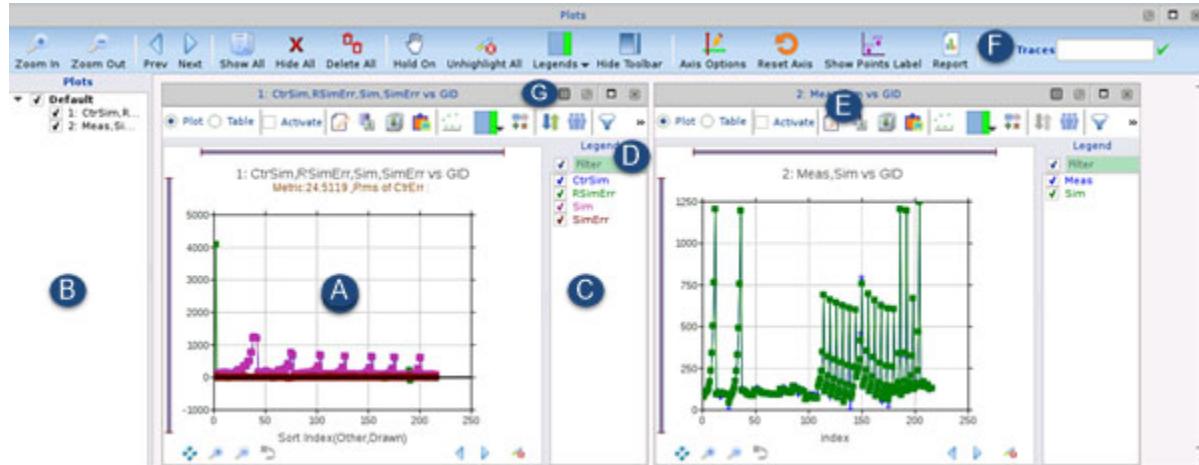
<b>Plots Tab .....</b>	<b>247</b>
<b>Plot Wizard, Gauge Data .....</b>	<b>252</b>
<b>Plot Wizard, Contour Data Plot .....</b>	<b>256</b>
<b>Plot Wizard, Cutline Plot .....</b>	<b>258</b>
<b>Plot Wizard, Bossung-Type Plots .....</b>	<b>260</b>
<b>Plot Wizard, Contour Plot .....</b>	<b>263</b>

## Plots Tab

Calibre nmModelflow Main window primary display tab

The **Plots** tab shows selected data traces for gauge information columns in a visual format. Multiple plots can be displayed.

**Figure 2-26. Plots Tab**



### Description

Plots are either created automatically by calibration jobs (from a successful run in the [Calibration Job Manager](#)) or by being activated from the Plots group in the Database Browser.

To create a plot, see the task “[Creating a Custom Plot](#).”

### Objects

**Table 2-18. Plot Viewer Controls**

Field	Description
A	<p>Plot viewer. Plot views appear in the main area of the window once activated, or after a successful calibration run.</p> <ul style="list-style-type: none"> <li>• Each plot has its own set of filtering and viewing controls.</li> <li>• Drawing a box around points in the plot selects the corresponding gauges in the <b>Gauges</b> tab.</li> <li>• Right-clicking on gauges in the plot viewer displays options to manipulate gauge data directly from the viewer.</li> </ul>
B	Plot selector. Only plots that are checked in this list are shown in the Plot viewer.
C	Traces selector. Only data sets that are checked in this list are shown in the related plot view.

**Table 2-18. Plot Viewer Controls (cont.)**

Field	Description
D	<p>Filter. Entering a string in this field retains only plot traces that contain the string in their legend name. Clearing the field restores the list of traces to the view.</p> <p>Note that you can use the trace filter to either show or exclude a set of filters by first selecting only filters with a specific string, then toggling the checkbox next to the Legend title.</p>
E	<p>Plot level controls. These buttons appear in every plot view, and control only items in that view. The controls appear in the following order:</p> <ul style="list-style-type: none"> <li>• <b>Plot/Table</b></li> <li>• <b>Activate</b></li> <li>• <b>Edit Plot</b></li> <li>• <b>Add Plot to Database</b></li> <li>• <b>Save Plot</b></li> <li>• <b>Copy Plot to Clipboard</b></li> <li>• <b>Remove Connecting Lines</b></li> <li>• <b>Change Visibility / Position of Legends</b></li> <li>• <b>Change Markers Style</b></li> </ul> <p><b>i Tip:</b> Setting the Marker Size to zero will hide a marker, if you need to see other markers occupying the same space.</p> <ul style="list-style-type: none"> <li>• <b>Apply/Remove Gauge Sorting</b></li> <li>• <b>Apply Plot Grouping</b></li> </ul> <p><b>i Tip:</b> Applying Plot Grouping for a SimErr scatter plot when the Group column is defined in the active gauge object can display the groups in a single consolidated graph.</p> <p><b>i Tip:</b> The <b>Settings &gt; Plot Settings</b> menu option allows you to group gauges with similar structure names together (matching up to the specified number of starting letters). Any gauges that have less than 1% of the gauge count are put into a “Misc” group.</p> <ul style="list-style-type: none"> <li>• <b>Apply / Remove Filters</b></li> <li>• <b>Refresh the Plot</b></li> <li>• <b>Hold On/Off Active Plot</b></li> <li>• <b>Format Axis Options</b></li> <li>• <b>Reset Axis Range</b></li> <li>• <b>Show Points Label</b></li> <li>• <b>Delete Plot</b></li> <li>• <b>Delete All Plots</b></li> </ul>

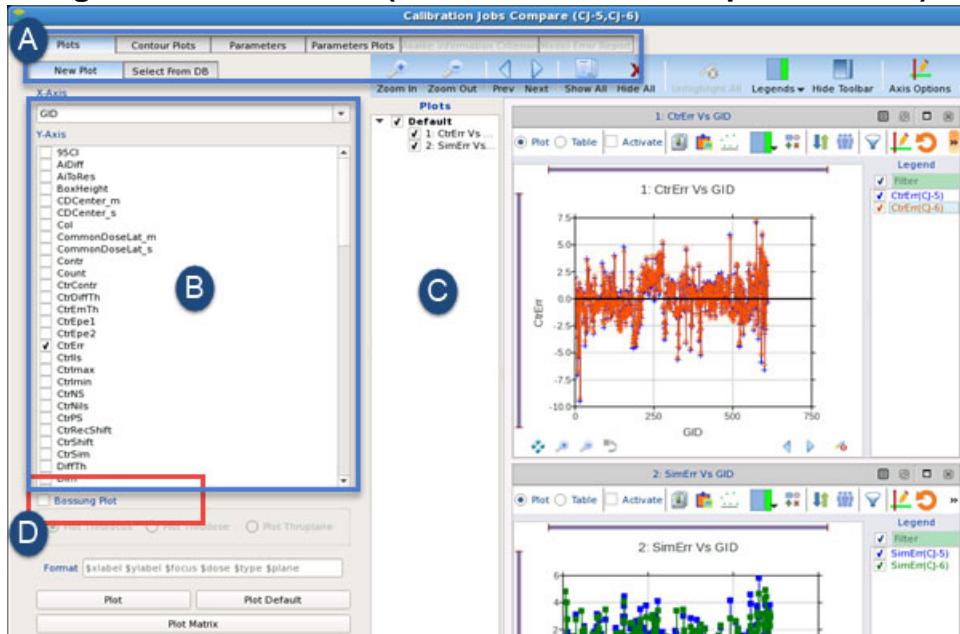
**Table 2-18. Plot Viewer Controls (cont.)**

<b>Field</b>	<b>Description</b>
F	<p>Plot menu bar controls. Controls in this bar apply to all active plot views.</p> <ul style="list-style-type: none"> <li>• <b>Zoom In, Zoom Out</b> — Zooms all plots.</li> <li>• <b>Prev, Next</b> — Cycles through the list of plots.</li> <li>• <b>Show All, Hide All</b> — Displays or hides all plot views.</li> <li>• <b>Delete All</b> — Deletes all plots.</li> <li>• <b>Hold On</b> — Keeps the current plot active; new plots are added to the held plot.</li> <li>• <b>Unhighlight All</b> — Removes all selection highlights.</li> <li>• <b>Hide/Show Legends</b> — Hides/ Shows legends in all plots.</li> <li>• <b>Hide/Show Toolbar</b> — Hides/Shows the toolbar across the top of all plots.</li> <li>• <b>Format Axis Options</b> — Controls to customize the range of both the x and y axes for all plots. Plots can be graphed on a user-specified spacing or logarithmic scale basis.</li> <li>• <b>Reset Axis</b> — Resets all axis back to the default settings.</li> <li>• <b>Show Points Label</b> — Labels each point in the graph with the X and Y data values of that point.</li> <li>• <b>Report</b> — Exports the plots to an HTML report.</li> <li>• <b>Filter Traces</b> — Similar to the legend filter, this text field filters all plot views for legends that contain a string. Remove the filter by deleting any text in the field and clicking the check button.</li> </ul>
G	<p>Plot window controls. These buttons appear at the top right of every plot view, and control the plot window. The icon buttons appear in the following order:</p> <ul style="list-style-type: none"> <li>• <b>Dock-in All Docked out Plot Widgets</b></li> <li>• <b>Dock/Undock Widget</b></li> <li>• <b>Maximize/Restore</b></li> <li>• <b>Close</b></li> </ul>

## Usage Notes

A variant version of the **Plots** tab appears when you click **Compare** in the **Calibration Job** tab for two or more completed jobs:

**Figure 2-27. Plots Tab (Calibration Jobs Compare Version)**



**Table 2-19. Plots Tab (Calibration Jobs Compare Version)**

Field	Description
A	<p>Mode control tabs. The following modes are available:</p> <ul style="list-style-type: none"> <li><b>Plots</b> — Select and view plots by picking gauge items to use as the X and Y axes.</li> <li><b>Contour Plots</b> — Select and view plots by picking contours to use as the X and Y axes.</li> <li><b>Parameters</b> — A list of parameters that can be compared, shown by value.</li> <li><b>Parameters Plots</b> — Select and view plots by picking parameters to use as the X and Y axes.</li> </ul> <p><b>Note:</b> The <b>Parameters</b> (as a right-click menu option in a column) and <b>Parameters Plots</b> (as a button on the bottom left corner) tabs have a Cluster Plot option that allows you to consolidate data from multiple calibration jobs into a single cluster plot.</p> <ul style="list-style-type: none"> <li><b>Akaike Information Criteria</b> — See the section “<a href="#">Comparing Akaike Information Criterion From Calibration Jobs</a>” on page 165.</li> </ul>
B	Plot item Selector. A single factor can be chosen for the X-axis; multiple factors can be chosen for the Y-axis.
C	Plot Viewer. Functions as described in the previous table.

**Table 2-19. Plots Tab (Calibration Jobs Compare Version (cont.)**

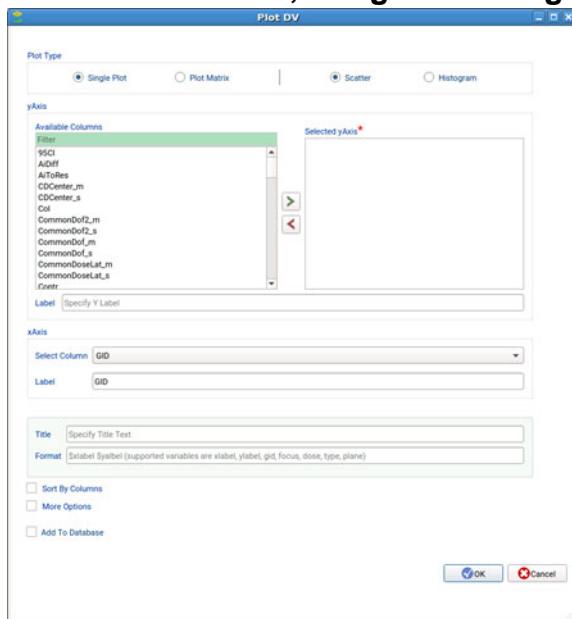
Field	Description
D	Bossung Plot Compare switch. Selecting this checkbox enables options to select process window plots for selected gauges.

## Plot Wizard, Gauge Data

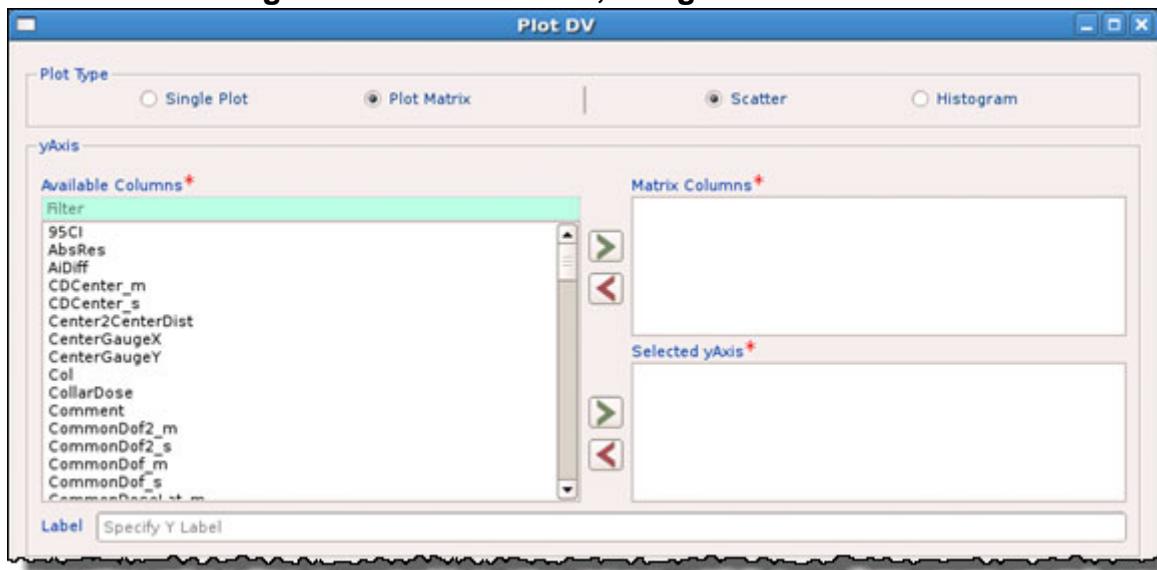
Plot Wizard dialog box

This wizard appears when you select the Gauge Data Plot item in the Plot Wizard.

**Figure 2-28. Plot Wizard, Gauge Data Single Plot**



**Figure 2-29. Plot Wizard, Gauge Data Plot Matrix**



### Description

Calibre nmModelflow allows you to create highly customized plots and add them to the default plots in a calibration job. The Plot Wizard assists you in choosing what data is displayed and how a plot is labeled when the plot is later displayed in the [Plots Tab](#). Either a single plot or a

plot matrix can be displayed by selecting the corresponding radio button. The plot matrix is used to create multiple plots of data sets with respect to a variable specified in the Matrix Columns. The plots can be viewed together in the **Plots** tab. The gauge data columns represent any column in the universal gauge data table.

## Objects

**Table 2-20. Plot Wizard, Gauge Data Contents**

Field	Description
<b>Plot Type</b>	
Single Plot	Selects between creating single or multiple plots.
Plot Matrix	
Scatter	Selects between plotting a scatter plot (individual data points) or histogram for the gauge item specified for the Y axis.
Histogram	
<b>yAxis</b>	
Available Columns	Shows all defined columns in the universal gauge data table.
Matrix Columns	Specifies a column for a data set in which multiple plots are created.  <b>Note:</b> This field is only available when Plot Matrix is selected as the plot type.
Selected yAxis	Choose one or more items from the Available Columns list to include in the plot along the Y axis.
Label	Choose the label for the Y axis.
Series Format Settings	Sets the appearance (marker type and size, line width and color) of each of the items selected for the Y axis.
<b>xAxis (Appears in Scatter Plot Mode Only)</b>	
Select Column	Choose one or more gauge data columns for the X axis. If not specified, a gauge ID index (GID) is used.
Group Name	Required and visible only for Plot Matrix type plots,, this is the label given to the group.
Sort By Columns	Opens a sub-panel that allows you to sort the plot results by specified gauge columns. By default, gauges are sorted by GID. Enabling this option sorts by the Drawn column first, then the Other column, with the ability to add more sort criteria as needed.
<b>Histogram (Appears in Histogram Mode Only)</b>	
X-axis bin criteria	Select between the number of histogram bins or a set histogram interval.

**Table 2-20. Plot Wizard, Gauge Data Contents (cont.)**

Field	Description
Y-axis representation	Select one or more of the following options to display on the Y axis: <ul style="list-style-type: none"> <li>• <b>Count</b> — The count in the bin</li> <li>• <b>Cumulative Count Percentage</b> — (count in current bin + previous bins) / (total count)</li> <li>• <b>Count Percentage</b> — Percent as (count in bin) / (total count)</li> </ul>
Options for labeling the graph are common to both Scatter and Histogram plots:	
Label	Optionally adds a label to the X axis.
Title	Optionally sets the title for the graph.
Format	Adds a custom format string for the labels.
Selecting <b>More Options</b> causes the following options to appear:	
Filter Expression	Optionally specifies a filter expression (derived from your defined filters) to select rows of the active gauge data spreadsheet. Filter expressions are considered a substring match. To specify an exact match of a filter expression, specify “==” before the string.
PW Condition	Optionally selects a process window condition to plot. Clicking the dropdown shows the list of process window conditions for the active super gauge object.
Metric	Selecting this checkbox opens up a selector for the current metrics in the database. Using this option adds the metric value as a subtitle to the plot.

## Usage Notes

Plot matrices are a presentation of facet graphs, which analyze data for various combinations of measurable data over categories of objects. Some examples of where a plot matrix would be used are:

- Model convergence for line/space patterns
- Simulated error for drawn CD

When you create a plot matrix, set the fields as follows for best results:

- **Matrix Columns** — Use columns that have integer or string values that are common to more than one gauge, such as Drawn (CD). If you have unique values in the column used for this field, the resulting plot matrix will have graphs with a single point in them.
- **Selected yAxis** — Use columns that contain values that can be graphed. Columns that contain strings are not permitted.
- **Select Column, xAxis** — Use columns that contain values that can be graphed. Columns that contain strings are not permitted.

- **Group Name** — This appears as the common title for each plot matrix instance.

## Related Topics

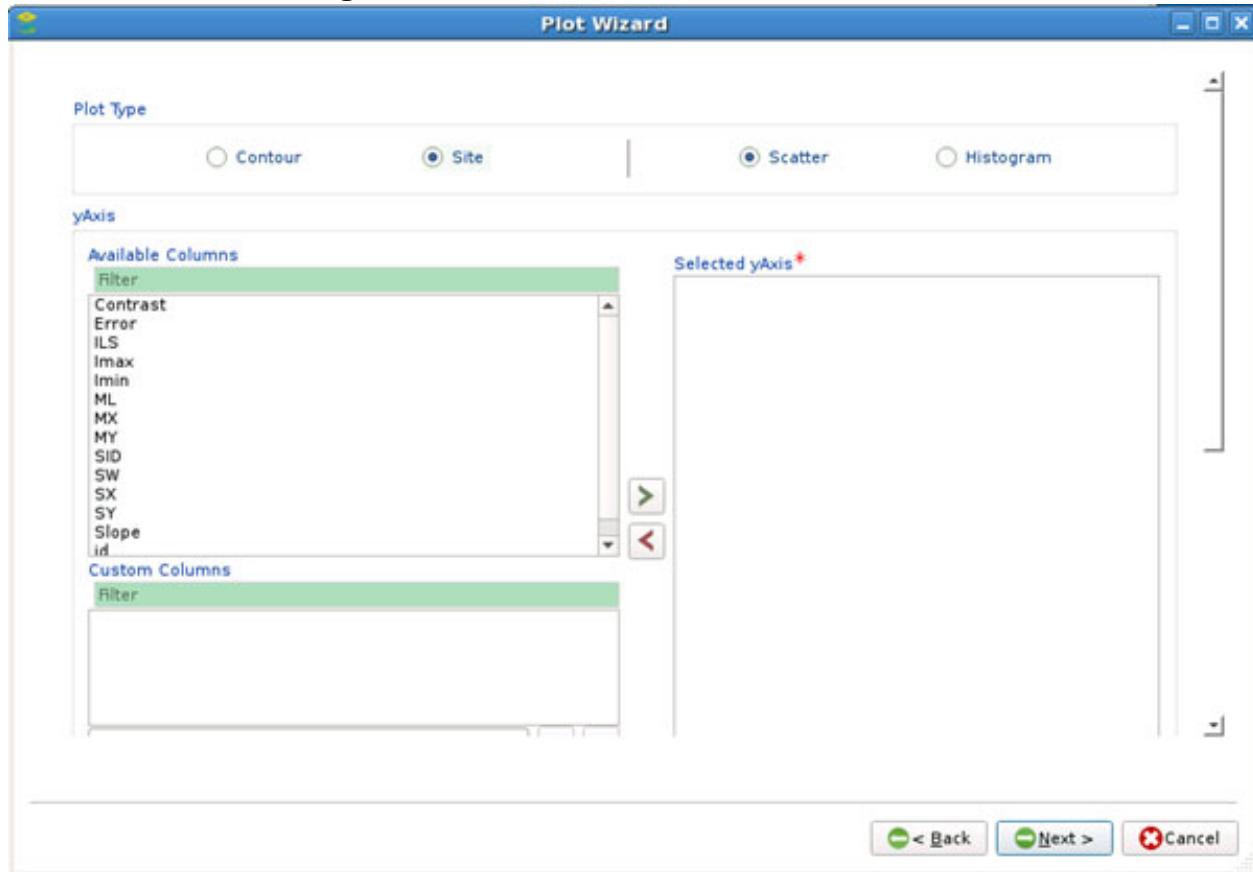
[Creating a Custom Plot](#)

## Plot Wizard, Contour Data Plot

Plot Wizard screen

Defines the appearance of the plots created using contour data.

**Figure 2-30. Plot Wizard, Contour Data Plot**



### Description

This wizard creates a simple contour plot for a contour or contour sites object at the active dose and defocus conditions.

### Objects

**Table 2-21. Plot Wizard, Contour Data Plot Contents**

Field	Description
Plot Type	Specifies type of contour data (Contour or Sites) and the type of plot (Scatter or Histogram).
yAxis	Specifies the columns to be plotted along the Y-axis.
Series Format Settings	Sets the appearance (marker type and size, line width and color) of each of the items selected for the Y axis.

**Table 2-21. Plot Wizard, Contour Data Plot Contents (cont.)**

Field	Description
xAxis	Specifies the columns to be plotted along the X-axis.
Label	Optionally adds a label to the X axis.
Title	Optionally sets the title for the graph.
Format	Adds a custom format string for the labels.
Group Name	Sets the group name for plots.
Selecting <b>More Options</b> causes the following options to appear:	
Filter Expression	Optionally specifies a filter expression (derived from your defined filters) to select rows of the active gauge data spreadsheet. Filter expressions are considered a substring match. To specify an exact match of a filter expression, specify “==” before the string.
Contour Block IDs	Optionally specifies a list of comma separated block IDs to include in the plot.

## Related Topics

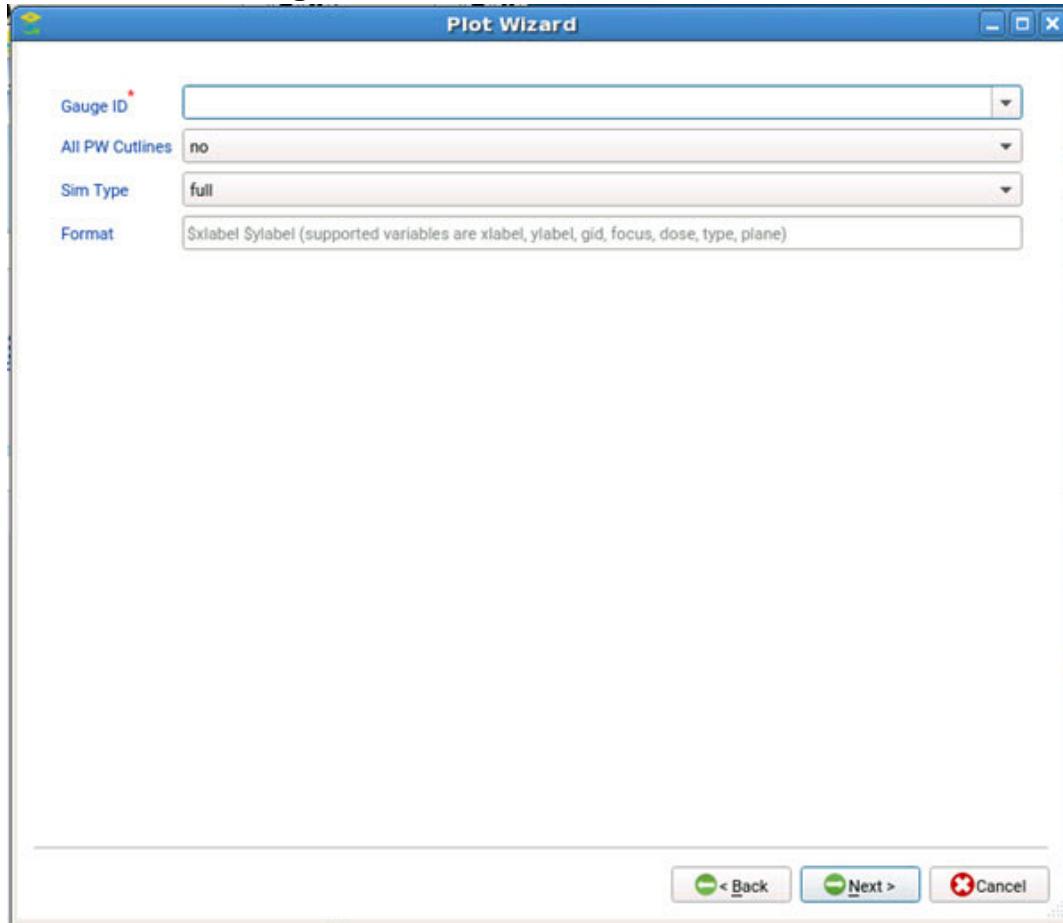
[Creating a Custom Plot](#)

## Plot Wizard, Cutline Plot

Plot Wizard dialog box

This wizard appears when you select the Cutline Plot item in the Plot Wizard.

**Figure 2-31. Plot Wizard, Cutline Plot**



### Description

The Cutline Plot wizard creates a plot for the cutline intensity of the specified gauge. It requires a gauge data or super gauge data object to be active in the **Gauge Analysis** tab, as well as an active lithomodel.

### Objects

**Table 2-22. Plot Wizard, Cutline Plot Contents**

Field	Description
Gauge ID	Specifies the gauge that appears in this plot.
All PW Cutlines	Toggles how many process window conditions are plotted; selecting "no" only plots the active condition; selecting "yes" plots all conditions.

**Table 2-22. Plot Wizard, Cutline Plot Contents (cont.)**

Field	Description
Sim Type	Sets the simulation type to be either “full” (uses full litho model) or “aerial” (uses the aerial image only).
Format	Adds a custom format string for the labels.

## Related Topics

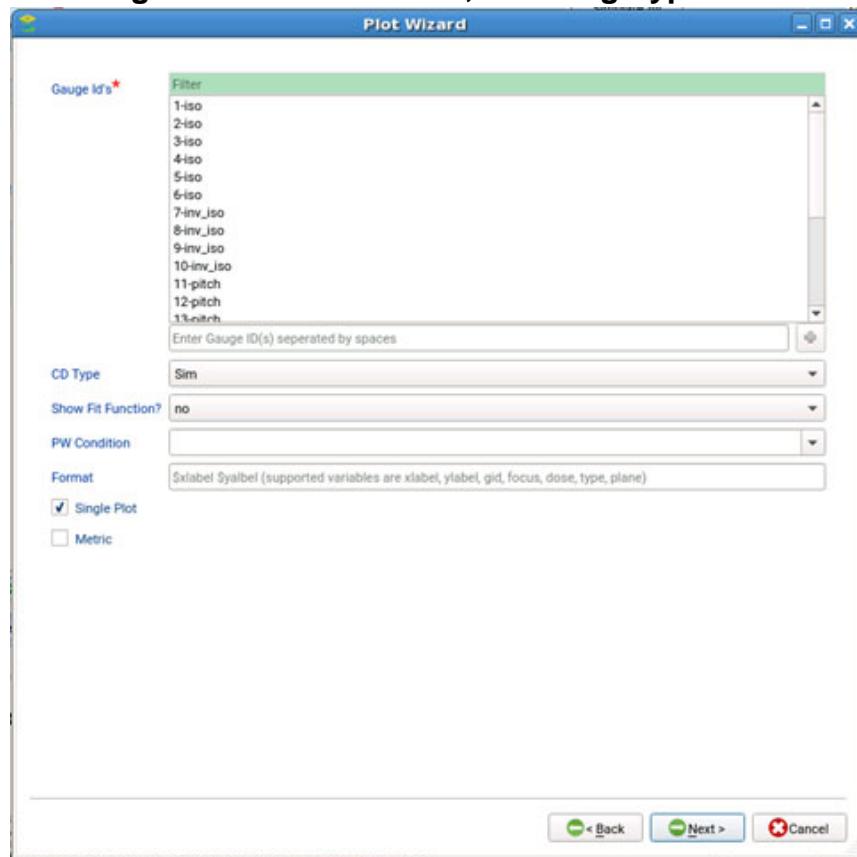
[Creating a Custom Plot](#)

## Plot Wizard, Bossung-Type Plots

Plot Wizard screen

This wizard appears when you select the **Thrufocus**, **Thrudose**, or **Thruplanes** buttons from the **Plot** button bar or the first screen of the Plot Wizard.

**Figure 2-32. Plot Wizard, Bossung-Type Plot**



### Description

Creating a plot with the Bossung Plot wizard creates a Bossung plot for a gauge.

## Objects

**Table 2-23. Plot Wizard, Bossung Plot Contents**

Field	Description
Plot Type	<p>Specifies the variable plotted on the x axis:</p> <ul style="list-style-type: none"> <li>Focus — CDs are plotted versus focus.</li> <li>Dose — CDs are plotted versus dose.</li> <li>Plane — CDs are plotted versus the depth in the photoresist for which gauge measurements were taken.</li> </ul>  <b>Note:</b> This control does not appear when the wizard is opened by the <b>ThruFocus</b> , <b>ThruDose</b> , or <b>ThruPlanes</b> buttons.
Gauge IDs	Specifies the gauge(s) to be plotted.
CD Type	<p>Specifies the type of data to be used to plot the bossung curve.</p> <ul style="list-style-type: none"> <li>Sim — Uses the simulated CDs.</li> <li>CtrSim — Uses simulated aerial image CDs.</li> <li>Meas — Uses the measured CDs.</li> <li>Shift — Uses the image shift difference between simulated and drawn CDs.</li> <li>CtrShift — Uses the image shift difference from the simulated aerial image.</li> <li>Meas Sim — Uses both simulated and measured CDs.</li> <li>Meas CtrSim — Uses both measured CDs and simulated aerial image CDs.</li> <li>Sim CtrSim — Uses both simulated CDs and simulated aerial image CDs.</li> </ul>
Show Fit Function	Toggles whether or not the parabola fit curve is shown on the plot with the data.
PW Condition	Optionally selects a process window condition to plot in the form of (focus, dose).

**Table 2-23. Plot Wizard, Bossung Plot Contents (cont.)**

Field	Description
Format	<p>Optionally sets the format for the legends, using the following variables:</p> <ul style="list-style-type: none"><li>• \$xLabel — The x-axis label.</li><li>• \$xVal — The x-axis value, in situations where IDs are used (such as GIDs).</li><li>• \$yLabel — The y-axis label.</li><li>• \$yVal — The y-axis label, in situations where IDs are used.</li><li>• \$T — The type.</li><li>• \$P — The plane.</li><li>• \$D — The dose.</li><li>• \$F — The focus.</li></ul> <p>Only items in the selected plot data that match a variable type in the string are printed; the rest are considered “”. For example, if the legend format specified for GIDs is \$ xlabel(\$gid) T(\$type) D(\$dose) _ \$ ylabel, the output is GID(12) T(CD) D(1) _ Meas, with focus and plane being ignored (both for being empty and not in the legend string).</p>
Single Plot	Specifies to create a single plot for all gauge data.
Metric	Selecting this checkbox opens an additional set of controls to add a metric to the plot results. The selected (or created) metric is listed as a subtitle to the plot.

## Related Topics

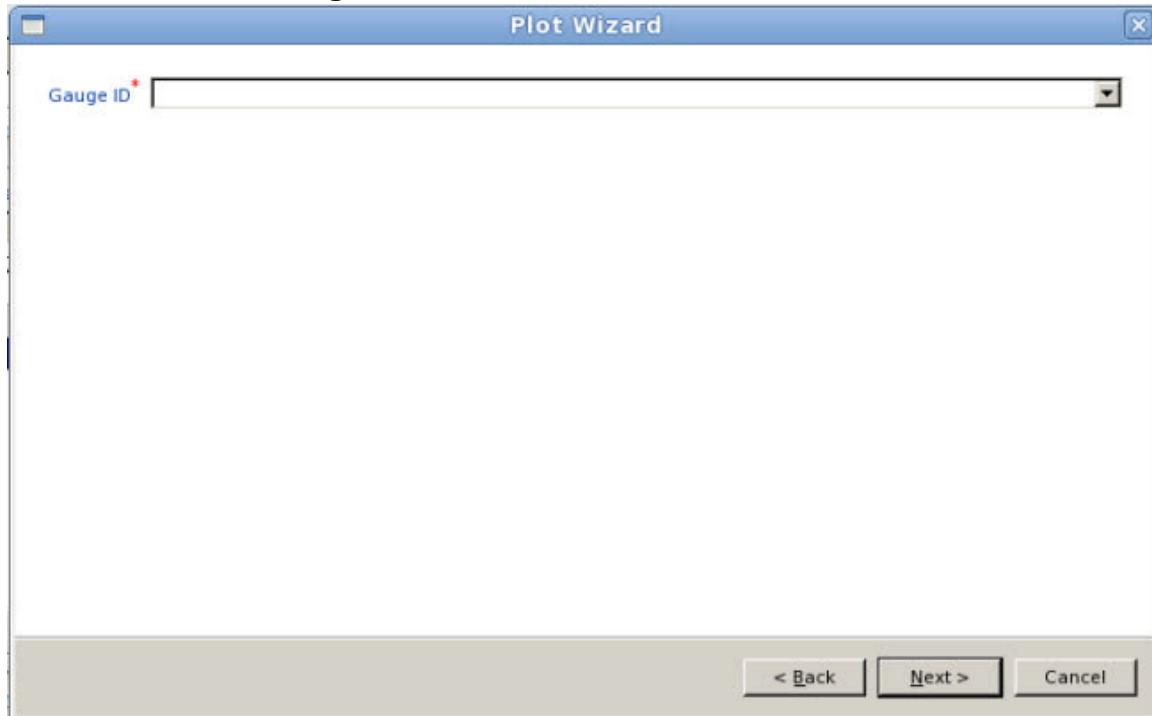
[Creating a Custom Plot](#)

## Plot Wizard, Contour Plot

Plot Wizard screen

This wizard appears when you select the Contour Plot item in the Plot Wizard.

**Figure 2-33. Plot Wizard, Contour Plot**



### Description

This wizard creates a simple contour plot for a specified gauge at the active dose and defocus condition. Contour plots are shown in the Calibre WORKbench layout window as a layout layer.

### Objects

**Table 2-24. Plot Wizard, Contour Plot Contents**

Field	Description
Gauge ID	Specifies the gauge contour to plot.

### Related Topics

[Creating a Custom Plot](#)

# Metrics Viewer Tab

Calibre nmModelflow Main window primary display tab

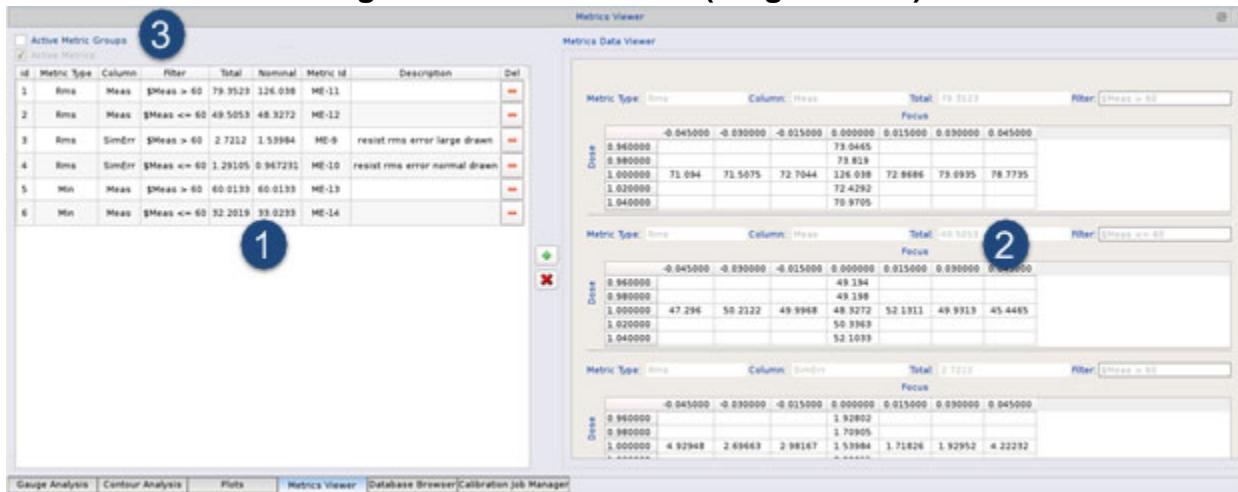
The **Metrics Viewer** tab shows a representation of values of interest from a calibration run. This tab is especially useful for process window configurations, as the data is output on a dose and focus matrix.

## Description

Two types of display are supported in the **Metrics Viewer** tab: individual metrics and metric groups.

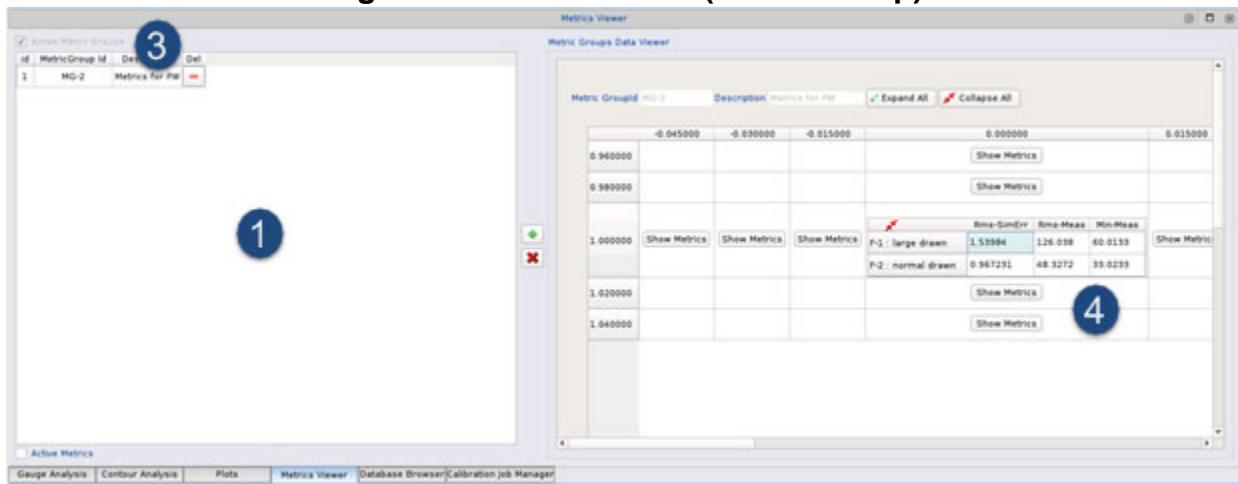
Individual metrics are based off of a single metric being tested versus the active gauge item.

**Figure 2-34. Metrics Tab (Single Metric)**



Metric groups are the equivalent of a test suite for goodness of fit; all metrics inside a metric group are run versus the active gauge item.

**Figure 2-35. Metrics Tab (Metric Group)**



**Note**

 To create a metric, see the task “[Creating a Custom Metric](#)” on page 94

---

## Objects

**Table 2-25. Metrics Tab Controls**

Field	Description
1	Metrics list. Active metrics being calculated for are shown in this list.
2	Individual Metric data display. In single metric mode, each active metric is given a chart with the best values for that metric shown process window matrix form.
3	Active Metric and Active Metric Group toggles. Individual Metrics and Metric Groups can be displayed simultaneously or individually by selecting these checkboxes.
4	Metric Group data display. For metric groups, the process window dose and focus matrix is shown; clicking any <b>Show Metrics</b> button causes the metrics for that condition to be shown.

## Related Topics

[Creating a Custom Metric](#)

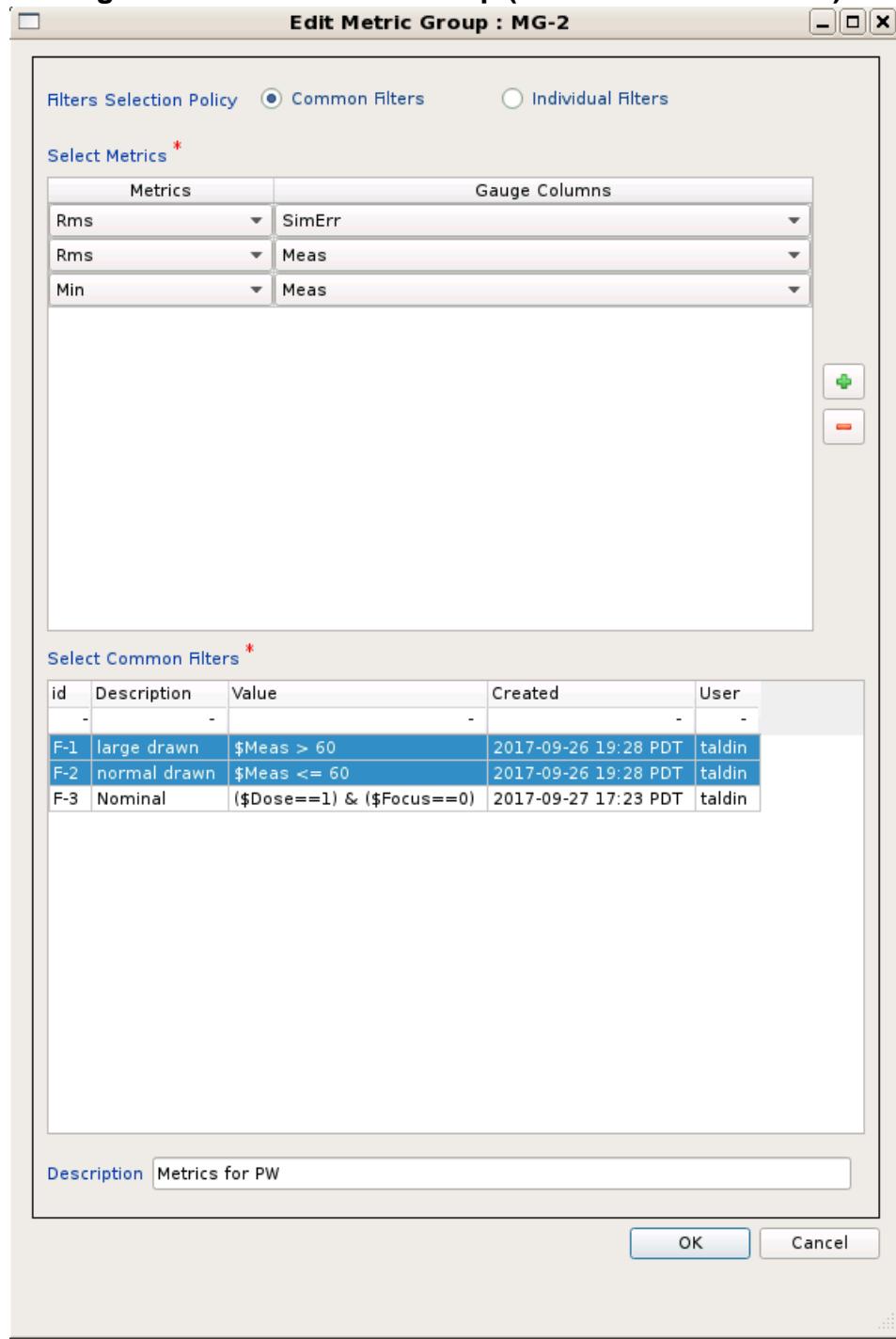
[Edit Metric Group Wizard](#)

## Edit Metric Group Wizard

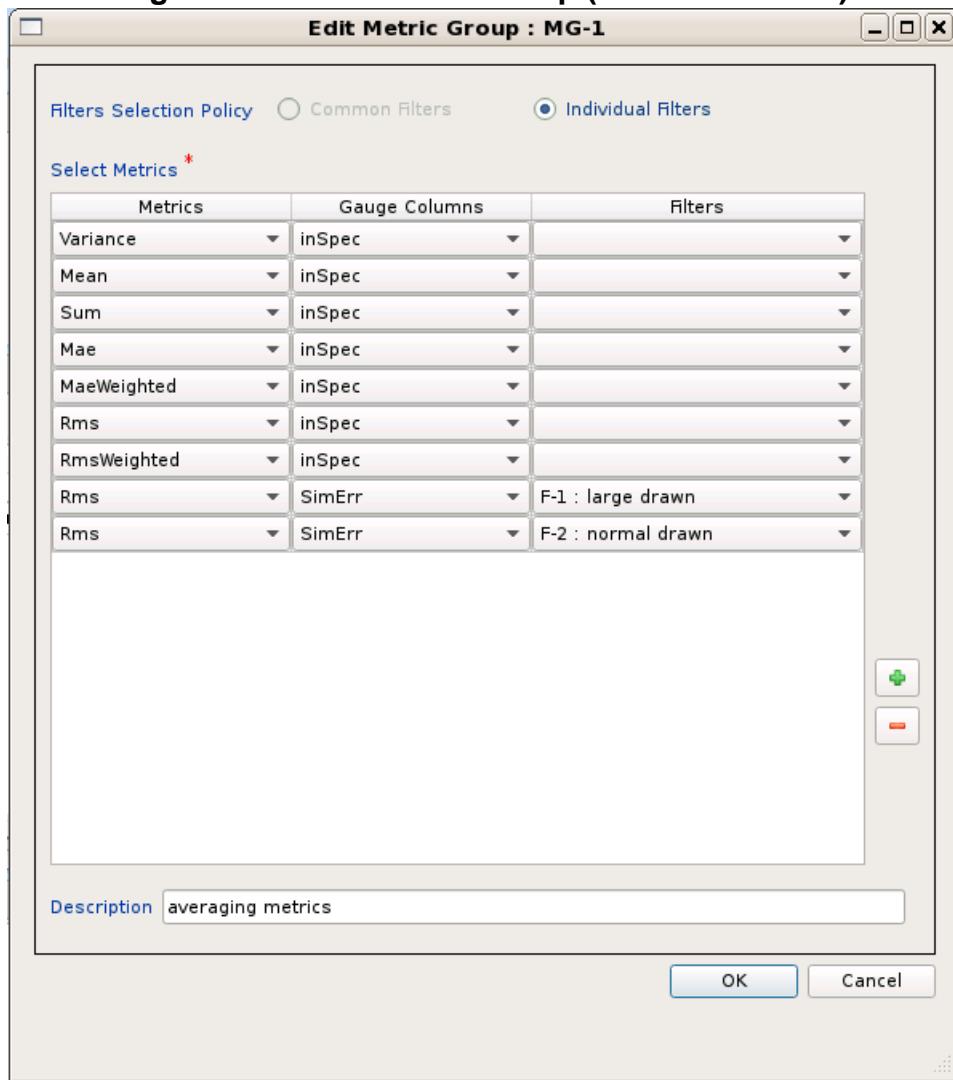
Metrics Viewer wizard

Metric groups are a combination of metrics and filters that can be run on the active gauge item. Use this wizard to quickly create a metrics group.

**Figure 2-36. Edit Metric Group (Common Filters Mode)**



**Figure 2-37. Edit Metric Group (Individual Mode)**



## Objects

- Common Filters mode

Common Filters mode allows you to create metrics by using selections from the dropdown lists. You must select at least one common filter from the list at the bottom. The metric group created is the combinations of each metric and filter selected. For example, defining three metrics and selecting two filters results in six metrics in the metric group.

- Individual Filters mode

Individual Filters mode allows you to create a group of metrics with selections from three different categories (metrics, gauge columns, and filters). It differs from the Common Filters mode in that individual filters can be created with no filters.

## Related Topics

[Metrics Viewer Tab](#)

## [Creating a Custom Metric](#)

# Chapter 3

## Job Execution User's Guide

---

By default, Calibre nmModelflow runs in multi-threaded (MT) mode. Creating a remote file allows you to run it in distributed (Calibre® MTflex™) mode. Calibre MTflex mode causes dispatcher jobs to run remotely.

Calibre nmModelflow introduces the concept of a dispatcher, which keeps the GUI fully active, allowing you to create more jobs and analyze data during ongoing runs. The dispatcher can be run in MT or Calibre MTflex modes.

<b>Creating Job Files .....</b>	<b>269</b>
<b>Job Execution Modes.....</b>	<b>271</b>
<b>Setting Up Dispatcher Mode.....</b>	<b>272</b>

## Creating Job Files

Remote files contain information about machines and CPUs where remote tasks should be run. At least one remote file is required to run in Calibre MTflex mode, and the dispatcher requires a special runscript file.

### Restrictions and Limitations

You must have login access to all machines you are using in your remote host list.

### Prerequisites

For security reasons and also because RHEL8 does not support rsh, Calibre nmModelflow replaced rsh in scripts with ssh as the default. This will require you to set up passwordless ssh on your remote machines, because nmModelflow jobs cannot prompt for user input. Passwordless ssh requires a key file installed in `~/.ssh/id_rsa`.

If your public key authentication fails with a Permission Denied error:

- Check to see if you have 'ssh' hardcoded in your scripts.
- Check if your key file requires a password (this may generate the error, "key file is not password-less")
- Set up passwordless-execution on the remote machines you execute jobs on.

```
cd ~/.ssh
ssh-keygen -t rsa -N "" -C "my_job_run_identity_file" -f ~/.ssh/ \
my_job_run_identity_file
cat ~/.ssh/my_job_run_identity_file >> ~/.ssh/authorized_keys
```

## Procedure

1. Create the remote file first.
  - a. In a text editor, create a file (the name is arbitrary, but should be relevant to the machine name) with entries for each remote host using the format:

```
REMOTE HOST hostname number_of_CPUS
```

- b. Save the file.
- c. Create additional remote files as needed.

2. Create a job resource file that references the remote file(s) from Step 1.

- a. In a text editor, create a file “*job\_resources.txt*” using the following syntax:

```
hostname max_jobs max_load /remote_file_name
```

where:

- o *hostname* is the network name of the host.
- o *max\_jobs* is the maximum amount of dispatcher jobs that can be sent to the machine.
- o *max\_load* is the maximum amount of load that is allowed on the machine before the dispatcher skips using it. Using a value of 0 means that the dispatcher uses this CPU regardless of the machine load.
- o *remote\_file\_name* is a file you created in Step 1. A best practice is to locate the remote files in the directory you invoked Calibre WORKbench from by using **\$CALIBRE\_INVOKE\_DIR/** as part of the remote filename.

3. Save the file. You can now use the job resource file as a reference in a run command for any *run\_rsh\_ssh.sh* runscript.

## Examples

### Example Remote Files

- Runs 4 CPU on the local machine:

```
REMOTE HOST localhost 4
```

- Runs 16 CPU on two separate hosts:

```
REMOTE HOST bluemax 8
REMOTE HOST redfive 8
```

### Example Job Resource File

Runs two remote files, each with its own separate remote file.

```
# host    max_jobs      max_load remote_file
blue_red     1           0          $CALIBRE_INVOKE_DIR/blue_red.txt
white2       1           0          $CALIBRE_INVOKE_DIR/white_box.txt
```

## Related Topics

[Setting Up Dispatcher Mode](#)

# Job Execution Modes

Calibre nmModelflow has multiple job execution modes that use different methods to run a job.

- **Dispatcher Mode** — This is the most often used mode. The job is executed in the background and monitored by a dispatcher process. You can exit the Calibre nmModelflow GUI and Calibre WORKbench session without terminating the job.  
  
To check on the status of a job, open Calibre WORKbench and the Calibre nmModelflow GUI. The status is reported in the **Calibration Job Manager** tab.
- **Direct Mode** — Used for launching multiple jobs simultaneously, or for debugging runscripts. After preparing the job, copy the job directory to where you want to run it, then execute the job.

---

### Note

 The job directory contains all the commands and support files Calibre nmModelflow uses to run the job. It is located inside the *mdf* database directory.

*mdf/database/repository/calibrationjobtable/CJ-<x>/data*

---

- **Standalone Mode** — This is the same as the direct mode, except the job directory is relocatable.

You can copy the entire job directory to a different directory (perhaps on a different network), change to that directory, execute the job, and copy the results back to the original job directory.

A typical case is where a UNIVA Grid is used to execute jobs, but the machines managed by that grid are on a completely different file system.

To use standalone mode, you must change the Jobtype field to include the “standalone” keyword (multiple keywords are allowed).

## Related Topics

[Running a Calibration Job From the Calibre nmModelflow GUI](#)

[Running a Calibration Job in Direct Mode](#)

[Running a Calibration Job In Standalone Mode](#)

[Calibre nmModelflow Licensing Information \[Calibre Administrator's Guide\]](#)

# Setting Up Dispatcher Mode

Dispatcher mode requires some specific instructions independent of Calibre MTflex configuration.

## Restrictions and Limitations

You must have login access to all machines you are using in your remote host list.

## Prerequisites

- [Creating Job Files](#)

## Procedure

1. Before running Calibre WORKbench, it is recommended as a best practice, but not required, to set the environment variable `CALIBRE_MDF_DISPATCHER_DIR`. This specifies the directory for dispatcher log output. The default directory is “`<current_directory/mdf/dispatcher`”.
2. Run Calibre WORKbench.
3. Open Calibre nmModelflow and raise the **Calibration Job** tab.
4. Choose a calibration job to run from the list.
5. Navigate to the run script file and click **Execute**.

## Results

Dispatcher information appears in the Application Logs window.

## Related Topics

[Creating Job Files](#)

[Running a Calibration Job From the Calibre nmModelflow GUI](#)

# Appendix A

## Best Practices for Calibre nmModelflow

---

Calibre nmModelflow includes a set of best practice filters, plots, and metrics that you can add to your database.

<b>Loading the Best Practice Database.....</b>	<b>273</b>
<b>List of Calibre nmModelflow Best Practices.....</b>	<b>274</b>

## Loading the Best Practice Database

Best practices are not loaded when you create a database.

### Restrictions and Limitations

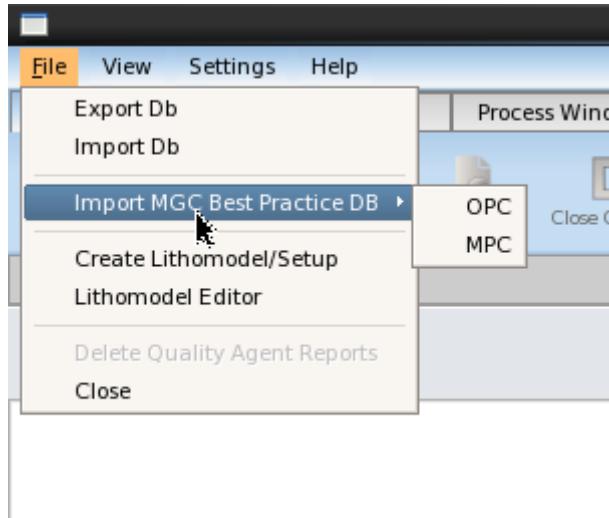
Best practices are reviewed on a per-release basis, and are subject to change without notice.

### Prerequisites

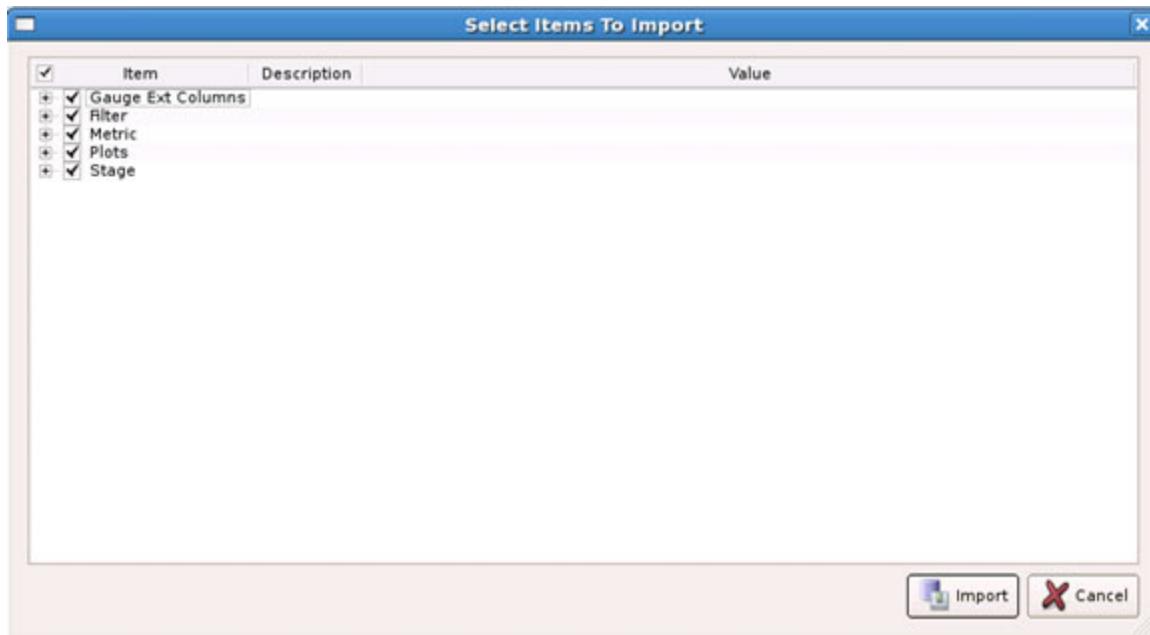
- Calibre WORKbench invoked, and the Calibre nmModelflow GUI active

### Procedure

1. In Calibre nmModelflow, select **File > Import MGC Best Practice DB** and choose the desired best practice database.



2. Select the parts of the Best Practice Database that you want to use, and click **Import**. By default, all parts of the Best Practice Database are selected.



## Results

Calibre nmModelflow loads the best practice database from the file: `$MGC_HOME/shared/pkgs/icv/examples/modeling/mdfv3/bestPracticesDB.tar`.

You can see the new items in the Database Browser.

## Related Topics

[List of Calibre nmModelflow Best Practices](#)

# List of Calibre nmModelflow Best Practices

The best practices for Calibre nmModelflow are current for the current release.

## Best Practice Filters

Filters are listed in the Database Browser. They are provided as examples that you can modify as needed.

**Table A-1. Best Practice Filters for Calibre nmModelflow**

Filter Description	Value
1D data	<code>\$Dim == 1</code>
2D data	<code>\$Dim == 2</code>

**Table A-1. Best Practice Filters for Calibre nmModelflow (cont.)**

Filter Description	Value
horizontal cutlines	$\$HV == 0$
vertical cutlines	$\$HV == 90$
enabled	$\$On$
disabled	$\$On == 0$
Bossung filter, CDswing=5, maxrms=3, focusdelta=0.05	{bossungfilter -cdtype meas -focusdelta 0.05 -cdswing 5 -maxrms3}
simulated error $\geq 5\text{nm}$	$\$SimErr > 5$
measured CD $< 30\text{ nm}$	$\$Meas < 30$
structure name includes pitch	[string match {*pitch*} \$Struc]
structure name includes iso	[string match {*iso*} \$Struc]
Group name includes verify	[string match {*verify*} \$Group]
Cross conditions: dose=1, focus=0	$\{\$Dose==1\} \parallel \{\$Focus==0\}$
Off-cross conditions: focus !0, dose !=1	$\{\$Dose !=1\} \&& \{\$Focus !=0\}$
CD gauges (assumes decimal point in measured CD)	{[string match {*.} \$Meas]}
non-printing SRAF gauges (assumes inequality gauges)	{[string match {*LT:0*} }
printing SRAF gauges (assumes inequality gauges)	{[string match {*GT:*} \$Meas]}

## Best Practice Metrics

Metrics are applied using filters, and are listed in the Database Browser. The metrics supplied with the Best Practices use the included filters. Each metric uses the Rms objective on the SimErr column in the gauge object.

**Table A-2. Best Practice Metrics for Calibre nmModelflow**

Metric Description	Metric Filter
Unweighted RMS on 1D data	1D Data
Unweighted RMS on 2D data	2D Data
Unweighted RMS on all data	(none)
Fraction of gauges in spec	gaugecol={inSpec} Metric={Mean}
Number of gauges in spec	gaugecol={inSpec} Metric={Sum}

**Table A-2. Best Practice Metrics for Calibre nmModelflow (cont.)**

Metric Description	Metric Filter
number of false printing SRAFs	gaugecol={falseSRAFprint} metric={Sum}

## Best Practice Plots

Plots can be defined and added to the general results of a calibration. The best practice stages included in the example database are meant as suggestions and should be adapted to your specific gauges (for example, the “GID 11, resist contour plot” is very specific to the gauge on line 11).

**Table A-3. Best Practice Plots**

Description	Notes
Image and CM1 CD vs. Gauge ID	mdf plot filter {1} -vals {\$CtrError} {\$SimErr} -ylabel {Image and CM1 CD Error} -xval {\$GID} -xlabel {Gauge ID} -title {Error vs. GID}
GID 11, image cutline	{mdf plot cutline 11 -simtype aerial}
GID 11, resist cutline	{mdf plot cutline 11 -simtype full}
GID 14, 15, measured and simulated Bossung plots	{mdf plot thrufocus -gids {14 15} -headings {Meas Sim}}
GID 14, 15, measured and simulated CD vs dose plots	{mdf plot thrudose -gids {14 15} -headings {Meas Sim}}
GID 11, resist contour plot	{mdf plot contour 11}

## Best Practice Stages

Stages are used to build calibration jobs. The best practice stages included in the example database are meant as suggestions and should be adapted to your specific process.

**Table A-4. Best Practice Stages**

Description	Notes
Simulate	
CTR Threshold Optimize	

**Table A-4. Best Practice Stages (cont.)**

Description	Notes
Beamfocus/defocus_start calibration + Bossung adjust to be used with process window data	For use with super gauge data objects and process window calibration.
Beamfocus/defocus_start calibration + Bossung adjust with pre-filtering to be used with process window data (focus sensitivity filtering set for 193nm/1.35 NA)	
Center Focus by Bossung Adjust for PW data (focus sensitivity filtering set for 193nm/13.5 NA)	
Center Focus by Bossung Adjust on Nominal Data (focus sensitivity filtering set for 193nm/13.5 NA)	
Mask bias calibration, 2 mask layers, clear field mask	For use with mask models.
Mask bias calibration, 2 mask layers, dark field mask	
Mask corner chop calibration, 2 mask layers	
Mask corner chop and bias calibration, 2 mask layers, clear field mask	
Mask corner chop and bias calibration, 2 mask layers, dark field mask	
Build Resist	For use when optimizing optical and mask models only.
MF11, 20, 21, 22, 31, and 120 resist calibrations	For use when calibrating CM1 resist models.
MF38, 40, 41, 42, 43, 44, 45, 46, 47, 48, 58, 78, and 144 resist calibrations (NTD)	For use with negative tone developer resists.
def_start={0nm - 98nm}, Center Focus By Bossung Adjust on Nominal Data	Optimizes the dose and beamfocus using the specified value, using a Bossung filter.
VEB: emodelform stage templates	Creates a stage using etch modelform templates.

## Best Practice Joint Optimization

When joint optimization is used to jointly calibrate mask bias/corner chop and resist model parameters, typically a 5 – 25% improvement in RMS fit error is achieved over sequential calibration. However, joint calibration uses one resist calibration for each combination of mask/optics/topo parameters compared to just a single resist calibration used in the entire sequential flow. The best practices for the Joint Optimization flow are the following:

1. Perform focus centering as recommended in Best Practice Stages section to set beamfocus/defocus\_start.

2. Fix mask stack slope at the recommended value: 86 degrees for Opaque MoSi on Glass (OMOG), and 88 degrees for Attenuated Phase Shift Mask (attPSM).
3. Optimize bias and corner chop jointly with CM1 using the Resist Subsearch.
4. Use full search in the outer loop over mask parameters for efficient distribution to remotes.
  - a. Use search range between 0.004 to 0.014 microns for mask corner chop parameter optimization for DUV applications.
  - b. Use search range between 0.002 to 0.01 microns for mask corner chop parameter optimization for EUV applications.
5. Use frontzoom search in the Resist Subsearch.
6. If you plan to further improve the model with subsequent tuning using tolerance1 objective or zoom calibration with new weights, use 20000 iterations for the Resist Subsearch with MF78.

---

**Note**

 Reducing the number of iterations by two to three times the recommended value for standard resist calibration will improve joint optimization runtime. This enables the search to find the optimum combination of the outer loop mask parameters. Once the optimum combination of mask parameters is found in joint calibration, a more accurate resist search with the recommended number of iterations can be performed to further improve the model error.

---

## Related Topics

[Creating a Stage With the Flow Stage Wizard](#)

[Creating a Custom Plot](#)

[Creating a Custom Metric](#)

[Creating a Filter](#)

[Selecting Focus-Sensitive Data](#)

# Appendix B

## System Flow And Runscript Information

---

It is useful to understand the system flow and runscripts used by the Calibre nmModelflow tool.

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<b>Manual Execution of Calibre nmModelflow Jobs .....</b>	<b>282</b>
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<b>Using the Static and Dynamic Core Allocation CalCM Runscripts .....</b>	<b>288</b>

## Calibre nmModelflow System Flow

The system flow in Calibre nmModelflow involves the use of specialized runscripts that are executed by calibration jobs.

The runscript is a required element of a calibration job. Multiple runscripts are available to you. When a runscript is executed, the following steps are performed by Calibre nmModelflow.

1. Calibre WORKbench prepares a job directory, generating the following read-only files:
  - o *job.sh* – Sources environment settings coming from the session, and calls the runscript with the user-specified arguments for that specific job along with all of the required options.
  - o *job.tcl* – Contains the stage commands to execute in the job on a remote host chosen exclusively by the runscript.
  - o *env.sh* – Contains script environment settings (including licensing). The settings can be changed by the code in the runscript. The *env.sh* file is required because some mechanisms such as rsh and ssh do not automatically preserve required environment settings (for example, license file variable settings, beta variable settings, etc.).
2. Calibre WORKbench starts a background dispatcher process, and the job is queued to the dispatcher. The dispatcher handles the execution of the runscript on the same host in parallel with and separately from the user session, so as to allow the user session to continue execution. This is to allow the user to monitor the job from that user session.

---

### Note

 The name “dispatcher” is a historical artifact; it is not doing any dispatching to distribution systems, but only executes the runscript, which then is in full control of dispatching to remote hosts through a dispatching system.

---

You can exit Calibre WORKbench at this point; the Calibre nmModelflow job continues execution, even if it is running on a separate host.

3. The runscript is executed with the job directory as the current working directory. The runscript may execute the *job.tcl* script on the local host or a remote host, depending on how it was written.
4. You can check on the status of the job using one of the following methods:
  - Examining the Status field in the **Calibration Job Manager** tab, in the Calibre nmModelflow GUI.
  - Opening the Calibration Job Record dialog box in the GUI, by clicking the job in the Calibration Job Manager View in the Calibre nmModelflow GUI.
  - Examining the *status* file in the job directory. This file is updated by the dispatcher process when the job completes (successfully or otherwise).
  - By using the mdf job wait command in batch mode or in the Command Window to wait for the job to complete.
5. After the job finishes, the dispatcher process detects an exit code from the runscript and updates the *status* file in the job directory. This action is performed independently of the active Calibre WORKbench session, if any.
6. If the job has any successors that are queued for execution, and the current job completed successfully, the successor jobs are executed next.
7. After about 10 seconds of inactivity (no jobs are running or queued), the dispatcher process ends. The dispatcher process has a separate log that can be examined for debugging purposes.

## Custom Runscripts

The runscript file can be customized, usually by a system administrator. All runscripts have specific requirements for use, but can be written in any scripting language.

Runscript examples are located in the product tree in the location:

```
$CALIBRE_HOME/pkgs/icmdf/pvt/runscripts
```

You can also set the **CALIBRE\_NMMODELFLOW\_JOB\_RUNSCRIPTS\_DIR** environment variable to specify where your custom scripts are kept.

Runscripts are plain text files. The example code is implemented as Tcl, /bin/sh, or /bin/bash. Both the user and system administrator have full control over the runscript content.

All runscripts should perform the following operations, in order.

1. Accept the standardized minimal arguments.

2. List usage information if the -h option was used, and exit.
3. Emit option metadata if the -optionmetadata option was used. This option should list the same information as would be emitted by the -h option, but in XML form for the GUI to use to populate the Update Runcommand dialog and provide per-option context-sensitive help.
4. Acquire or identify a host to execute the calibrewb job session. This can use either MT or Calibre MTflex (for example, by requiring the user to specify the -remotefile option). This host will be used as the Calibre MTflex primary host. The hostname can be hardcoded in the runscript, but the intention is for the host to be acquired by a distributed processing system.
5. If the runscript is designed to run Calibre MTflex, it should also perform the following steps:
  - o Acquire or identify one or more hosts for Calibre MTflex remotes. These hosts can also be hardcoded, but the intention is for the remotes to be retrieved from the distribution system, similar to the Calibre MTflex primary host.
  - o Construct a remote configuration file to pass to the calibrewb job. This can be a static file, but it is more effective when the remote configuration file is generated by the script.

Alternatively, since calibrewb uses standard MTflex, a REMOTE COMMAND can be specified in the remote configuration file instead of hosts; this command would use a distribution system to launch the remote computing server processes (note that you would use “calibrewb -mtflex H:P” instead of “calibre -mtflex”)

6. The runscript should next execute calibrewb and pass it the *job.tcl* script, along with the -remote configuration file option if Calibre MTflex execution has been chosen. The calibrewb execution command should:
  - o Redirect all standard output and standard error messages from the execution of calibrewb into the *job.transcript* file.
  - o Pass all other output from the script without redirecting them to a file; the dispatcher process will redirect all other standard output and standard error into the *runscript.transcript* file.

The *runscript.transcript* file output represents failures in execution to distribution systems (such as failure to rsh into systems, failures in requesting job execution to the distributed system, and so on), which is separate from the calibrewb execution output sent to the *job.transcript* file.

This is so the user can view the *runscript.transcript* file separately from the *job.transcript* file, and is intended for viewing in the Calibration Job Record dialog box in the Calibre nmModelflow GUI.

7. The runscript must wait for the calibrewb job to finish, even if it is running on a remote host indirectly through a distribution system.

The exit code from the calibrewb process must be returned from the runscript as its exit code, regardless of whether the runscript ran the job on the local host or dispatched it to a remote host. This is so the dispatcher process can update the status file and also execute dependent jobs upon successful completion (jobs that have this job as their Predecessor in the Calibration Job table).

## Manual Execution of Calibre nmModelflow Jobs

Jobs can be executed manually, outside of the dispatcher. However, this methodology is only intended as a debugging tool, and should not be used for normal job execution.

The flow for manually executing jobs is as follows:

1. Invoke Calibre WORKbench and configure a Calibre nmModelflow job, specifying a runscript. This runscript can be one that is modified and stored in a specific directory, or can be one of the built-in runscripts, as follows:

- o If the script is one of the built-in example runscripts, you can simply name it without using a full pathname (*run\_rsh\_ssh.sh*)

```
mdf db update calibrationjobtable -key CJ-23 -runcommand  
{run_rsh_ssh.sh arguments ...}
```

- o If you copy and modify one of the built-in example runscripts and store it in a global directory, you must refer to it using a fully qualified hard-coded path to that directory.

```
mdf db update calibrationjobtable -key CJ-23 -runcommand {/home/  
caltests/bin/my_run_local.sh arguments ...}
```

- o If you copy and modify one of the built-in example scripts and store it in the directory you invoked Calibre WORKbench from, this can be indicated using the **CALIBRE\_INVOKE\_DIR** environment variable.

```
mdf db update calibrationjobtable -key CJ-23 -runcommand  
{$CALIBRE_INVOKE_DIR/my_run_local.sh arguments ...}
```

---

### Note

 It is extremely important that you not store any runscript files in your job directory; this directory is deleted and reconstructed when a job is prepared.

---

2. Enter the command:

```
mdf job prepare key
```

where *key* is the job identifier as shown in the Jobs list (CJ-23, for example).

Calibre nmModelflow prepares a job directory with the job executable files, but does not run them.

3. Exit Calibre WORKbench.
4. In a terminal window, navigate to the job directory.
5. (Optional) Edit the runscript file as needed to select remote hosts, allocation parameters, or other relevant items.
6. Invoke the *job.sh* script. The job script should source the *env.sh* script containing the required environment variables, and then execute the runscript. One of the environment variables set in that *env.sh* file is *CALIBRE\_INVOKE\_DIR*, which refers to the current working directory used before step 2 (and not the job directory, which is overwritten by newly-created jobs).

If the script is then copied to the same directory where you invoke Calibre WORKbench, you can configure the job run command to execute the script such as in the following example:

```
mdf db update calibrationjobtable -key CJ-23 -runcommand  
{${CALIBRE_INVOKE_DIR}/my_run_local.sh}
```

You must wait for the job to complete, since it is running in the terminal window. Only output from the runscript shows in the terminal window; no calibration job output is shown. The calibration job output is written to the *job.transcript* file.

If the runscript exits with an error, or the calibration job exits with an error, the status file will not be updated; this is expected, since this flow is for debugging purposes only. However, if the user invokes the Calibre nmModelflow GUI, the state for the job shows “Ready” instead of “Done” or “Error”.

## Example Batch Execution, No Waiting

This example code executes a job and lets it run to completion without waiting. It generates a Tcl script, and the script executes Calibre WORKbench.

```
#!/bin/bash
# Set the nmModelFlow environment variables:
export CALIBRE_MDF_WORKDIR_DEFAULT=".tmpworkdir"
export CALIBRE_MDF_DISPATCHER_DIR=".mdfdispatcher"
export CALIBRE_MDF_DB_HOME=".mdfdatabase"

# Process command-line options:
JOB_KEY=$1
if [ -z "$JOB_KEY" ]
then
    echo "USAGE: $0 JOB_KEY"
    exit 1
fi

# Create a temporary Tcl script file:
tmp_script_file=/tmp/tmp$$_.tcl
cat > $tmp_script_file <<EOF

# Clear the job :
mdf job clear $JOB_KEY

# Execute the job:
mdf job execute $JOB_KEY
EOF

# Run calibrewb on the script file:
$MGC_HOME/bin/calibrewb $tmp_script_file
# Remove the temporary script file
rm -f $tmp_script_file
```

## Example Batch Execution, Job Wait

This example code shows a script that executes a job, but waits for it to complete. It generates a Tcl script, and executes Calibre WORKbench. The script completes when the job completes, with a state of success (Done) or an error (Error).

The only difference between this example and the previous one is the use of the mdf job wait command.

```
#!/bin/bash

# Set the nmModelFlow environment variables:
export CALIBRE_MDF_WORKDIR_DEFAULT=".tmpworkdir"
export CALIBRE_MDF_DISPATCHER_DIR=".mdfdispatcher"
export CALIBRE_MDF_DB_HOME=".mdfdbdatabase"

# Process command-line options:
JOB_KEY=$1
if [ -z "$JOB_KEY" ]
then
    echo "USAGE: $0 JOB_KEY"
    exit 1
fi

# Create a temporary Tcl script file:
tmp_script_file=/tmp/tmp$$_.tclcat > $tmp_script_file <<EOF

# Clear the job :
mdf job clear $JOB_KEY
# Execute the job:
mdf job execute $JOB_KEY

# Wait for the job to finish; dump out transcripts for any errors:
mdf job wait {Done Error Stopped} 0 $JOB_KEY -dump_transcripts_upon_error

EOF
# Run calibrewb on the script file:
$MGC_HOME/bin/calibrewb $tmp_script_file
# Remove the temporary script file
rm -f $tmp_script_file
```

## Using the Platform LSF Runscript

The *run\_lsf.sh* runscript executes jobs within the Calibre nmModelflow environment using the Platform LSF distribution system.

### Prerequisites

- \$PATH environment variable must have the LSF bsub command included

### Procedure

1. Create a script to set up your environment for Calibre nmModelflow, similar to the following.

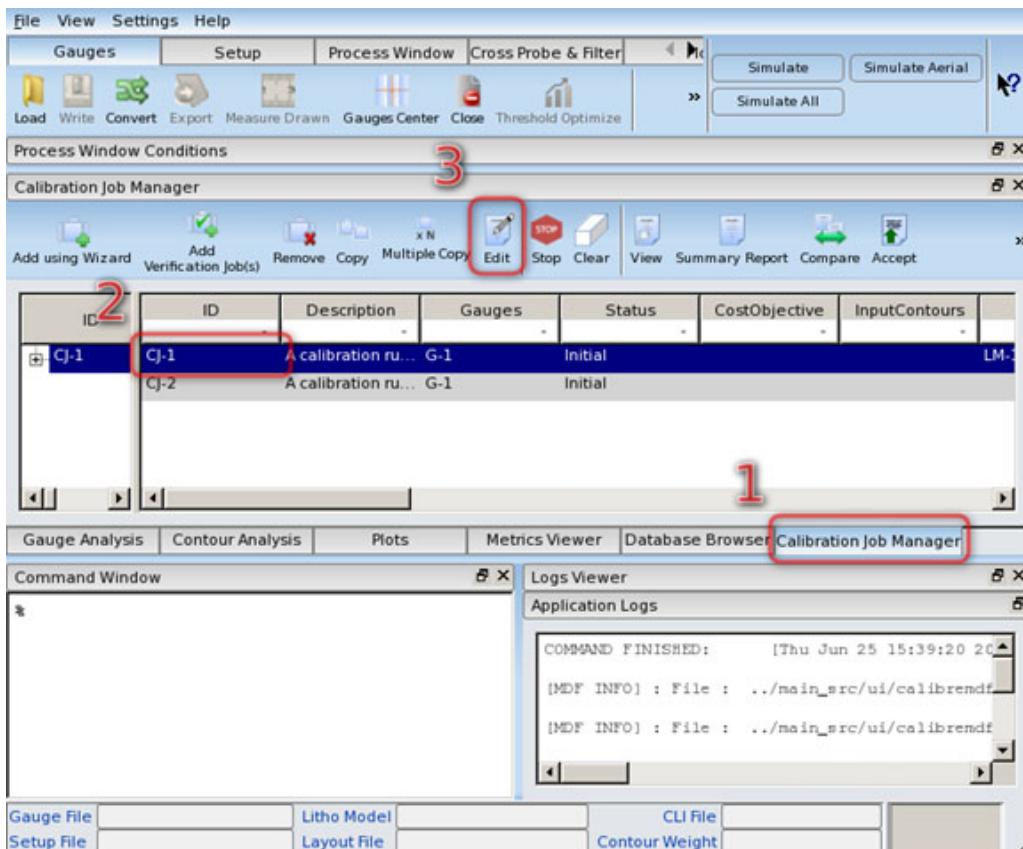
```
#!/bin/bash
export CALIBRE_MDF_WORKDIR_DEFAULT=".tmpworkdir"
export CALIBRE_MDF_DISPATCHER_DIR=".mdfdispatcher"
export CALIBRE_MDF_DB_HOME=".mdfdbdatabase"
$MGC_HOME/bin/calibrewb
```

2. Run the script to invoke Calibre WORKbench, then select **Litho > nmModelflow** to open the Calibre nmModelflow GUI.

## System Flow And Runscript Information Using the Platform LSF Runscript

3. Edit an existing job by clicking on the following items in succession:

- Calibration Job Manager tab
- The job to edit
- The **Edit** button



4. Change the Runcommand field to specify the *run\_lsf.sh* script and provide the arguments as follows:

```
run_lsf.sh -nummastercpus NUM_MASTER_CPUS -numremotecpus  
NUM_REMOTE_CPUS -masterbsuboptions MASTER_BSUB_OPTIONS  
-remotebsuboptions REMOTE_BSUB_OPTIONS
```

where:

- NUM\_MASTER\_CPUS is the number of CPUs the primary host should contain. LSF will be instructed to allocate a single machine with that number of cores to be the primary host.
- NUM\_REMOTE\_CPUS is the number of remote cores to allocate to the job. LSF will be instructed to launch Calibre MTFlex remotes on that many cores on LSF-allocated machines.

An example runcommand might look like the following:

```
run_lsf.sh -nummastercpus 8 -numremotecpus 8 -masterbsuboptions  
'type=Linux -q queue42' -remotebsuboptions 'type=Linux -q queue42'
```

Save the runcommand.

- When prompted for mask layer mapping, set the mask layers as appropriate, then click **OK**.

Calibre nmModelflow generates an update command similar to the following:

```
mdf db update calibrationjobtable -key JOB_KEY -runcommand  
{run_lsf.sh -nummastercpus 8 -numremotecpus 8 -masterbsuboptions  
'type=Linux -q queue42' -remotebsuboptions 'type=Linux -q queue42'}
```

---

#### Note

 To update jobs from a Tcl script without using the GUI, you can use the mdf db update command as shown above. Adding it to a Tcl script file and invoking the script file from the command line provides the same result.

You can also copy or save the session commands directly from the Command Window to a file.

---

- Execute the job by clicking the **Execute** button.

The job executes in the background; the Calibre nmModelflow GUI can be safely closed if needed.

---

---

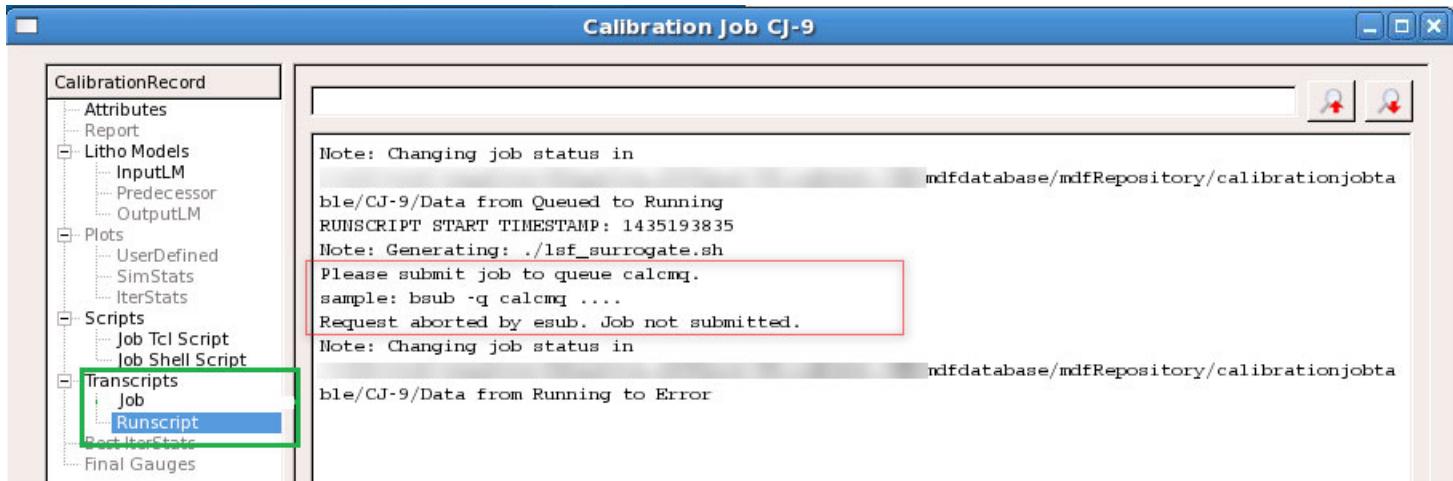
#### Tip

 A job can also be executed from a Tcl script or the Command Window using the command:

```
mdf job execute JOB_KEY
```

---

- Double-click on the name of the running job to check on its status. The calibration job record is displayed; click the Runscript item from the list to see the results of the script. Any bsub errors are shown in the Runscript transcript.



In the figure above, note the following:

- The *lsf\_surrogate.sh* script is a temporary script generated by the *run\_lsf.sh* script, and its call to bsub has failed. (The reason for this error in this case was that the “q” was missing in the “calcmq” argument provided to the script.)
- The job transcript is unavailable because the job was never launched, since the bsub command failed.

## Using the Static and Dynamic Core Allocation CalCM Runscripts

The *run\_calcm\_static.sh* and *run\_calcm\_dynamic.sh* runscripts execute jobs within the Calibre nmModelflow environment using the Calibre CalCM server distribution system.

### Prerequisites

- Calibre CalCM software previously installed

#### Note

For more information on Calibre CalCM, see the [Calibre Cluster Manager \(CalCM\) User’s Manual](#).

Users attempting to run Calibre nmModelflow in MT mode with CalCM might find the section “[Customizing CalCM for Remote Shell](#)” of particular interest.

---

### Procedure

1. Start a CalCM server. Make note of the calcm queue directory for use with the *-calcqueuedir* option. This directory is where the CalCM server provides the *calcm\_submit\_job* script used in the runscript by CalCM.

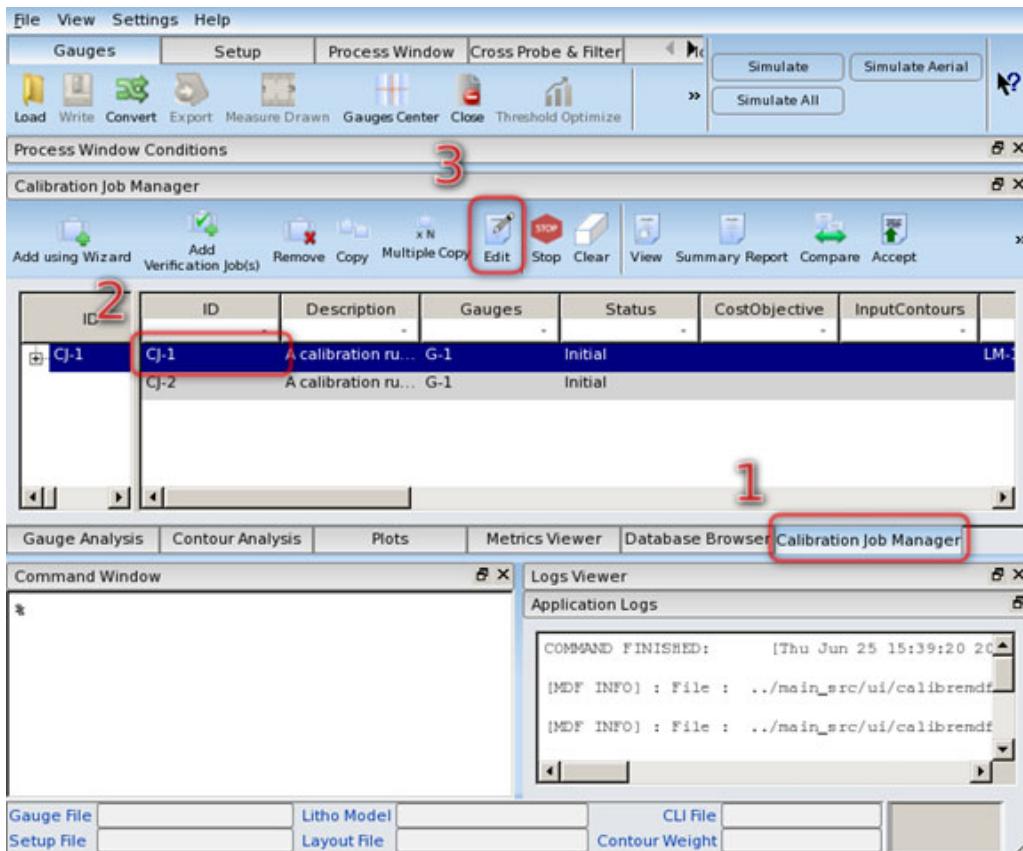
2. Set up the environment for Calibre nmModelflow and invoke Calibre WORKbench. A suggested script containing the environment variables is as follows:

```
#!/bin/bash
export CALIBRE_MDF_WORKDIR_DEFAULT=".tmpworkdir"
export CALIBRE_MDF_DISPATCHER_DIR="./mdfdispacher"
export CALIBRE_MDF_DB_HOME=".mdfdbase"
$MGC_HOME/bin/calibrewb
```

3. Select **Litho > nmModelflow** to invoke the Calibre nmModelflow GUI.

4. Edit an existing job by clicking on the following items in succession:

- **Calibration Job Manager** tab (1 in the figure)
- The job to edit (2 in the figure)
- The **Edit** button (3 in the figure)



5. Change the Runcommand field to specify the runscript and provide its arguments as follows:

- For static core allocation under MTFlex only, use *run\_calcm\_static.sh*:

```
run_calcm_static.sh -calcmdqueuedir CALCMD_QUEUE_DIR -numcpus NUM_CPUS
```

- For dynamic cores for either MT or MTFlex execution, use *run\_calc\_m\_dynamic.sh*:
  - For MT execution, use this set of command arguments:

```
run_calc_m_dynamic.sh -calcmdqueuedir CALCMD_QUEUE_DIR -jobmode MT
```

- For MTFlex execution, use this set of command arguments:

```
run_calc_m_dynamic.sh -calcmdqueuedir CALCMD_QUEUE_DIR \
[-jobmode MTFLEX] -numcpus NUM_CPUS -numcpusmax NUM_CPUS_MAX
```

where:

- *CALCMD\_QUEUE\_DIR* is the path to the queue directory you created in Step 1.
- *-jobmode* takes arguments of either “MT” or “MTFLEX”, and is only available for the *run\_calc\_m\_dynamic.sh* script. MTFLEX is the default.
- *NUM\_CPUS* is the number of cores to allocate to this specific job.
- *NUM\_CPUS\_MAX* is the maximum number of cores to allocate to the job. This option is used only for Dynamic Core Allocation (DCA) mode.

An example run command might look like the following:

```
run_calc_m_static -calcmdqueuedir /tmp/calcmd_queue_dir -numcpus 32
```

Save the file.

---

**Tip**

 You can also specify an extra CalCM *job.conf* file to be added to the one used in the job run by using the *-jobconf JOB\_CONF* option. The runscript generates its own *job.conf* file, and appends the user-supplied *job.conf* file to the generated file.

For *run\_calc\_m\_dynamic.sh*, if you specify JOB MODE MT in the *job.conf* file, it overrides a *-jobmode* argument to the *run\_calc\_m\_dynamic.sh* command.

---

6. When prompted for the mask layer mapping, select the appropriate lithomodel layers.

Calibre nmModelflow generates an update command similar to the following:

```
mdf db update calibrationjobtable -key JOB_KEY -runcommand
{run_calc_m_static.sh -calcmdqueuedir CALCMD_QUEUE_DIR -numcpus
NUM_CPUS}
```

---

**Note**

 To update jobs from a Tcl script without using the GUI, you can use the *mdf db update* command as shown above. Adding it to a Tcl script file and invoking the script file from the command line provides the same result.

You can also copy or save the session commands directly from the Command Window to a file.

---

7. Execute the job by clicking the **Execute** button.

The job executes in the background; the Calibre nmModelflow GUI can be safely closed if needed.

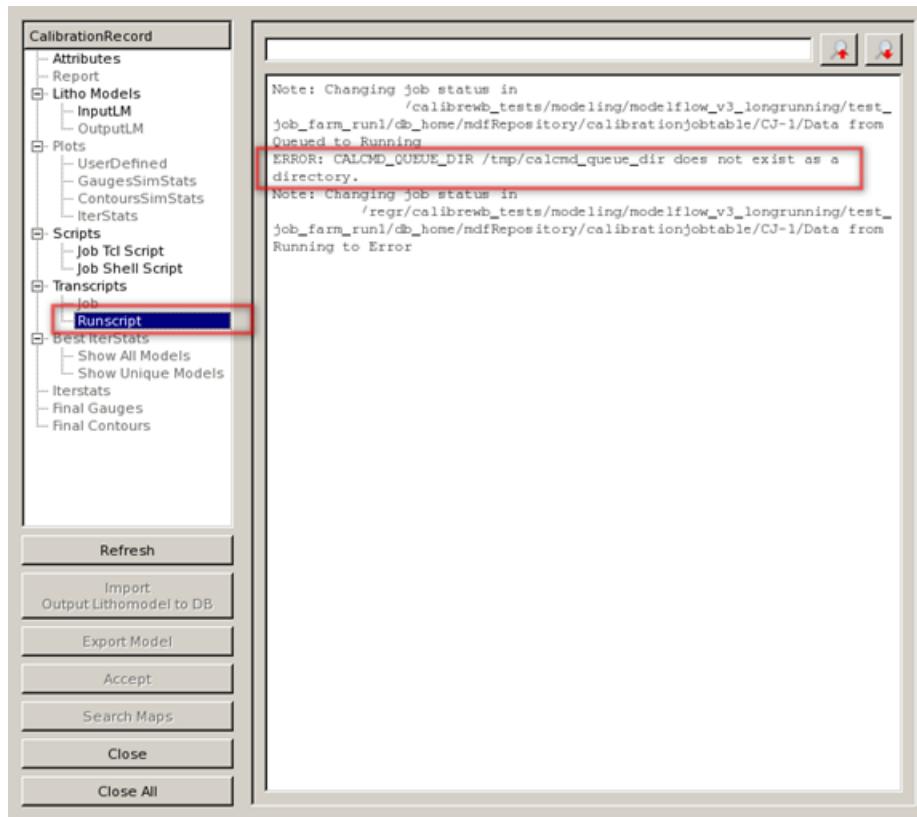
**Tip**

A job can also be executed from a Tcl script or the Command Window using the command:

```
mdf job execute JOB_KEY
```

8. Double-click on the name of the running job to check on its status. The calibration job record is displayed; click on the Runscript item from the list to see the results of the script.

In the following figure, the run has stopped due to an error from the calcmd server name either being incorrect or not running:





# Appendix C

## Gauge Column Listing

The **Gauge Analysis** tab contains displayed gauge columns from the active gauge object. Because there are more gauge columns than can easily fit in the visible area of the tab, most columns are hidden by default.

Columns are broken up into functional groups into the tables as shown. The columns come in the following types:

- **Input** — Items that are part of the input gauge file or super gauge file.
- **Sim** — Values that are generated by running a simulation, or upon completion of a calibration job.
- **CLI** — Values that are generated by running a command from the Command Pane.

In the Column Manager, there are three set group types (Basic, Min, and Cot), along with All, which displays all gauge columns available for selection. Each of the tables uses the following key for the group display:

- **On** — Item is visible for the column, and is selected by default.
- **Off** — Item is visible for the column, and is not selected by default.
- **No** — Item is not visible for the group.

For example, the “Comment” column is visible but not selected by default for the Basic and Cot groups, and not visible for the Min group; its listing in the table is “Off”, “No”, and “Off”.

Any column can be accessed with the All group setting, and can be added to a custom group.

- The Basic Info group is the default display for a loaded gauge file. It contains the critical information about each gauge. This information is all input-based, meaning that it was derived from the input gauge object.

**Table C-1. Basic Info Group**

Column	Description	Type	Basic	Min	Cot
On	“Enabled” flag for the gauge. Any disabled gauges are skipped.	Input	On	On	On
Struc	Structure name.	Input	On	On	On
Col	Column number of the gauge, from the gauge file.	Input	On	No	On
GID	Gauge ID (row number).	Input	On	On	On

**Table C-1. Basic Info Group (cont.)**

Column	Description	Type	Basic	Min	Cot
Weight	Weight value for the gauge.	Input	On	On	On
Drawn	Drawn CD width/space of the gauge.	Input	On	On	On
Other	Other (secondary) width/space information for the gauge.	Input	On	On	On
Comment	Notes for the gauge.	Input	Off	No	Off
ErrorInfo	Used when importing gauge files. Contains “Duplicate” when imported gauges have identical coordinates.	Input	Off	No	Off

- The MoreInfo group consists of a mixture of secondary gauge input, simulation results, and individual columns created by running a specific command.

**Table C-2. MoreInfo Group**

Column	Description	Type	Basic	Min	Cot
Loc	Type of measurement (0 for polygon and 1 for space).	Input	On	On	On
Group	Group name for a gauge group. Must be one word, limit 256 characters.	Input	Off	No	Off
HV	Gauge orientation (Horizontal/Vertical/Angled).	Sim	No	No	Off
Dim	Dimensionality of the gauge as scanned using the “mdf gauges dimensionality” command. The values are 1 for 1D, 2 for 2D, -1 for geometry of unknown dimension, and 0 for no detected geometry.	CLI	No	No	Off
DimUSIR	Dimensionality determined for the user specified interaction radius with the “mdf gauges dimensionality” command.	CLI	No	No	Off
NWeight	Gauge weight normalized so that their sum over all process conditions is equal to 1. This value is recalculated every time you add or remove a process condition, or if you change the Weight column in the BasicInfo group.	Sim	No	No	Off
MeasDrawn	Results of the measurement in nm performed with the “mdf gauges measuredrawn” command.	CLI	No	No	Off

**Table C-2. MoreInfo Group (cont.)**

<b>Column</b>	<b>Description</b>	<b>Type</b>	<b>Basic</b>	<b>Min</b>	<b>Cot</b>
SrafCount	Number of SRAFs in the gauge vicinity found using the “mdf gauges srafcount” command.	CLI	No	No	Off
ROW	Original row number of the gauge from the input gauge file. This is preserved for cases where the GID is reassigned differently from the input row number.	Input	Off	No	Off
FD, SD CtrFD, CtrSD	First and second derivatives of the intensity profile at the threshold for either the full simulation (FD and SD) or the aerial image (CtrFD and CtrSD). These columns only appear after issuing the “mdf gauges computederivatives” command.	CLI	Yes	No	Yes
<i>User Max AI Weight Diff Name</i>	Result of running a custom resist AI difference column. This column only appears if you have a user defined weight column and specify it using the “mdf optimize set_resist maxaidiffweightcol <i>name</i> ” command.	CLI	Off	No	Off
Cs1Diff, Cs2Diff, BpDiff	Simulation consistency check results. These columns only appear after issuing the “mdf optimize do_consistency_check on” command.	CLI	Off	No	Off
GSC_CTR, GSC_CM1, GSC_VEB, GSC_N2R, GSC_N2E	Gridshift consistency results. These columns only appear after issuing the “mdf simulate gridshift” command.  The CM1 and VEB columns only appear if your input litho model contains a non-machine learning CM1 or VEB model, respectively.  The N2R and N2E columns only appear if the input litho model contains a machine learning model.	CLI	On	No	On
AnchorDiff	Integrated difference between the anchor term and full resist cutlines. This column is hidden until the “mdf gauges anchordiff” command is issued.	CLI	Yes	No	Yes
PSK_PATTERN, PSK_BASE_CD, PSK_BASE_ERR, PSK_OPT_CD, PSK_OPT_ERR	Results from running the “mdf optimize psk” command.	CLI	Yes	No	Yes

**Table C-2. MoreInfo Group (cont.)**

<b>Column</b>	<b>Description</b>	<b>Type</b>	<b>Basic</b>	<b>Min</b>	<b>Cot</b>
SimArea	Stochastic area measurement. Output by the “mdf stochastic apa” command.	CLI	Yes	No	Yes

- The PWInfo group is only used with process window gauges (super gauge data files).

**Table C-3. PWInfo Group**

<b>Column</b>	<b>Description</b>	<b>Type</b>	<b>Basic</b>	<b>Min</b>	<b>Cot</b>
PWID	Process window ID. Generated when a super gauge data file is loaded in.	Input	No	No	Off
Dose	Dose of the active gauge.	Input	No	No	Off
Focus	Defocus for the active gauge.	Input	No	No	Off
PwWeight	Weight value for the active gauge.	Input	No	No	Off

- The EtchInfo group is used mainly when the active gauge object has an etch model active.

**Table C-4. EtchInfo Group**

<b>Column</b>	<b>Description</b>	<b>Type</b>	<b>Basic</b>	<b>Min</b>	<b>Cot</b>
MEtch	Measured etch CD in nm.	Input	Off	No	Off
SEtch	Simulated etch CD in nm.	Sim	Off	No	Off
EtchErr	CD or bias etch error in nm depending on whether absolute or relative fit is set.	Sim	No	No	Off
EtchCdErr	CD etch error, defined as the difference between etch simulated and measured CD in nm.	Sim	No	No	Off
MEtchBias	Etch measured bias, defined as the difference between etch and resist measured CD in nm.	Sim	No	No	Off
SEtchBias	Etch simulated bias defined as the difference between etch and resist simulated CD in nm.	Sim	No	No	Off
EtchBiasErr	Bias etch error defined as the difference between simulated and measured etch bias in nm.	Sim	No	No	Off
EtchSWA_1	Approximation of the resist sidewall angle value for the low left gauge point. Generated with etch models containing the resist_profile “on” setting in a litho model.	Sim	No	No	No

**Table C-4. EtchInfo Group (cont.)**

<b>Column</b>	<b>Description</b>	<b>Type</b>	<b>Basic</b>	<b>Min</b>	<b>Cot</b>
EtchSWA_2	Approximation of the resist sidewall angle value for the upper right gauge point. Also generated with etch models containing the resist_profile “on” setting in a litho model.	Sim	No	No	No

- The ResistInfo group is used mainly for resist calibration and simulation operations.

**Table C-5. ResistInfo Group**

<b>Column</b>	<b>Description</b>	<b>Type</b>	<b>Basic</b>	<b>Min</b>	<b>Cot</b>
Meas	Resist measured CD in nm.	Input	On	On	On
Sim	Resist simulated CD in nm.	Sim	On	On	On
SimErr	Resist simulation, error defined as the difference between simulated and measured CD in nm.	Sim	Off	Off	Off
RSimErr	Relative error (percentage difference between simulated and measured CD).	Sim	Off	Off	Off
PS	Print status, which is 0 for successfully resolved gauges and 1 otherwise.	Sim	No	No	Off
EmTh	Empirical threshold. This is the threshold value at which the simulated CD of a given gauge is equal to its measured CD.	Sim	No	No	Off
DiffTh	Difference between the empirical and model threshold.	Sim	No	No	Off
Imin	Minimum intensity value attained along the gauge.	Sim	No	No	Off
Imax	Maximum intensity value attained along a given gauge.	Sim	No	No	Off
Contr	Contrast value, defined as: $(\text{Imax} - \text{Imin}) / (\text{Imax} + \text{Imin})$	Sim	No	No	Off
NS	Normalized slope value for the gauge.	Sim	No	No	Off
Ils	Image log slope in 1/um.	Sim	No	No	Off
Nils	Normalized image log slope.	Sim	No	No	Off
AiToRes	Ratio of integrated AI intensity to that of resist (for resist only).	Sim	No	No	Off
AiDiff	Integrated difference between AI and resist cutlines (for resist only).	Sim	No	No	Off

**Table C-5. ResistInfo Group (cont.)**

<b>Column</b>	<b>Description</b>	<b>Type</b>	<b>Basic</b>	<b>Min</b>	<b>Cot</b>
MinAiDiff	Minimum difference between AI and resist image intensity values (for resist only).	Sim	No	No	Off
MaxAiDiff	Maximum difference between AI and resist image intensity values (for resist only).	Sim	No	No	Off
Shift	Relative shift for the simulation. Returns a positive value if the center point of the simulated geometry is located to the left of (for vertical gauges lower than) the drawn one.	Sim	No	No	Off
Epe1	Left-hand-side EPE in nm (approximate estimate based on the assumption that the geometry is symmetric).	Sim	No	No	Off
Epe2	Right-hand-side EPE in nm (approximate estimate based on the assumption that the geometry is symmetric).	Sim	No	No	Off
SymmDiff	CD difference in nm. Generated with the “mdf gauges checksymmetry -simtype full” command.	CLI	No	No	Off
RecShift	Recommended gauge shift in nm. Generated with the “mdf gauges checksymmetry -simtype full” command.	CLI	No	No	Off
Prediction	Contains the results of SRAF Print Avoidance. (See “ <a href="#">Calibrating for SRAF Print Avoidance</a> ” on page 167.)	Sim	No	No	Off

- The AerialInfo Group is used for aerial image (optical model) simulation and calibration operations.

**Table C-6. AerialInfo Group**

<b>Column</b>	<b>Description</b>	<b>Type</b>	<b>Basic</b>	<b>Min</b>	<b>Cot</b>
CtrSim	CTR simulated CD in nm.	Sim	No	No	Off
CtrErr	Error defined as the difference between CTR simulated and measured CD in nm.	Sim	No	No	Off
CtrPS	Print status for the gauge. 0 is used for successfully resolved gauges, and 1 for gauges that did not resolve.	Sim	No	No	Off
CtrEmTh	Empirical threshold.	Sim	No	No	Off
CtrDiffTh	Difference between empirical and CTR model threshold.	Sim	No	No	Off

**Table C-6. AerialInfo Group (cont.)**

<b>Column</b>	<b>Description</b>	<b>Type</b>	<b>Basic</b>	<b>Min</b>	<b>Cot</b>
Ctrlmin	Minimum AI intensity value attained along a given gauge.	Sim	No	No	Off
Ctrlmax	Maximum AI intensity value attained along a given gauge.	Sim	No	No	Off
CtrContr	Contrast for the gauge, defined as: $(I_{max} - I_{min}) / (I_{max} + I_{min})$ .	Sim	No	No	Off
CtrnS	Normalized AI slope.	Sim	No	No	Off
CtrlIs	AI log slope in $1/\mu m$ .	Sim	No	No	Off
CtrNils	Normalized AI log slope.	Sim	No	No	Off
CtrShift	Relative shift for the simulation. Positive if the center point of the simulated geometry is located to the left of (for vertical gauges lower than) the drawn one.	Sim	No	No	Off
CtrEpe1	Left-hand-side EPE in nm (approximate estimate based on the assumption that the geometry is symmetric).	Sim	No	No	Off
CtrEpe2	Right-hand-side EPE in nm (approximate estimate based on the assumption that the geometry is symmetric).	Sim	No	No	Off
CtrSymmDiff	CD difference in nm. Generated with the “mdf gauges checksymmetry” command.	CLI	No	No	Off
CtrRecShift	Recommended gauge shift in nm. Generated with the “mdf gauges checksymmetry” command.	CLI	No	No	Off
DeltaCD, CtrDeltaCD, LayerDeltaCD	Estimated CD difference from the polynomial fit if the gauge is moved to the new position $ CDSim - CD(\text{polynomial fit estimate}) $ . These columns are used with the “mdf gauges checksymmetry” command and are hidden until that command is issued.	CLI	Yes	No	Yes
CtrRecShiftCode LayerRecShiftCode	Numeric code that specifies how the recommended shift is determined. These columns are used with the “mdf gauges checksymmetry” command and are hidden until that command is issued.	CLI	Yes	No	Yes

- The Coord group contains the locations and length of the gauge in the design. It is set when the gauge object is imported.

**Table C-7. Coord Group**

Column	Description	Type	Basic	Min	Cot
X1	X-coordinate of the lower left gauge point in dbu.	Input	Off	No	Off
Y1	Y-coordinate of the lower left gauge point in dbu.	Input	Off	No	Off
X2	X-coordinate of the upper right gauge point in dbu.	Input	Off	No	Off
Y2	Y-coordinate of the upper right gauge point in dbu.	Input	Off	No	Off
Length	Gauge length in nm.	Input	Off	No	Off

- Elements in the FocusInfoSim group require a process window super gauge data object and a matching process window litho model. They are generated when you run a Center Focus calibration job.

**Table C-8. FocusInfoSim Group**

Column	Description	Type	Basic	Min	Cot
FCenter_s	Focus center from a parabolic fit to CD Sim. Derived using the equation: $cd(f) = CDcenter + A2*(f - fcenter)^2$	Sim	No	No	No
CDCenter_s	CDcenter from a parabolic fit to CD Sim. Uses the equation: $cd(f) = CDcenter + A2*(f - fcenter)^2$	Sim	No	No	No
FCurve_s	A2 from parabolic fit to CD Sim. Uses the equation: $cd(f) = CDcenter + A2*(f - fcenter)^2$	Sim	No	No	No
FRmsErr_s	RMS error of $(cd(f) - cdsim)$ for available CD Sim values.	Sim	No	No	No
FMeanErr_s	Mean error of $(cd(f) - cdsim)$ for available CD Sim values.	Sim	No	No	No
FMaxErr_s	Max error of $(cd(f) - cdsim)$ for available CD Sim values.	Sim	No	No	No
FCDSwing_s	Swing of the focus curve, defined as: $FCurve_s * (defocus\_max - defocus\_min)^2/4$	Sim	No	No	No
FNPoints_s	Number of Sim data points used to fit the parabola.	Sim	No	No	No

- Elements in the FocusInfoMeas group require a process window super gauge data object and a matching process window litho model. They are generated when you run a Center Focus calibration job.

**Table C-9. FocusInfoMeas Group**

Column	Description	Type	Basic	Min	Cot
FCenter_m	Focus center from a parabolic fit to CD Meas. Derived using the equation: $cd(f) = CDcenter + A2 * (f - fcenter)^2$	Sim	No	No	No
CDCenter_m	CDcenter from a parabolic fit to CD Meas. Uses the equation: $cd(f) = CDcenter + A2 * (f - fcenter)^2$	Sim	No	No	No
FCurve_m	A2 from parabolic fit to CD Meas, from the equation: $cd(f) = CDcenter + A2 * (f - fcenter)^2$	Sim	No	No	No
FRmsErr_m	RMS error of $(cd(f) - cdmeas)$ for available CD Meas values.	Sim	No	No	No
FmeanErr_m	Mean error of $(cd(f) - cdmeas)$ for available CD Meas values.	Sim	No	No	No
FMaxErr_m	Max error of $(cd(f) - cdmeas)$ for available CD Meas values.	Sim	No	No	No
FCDSwing_m	Swing of the focus curve, calculated as: $FCurve_m * (defocus_max - defocus_min)^2 / 4$	Sim	No	No	No
FNPoints_m	Number of Meas data points used to fit the parabola.	Sim	No	No	No

- The StatMeasInfo group is used for standard deviation calculations. It is typically initially populated from the input gauge object.

**Table C-10. StatMeasInfo Group**

Column	Description	Type	Basic	Min	Cot
Prec	Precision, defined as the absolute error in nm with which empirical data were extracted.	Input	Off	No	Off
StDev	Standard deviation in nm characterizing measurement statistics.	Input	Off	No	Off
Count	Number of samples used to obtain StDev.	Input	Off	No	Off
95CI	95% confidence interval in nm.	Input	Off	No	Off
Sem	SEM picture name.	Input	Off	No	Off
BoxHeight	BoxHeight value used for this gauge.	Input	Off	No	Off

- The DoseInfoSim and DoseInfoMeas groups are used only for process window simulations.

**Table C-11. DoseInfoSim Group**

<b>Column</b>	<b>Description</b>	<b>Type</b>	<b>Basic</b>	<b>Min</b>	<b>Cot</b>
DoseLo_s	Lowest dose for CD Sim at nominal focus for which CD is +/-10% of nominal.	Sim	No	No	No
DoseHi_s	Highest dose for CD Sim at nominal focus for which CD is +/-10% of nominal.	Sim	No	No	No
Dose_Lat_s	DoseHi_s-DoseLo_s value.	Sim	No	No	No
CommonDoseLat_s	In the range (lo--cen--hi), the smaller of (cen-lo) or (hi-cen) or 0 if cen outside bounds.	Sim	No	No	No

**Table C-12. DoseInfoMeas Group**

<b>Column</b>	<b>Description</b>	<b>Type</b>	<b>Basic</b>	<b>Min</b>	<b>Cot</b>
DoseLo_m	Lowest dose for CD Meas at nominal focus for which CD is +/-10% of nominal.	Sim	No	No	No
DoseHi_m	Highest dose for CD Meas at nominal focus for which CD is +/-10% of nominal.	Sim	No	No	No
Dose_Lat_m	DoseHi_m-DoseLo_m.	Sim	No	No	No
CommonDoseLat_m	In the range (lo--cen--hi), the smaller of (cen-lo) or (hi-cen) or 0 if cen outside bounds.	Sim	No	No	No

- The TopoInfo group is used only when calibrating a topo model.

**Table C-13. TopoInfo Group**

<b>Column</b>	<b>Description</b>	<b>Type</b>	<b>Basic</b>	<b>Min</b>	<b>Cot</b>
TopoEnclosure	Negative when a CD site is inside an underlying feature. Positive if it is not enclosed. Generated using the “mdf gauges topoenclosure” command.	CLI	No	No	Off
RxWidth	Minimum width of underlying active layer features. Generated with the “mdf gauges topomeas -underlying active” command.	CLI	No	No	Off
RxSpace	Minimum space of underlying active layer features. Generated with the “mdf gauges topomeas -underlying active” command.	CLI	No	No	Off

**Table C-13. TopoInfo Group (cont.)**

<b>Column</b>	<b>Description</b>	<b>Type</b>	<b>Basic</b>	<b>Min</b>	<b>Cot</b>
PolyWidth	Minimum width of underlying poly layer features. Generated with the “mdf gauges topomeas -underlying poly” command.	CLI	No	No	Off
PolySpace	Minimum width of underlying poly layer features. Generated with the “mdf gauges topomeas -underlying poly” command.	CLI	No	No	Off



# Appendix D

## Resist 3D Calibration Support in Calibre nmModelflow

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Resist 3D (R3D) Calibration refers to modeling one of a number of height-sensitive process models. Calibre nmModelflow supports the following types of R3D configurations:

**Table D-1. Types of Resist 3D Models**

Type	Description
SRAF	SRAF printing prediction for simulation and calibration using measurements at multiple planes.
Toploss	Resist profile prediction for simulation and calibration using measurements at multiple planes.

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## Common R3D Concepts and Flows

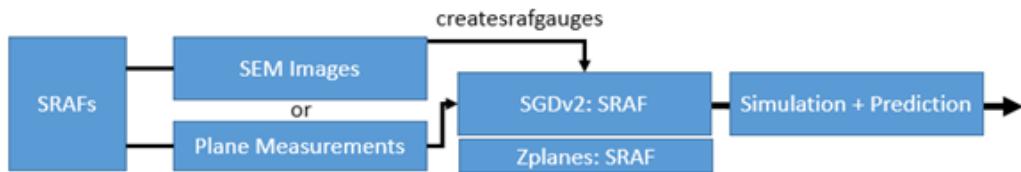
Resist 3D models have some similar concepts and some qualities that are specific to a type of R3D model.

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## Resist 3D Calibration Options

Understanding which type of resist 3D modeling you are working with sets the type of information you need to specify in the litho model, gauge data file, and calibration stages. It also sets the kind of output you receive after a successful simulation or calibration run.

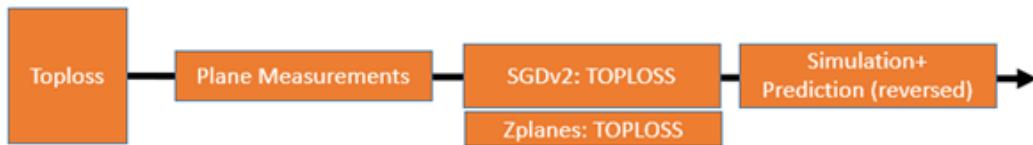
### SRAF Printing Prediction Flow



SRAF printing prediction involves training a model to simulate and calibrate optical and resist models for SRAFs that may or may not print in order to establish an SRAF printing threshold.

- SRAF printing prediction data can be sourced from plane measurements taken at the top and bottom of the resist, or using SEM images and the Calibre WORKbench [createsrafgauges](#) command.
- SRAF prediction uses the SRAF keyword in a Super Gauge Data file, and expects inequalities in the Meas column in place of measurements.
- ZPlanes models are used for SRAF prediction in Calibre nmModelflow, and are separate models from the optical and resist models.
- A prediction is made for SRAF printing when the litho model containing a ZPlanes model and a Super Gauge Data file with SRAF type is simulated or calibrated. A Prediction column is added to the **Gauge Analysis** tab.

## Toploss Prediction Flow



Toploss prediction is similar to SRAF prediction, except it attempts to predict resist toploss and sidewall defects, and tests for printing or not printing inversely from SRAFs.

- Toploss prediction data is sourced from plane measurements at various heights.
- ZPlanes models are used for toploss prediction in Calibre nmModelflow, and are separate from the optical model file.
- A prediction is made for toploss printing when a litho model containing a ZPlanes model and a Super Gauge Data file containing a TOPLOSS plane data set is simulated or calibrated. A Prediction column is added to the **Gauge Analysis** tab, and the Sim column contains predicted top of resist heights.

## Super Gauge Data v2 File Usage

The Super Gauge Data file contains multiple gauge data sets. It was originally designed for process window calibration, because it could store gauge data sets at different dose and defocus values in a single file, but has been modified starting with version 2 to store Resist 3D data sets.

The [Super Gauge Data File Format](#) is documented in the *Calibre WORKbench User's and Reference Manual*. It uses the following format:

```

# this is a comment
version 2
gaugeSetCount number_of_gaugefiles

# first gauge file
gaugeSet n {
    dose dose_value1
    defocus defocus_value1
    type {CD | SRAF | TOPLOSS | HEIGHT}
    [plane TOP | MIDDLE | BOTTOM | value1 ]
    weight weight1
    gaugeFile {gaugefilename1 | NA}
    [opticalDirectory modelpath1a]
    [secondOpticalDirectory modelpath1b]
    [thirdOpticalDirectory modelpath1c]
    data {
        gaugefile
    }
}

```

For Resist 3D models, the type parameter becomes required, because it sets the type of gauge data set.

- CD — The standard gauges on test structures.
- SRAF — A set of gauges on SRAFs. Must be combined with a plane keyword. The Meas column should show either “LT:x” or “GT:x” where x is the expected height of the SRAF (0 for no SRAF expected).
- TOPLOSS — A set of gauges measuring the expected top of the resist. The Meas column should show either “LT:x” or “GT:x”, where x is the expected value.
- HEIGHT — A set of gauges measuring resist height at multiple planes (calibration of height-type gauges is not currently supported in Calibre nmModelflow). The Meas column is the height that was measured as opposed to the width. All Meas values must be less than the original resist height.

---

#### **Note**

 Not all combinations of type and plane are valid:

- **SRAF printing** — Use only type SRAF and a plane setting of TOP or BOTTOM.
  - **Toploss modeling** — Use type TOPLOSS. No plane setting is needed.
  - **Resist 3D (profile) modeling** — Use type HEIGHT or type CD with a plane setting.
- 

## ZPlanes File Usage for Calibration

The ZPlanes file is used in both SRAF and toploss prediction. It contains parameters that are specific to the SRAF and toploss flows.

A ZPlanes file uses the following format:

```
version 1
modelType ZPLANES
# SRAF top group
[sraf_top_plane z]
[sraf_top_dose dose]
[sraf_top_mincd cd]
[sraf_top_maxcd cd]
# SRAF bottom group
[sraf_bottom_plane z]
[sraf_bottom_dose dose]
[sraf_bottom_mincd cd]
[sraf_bottom_maxcd cd]
# toploss group
[toploss_plane z]
[toploss_slope s]
[toploss_mincd cd]
```

Only parameters that appear in the ZPlanes file can be calibrated. Attempting to calibrate a parameter that is not present in the file will cause an error, with the exception of the sraf\_top\_dose and sraf\_bottom\_dose parameters. These will be added to the output ZPlanes file.

## Prediction Concepts

For SRAF and toploss models, prediction simulations involve printing versus not-printing characteristics tested on the gauges in the gauge data file.

Prediction uses inequality values as their gauge measurement column. Instead of a value in nanometers, an inequality gauge contains a composite string; GT for greater than or LT for less than, plus a numeric value separated by a colon. For example: GT:0 and LT:8.

When a simulation or calibration run is performed for SRAF and toploss models, Calibre nmModelflow adds a Prediction column to the active gauge object to accompany the Sim column value. However, the meaning of this column is dependent on the type of prediction being performed.

- Negative means a defect is absent on the wafer.
- Positive means a defect is present on the wafer.

For SRAF gauges, LT:X means there is no defect (printing) on the wafer. This results in four possibilities:

- GT:X and Sim > X — TruePositive (model matches wafer, SRAF prints), used to test for a deliberately printing SRAF. The expected value is printing, so GT:X and a Sim of X or greater is a printing SRAF.
- LT:X and Sim < X — TrueNegative (model matches wafer, SRAF does not print), used to test a real SRAF. A typical LT:X value for SRAFs is LT:0, meaning that the Sim result column would need to be -8888 (nothing printing, represented by a value of -1 in modelflow\_v2) to have this gauge show as a TrueNegative result.
- GT:X and Sim < X — FalseNegative (model shows no SRAF, but the SRAF is supposed to print on the wafer), where a deliberately printing SRAF was not simulated.
- LT:X and Sim >X— FalsePositive (model shows SRAF, but no SRAF was supposed to print), where a non-printing SRAF returned a simulated value.

For Toploss gauges, LT:X is a test for a defect on the wafer, which is the *inverse* of SRAFs. This leads to four possibilities:

- GT:X and Sim > X — TrueNegative (model matches the wafer, resist was found), where the measured top of the resist is higher than the predicted value.
- LT:X and Sim < X — TruePositive (model matches the wafer, no resist was found), where the measured top of the resist is intended to find a zero toploss location (a LT:0 and Sim of -8888 is a TruePositive result for no resist found at that location).

- GT:X and Sim < X — FalsePositive (model shows toploss, but resist was found on the wafer), where the toploss does not come to the expected height.
- LT:X and Sim > X — FalseNegative (model shows remaining resist, but resist toploss was observed on the wafer), where the measured top of the resist is higher than the expected height.

## Notes on R3D Models From Previous Releases

Some of the resist 3D modeling solutions have been available for a number of years from Siemens EDA, but the methods and requirements are slightly different for Calibre nmModelflow.

### Development History

The original SRAF calibration was first to be released in 2015. It used a simpler super gauge data (version 1) database. It is described in Appendix I of the *Calibre WORKbench User's and Reference Manual*.

- It used separate SRAF-specific optical models and separate SRAF gauge files for calibration only, using modelflow\_v2.
- The SRAF optical model was calibrated using the errate objective.

Calibre nmModelflow added support for SRAF calibration in the 2018.2 release.

- The SGDv1 based calibration flow was ported into Calibre nmModelflow, still using a separate optical model and SRAF gauges. The SRAF gauge file format was improved to perform prediction.
- As an alternative, the createsrafgauges command was implemented to set SRAF gauges using a SEM image file.

The current version uses super gauge data (version 2, also known as SGDv2) files, which combine CD and SRAF/TOPLOSS/HEIGHT data into a single file. This allows you to use a single litho model to hold all your data and model files.

- The ZPlanes model was added to capture extra SRAF and TOPLOSS modeling parameters.
- ZPlanes models are also supported in Calibre nmOPC and Calibre OPCverify simulations.
- The ZPlanes model is calibrated separately in the Calibre nmModelflow GUI.

## Migration Notes

SGDv1 Calibration can be performed with Calibre nmModelflow, with the following considerations:

- Do not use a ZPlanes model.
- Use vertical\_diffusion info in the optical model to model the 3D effects.

SGDv2 Calibration:

- Ensure that the type and plane settings are set properly for SRAF or toploss gauges.

# SRAF Calibration in Calibre nmModelflow

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SRAF Calibration in the Calibre nmModelflow GUI can be implemented using the Flow Stage Wizard.

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## Litho Model Information for SRAF Calibration

SRAF calibration in Calibre nmModelflow has the following additional information specific to configuring a litho model.

The *Lithomodel* file should include a ZPlanes model containing SRAF parameters, and look similar to the following code:

```
version 1
resist resist.mod
mask 0 { optical sraf_opt
    background 0.0259 -0.0095
    mask_layer 0 TRANS 0.9741 0.0095
}
zplanes zpl.mod
```

The accompanying ZPlanes model should have SRAF parameters in it, similar to the following (not all parameters are required):

```
version 1
modeltype ZPLANES
sraf_top_plane 0.05
sraf_bottom_plane 0.05
sraf_bottom_dose 1.00
```

---

### Note

 When this ZPlanes model is calibrated, *sraf\_top\_dose* will be added with the default value of 1.0, because an *sraf\_top* value was included with the ZPlanes parameters.

---

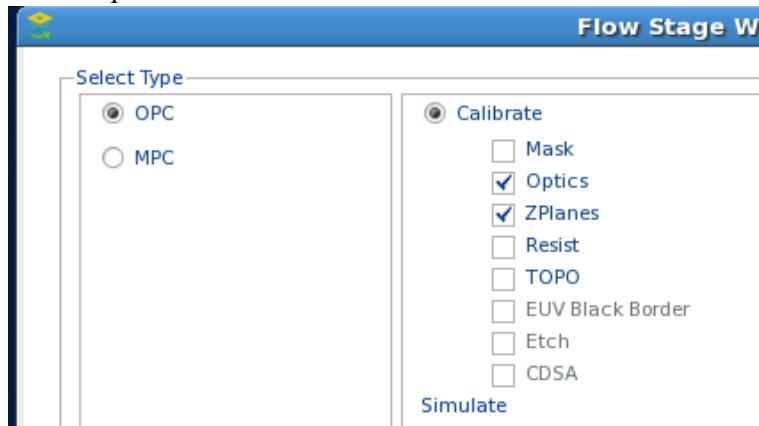
## Stage Creation Information for SRAF Calibration

Configuring a stage for SRAF Calibration uses the Optics, ZPlanes and Resist stages.

Calibration is performed with two separate stages: one for the optics and ZPlanes models, and one for the resist model.

## Optics and ZPlanes Stage for SRAF Calibration

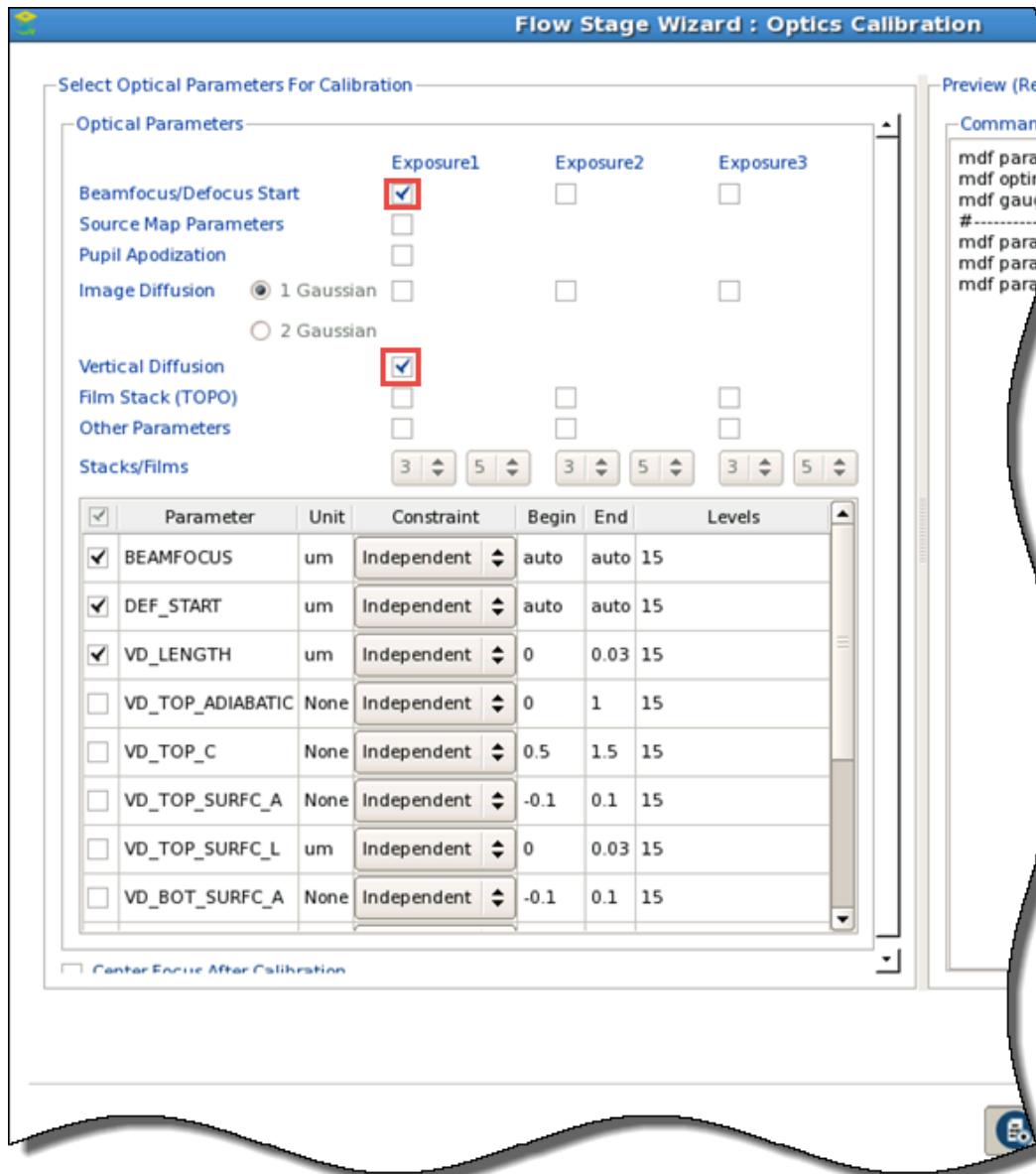
The Optics and ZPlanes stage are calibrated together. Calibre nmModelflow displays separate parameter pages for the optical and ZPlanes models.



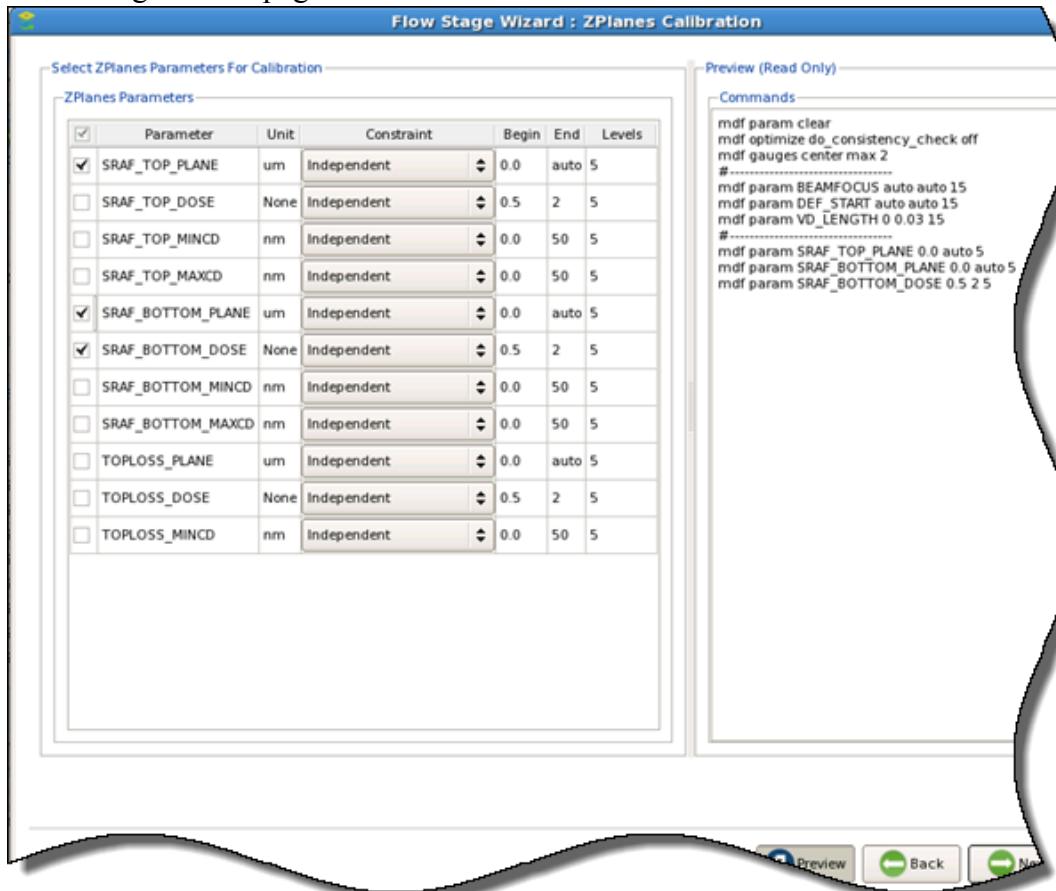
On the Optics page, always select the Beamfocus / Defocus Start checkbox. If your optical model includes any vertical parameters, select the Vertical Diffusion checkbox.

**Note**

Select only parameters that exist in your optical model; attempting to optimize a parameter that is not present in your optical model causes the calibration to exit with an error.

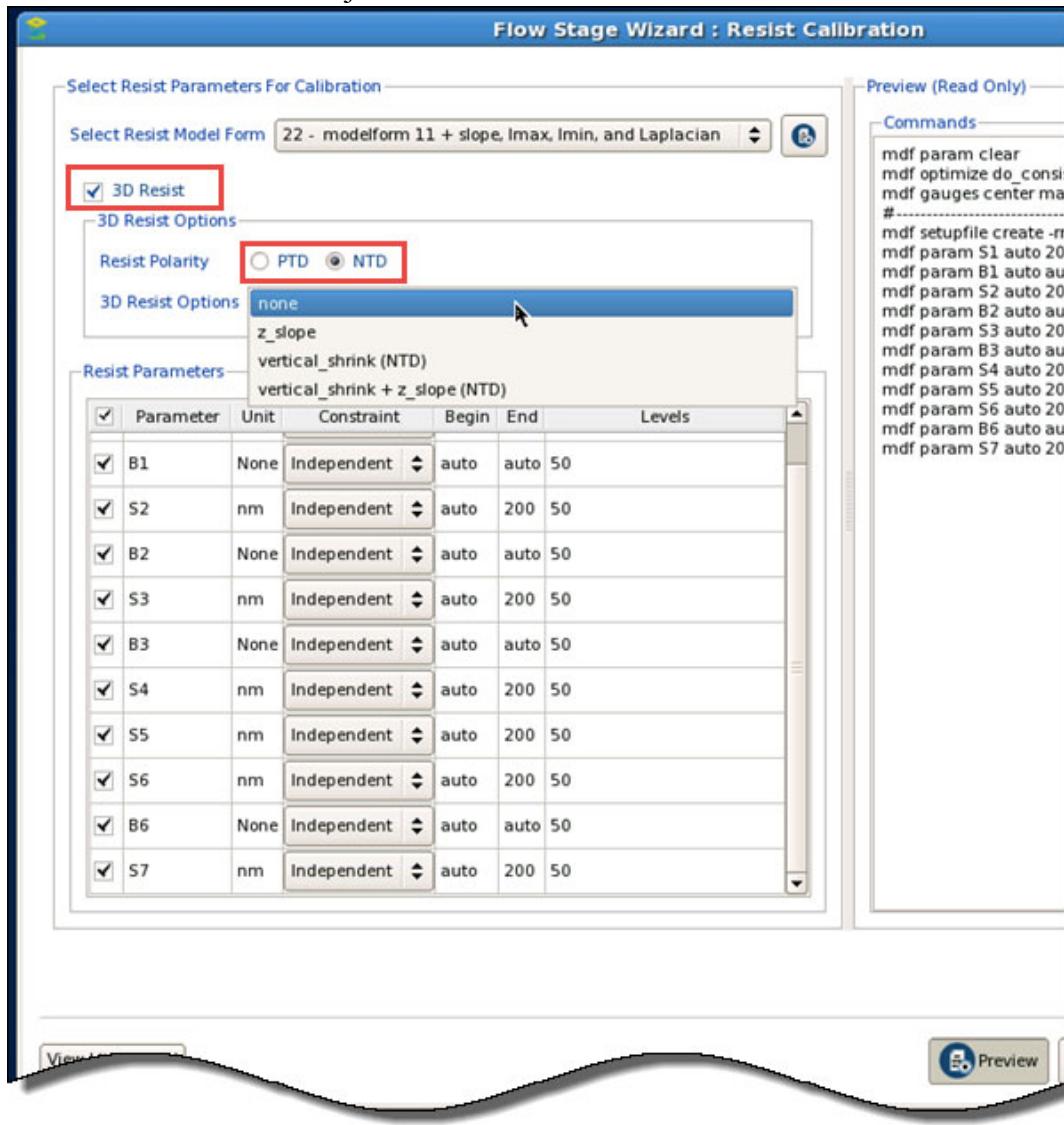


Similarly, select only ZPlanes parameters that appear in your ZPlanes model. Do not select Toploss settings on this page.



## Resist Stage (SRAF)

You can either create the Resist stage as a standalone calibration stage or as a descendant of an optics and ZPlanes calibration job.



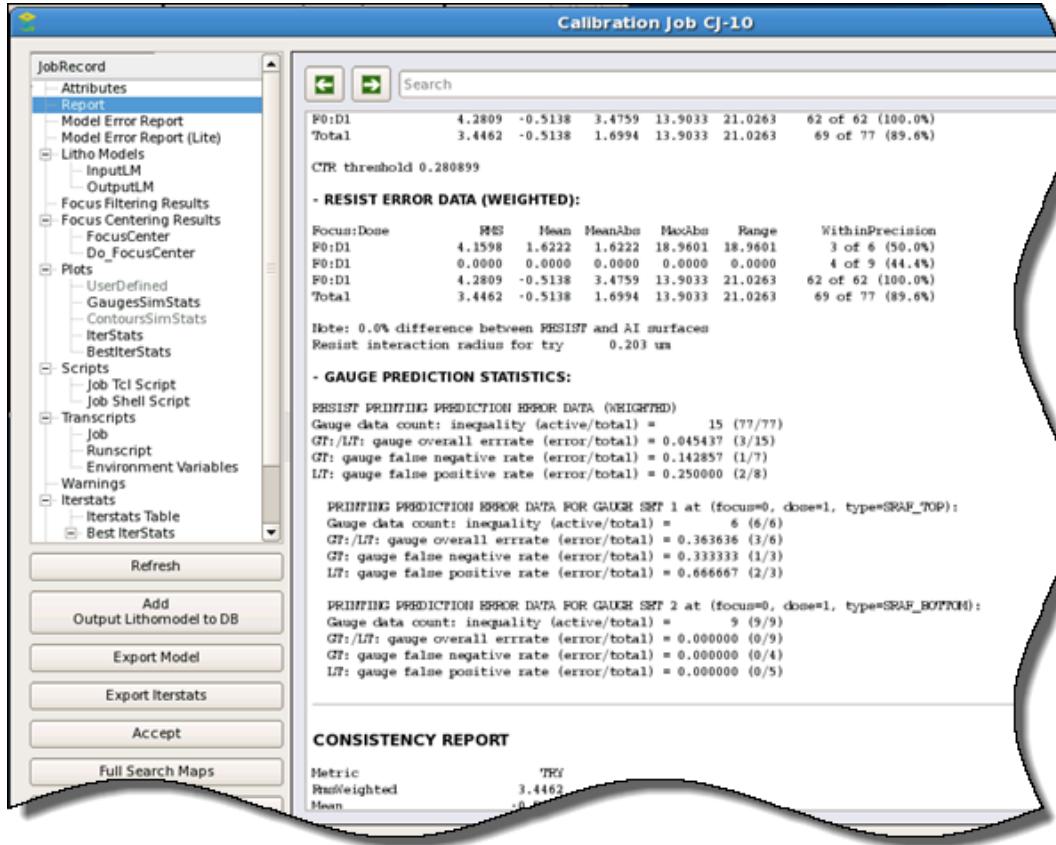
- Select the 3D Resist checkbox to expand the 3D Resist Options area as shown in the figure.
- Select the correct type of resist model (PTD or NTD) based on the modelform you are using for the resist model.
- By default, no additional 3D model parameters are added; you can select one of the options from the list as shown to add them to the parameter list. For example, if your resist modelform contains Z\_SLOPE, select the appropriate option.

## SRAF Prediction Results Analysis

When an SRAF calibration job successfully completes, use the **View** button in the Calibre nmModelflow GUI to view the results.

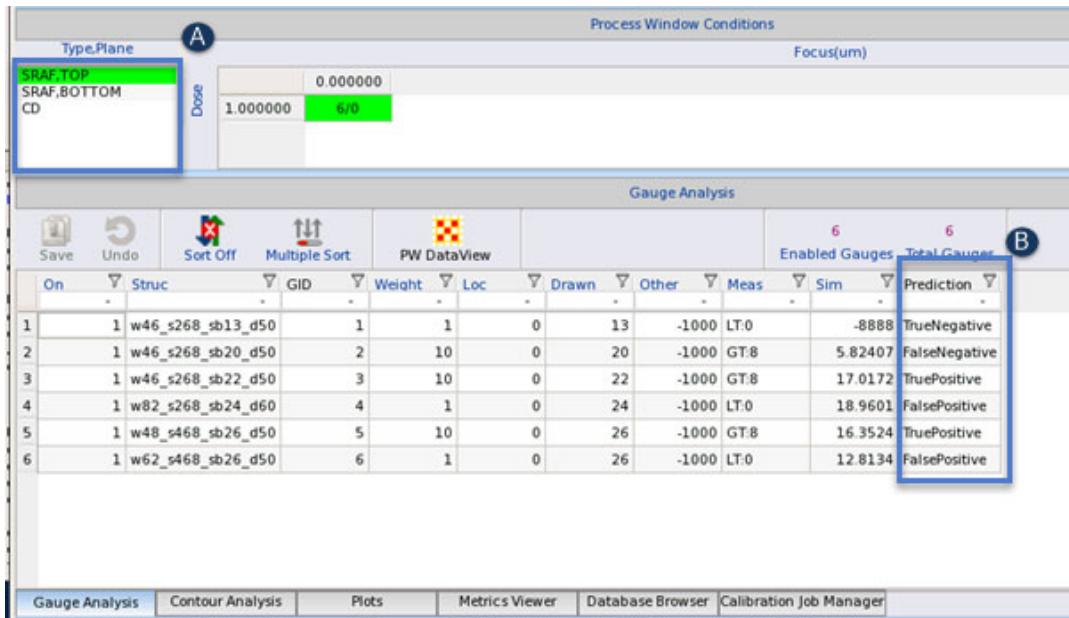
Prediction results can be found in the following locations:

- **Report section** — The Report section includes a Gauge Prediction Statistics subsection as part of the Simulation (Try) Report.



- **Gauge Analysis tab** — Click **Accept** to view the prediction in the **Gauge Analysis** tab. You may need to select the SRAF type in the Type/Plane selector (A in the figure) if CD

is the default display. The Prediction column (**B** in the figure) shows the result of the calibration run.



# Toploss Calibration in Calibre nmModelflow

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Toploss Calibration in the Calibre nmModelflow GUI can be implemented using the Flow Stage Wizard.

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## Litho Model Information for Toploss Calibration

Toploss calibration in Calibre nmModelflow has the following additional information specific to configuring a litho model.

The Lithomodel file should include an optical model and multiple mask layers for each plane sampled for toploss. A DDM model is recommended. It should look similar to the following code:

```
version 1
resist resist.mod
mask 0 { optical e1_f+0.0000
    background atten 0.06
    mask_layer 0 TRANS clear DDM x1.ddm
    mask_layer 1 TRANS clear DDM x1.ddm
    mask_layer 2 TRANS clear DDM x1.ddm
}
zplanes zpl.mod
}
```

The ZPlanes model should have toploss parameters in it, similar to the following code:

```
version 1
modeltype ZPLANES
toploss_plane 0.0
toploss_dose 1.0
toploss_mincd 0.0
```

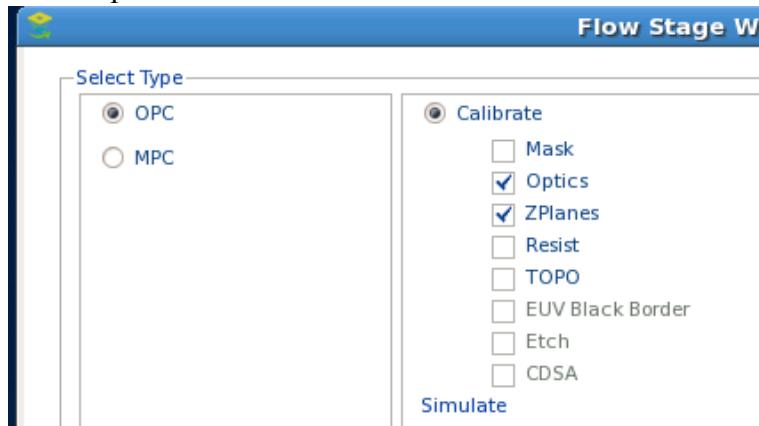
## Stage Creation Information for Toploss Calibration

Configuring a stage for toploss calibration uses the Optics, ZPlanes and Resist stages.

Calibration is performed with two separate stages: one for the optics and ZPlanes models, and one for the resist model.

## Optics and ZPlanes Stage for Toploss Calibration

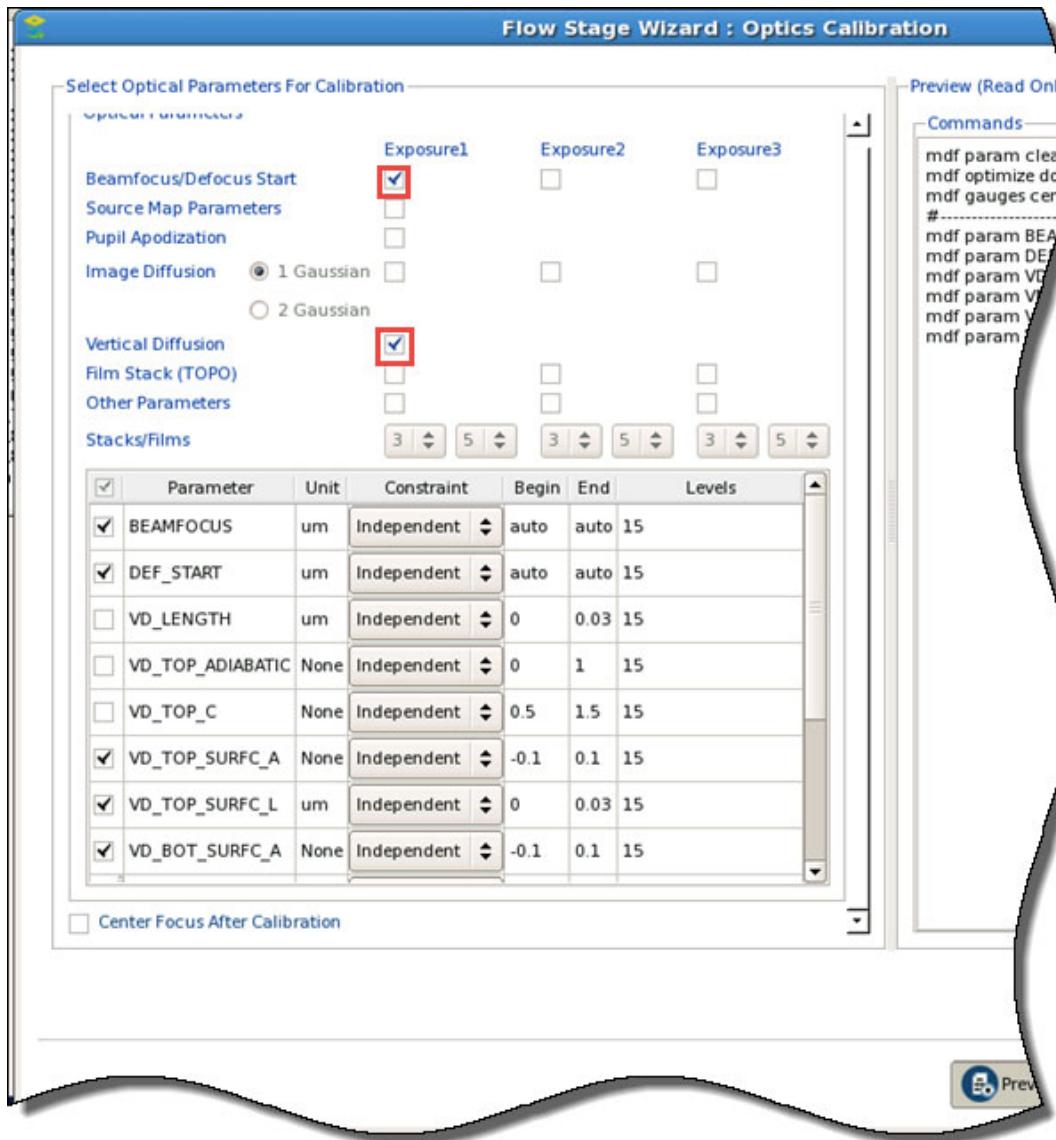
The Optics and ZPlanes stage are calibrated together. Calibre nmModelflow displays separate parameter pages for the optical and ZPlanes models.



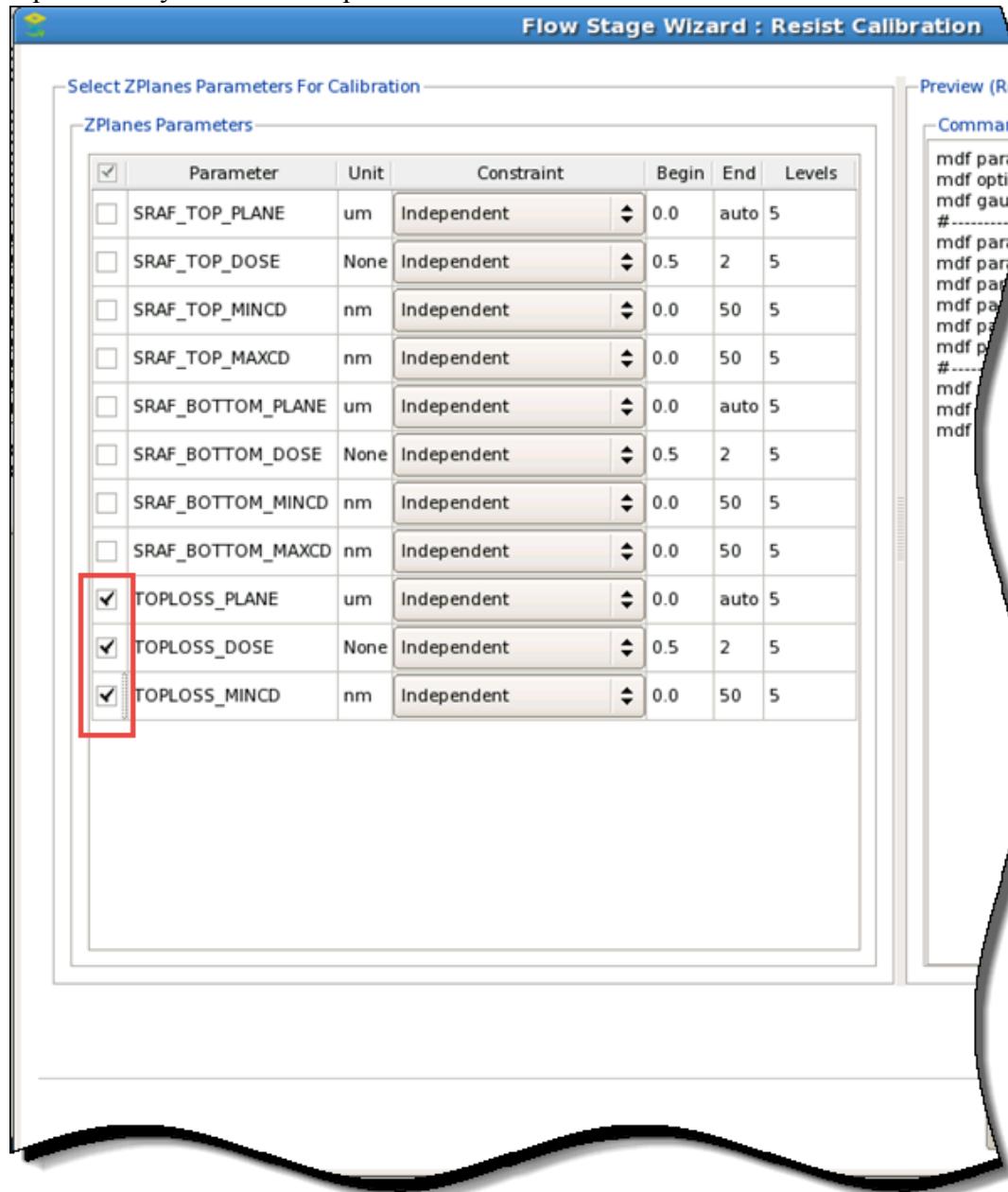
On the Optics page, always select the Beamfocus / Defocus Start checkbox. Additional options are based off of your optical model contents. If your optical model includes any vertical parameters, select the Vertical Diffusion checkbox.

### Note

 Select only parameters that exist in your optical model; attempting to optimize a parameter that is not present in your optical model causes the calibration to exit with an error.



Similarly, the ZPlanes page should only select one or more of the toploss parameters. It should not optimize any of the SRAF parameters.



## Resist Stage (Toploss)

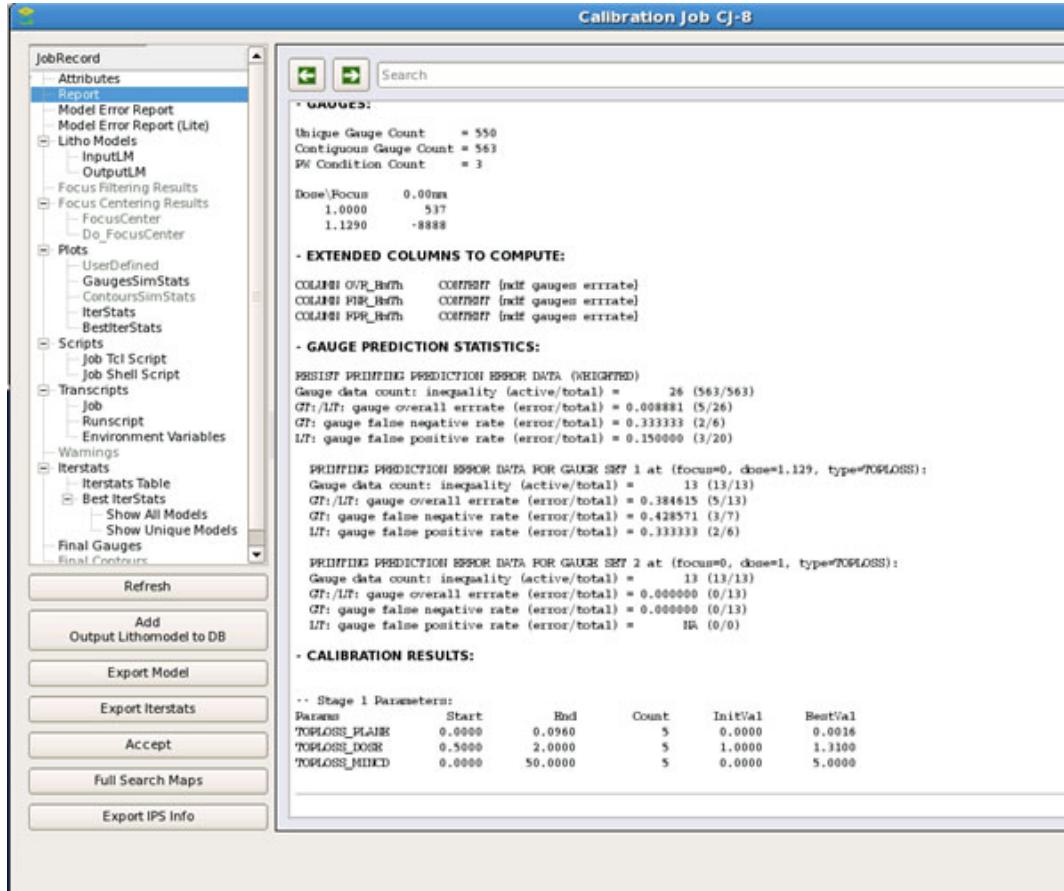
You can either create the Resist stage as a standalone calibration stage or as a descendant of the optics and ZPlanes calibration job. The resist parameters do not need to be specifically modified for toploss calibration.

# Toploss Prediction Results Analysis

When a toploss calibration job successfully completes, use the **View** button in the Calibre nmModelflow GUI to view the results.

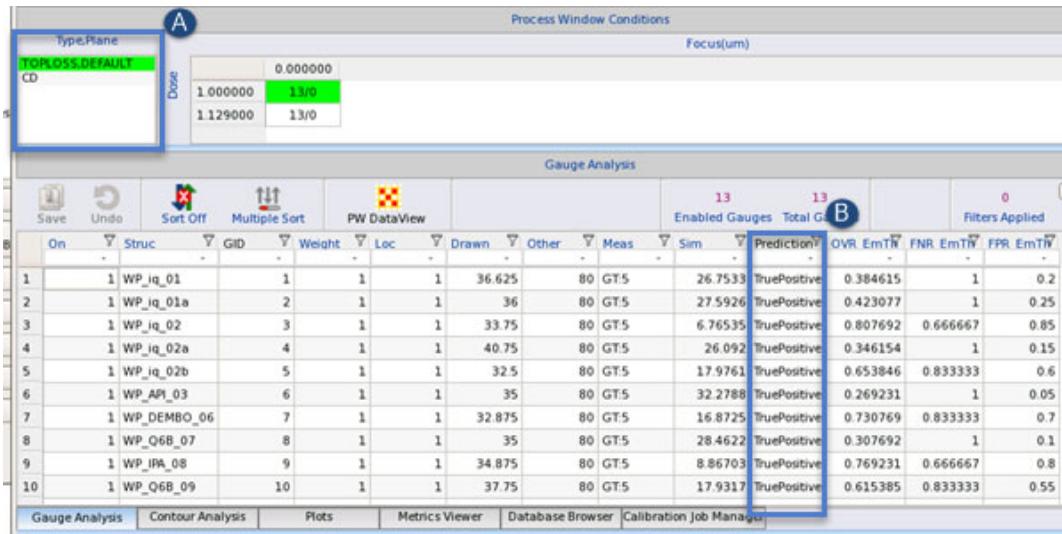
Prediction results can be found in the following locations:

- **Report section** — The Report section includes a Gauge Prediction Statistics subsection as part of the Optimization Report.



- **Gauge Analysis tab** — Click **Accept** to view the prediction in the Gauge Analysis tab. You may need to select the SRAF type in the Type/Plane selector (**A** in the figure) if CD

is the default display. The Prediction column (**B** in the figure) shows the result of the calibration run.



## Using R3D Models In Calibre nmOPC

Resist 3D models are loaded into Calibre nmOPC using a litho model, and are accessed via the `pw_condition` command.

### Prerequisites

- A completed calibration job from an SRAF, toploss, or resist profile data set.
- An OPC design to use the new models on.
- An understanding of Calibre nmOPC rule file definition, as described in the [Calibre nmOPC User's and Reference Manual](#).

### Procedure

1. In Calibre nmModelflow, select the job with the best objective value, then click **View** to open the Calibration Job report for the job.
2. Click **Export Model**, then fill out the Save Lithomodel dialog to write a new litho model directory. (This step is required because Calibre nmModelflow stores litho model files in a database.)
3. In the new directory, create a Calibre nmOPC rule file. Elements specific to resist 3D models are as follows:
  - **image** — Specify the litho model from the previous step.

- **pw\_condition** — Select the appropriate keywords:

```
pw_condition name [[mask n] [focus fnm] [dose d] [bias b]]*
[aerial {val| model} [thr_delta val[%]]]
plane {zval_um | SRAF_POSITIVE | SRAF_NEGATIVE | TOPLOSS_PLANE}
[no_etch|with_etch]
[inside|outside|not_inside|not_outside layer] [no_opc] [pvband]
[3DSlice] [spa] [cd_only] [exclude_from_no_simulate]
```

- **plane** — Set the Z-position in the film where the image is computed.
  - **SRAF models** — Select SRAF\_POSITIVE or SRAF\_NEGATIVE according to the combination of the resist process polarity (positive or negative) and the mask tone (clear or dark). Typically, you would choose SRAF\_POSITIVE for positive SRAFs (additional drawn polygons) and SRAF\_NEGATIVE for negative SRAFs (holes in target shapes).
  - **Toploss models** — Select TOPLOSS\_PLANE.
  - **Resist profile models** — Specify a *zval\_um* value matching the *imageplanes* value in the optical model.
- **3DSlice** — Specifies that this is a resist toploss model, but this parameter is only used with process window conditions, and not for a nominal condition.
- **spa** — Specifies that this is a SRAF print avoidance condition. Use only for SRAFs.

4. Save and run the script as normal.

## Using R3D Models in Calibre OPCverify

Resist 3D models are loaded into Calibre OPCverify in a litho model, and are accessed via the *image* command.

### Prerequisites

- A completed calibration job from an SRAF, toploss, or resist profile data set.
- An OPC design to use the new models on.
- An understanding of Calibre nmOPC rule file definition, as described in the *Calibre OPCverify User's and Reference Manual*.

### Procedure

1. In Calibre nmModelflow, select the job with the best objective value, then click **View** to open the Calibration Job report for the job.
2. Click **Export Model**, then fill out the Save Lithomodel dialog to write a new lithomodel directory. (This step is required because Calibre nmModelflow stores litho model files in a database.)

3. In the new directory, create a Calibre OPCverify rule file. Elements specific to resist 3D models are as follows:

- **image\_options** — Set the litho model containing your models in this command.
- **image** — Select the appropriate keywords:

```
setlayer layername = image image_options_name
[[maskN | mask N] [focus fnm] [dose d] [bias b]
 [xshift x] [yshift y]...]
[aerial {value | model} [thr_delta val[%]]]
plane {zval_um | SRAF_POSITIVE | SRAF_NEGATIVE | TOPLOSS_PLANE }
[no_etch]
```

- **plane** — Set the Z-position in the film where the image is computed as either a specific plane height in nm, measured from the bottom of the resist as 0.0nm (with the **zval\_um** argument) or the top or bottom of the resist for SRAFs or the top of the resist for toploss.
  - **SRAF models** — Select SRAF\_POSITIVE or SRAF\_NEGATIVE according to the combination of the resist process polarity (positive or negative) and the mask tone (clear or dark). Typically, you would choose SRAF\_POSITIVE for positive SRAFs (additional drawn polygons) and SRAF\_NEGATIVE for negative SRAFs (holes in main polygons).
  - **Toploss models** — Select TOPLOSS\_PLANE.
  - **Resist profile models** — Specify a *zval\_um* value matching the *imageplanes* value in the optical model.
4. Save and execute the file as normal.

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## **Third-Party Information**

Details on open source and third-party software that may be included with this product are available in the `<your_software_installation_location>/legal` directory.

