

# Automated Layout-based SEM Metrology

*...with ProSEM and InSPEC*



- Introduction & Motivation
- **ProSEM** Software with SEM Automation
- New **InSPEC** Metrology Upgrade Kit
- Summary

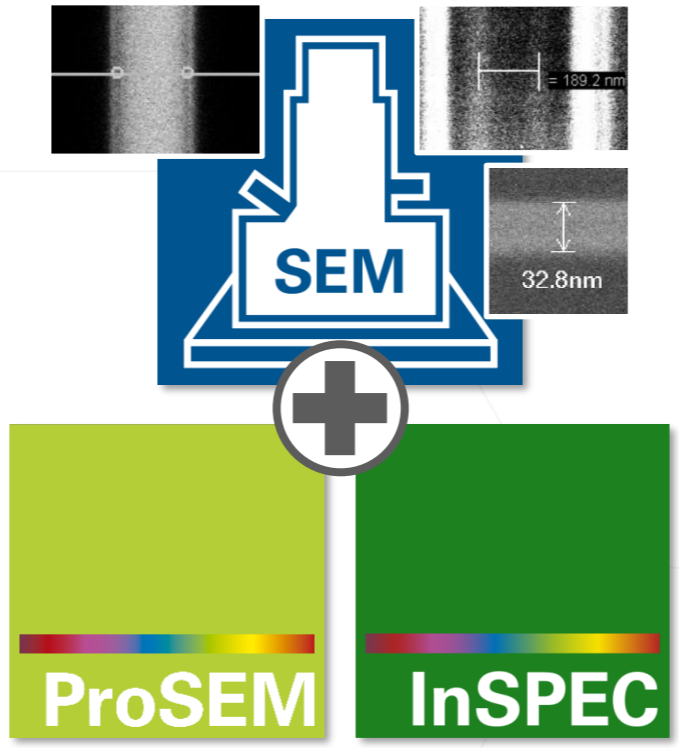
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# The Metrology Challenge

Various dedicated and optimized lithography tools



*Metrology with a versatile microscope...?*



Specialized and fully automatic CD-SEM

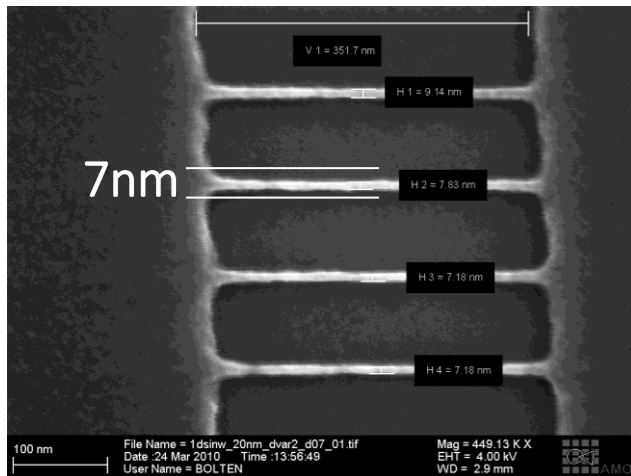


## Growing Customers and Use Cases

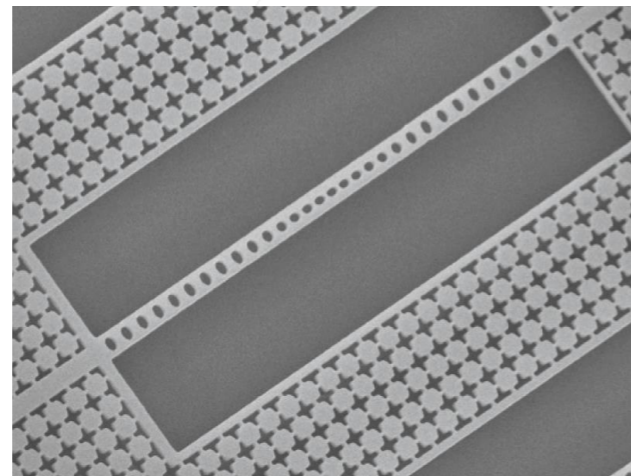
- Large R&D institutes or nano centers
- Small batch manufacturing companies
- E-beam, laser, optical, and imprint litho
- Micro/ nano fabrication processes & devices
- Calibration, monitoring, optimization

## Open SEM Requirements

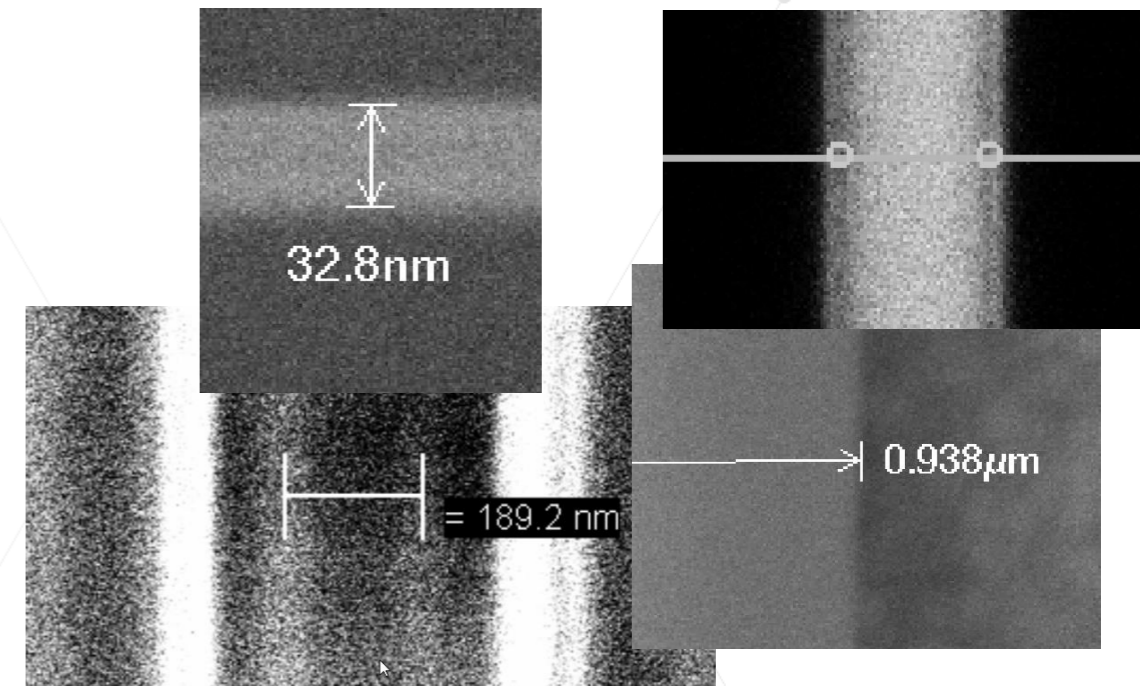
- Hand-drawn cursors
- Subjective and operator dependent
- Tedious and time-consuming
- Inconsistent and no statistics



AMO GmbH – Germany



NIST CNST – USA



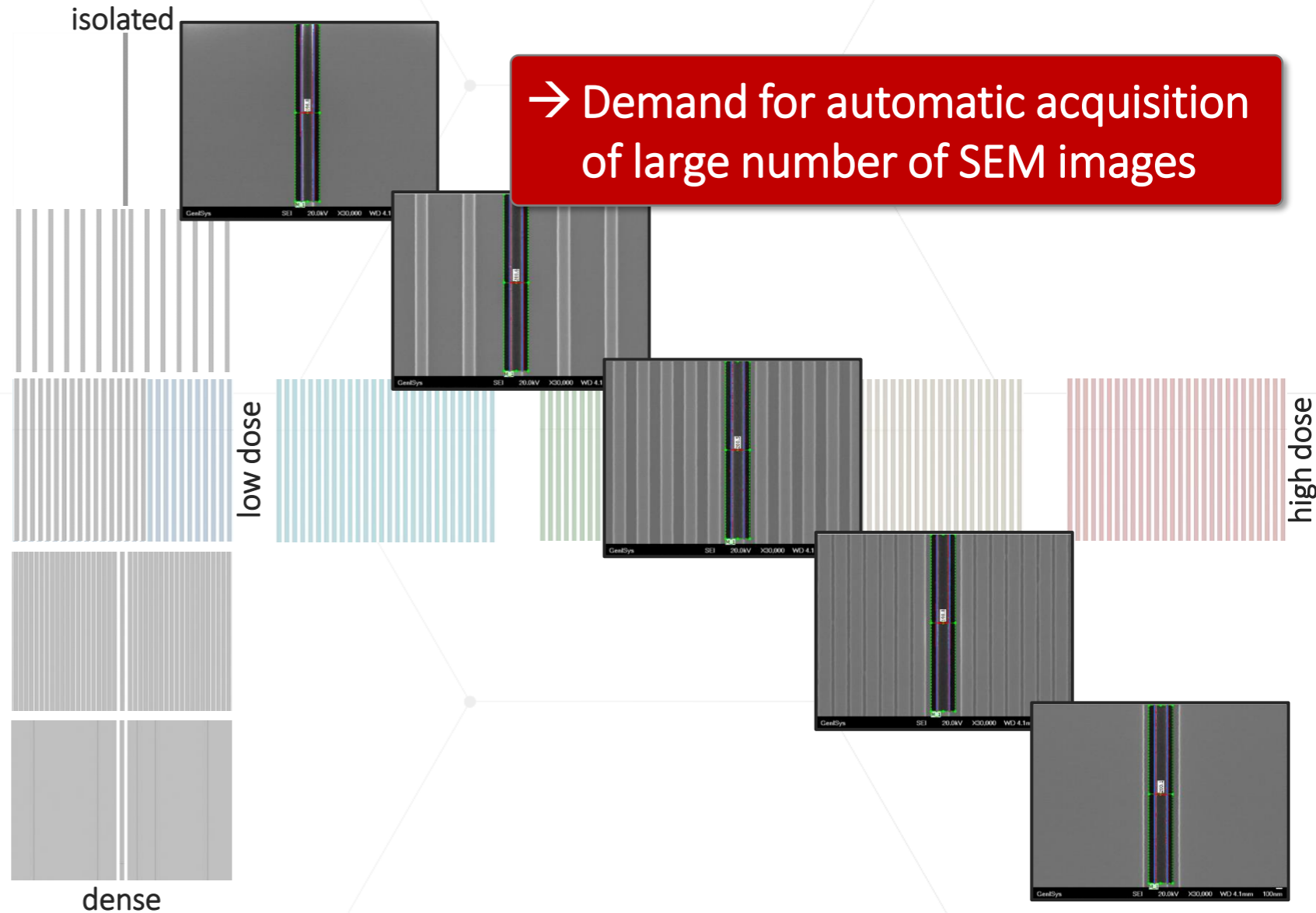
Determining process and correction parameters

Expose calibration pattern

- Dose scaling
- Density of shapes

Evaluation with numerous images

- Scan images automatically
- Measure line width
- Analyze data





*SEM Metrology &  
Automation Software*

→ Fully launched package  
including SEM interfacing

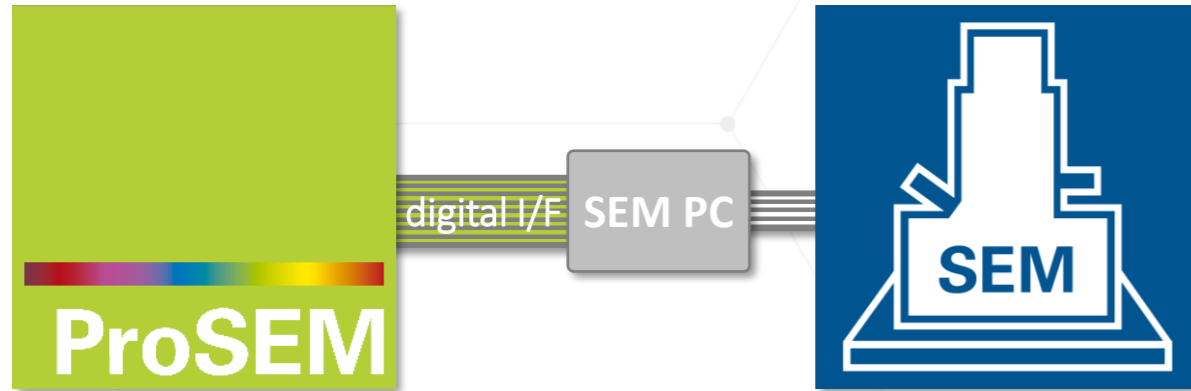


*Integrated SEM Metrology &  
Inspection Upgrade Kit*

→ New product in pilot phase  
→ Launch planned for June

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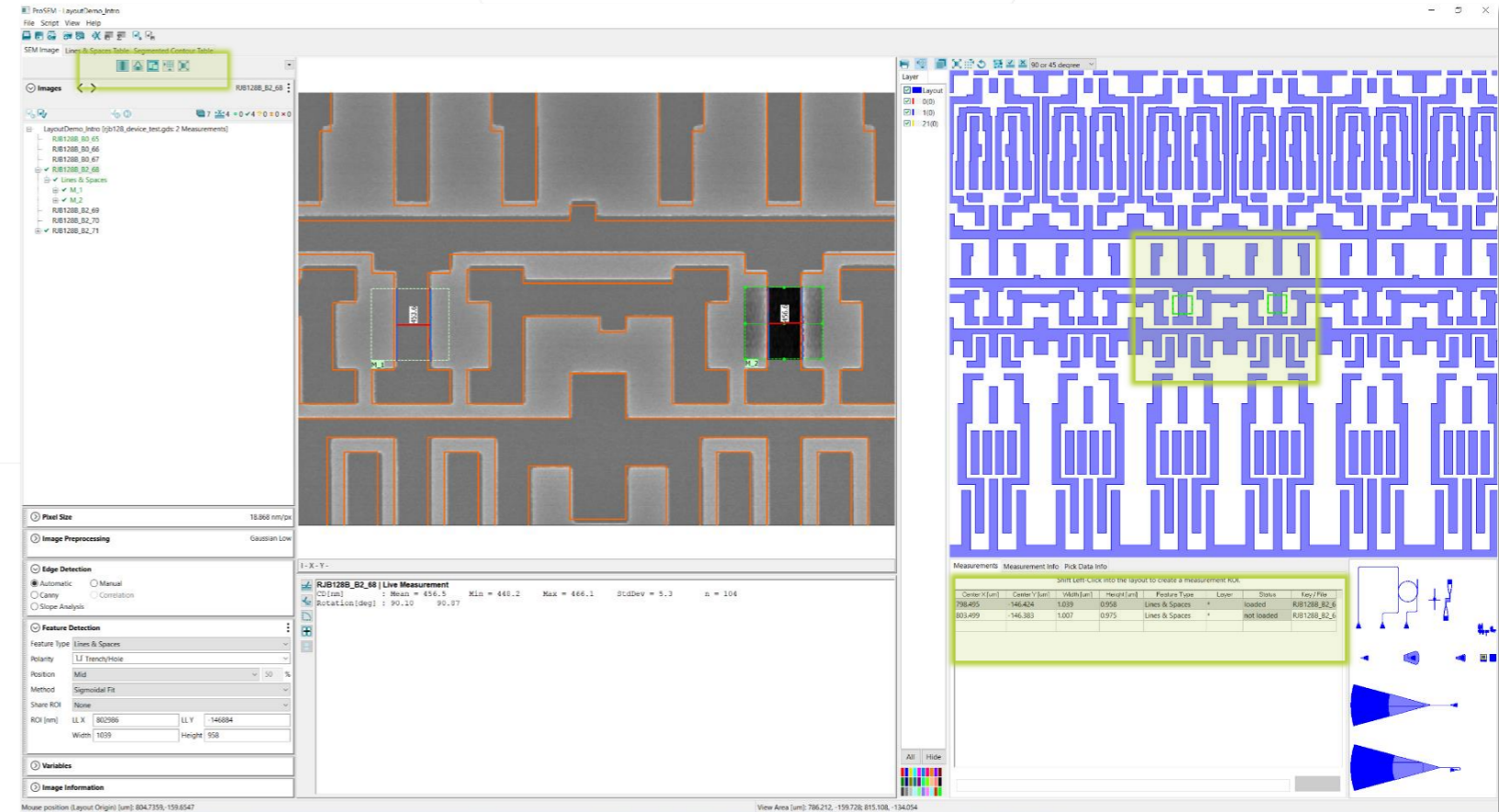
SW for SEM Image  
Analysis & Metrology

Easy-to-use Offline  
Software Package

Optional Automation via  
digital PC interface

## User Interface with CAD layout

- Display area for image and layout
- Viewer functionality integrated
- Metrology job with measurements corresponding to layout
- Used for navigation and automated SEM image acquisition



→ Enables advanced SEM investigation of nano patterns

→ Automated layout-based SEM image acquisition and metrology

## Match positions and coordinate systems

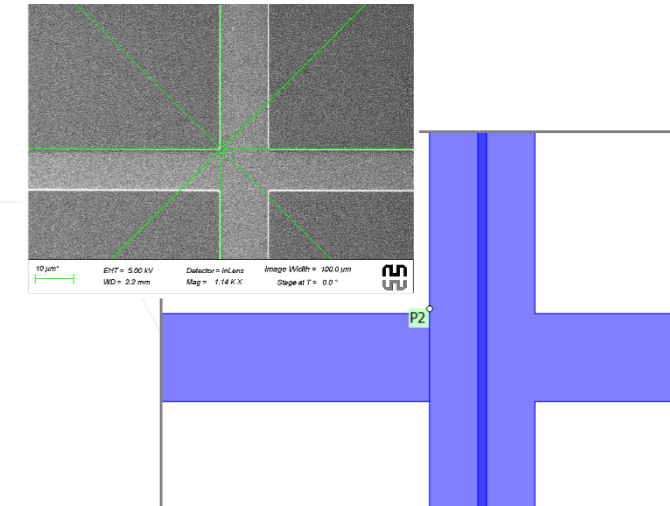
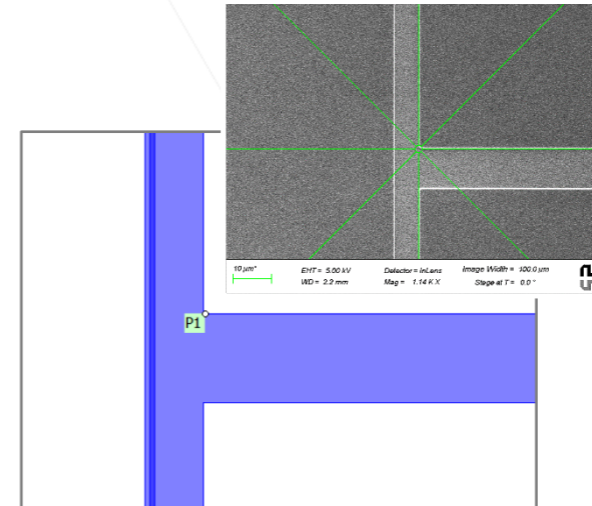
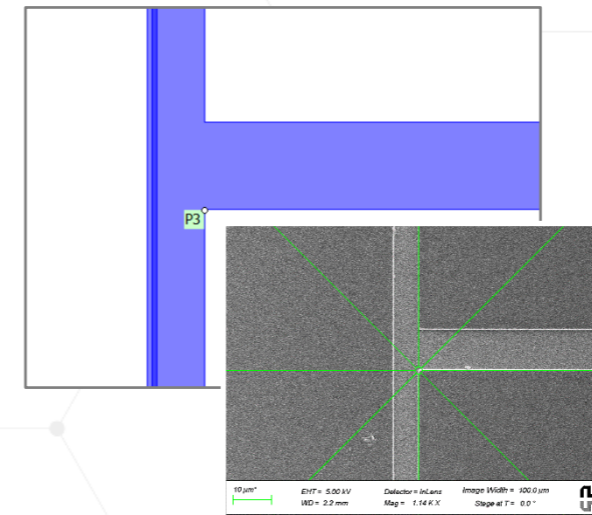
- Use 3 markers or specific locations
- Pick layout coordinates from design in ProSEM
- Drive SEM to corresponding sample locations
- Read stage coordinates into ProSEM

Layout Coordinates [um]		Stage Coordinates [mm]		Focus [mm]			
P1	-1200.000	1558.000	Pick	40.2009	36.6407	Read	3.986
P2	-800.000	1558.000	Pick	39.8003	36.6301	Read	3.986
P3	-800.000	2118.000	Pick	39.8090	36.0702	Read	3.986

Apply Focus Interpolation

Current: -1494.000 2173.000 40.5049 36.0334 Read  Live Update

Navigation: -1494.000 2173.000 Pick 40.5049 36.0334 Move To Scan Image



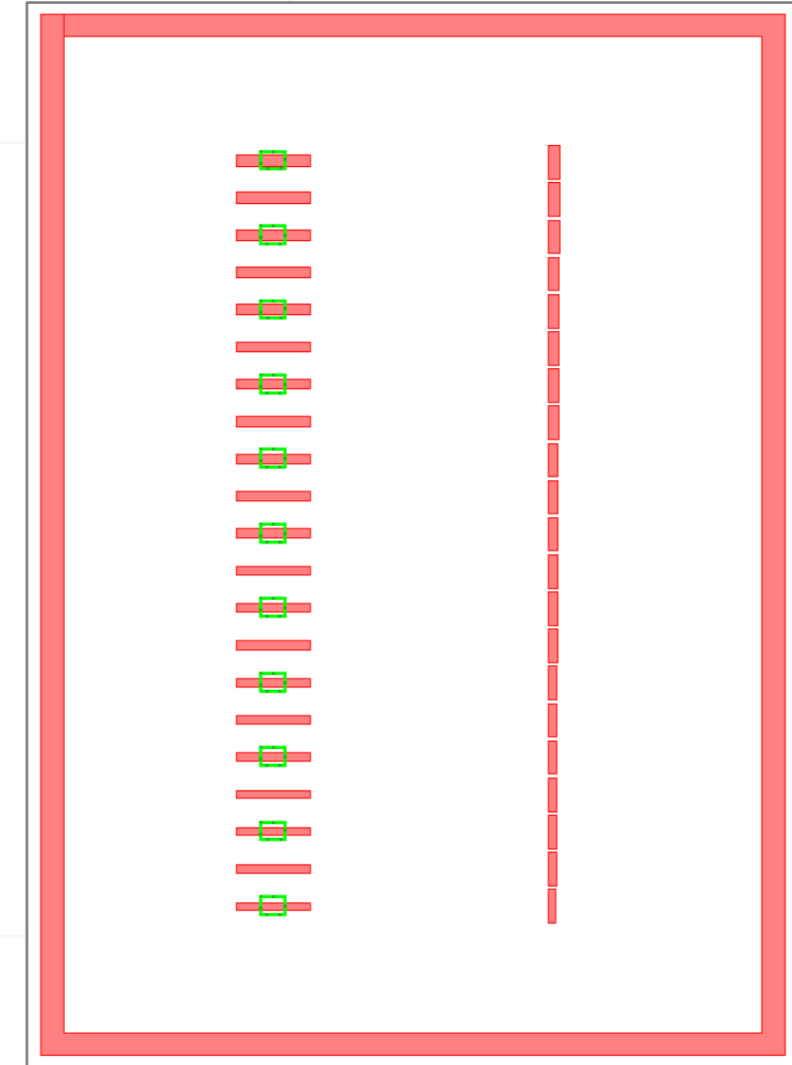
## Automation and measurement list

- Load pre-defined project with metrology job
- Import/ export of measurement list

→ Start job execution

Center X [um]	Center Y [um]	Width [um]	Height [um]	Feature Type	Find Similar	Layer	Status	Key / File
-1075.000	2039.000	14.000	10.000	Lines & Spaces	<input type="checkbox"/>	0(1000)	scan finished	<automatic>
-1075.000	1998.900	14.000	10.000	Lines & Spaces	<input type="checkbox"/>	0(1000)	scan finished	<automatic>
-1075.000	1958.800	14.000	10.000	Lines & Spaces	<input type="checkbox"/>	0(1000)	scan finished	<automatic>
-1075.000	1918.700	14.000	10.000	Lines & Spaces	<input type="checkbox"/>	0(1000)	scan finished	<automatic>
-1075.000	1878.600	14.000	10.000	Lines & Spaces	<input type="checkbox"/>	0(1000)	scanning	<automatic>
-1075.000	1838.500	14.000	10.000	Lines & Spaces	<input type="checkbox"/>	0(1000)	scan pending	<automatic>
-1075.000	1798.400	14.000	10.000	Lines & Spaces	<input type="checkbox"/>	0(1000)	scan pending	<automatic>
-1075.000	1758.300	14.000	10.000	Lines & Spaces	<input type="checkbox"/>	0(1000)	scan pending	<automatic>
-1075.000	1718.200	14.000	10.000	Lines & Spaces	<input type="checkbox"/>	0(1000)	scan pending	<automatic>
-1075.000	1678.100	14.000	10.000	Lines & Spaces	<input type="checkbox"/>	0(1000)	scan pending	<automatic>
-1075.000	1638.000	14.000	10.000	Lines & Spaces	<input type="checkbox"/>	0(1000)	scan pending	<automatic>

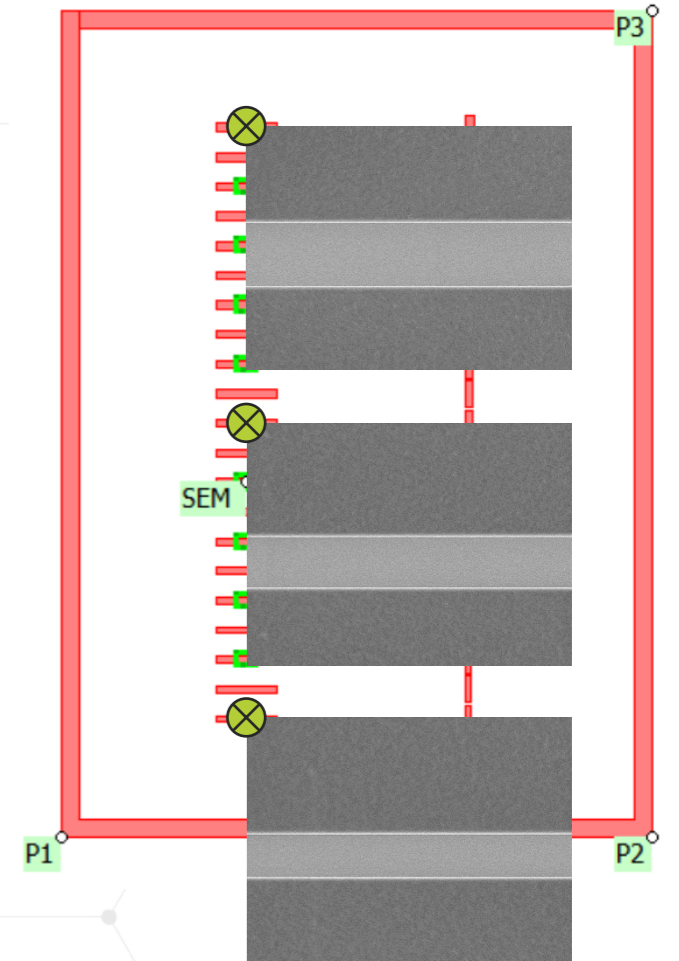
Stop



# Step 1: Image Acquisition

## Automated metrology

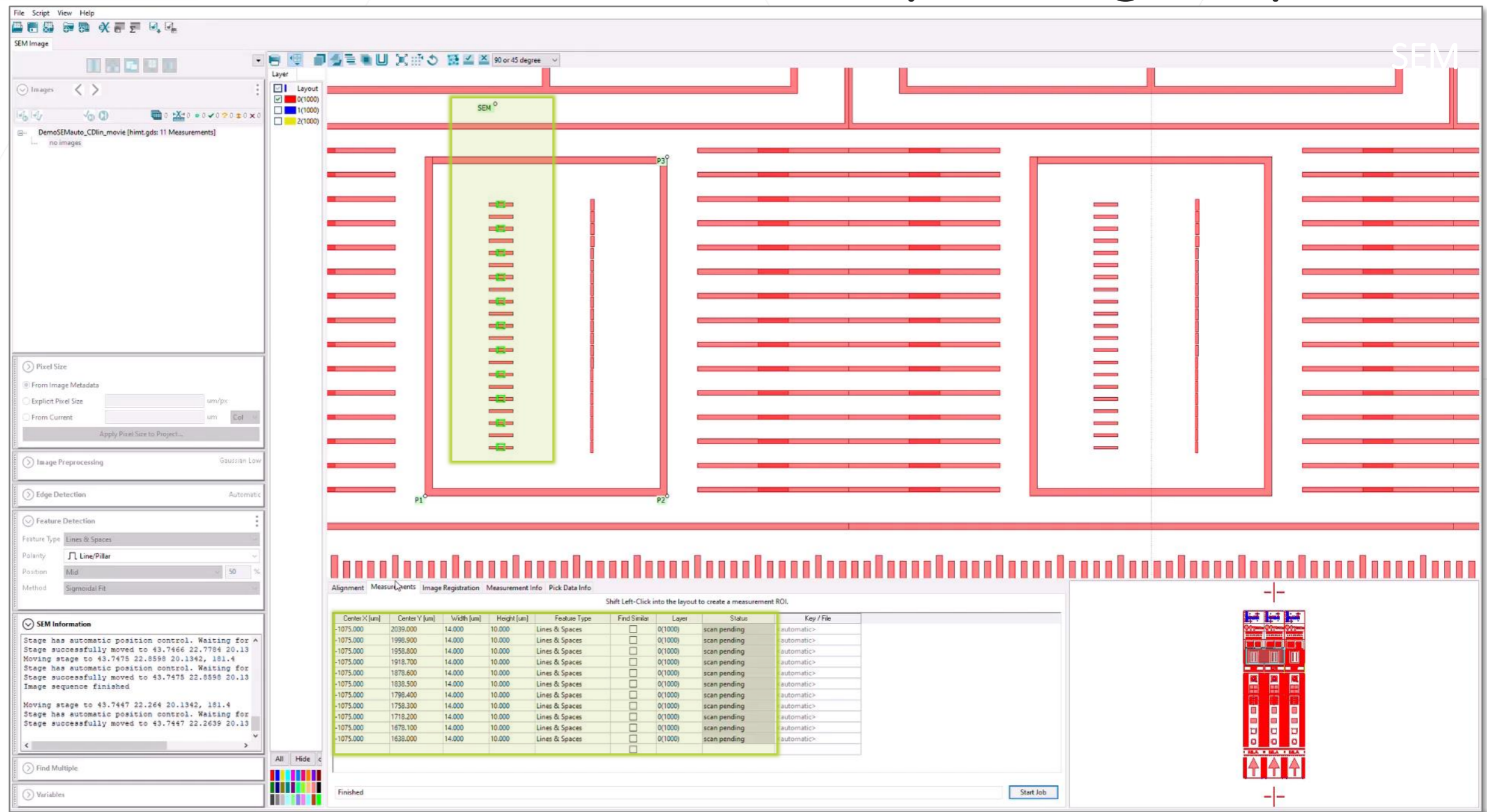
- Drive SEM stage and acquire set of images



Center X [um]	Center Y [um]	Width [um]	Height [um]	Feature Type	Find Similar	Layer	Status	Key / File
-1075.000	2039.000	14.000	10.000	Lines & Spaces	<input type="checkbox"/>	0(1000)	scan finished	<automatic>
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Stop

# Step 1: Image Acquisition



SEM Image

File Script View Help

90 or 45 degree

Layer

- Layout
- 0(1000)
- 1(1000)
- 2(1000)

Images < >

DemoSEMAuto\_CDlin\_movie [hmt.gds: 11 Measurements]

no images

Pixel Size

- From Image Metadata
- Explicit Pixel Size  um/px
- From Current  um

Apply Pixel Size to Project...

Image Preprocessing Gaussian Low

Edge Detection Automatic

Feature Detection

Feature Type Lines & Spaces

Polarity  Line/Pillar

Position Mid 50 %

Method Sigmoidal Fit

SEM Information

Stage has automatic position control. Waiting for Stage successfully moved to 43.7466 22.7784 20.13  
 Moving stage to 43.7475 22.8598 20.1342, 181.4  
 Stage has automatic position control. Waiting for Stage successfully moved to 43.7475 22.8598 20.13  
 Image sequence finished

Moving stage to 43.7447 22.264 20.1342, 181.4  
 Stage has automatic position control. Waiting for Stage successfully moved to 43.7447 22.2639 20.13

Find Multiple

Variables

Alignment Measurements Image Registration Measurement Info Pick Data Info

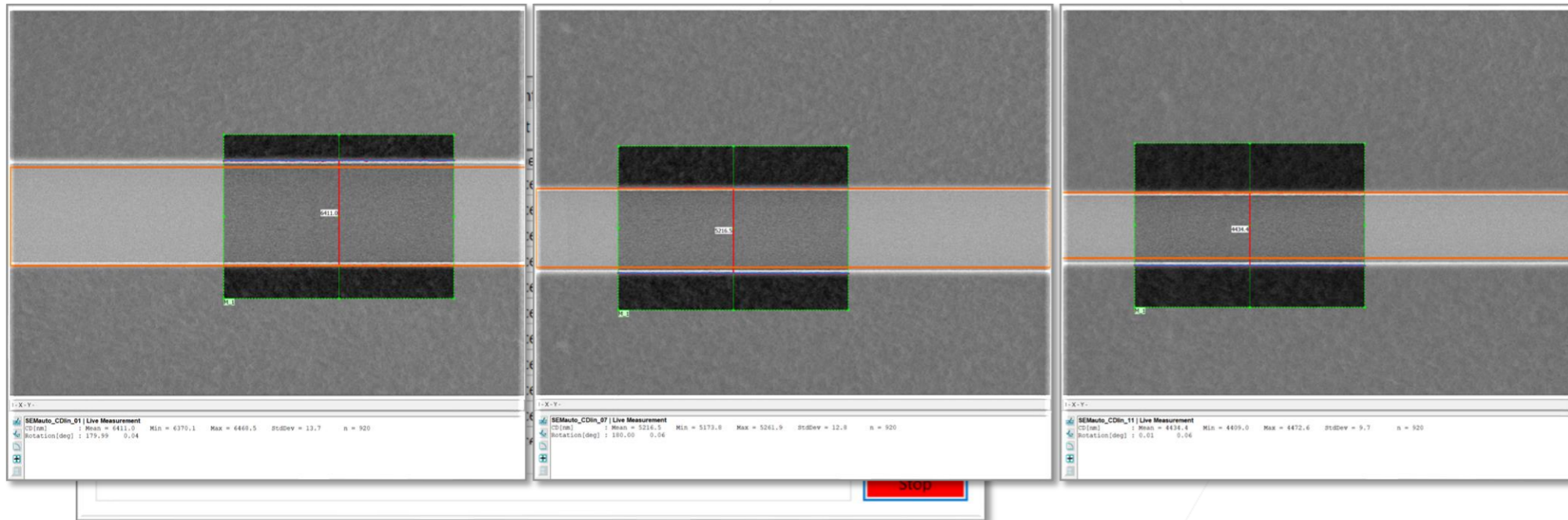
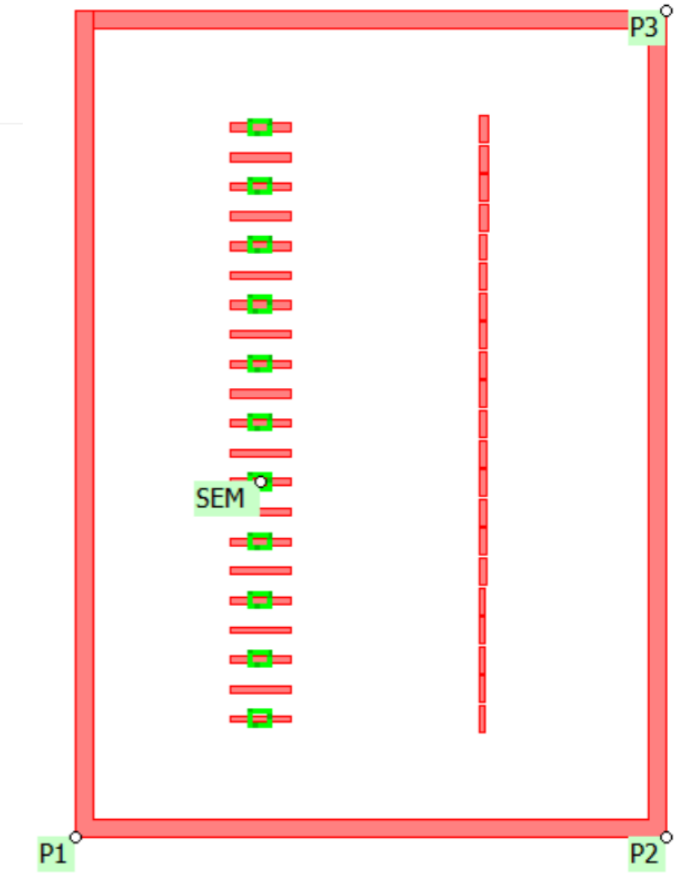
Shift Left-Click into the layout to create a measurement ROI.

Center X [um]	Center Y [um]	Width [um]	Height [um]	Feature Type	Find Similar	Layer	Status	Key / File
-1075.000	2039.000	14.000	10.000	Lines & Spaces	<input type="checkbox"/>	0(1000)	scan pending	automatic>
-1075.000	1998.900	14.000	10.000	Lines & Spaces	<input type="checkbox"/>	0(1000)	scan pending	automatic>
-1075.000	1958.800	14.000	10.000	Lines & Spaces	<input type="checkbox"/>	0(1000)	scan pending	automatic>
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-1075.000	1718.200	14.000	10.000	Lines & Spaces	<input type="checkbox"/>	0(1000)	scan pending	automatic>
-1075.000	1678.100	14.000	10.000	Lines & Spaces	<input type="checkbox"/>	0(1000)	scan pending	automatic>
-1075.000	1638.000	14.000	10.000	Lines & Spaces	<input type="checkbox"/>	0(1000)	scan pending	automatic>

Finished

## Automated metrology

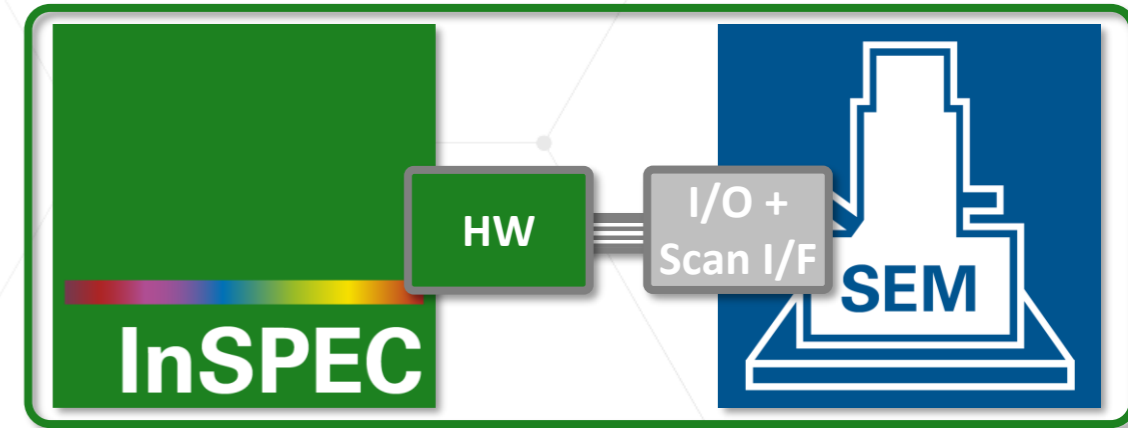
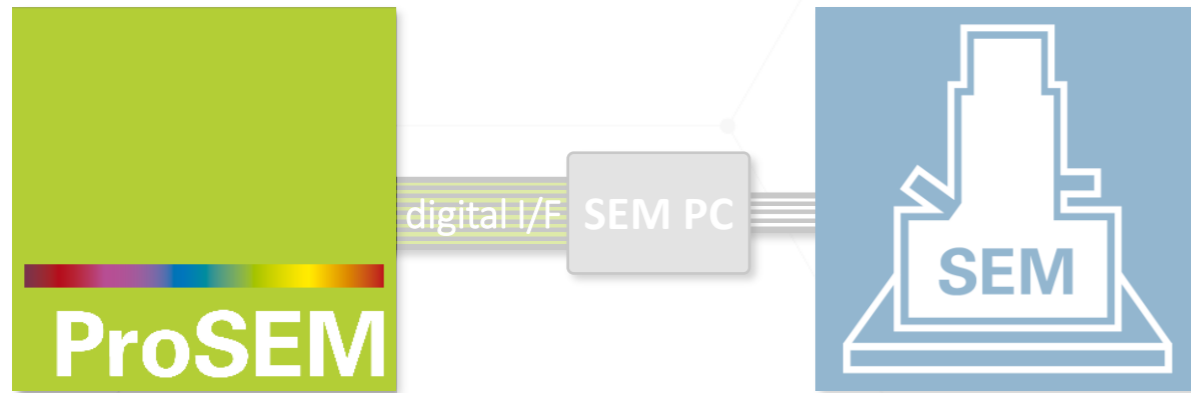
- Drive SEM stage and acquire set of images
- Load images with (local) alignment
- Apply pre-defined measurements automatically
- Save results to data table



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- **ProSEM Software with SEM Automation**
- **New InSPEC Metrology Upgrade Kit**
- Summary



# ProSEM vs. InSPEC



SW for SEM Image Analysis & Metrology

Easy-to-use Offline Software Package

Optional Automation via digital PC interface

Upgrade Kit for a Metrology SEM

Direct SEM control with hardware integration

Comprehensive full layout-based workflow

Integrated scanning, automation & metrology

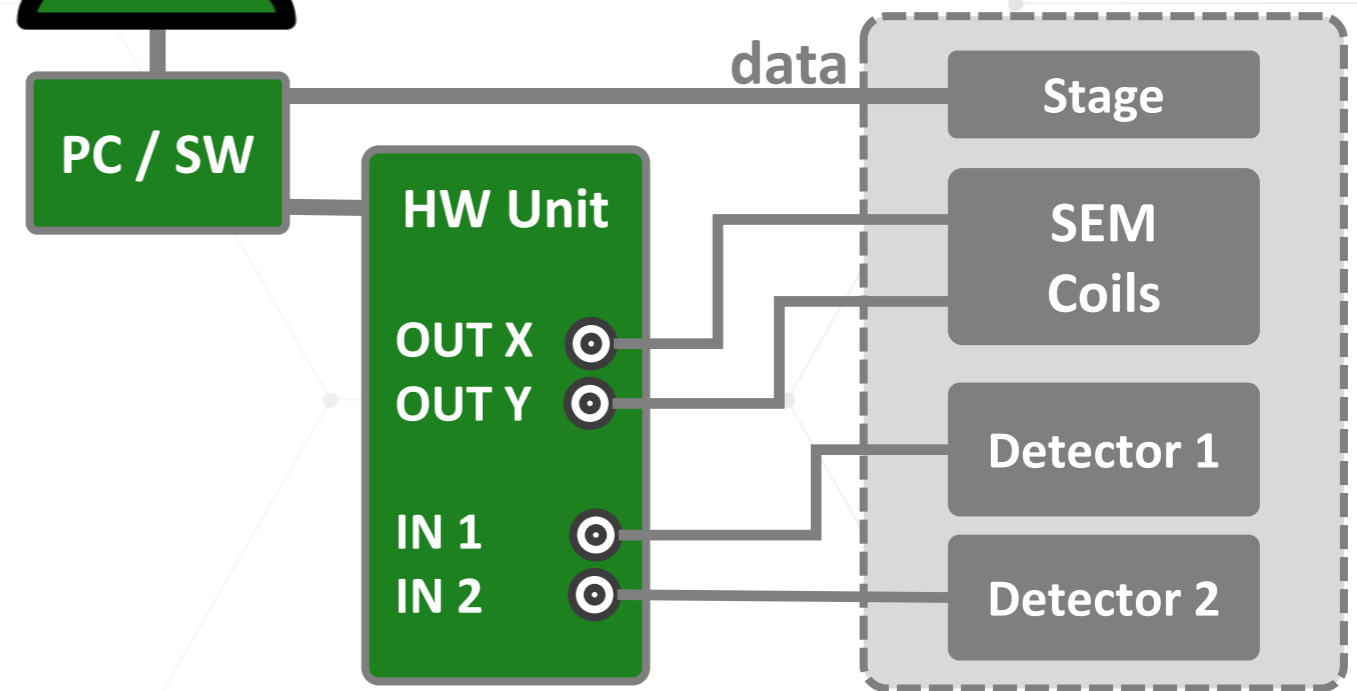
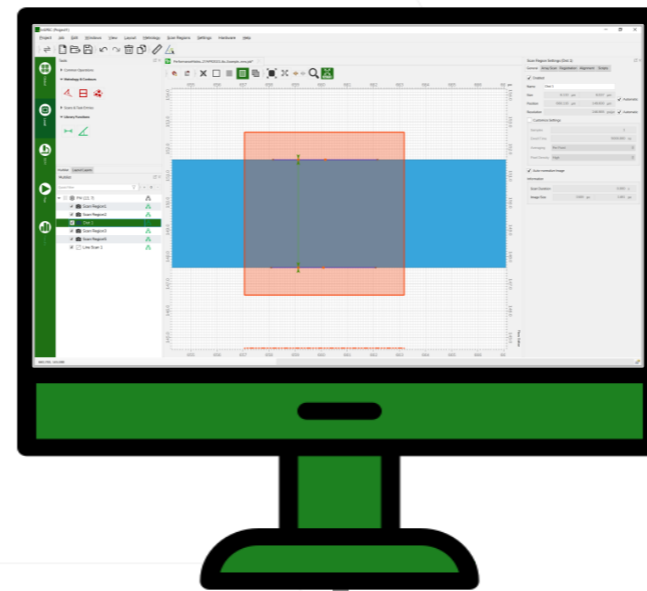
Multi-Chip jobs with hierarchical structure

Expert metrology & data processing with "FLOW"

## Integrated Metrology & Inspection Kit

- Software package
- PC and screen
- Scanning and I/O hardware

- Direct control of SEM beam, stage, scanning
- Use the designed I/F and safety mechanisms
- All beam shaping settings
- Scanning and tool operation through InSPEC



# Integrated Workflow along 5 Main Modes

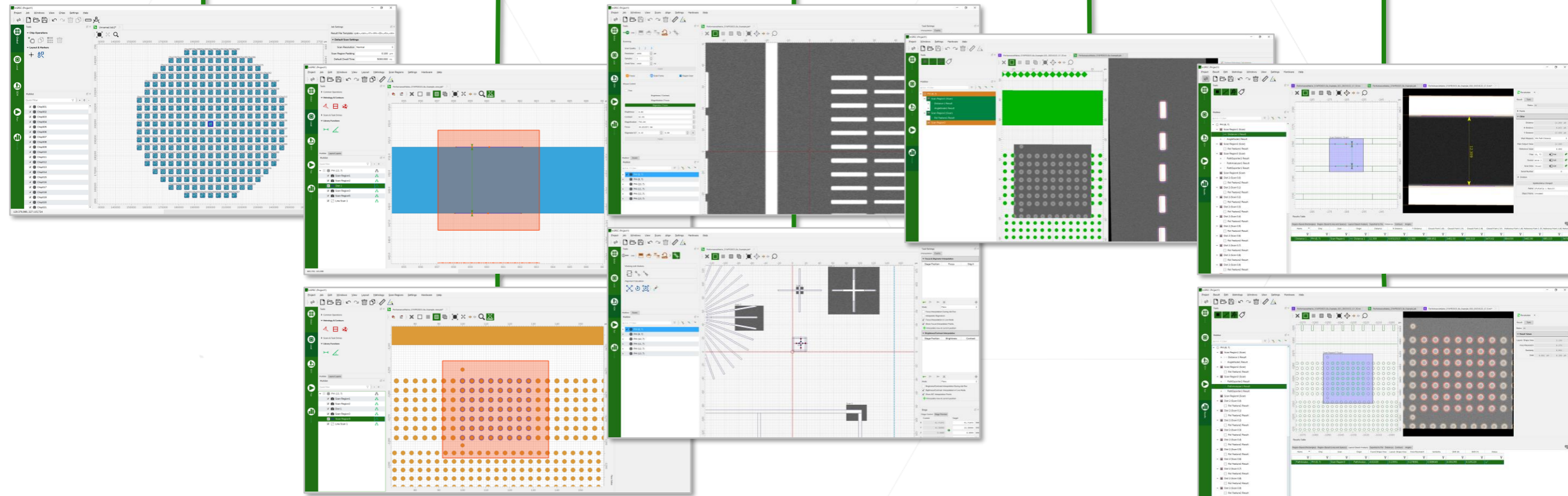
Global  
Setup

Local  
Content

SEM  
Control

Run  
Job

Results  
Review



## 5 Main modes with adaptive panels

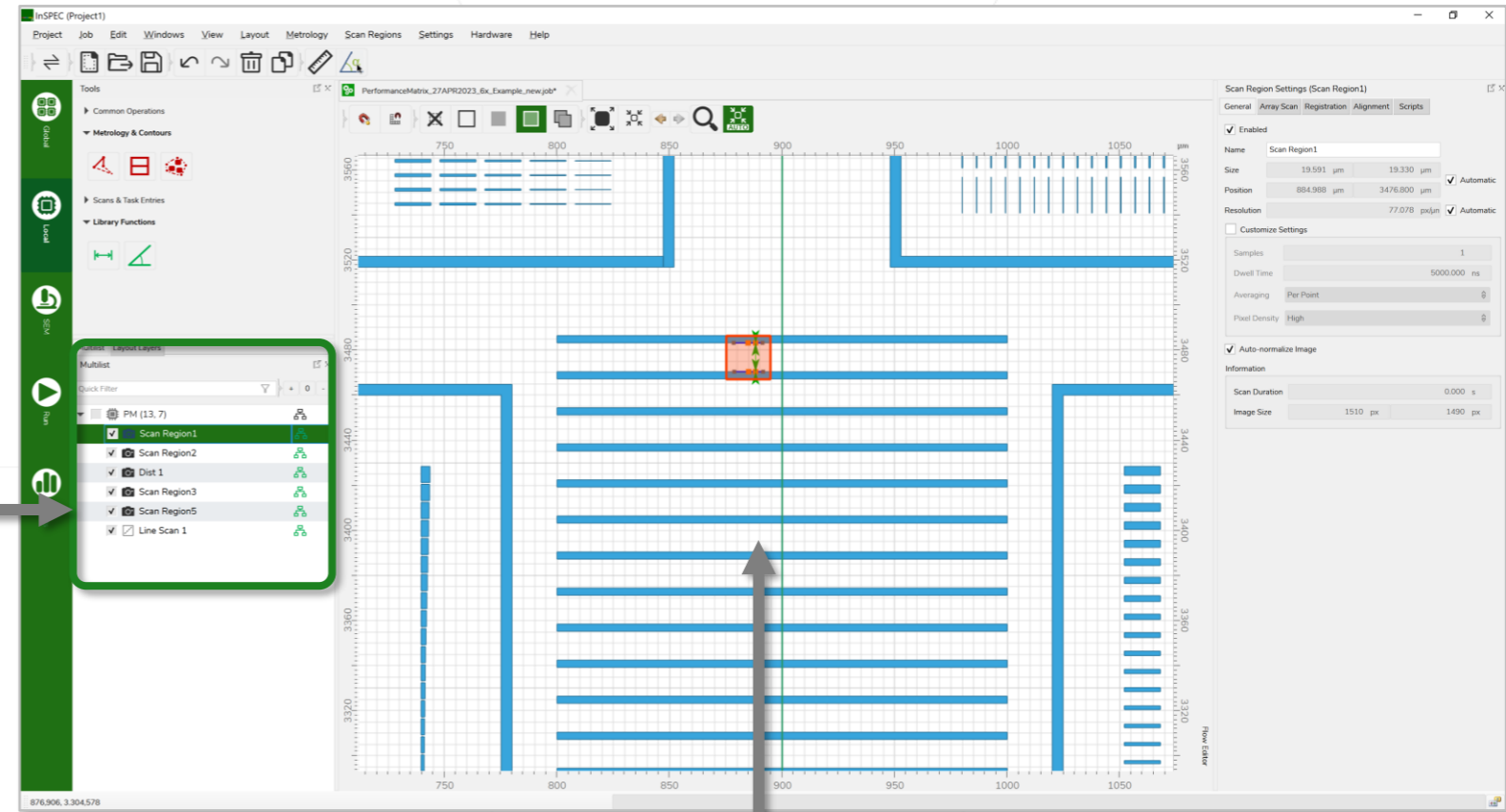
- Global and Local definitions
- SEM Live and SEM Layout
- Run job and Results review/ tune

## Workflow along job sequence

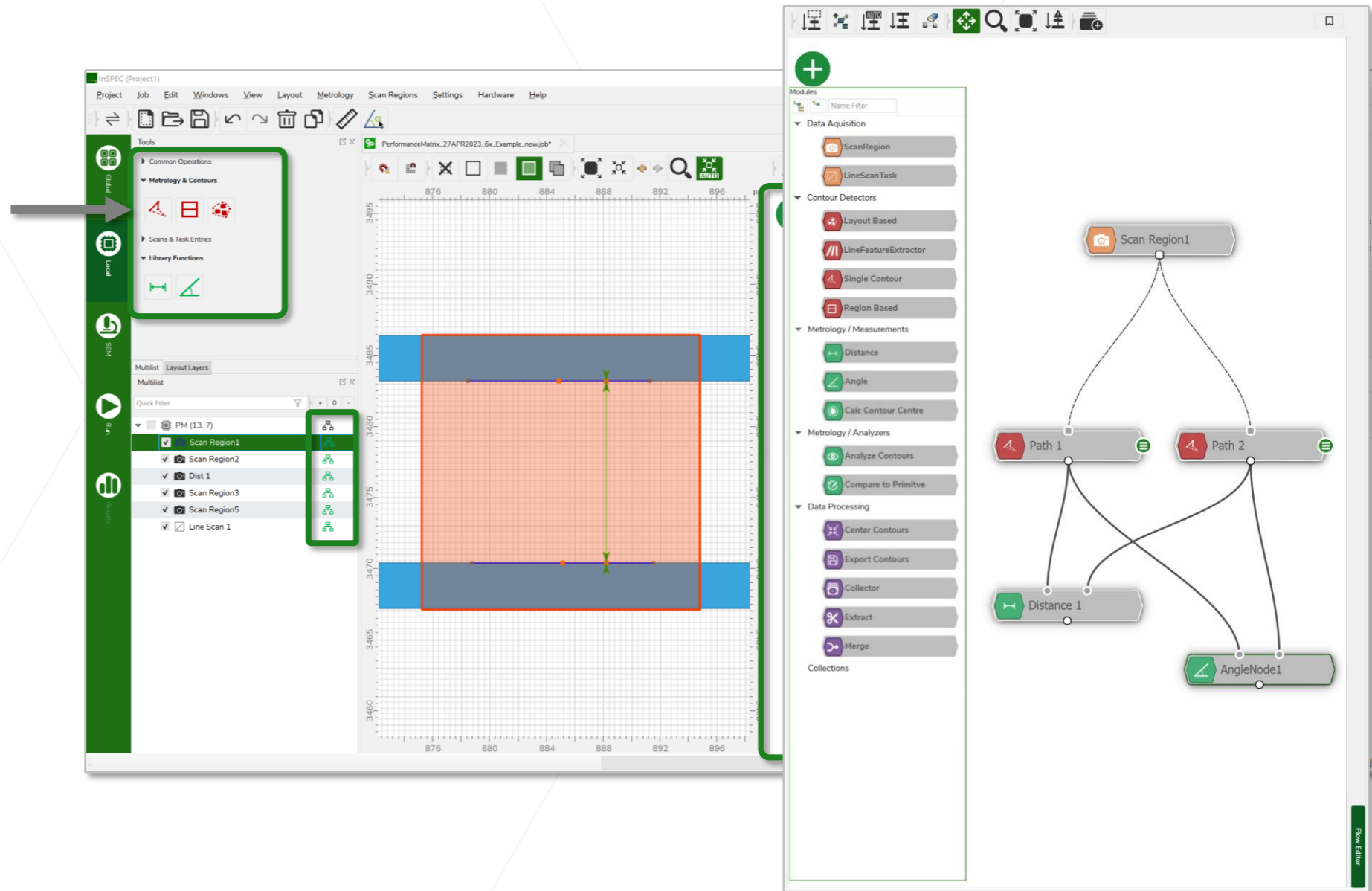
- Smart and simplified metrology job

## Working area

- Center visual area with layout
  - Can split for layout view & FLOW editor

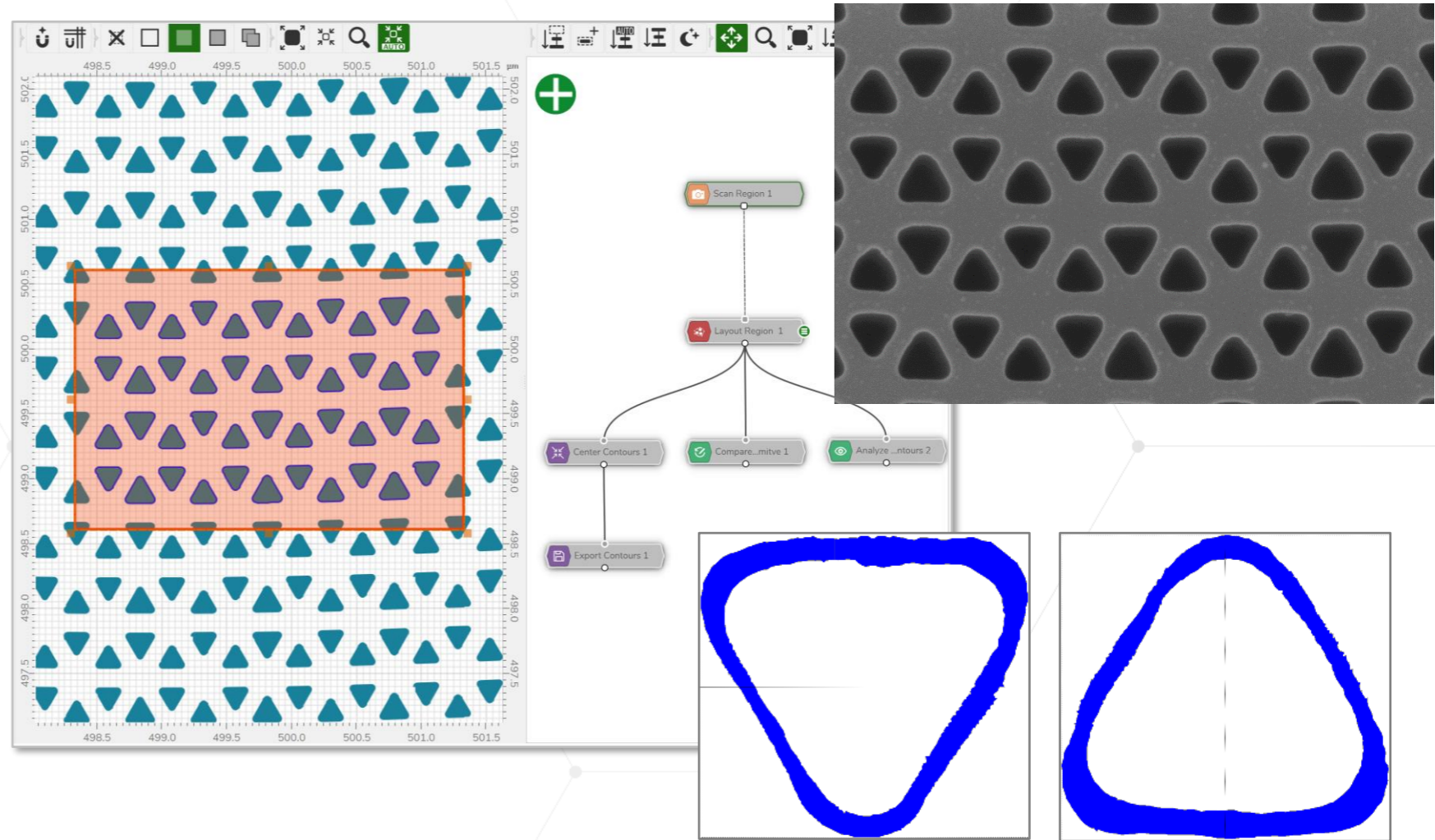


- Definition of job entries
  - Using visual tools with pre-defined functionality/ FLOW
  - FLOW contains all methods for obtaining metrology results
  - Modules for
    - Scanning (region, line)
    - Edge/ contour detection
    - Metrology & analysis
    - Data processing
  - Extended comprehensive tasks
  - Create personal templates



The screenshot displays the GenISys software interface. The main window shows a metrology job setup with a central grid and a highlighted scan region. The left sidebar contains a 'Tools' panel with categories like 'Common Operations', 'Metrology & Contours', 'Scans & Task Entries', and 'Library Functions'. Below this is a 'Multilist' panel showing a list of tasks including 'Scan Region1', 'Scan Region2', 'Dist 1', 'Scan Region3', 'Scan Region5', and 'Line Scan 1'. The right sidebar shows a 'Modules' panel with various metrology tasks such as 'ScanRegion', 'LineScanTask', 'Contour Detectors', 'Metrology / Measurements', 'Metrology / Analyzers', and 'Data Processing'. A flowchart on the right side of the interface illustrates the job flow, starting with 'Scan Region1', which branches into 'Path 1' and 'Path 2'. 'Path 1' leads to 'Distance 1', and 'Path 2' leads to 'AngleNode1'. The flowchart also shows 'Distance 1' leading to 'AngleNode1'.

- FLOW editor
  - FLOW contains all methods for obtaining metrology results
  - Modules for
    - Scanning (region, line)
    - Edge/ contour detection
    - Metrology & analysis
    - Data processing
- Example (PSU)
  - SEM scanning region
  - Multiple contour extraction
  - Compare to triangle and layout
  - PV band creation/ export (process variation)



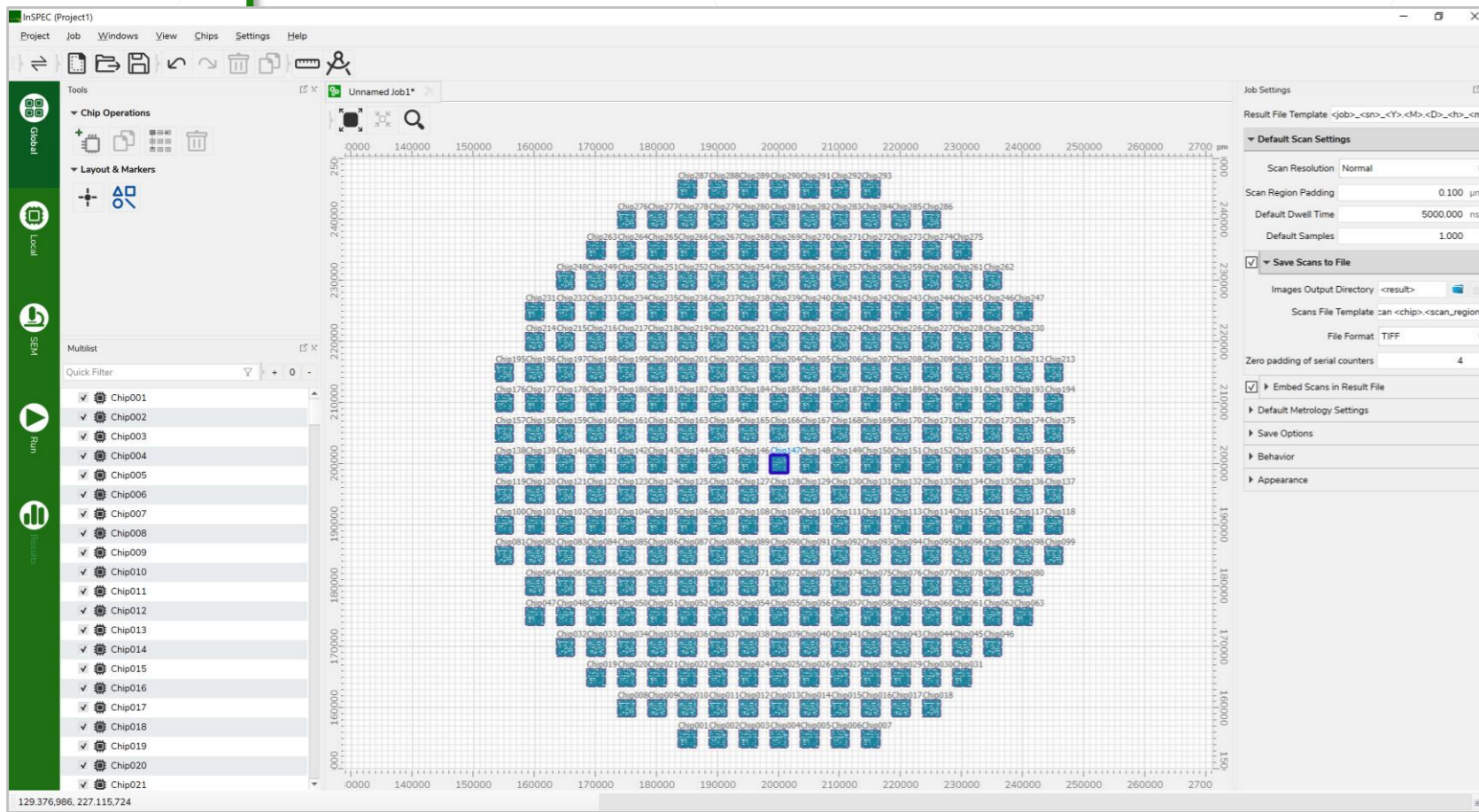
Global Setup

Local Content

SEM Control

Run Job

Results Review



- General arrangement

- Chips/ field size and position
- Matrix setups
- Enable/ disable chips/ fields
- Reference layout(s)

Global  
Setup

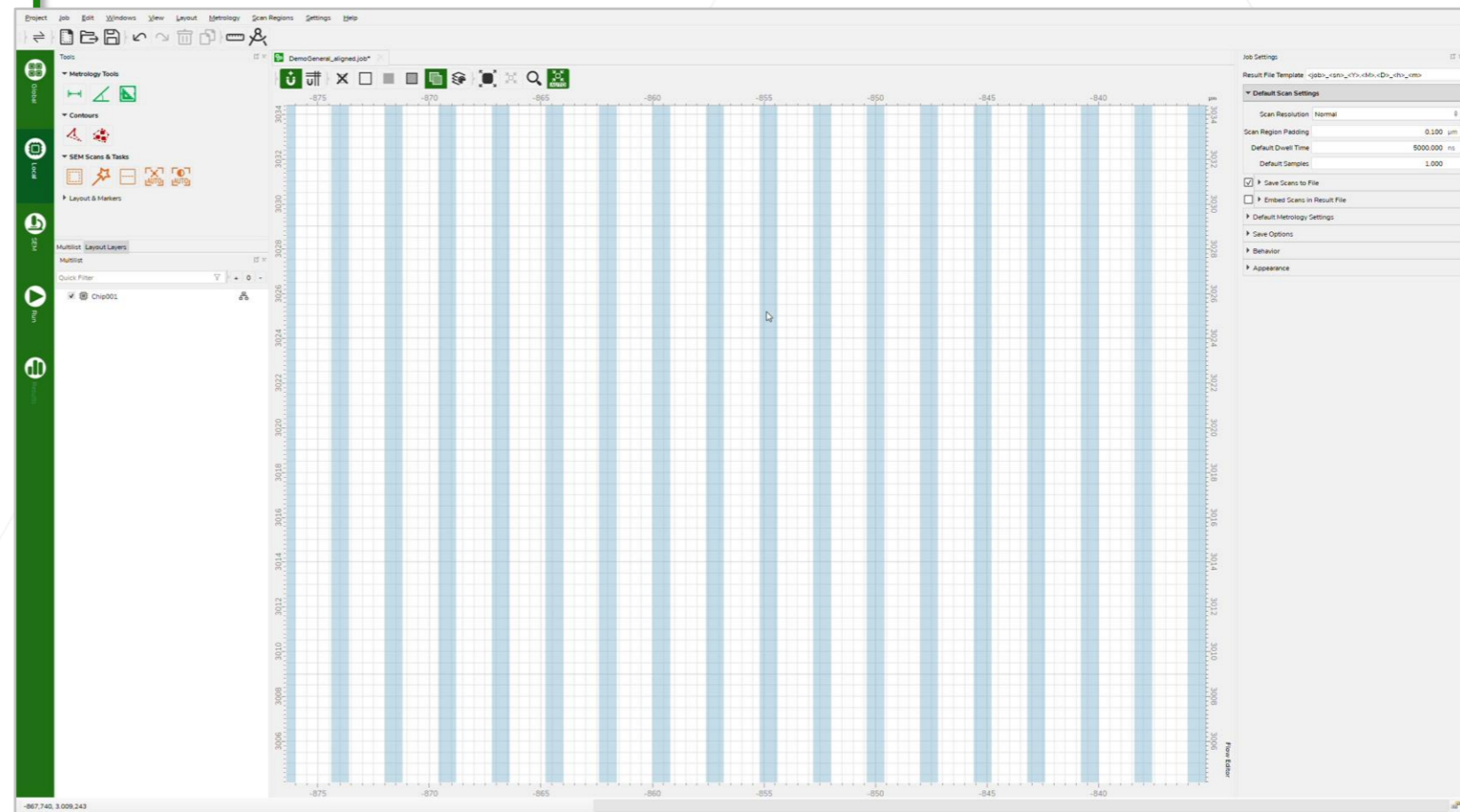
Local  
Content

SEM  
Control

Run  
Job

Results  
Review

- Chip/ field level
  - Based on detailed layout
    - Create measurements
    - Extract contours
      - Automatic scan definition
  - SEM scans (region, line)
- Job list can contain
  - Scans
  - Scans and contour
  - Scans and contour/ metrology
  - Plus data processing
  - Chip level data processing





# „Layout-less“ based on Metrology Region

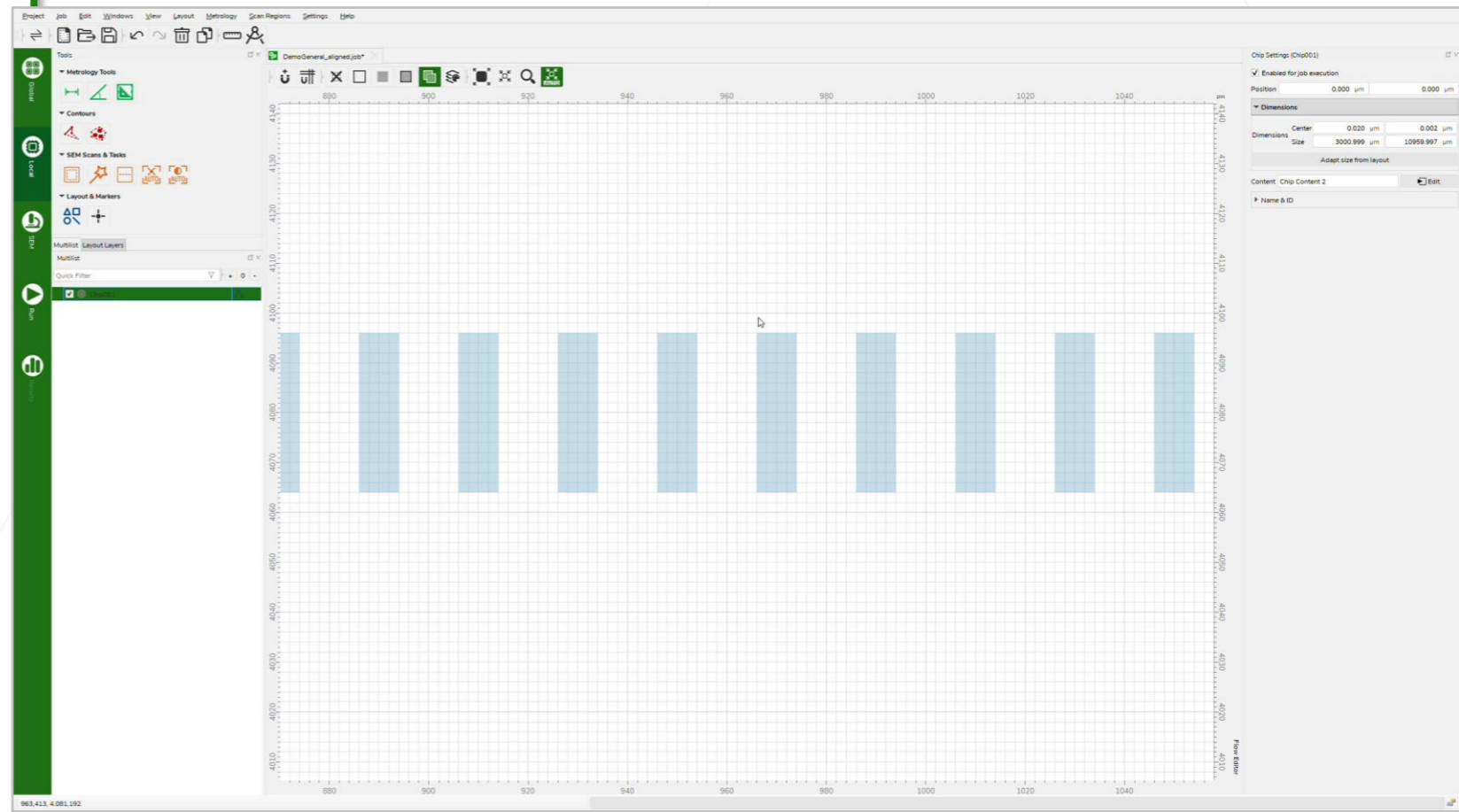


- Use case

- No (full) layout available
- Layers are bad representation
- Strong process bias/ issues

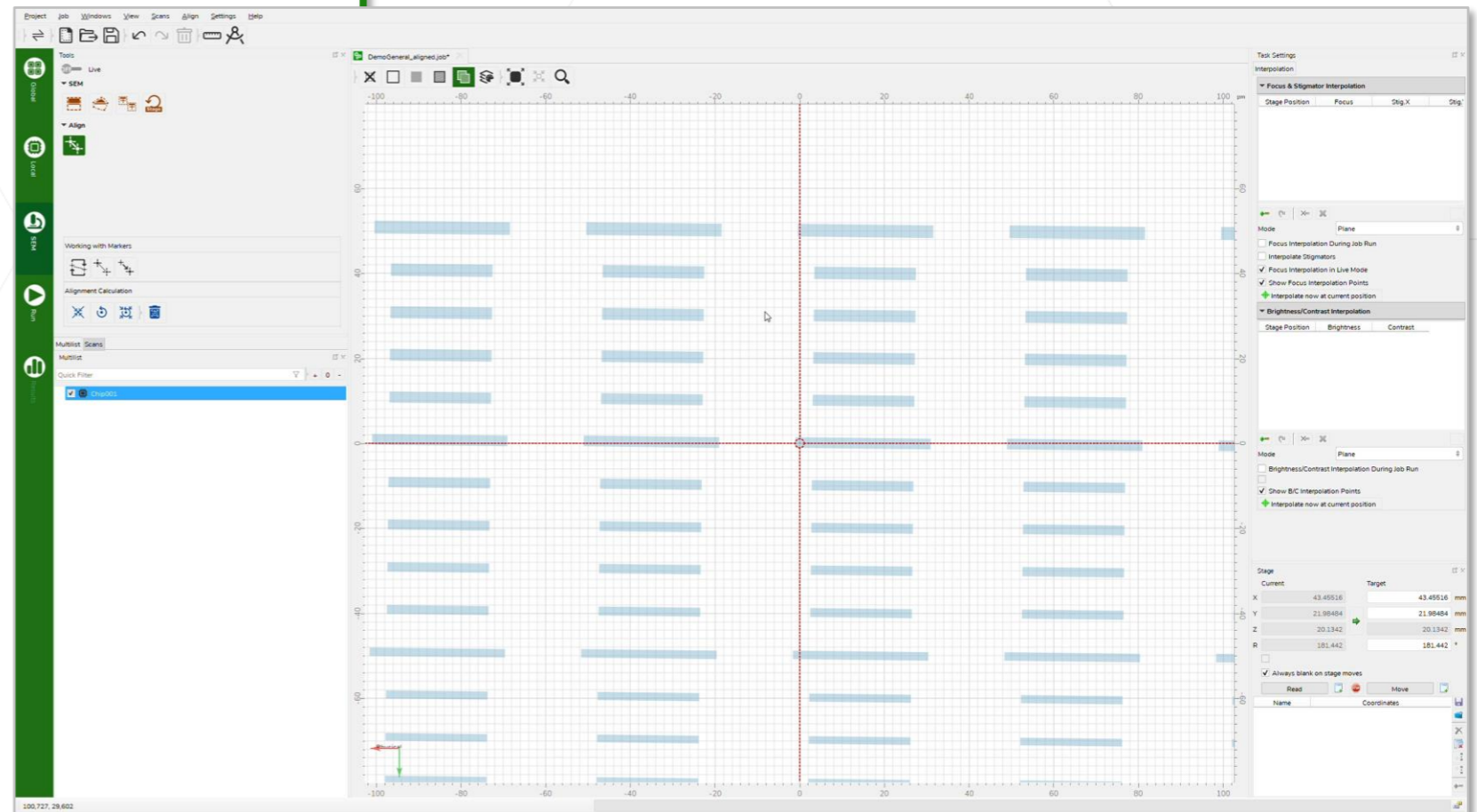
- Metrology region

- Layout only as background
- No comparison with layout
- Provides contours (shapes)
- Fitting for
  - Lines&Spaces
  - Circle, ellipse
  - Rectangle, triangle





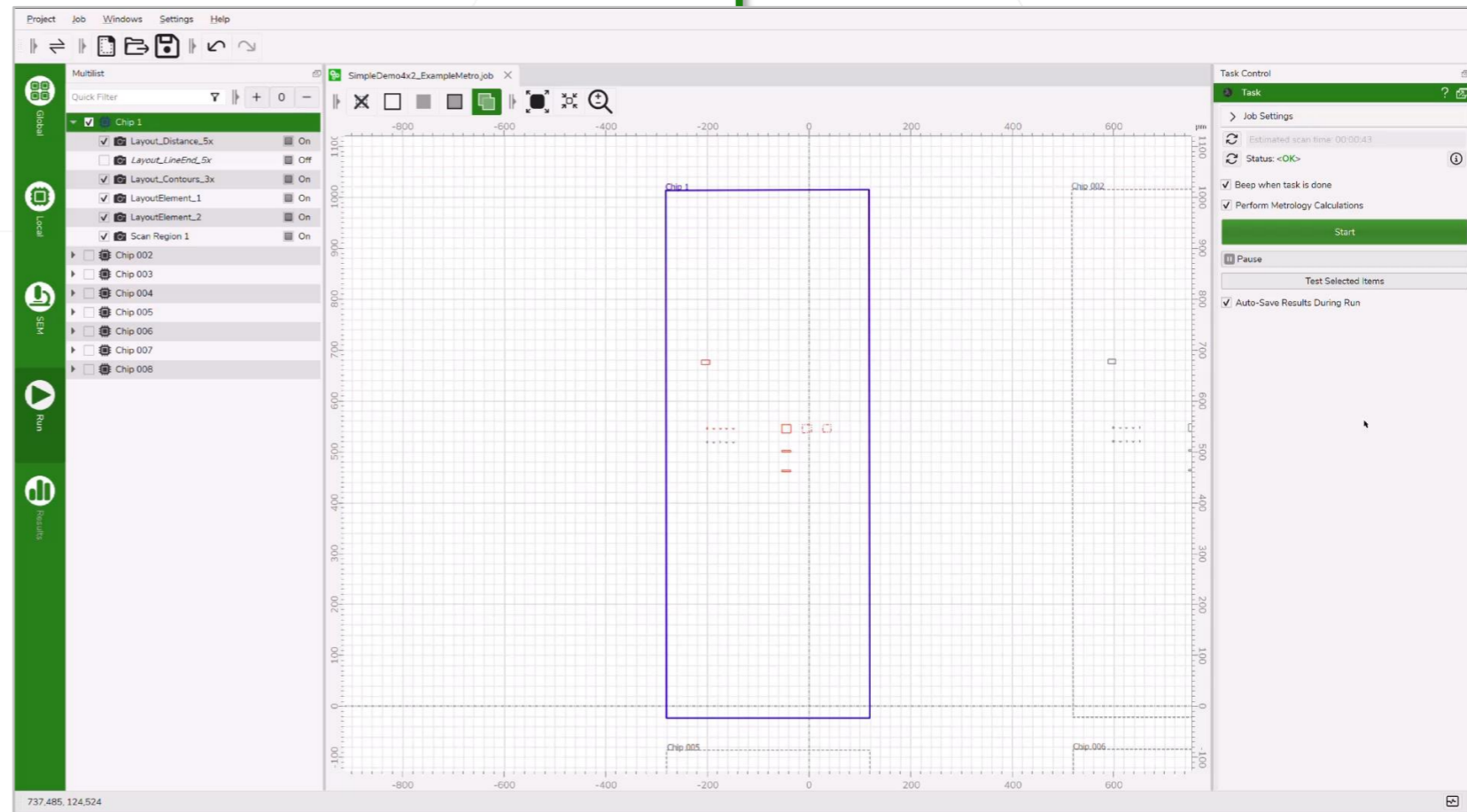
- SEM Control “LIVE”
  - Scanning with preset speeds
  - Full control of beam shaping
    - Contrast/ brightness
    - Magnification/ focus
    - Stigmation/ focus
  - Stage control



# Run the Metrology Job



- Job execution and progress
  - Job start and pause/ stop
  - Progress along job sequence
  - Live display of scans on layout
  - Remaining time estimate
  - Parallel activities
    - Scanning
    - Contour detection
    - Metrology
    - Data processing
  - Result file created





- Results summary
  - Job list including data
  - Display
    - Layout with definitions
    - Scan with measurements
    - Results tables with tabs
  - Details for review/ tuning

The screenshot displays the GenISys software interface. On the left, a tree view shows a project structure with folders for 'Layout\_Distance\_Sx' and 'Layout\_Contour\_Sx'. The main window shows a 'Results Table' with columns for 'Name', 'Chip', 'Task', 'Distance', 'X-Distance', 'Y-Distance', and 'Main Measure'. A 'Results Table' dialog is open, showing a table with columns: 'Region', 'Skewed', 'Lines and Spaces', 'Distances', and 'Contours'. The table contains data for 'Distance 1 Result' and 'Layout\_Distance\_Sx'. A measurement view shows two red rectangles with a vertical double-headed arrow between them, labeled '30.987'.

Region	Skewed	Lines and Spaces	Distances	Contours
Distance 1 Result	Chip 1	<Margin>	36.5974	-0.020958
Layout_Distance_Sx	1.36441	-0.0716509	378.32	3628.02
Layout_Distance_Sx	1.32796	0.0097909	690.44	3628.78
Layout_Distance_Sx	1.42502	-0.0224416	604.006	3628.94
Layout_Distance_Sx	1.48514	1.49407	-0.0288749	617.898
Layout_Distance_Sx	1.36991	1.36956	-0.0310048	582.199

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## Demand for Automated SEM Metrology

- Lithography and application advancements need to be complemented in process monitoring
- Improvements between analytical SEM and CD-SEM are an opportunity

## ProSEM with SEM Automation Package

- Offline software helps getting more data (quality) out of existing images
- Offers easy-to-use basic automation for SEM acquisition and measurements

## **NEW** InSPEC Integrated SEM Metrology Kit

- Upgrade package enables a versatile SEM with additional inspection capabilities
- Hardware integration and more corrections plus hierarchical jobs with advanced FLOW
- Next level: hardware/ scan control, automation, contour extraction, metrology, data processing



# Thank You!

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