



Automotive  
Test Solutions

Embedded  
JTAG Solutions

Industrial  
Function Test

Inspection Solutions  
AOI · AXI · SPI · IVS

Detect faults early and optimize processes combined advantages through 3D solder paste inspection

David Whetstone

# Profile



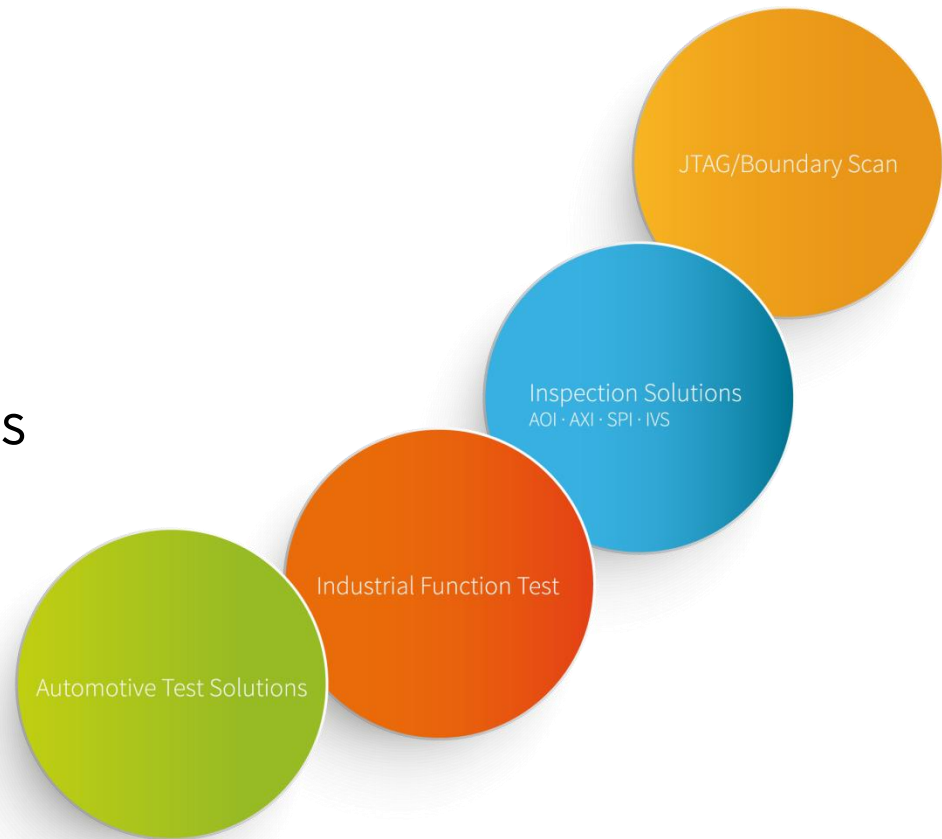
- Company founded in 1991
- Management board
  - Holger Göpel
  - Jörg Schneider
  - Thomas Wenzel
- Headquarters in Jena, Germany
- Branches
  - USA · Austin
  - UK · Cambridge
  - China · Hongkong, Chengdu
  - Indien · Bangalore



# Business Units

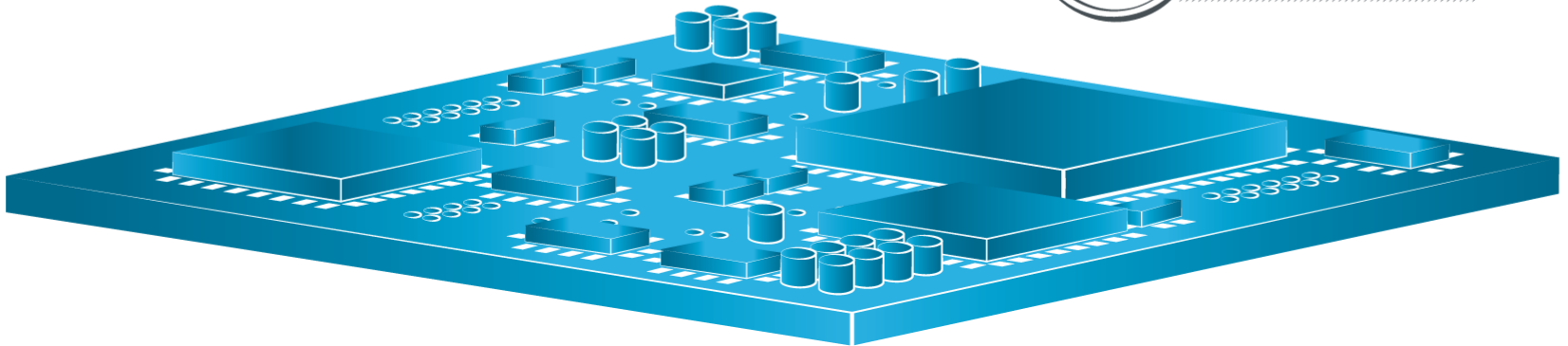
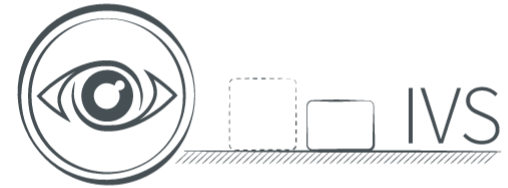
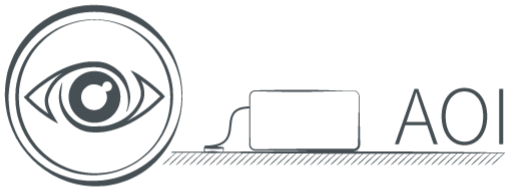
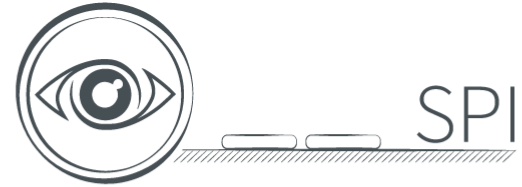
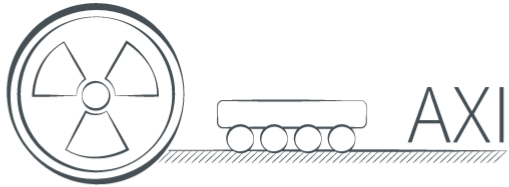


- JTAG/Boundary Scan
- Inspection solutions
- Industrial Function Test
- Automotive Test Solutions

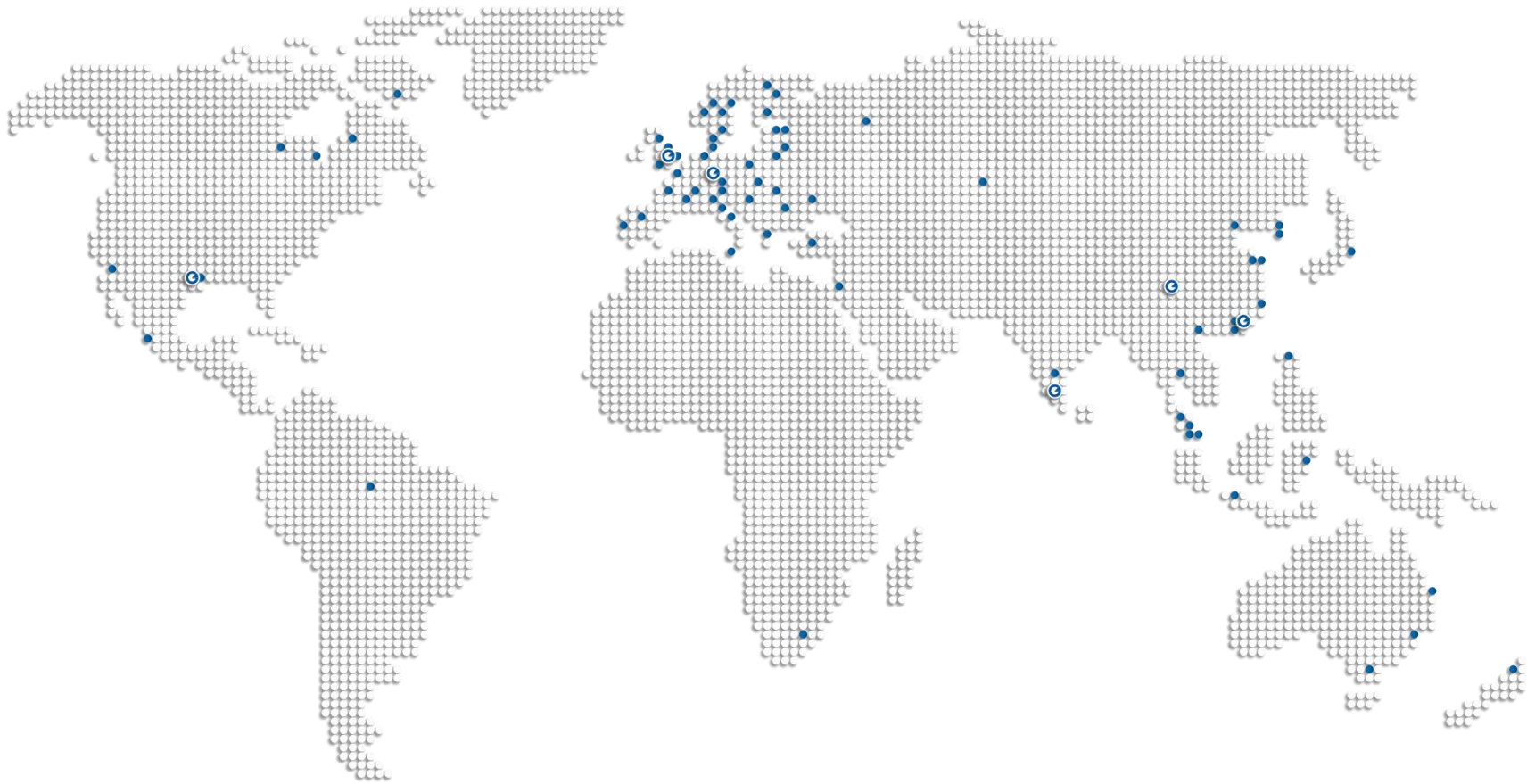


# Inspection Solutions

AOI · AXI · SPI · IVS

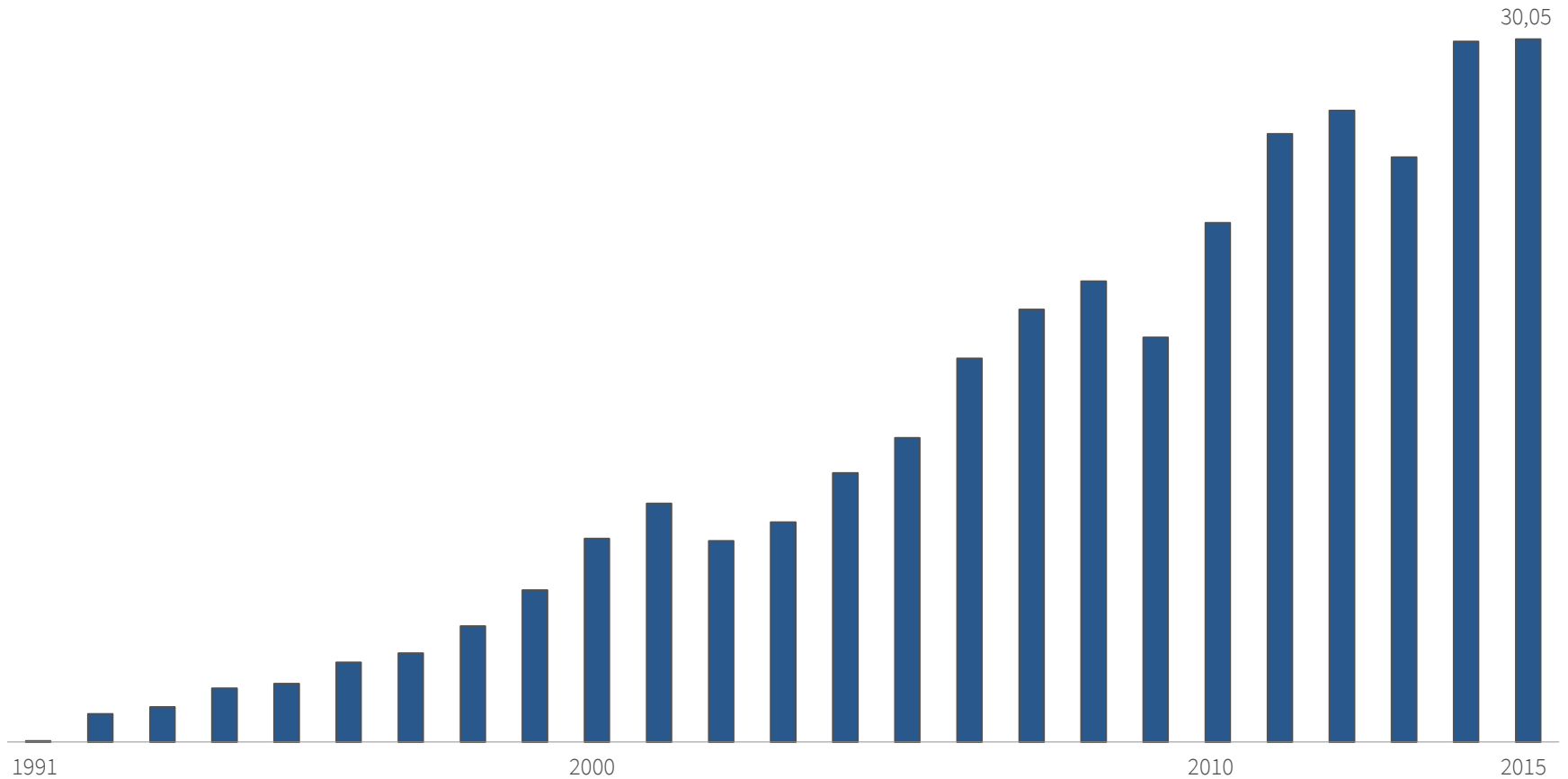


# International presence



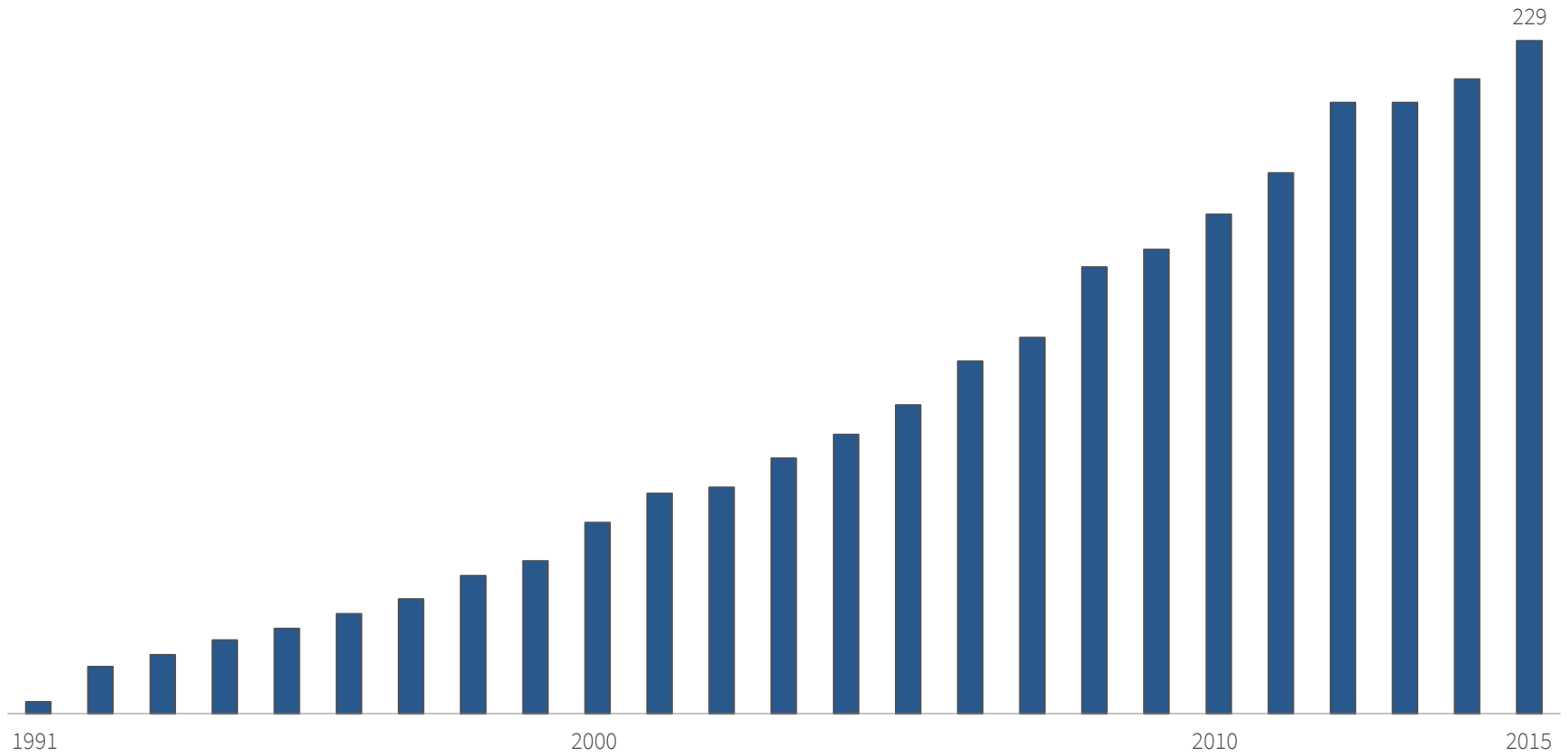
# Success story

Turn over in Mio EUR



# Success Story

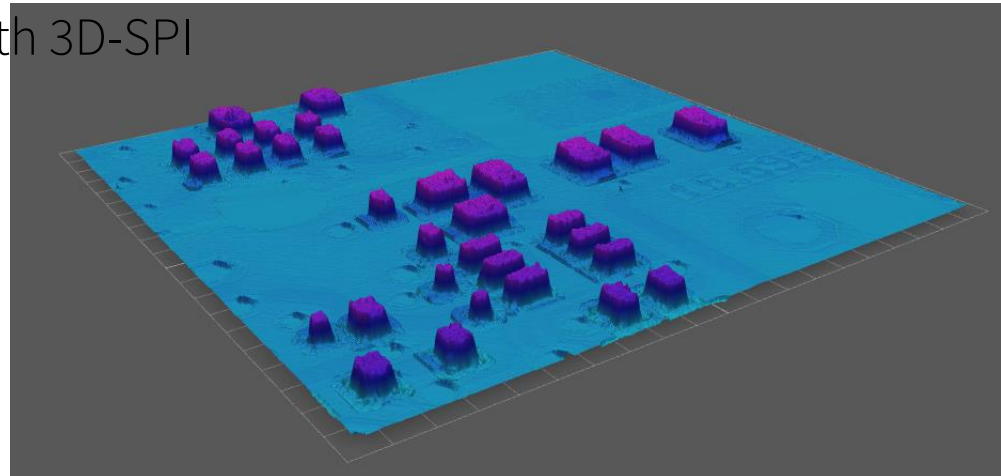
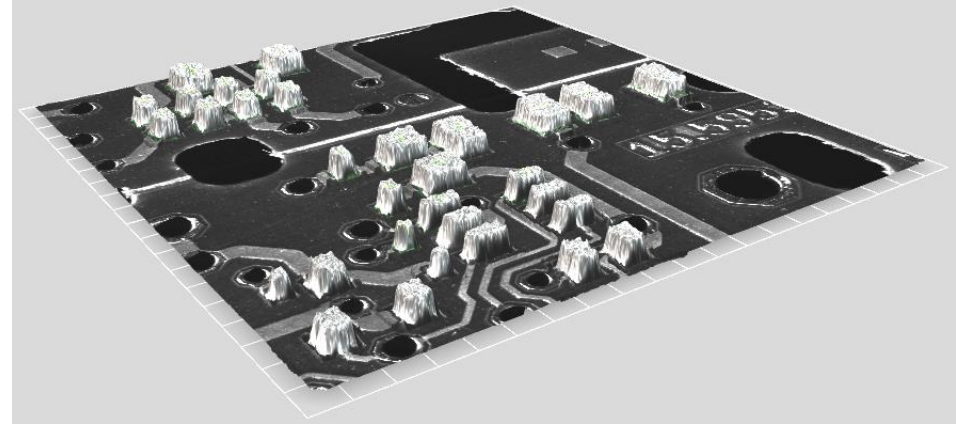
## Employees



# Content



- 1. Why 3D solder paste inspection
- 2. Requirements on SPI systems
- 3. SPI-Line 3D
- 4. Inspection of sinter paste
- 5. Process optimization with 3D-SPI
- 6. Summary

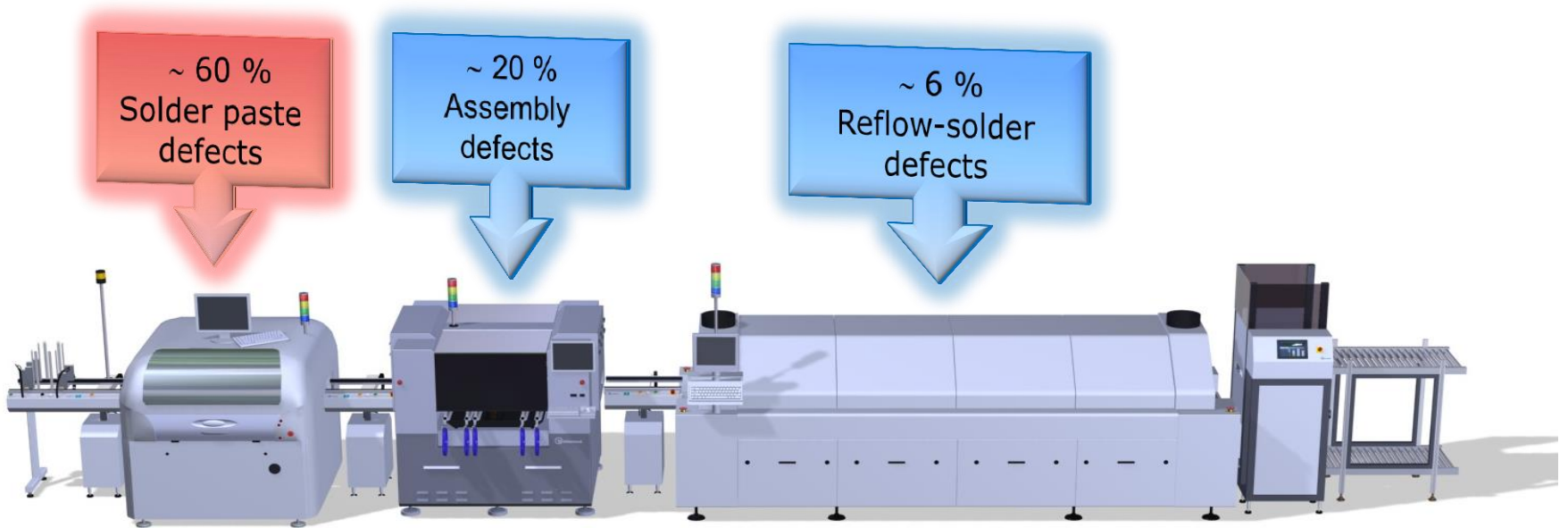




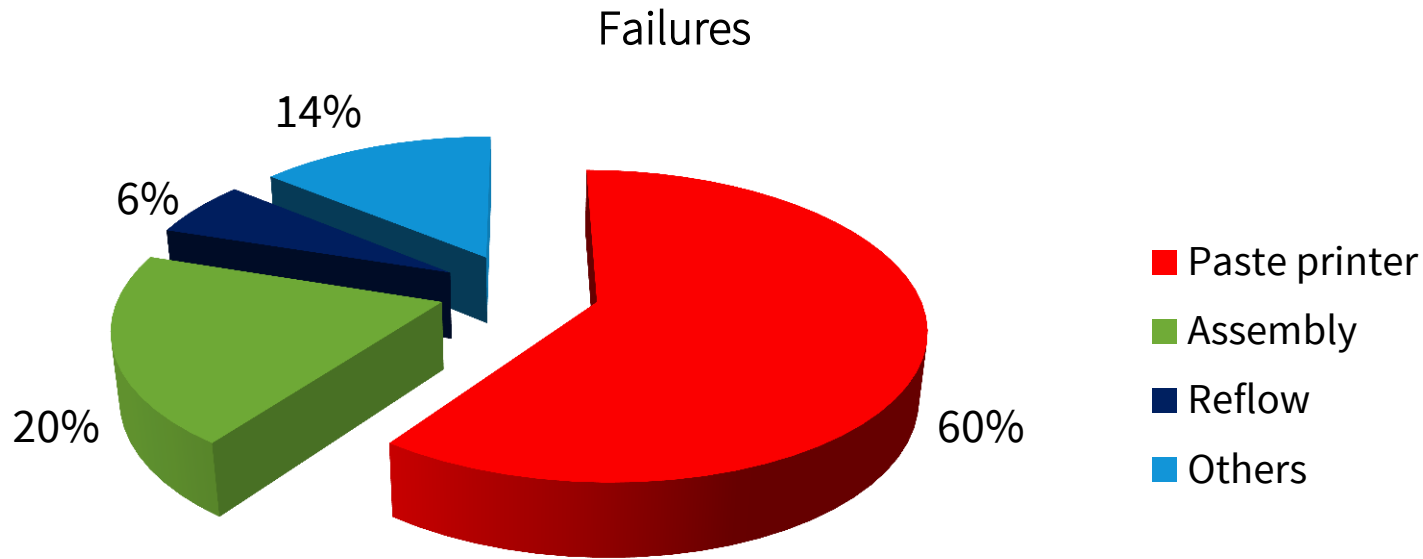


# Why Solder Paste Inspection?

- Failures can happen at different places in the production
- About 60% of the failures are caused by faulty solder paste printing



# Why 3D solder paste inspection?



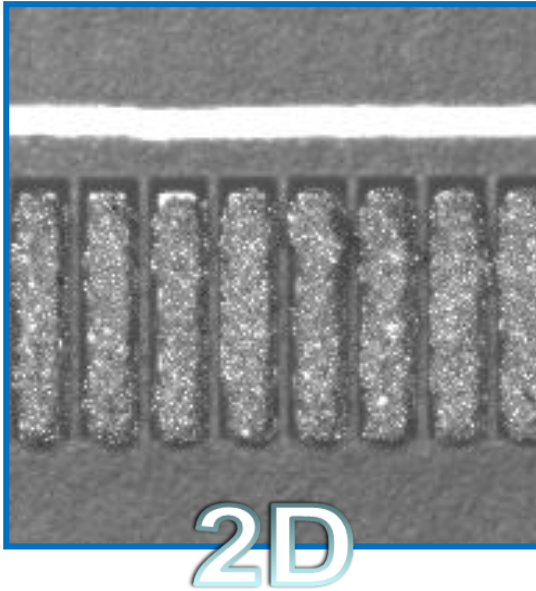
What can we do?

Detect paste failures = Avoid consequential failures

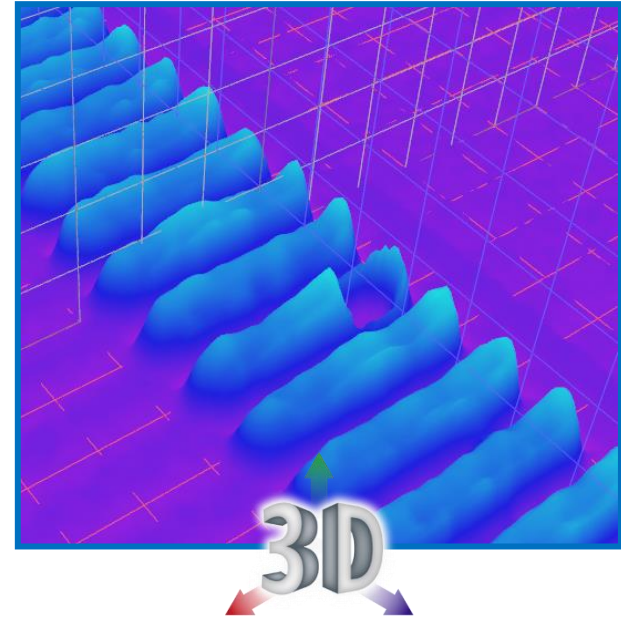
# Why 3D Solder Paste Inspection?



Difference 2D / 3D test criteria



- OFFSET
- BRIDGES
- SURFACE COVERAGE



- HEIGHT
- VOLUME

Total test coverage is **only** possible with 3-dimensional analysis.



# How complex is 3D solder paste inspection?

- Reliable inspection
- High precision
- High repeatability and reproducibility (Gage R&R)
- High speed

What is missing?

- Easy programming



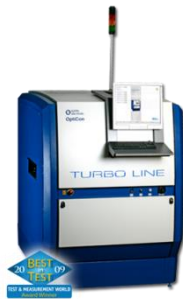
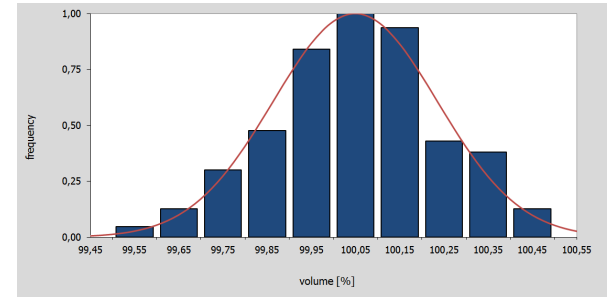
System characteristics



# How complex is 3D solder paste inspection?



- Comfortable statistical evaluation possibilities
- Closed loop to paste printers
- Link to other inspection systems



Additional tools for process optimization

# SPI-Line 3D

Special features:

- High speed 3D double projection head sensor
- Highly dynamic linear axis system
- Very intuitive and user friendly software
- Short programming times

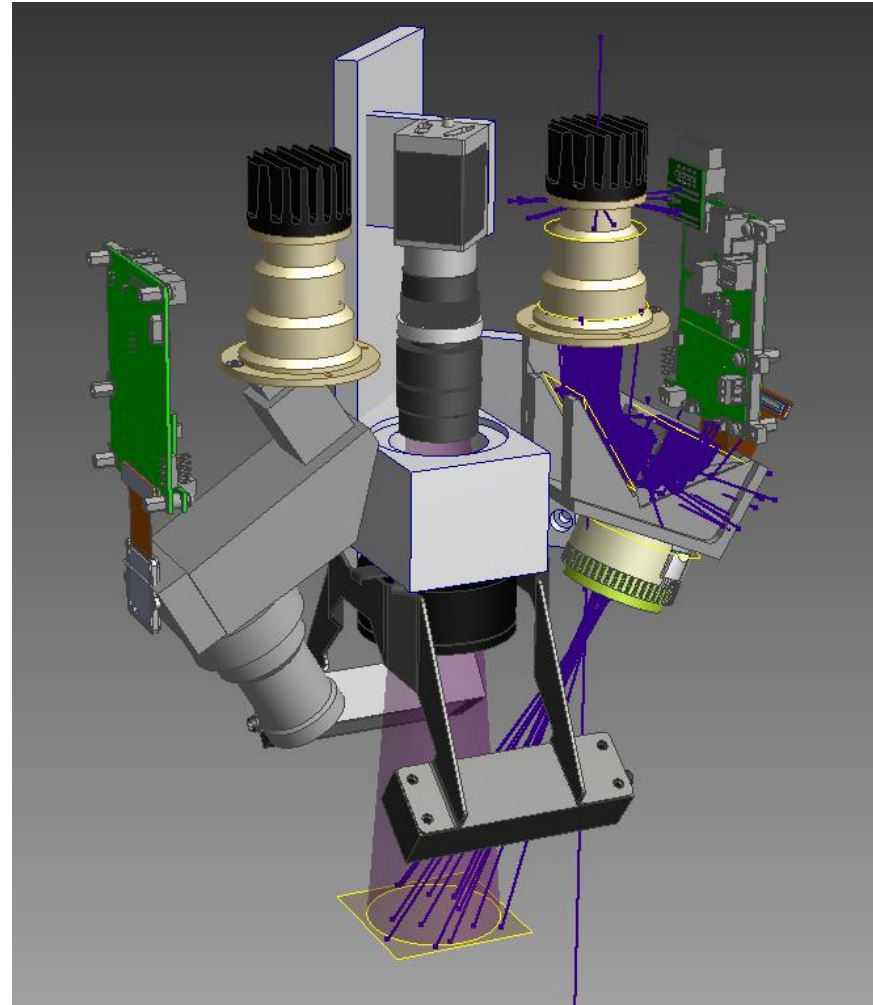


# SPI-Line 3D



High Speed 3D-Sensor:

- Double projection sensor based on LCoS\* Micro display
- Pros:
  - Redundant measurement results
  - Maximum reliability



\*LCoS- Liquid Crystal on Silicon



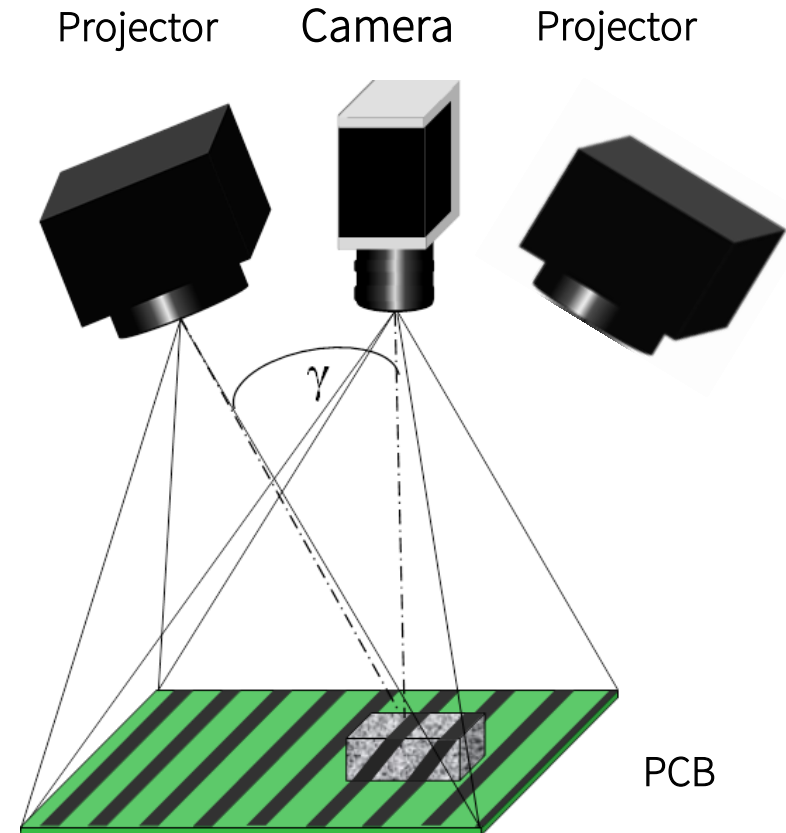
Own development by GÖPEL electronic in Jena

# SPI-Line 3D



High speed 3D sensor:

- Fringe projection
- 4 mega pixel CMOS camera, 180 fps
- LCoS\* mikrodisplay, 180 fps
- Triangulation angle  $\approx 30^\circ$



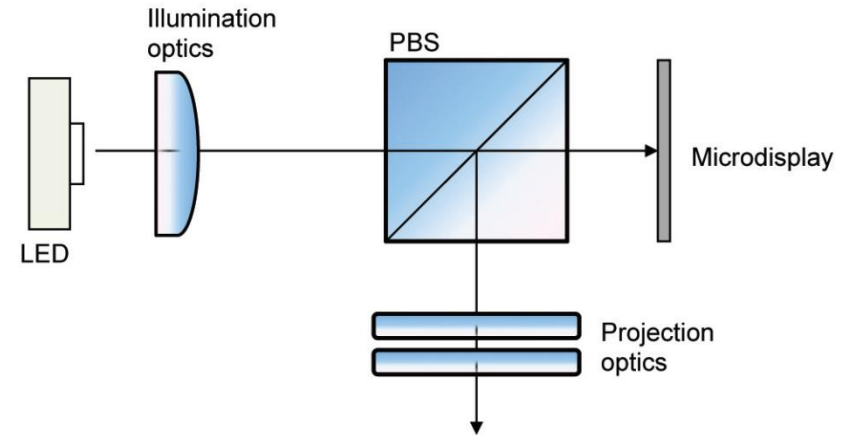
\*LCoS- Liquid Crystal on Silicon



# SPI-Line 3D

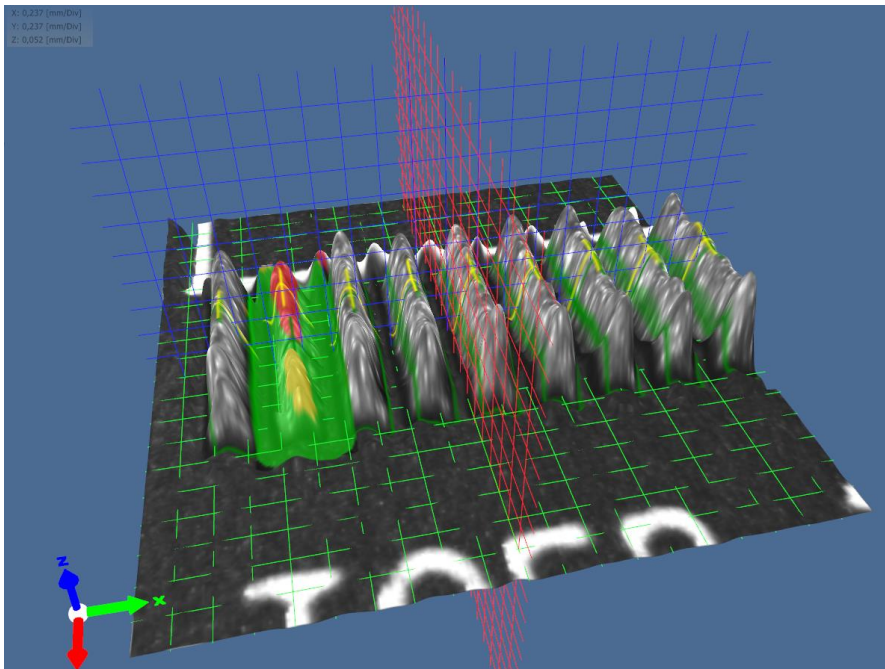
Electronic projector – Advantages:

- Area based measurement
- Short measurement times reachable
- Flexibility
- Extremely high resolution and precision
- No moving mechanical parts in the measuring head (very robust / minimized calibration operation)



# SPI-Line 3D

## Inspection parameters



- *Volume* ✓
- *Height* ✓
- *Offset* ✓
- *Form* ✓
- *Shorts* ✓

# SPI-Line 3D



Intuitive user friendly software interface

The screenshot displays the SPI-Line 3D software interface. At the top, a navigation bar includes icons for user management, transport, error handling, results, library, editing, and closing. Below this, a green header bar identifies the current project as "Produkt 'MyData1' (ID 123) [100%]".

The main workspace is divided into several sections:

- Left Panel:** A vertical toolbar with icons for Home, Volumen (Volume), Höhe (Height), Form, Brücken (Bridges), Versatz X (Offset X), and Versatz Y (Offset Y).
- Center:** A 3D perspective view of a PCB layout with multiple boards arranged in a grid.
- Right Panel:** A detailed view of a single board, labeled "Demo Board 17 L", showing a "uPGA 49E" component and "S014" pads. Text above the board reads "For a fast changing world".
- Bottom Left:** A "Histogramm Volumen" (Volume Histogram) showing a distribution of volume values between "Min" and "Max", with markers for "Untere Grenze" (Lower Limit) and "Ideal".
- Bottom Right:** A control panel with a "Maschinenkontr." (Machine Control) section and a hand icon pointing at a button.

On the far right, a sidebar provides an overview of the system status:

- Übersicht [15:19:21]:** Shows the user as "Administrator" and a status table with columns for "Aktueller Test", "Letzter Test", "Status", and "Prozess".
- System [Leerlauf]:** Indicates the system is idle.
- Produktinfo:** Lists product details: Name: MyData1, Losnummer: 123, Bilder: 16 (16), ID: 123, Pads: 2988 (2988), Passmarken: 3.
- Total (2 - Boards):** A summary table for the current production run.
- Fail (2 - Boards):** A table listing failed boards.

| Name      | Alle     | Aktuelles |
|-----------|----------|-----------|
| Volumen   | 21 (0 %) | 10        |
| Höhe      | 14 (0 %) | 8         |
| Form      | 8 (0 %)  | 4         |
| Brücken   | 6 (0 %)  | 3         |
| Versatz X | 33 (1 %) | 18        |
| Versatz Y | 37 (1 %) | 21        |

| Name      | Alle     | Aktuelles |
|-----------|----------|-----------|
| Volumen   | 21 (0 %) | 10        |
| Höhe      | 14 (0 %) | 8         |
| Form      | 8 (0 %)  | 4         |
| Brücken   | 6 (0 %)  | 3         |
| Versatz X | 33 (1 %) | 18        |
| Versatz Y | 37 (1 %) | 21        |

At the bottom of the interface, a control bar contains icons for Start, Stop, Automatisch, Nächste PCB, PCB FAIL, PCB PASS, and Maschinenkontr.



# SPI-Line 3D



... fast programming by using SPI-Wizard

The screenshot displays the SPI-Wizard software interface. At the top, there is a toolbar with icons for navigation and operations: Zurück, Layout öffnen, Bild Layout, Passmarken, Bareboard anlernen, Stufenmasken, Boards aktivieren, Grenzen, and Speichern. Below the toolbar is a blue header bar labeled 'Projektinfo'. The main area contains several input fields and controls:

- Projektname :** MyData
- Produktions ID :** 123
- Lotpastentyp :** 123
- Transportbreite [mm] :** 100 (with left and right arrow buttons)
- Fail Operationen:**
  - Klassifikation: [Slider]
  - Max Fehleranzahl [#]: 1 (with left and right arrow buttons)
  - Sirene bei Fehler: [Slider]
- Beleuchtung:**
  - Beleuchtung 3D [%]: 50 (with left and right arrow buttons)

# SPI-Line 3D



## Data import

**Layout Importieren**

**Boardübersicht**

Name : 1  
XML-Version : 1.0  
XML Name : ePM\_SPI\_GOEPEL  
Einheit : mm  
Ursprung : LL  
Genauigkeit : 3  
Größe X : 160,000  
Größe Y : 100,000

**Board Statistik**

Boards : 6  
Bauteile : 10  
Pads : 2988  
Passmarken : 3

|                  |                                                                                                               |
|------------------|---------------------------------------------------------------------------------------------------------------|
| <b>Gerber</b>    | 274D, 274D No Aperture, 274X, Fire9XX0                                                                        |
| <b>ECAD Tool</b> | Cadence (Allegro, Spectra), Pads, ODB++, Mentor Neutral, Zuken (PWS, DB), PCAD, Protel, FabMaster, GenCAD ... |
| <b>Etc</b>       | Various CAD X-Y, JPG, BMP ...                                                                                 |

# SPI-Line 3D



Intuitive parameterization

The image displays the SPI-Line 3D software interface. On the left, a 3D model of a PCB is shown in a green wireframe view. Overlaid on the model are several parameterization panels. The top panel is labeled 'Basis' and shows 'Höhe [0,120 mm]'. Below it is a panel for 'Level - 0' with 'Höhe [0,150 mm]' and 'Pad Anzahl = [0]'. A large panel in the center shows 'Höhe [mm]' with a value of '0,150' and left/right arrow buttons. On the right side, there are several vertical panels for advanced parameters:

- Positionstoleranz in mm [0.0 - 1.0]**
  - dx max: 0,12
  - dy max: 0,12
- Volumen in % des Nennwertes [0 - 500]**
  - Volumen max: 120
  - Volumen min: 80
- Form [0=Schlecht ... 1=Exakt]**
  - min: 0,95
- Brücken in mm [0.0 - 5.0]**
  - Länge: 0,2
- Höhe in µm [0 - 200]**
  - Höhe max: 150
  - Höhe min: 90
  - Schwelle: 0





# SPI-Line 3D



## Fiducial training and bare board teaching

Back Conveyor Next Panel

Minimize Exit

**Fiducial Training**

uBGA 49E

S014

Demo Board

Offset X = 1,00

Offset Y = -1,00

Result... = Found  
Calc Time = 14,50 ms  
Type... = Static Binarized  
RawPos... = (1017,586, 1015,593)  
Pos [mm], = (5,259, 6,162)  
Quality.. = (98,102)

Do all globats Do all Locals Cancel

**FIDU1** Global  
Footprint = FIDU1 Pos = [5,38; 6,00]; ImageID = [1]

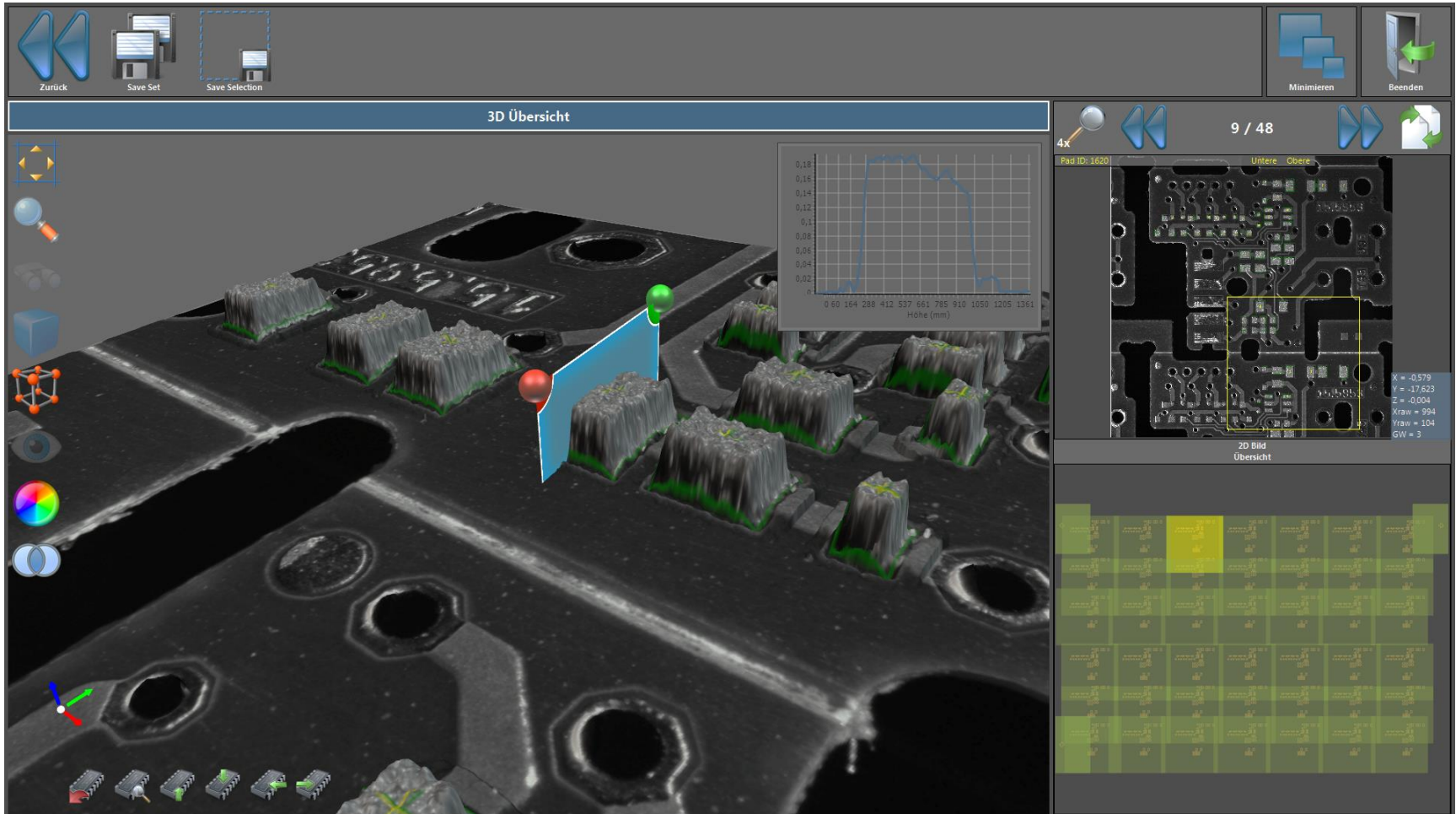
**FIDU3** Global  
Footprint = FIDU1 Pos = [112,08; 94,00]; ImageID = [2]

**FIDU5** Global  
Footprint = FIDU2 Pos = [154,60; 6,00]; ImageID = [3]

# SPI-Line 3D



## Inspection results





# SPI-Line 3D



## Inspection results

The screenshot displays the SPI-Line 3D software interface. The main window is titled "3D Übersicht" (3D Overview) and shows a 3D topographical map of a printed circuit board (PCB) surface. A blue plane is positioned above the surface, and a red sphere and a green sphere are visible on the plane. The 3D map shows two prominent rectangular features with a height profile graph overlaid on them. The graph plots height in millimeters (mm) on the y-axis (ranging from 0 to 0.18) against distance in millimeters (mm) on the x-axis (ranging from 0 to 1361). The profile shows a sharp rise to a plateau at approximately 0.16 mm, followed by a sharp drop to 0 mm.

On the right side, there is a "2D Bild Übersicht" (2D Image Overview) window showing a top-down view of the PCB. A yellow box highlights a specific area, and a data box provides coordinates: X = -3.920, Y = 11.057, Z = 0.002, Xrow = 119, Yrow = 1601, and GW = 27. The interface also includes a toolbar with icons for navigation (Zurück, Save Set, Save Selection), window management (Minimieren, Beenden), and a 2D grid overview at the bottom right.

# SPI-Line 3D



## Inspection results

Fertig Grenzen vorverfeinern Klass. Nutzer **Nutzer: Administrator** Minimieren Beenden

**Manuelle Klassifizierung [72 / 279]**

| Merkmal        | Untere                | Obere          |
|----------------|-----------------------|----------------|
| Volumen (%)    | 106.524 [PASS] OK     | 50.000 150.000 |
| Hohe (%)       | 207.906 [FAIL] HLimit | 50.000 160.000 |
| Form           | 0.997 [PASS] OK       | 0.300 1.000    |
| Brücken (mm)   | 0.000 [PASS] OK       | 0.000 0.900    |
| Versatz X (mm) | -0.111 [PASS] OK      | -0.120 0.120   |
| Versatz Y (mm) | 0.015 [PASS] OK       | -0.120 0.120   |

**Nicht klassifiziert**

Vorheriges FAIL PASS deklarieren Überspringen Grenzen bearbeiten

Board: 507467  
Pin-Typ ID: 9  
Nutzen: Block1  
Footprint: FOOT6  
Pad ID: 483

Boardübersicht

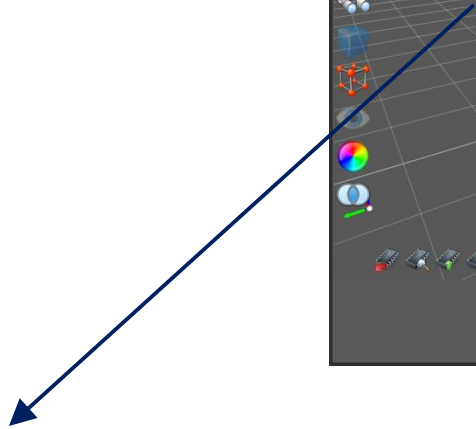
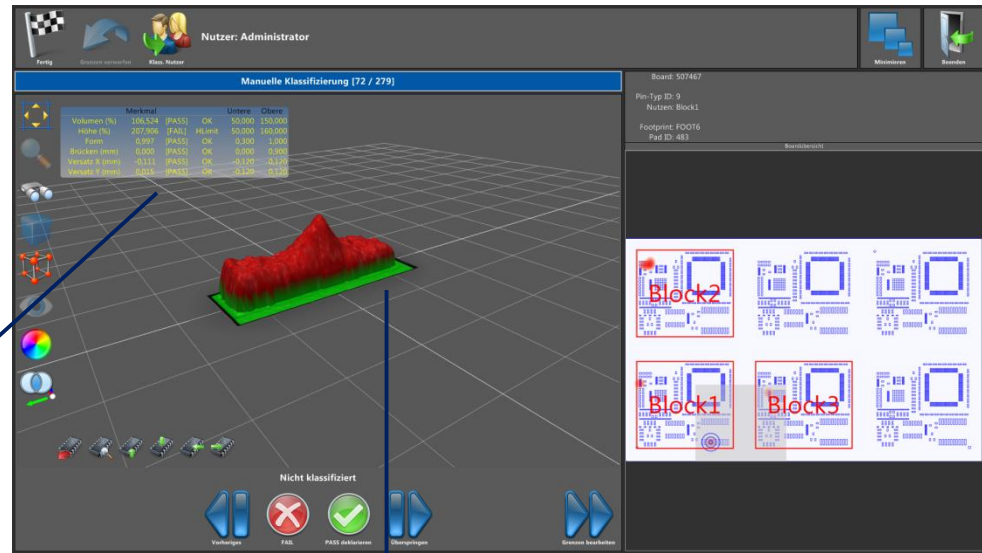
**Block2**

**Block1** **Block3**

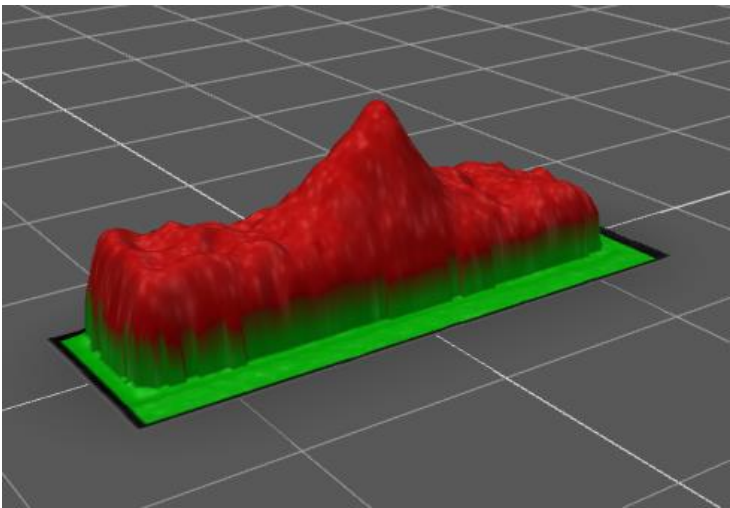
# SPI-Line 3D



Failure detection/  
paste height



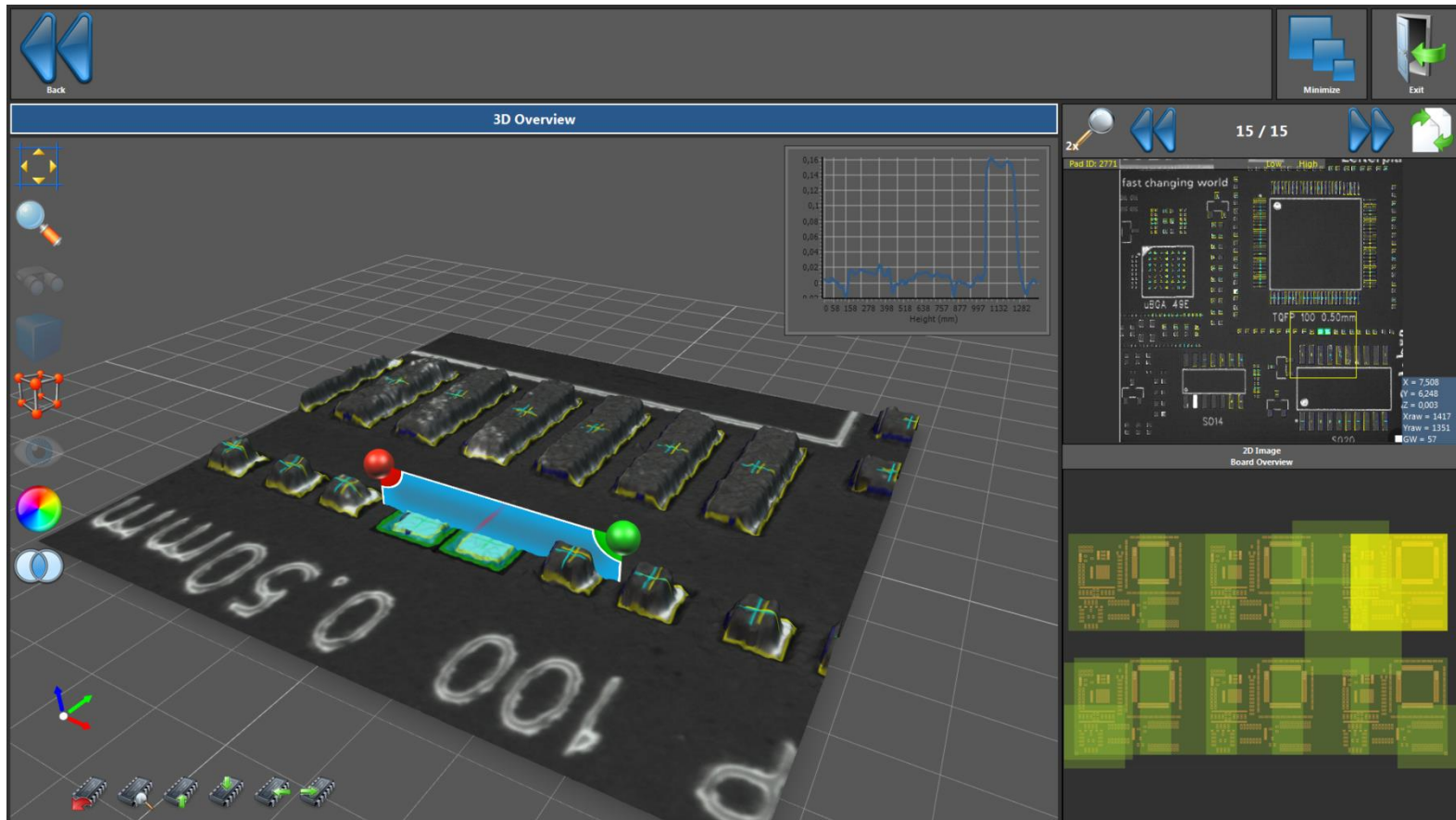
|  | Merkmal        |         |               | Untere | Obere   |
|--|----------------|---------|---------------|--------|---------|
|  | Volumen (%)    | 106,524 | [PASS] OK     | 50,000 | 150,000 |
|  | Höhe (%)       | 207,906 | [FAIL] HLimit | 50,000 | 160,000 |
|  | Form           | 0,997   | [PASS] OK     | 0,300  | 1,000   |
|  | Brücken (mm)   | 0,000   | [PASS] OK     | 0,000  | 0,900   |
|  | Versatz X (mm) | -0,111  | [PASS] OK     | -0,120 | 0,120   |
|  | Versatz Y (mm) | 0,015   | [PASS] OK     | -0,120 | 0,120   |



# SPI-Line 3D



Failure detection/  
No paste

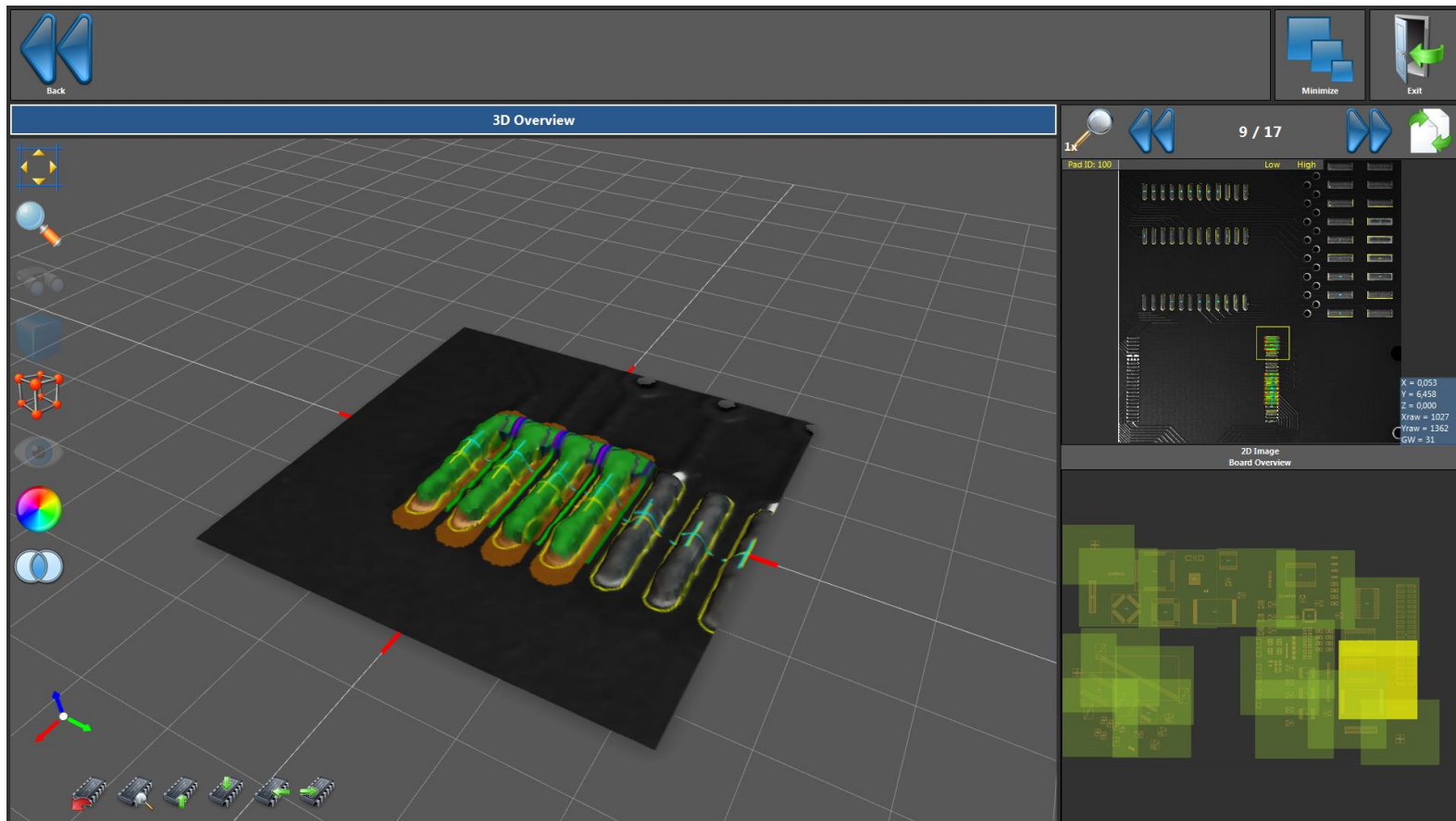




# SPI-Line 3D



Failure detection/  
Bridges



# SPI-Line 3D



Failure detection/  
Offset

The screenshot displays the SPI-Line 3D software interface. The main window shows a 3D overview of a PCB with several components. The interface includes a toolbar with navigation and analysis tools, a data table for a selected pad, a 2D image board overview, and a 3D model of the PCB.

**3D Overview**

Back

Minimize

Exit

1x

15 / 15

| Pad ID: 2757 | Low            | High              |
|--------------|----------------|-------------------|
| Volume (%)   | 73.018 [PASS]  | OK 13,000 200,000 |
| Height (%)   | 117.529 [PASS] | OK 50,000 200,000 |
| Boreing (%)  | 0.003 [PASS]   | OK 0,000 25,000   |
| Delta X (%)  | 7.489 [PASS]   | OK 25,000 25,000  |
| Delta Y (%)  | -0.884 [PASS]  | OK 25,000 25,000  |
| Surface (%)  | 62.999 [PASS]  | OK 13,000 150,000 |

X = -10.625  
Y = 3.825  
Z = -0.013  
Xraw = 468  
Yraw = 1224  
GW = 27

2D Image  
Board Overview

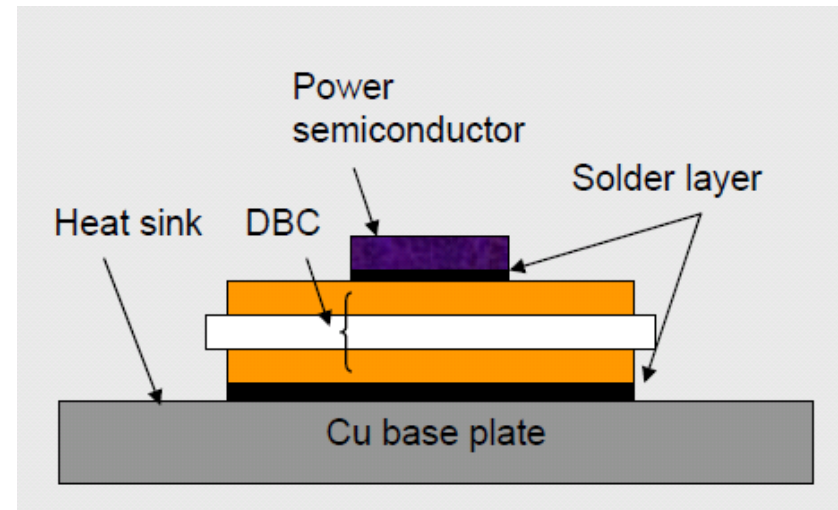


# Inspection of Sinter paste

Sinter technology – why?

- Semiconductor power modules built as a thermal stack
- State of the art is large area soldering
- For long life-requirements the silver sintering promises big improvement

Source: Fachhochschule Kiel / Institut für Mechatronik

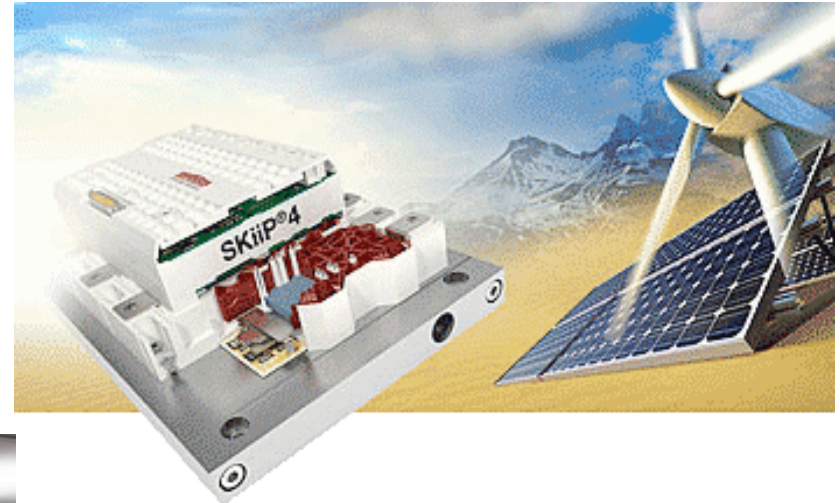




# Inspection of Sinter paste

## Sinter technologie – applications

- Photovoltaic
- Wind power stations
- Electric mobility



Source: SEMIKRON Elektronik GmbH & Co. KG



Source: VW AG





# Inspection of Sinter paste

## Inspection tasks for Sinter paste

- Height
- Volume
- Offset
- Holes in surface (cavities, scratches)
- Fringes on edge
- Coplanarity

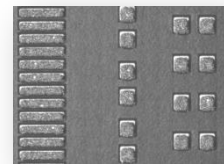
....



# Inspection of Sinter paste

Differences between solder paste and Sinter paste:

|                | Solder paste                                | Sinter paste                                                                      |
|----------------|---------------------------------------------|-----------------------------------------------------------------------------------|
| Paste height   | 80 $\mu\text{m}$ ... 150 $\mu\text{m}$      | 20 $\mu\text{m}$ ... 50 $\mu\text{m}$                                             |
| Paste area     | ~ $\text{mm}^2$                             | ~ $\text{cm}^2$                                                                   |
| Structure size | 25-45 $\mu\text{m}$                         | < 3 $\mu\text{m}$                                                                 |
| Test fonctions | Height, area, volume, offset, form, bridges | Height, area, volume, offset, form, bridges, particles, scratches, holes, fringes |

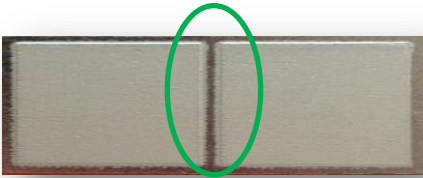


# Inspection of Sinter paste

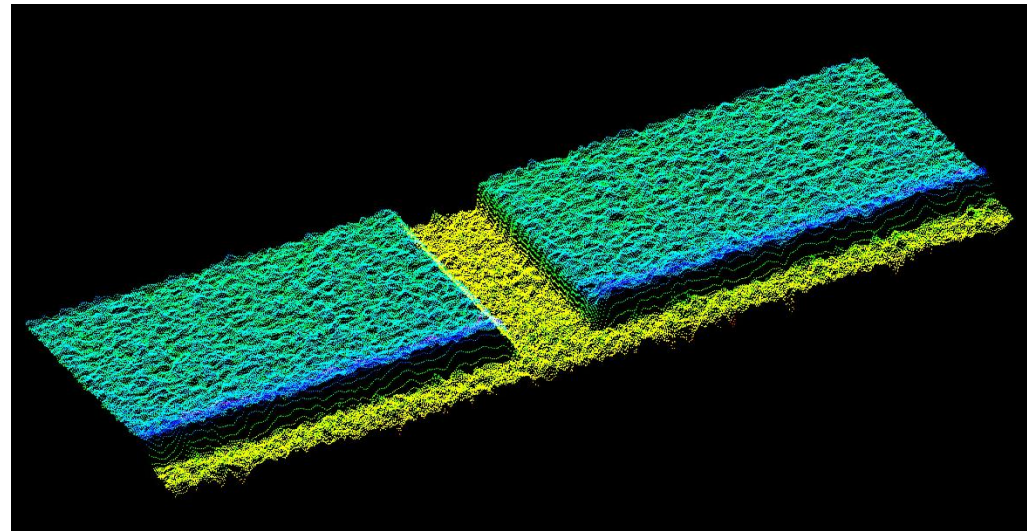


A highly precise measurement of Sinter paste is possible!

2D-image



3D-image with SPI-Line 3D



# Process optimization g

Closed-Loop



Paste printer



- Many parameters
- Random failures
- Serial failures



SPI-Line 3D



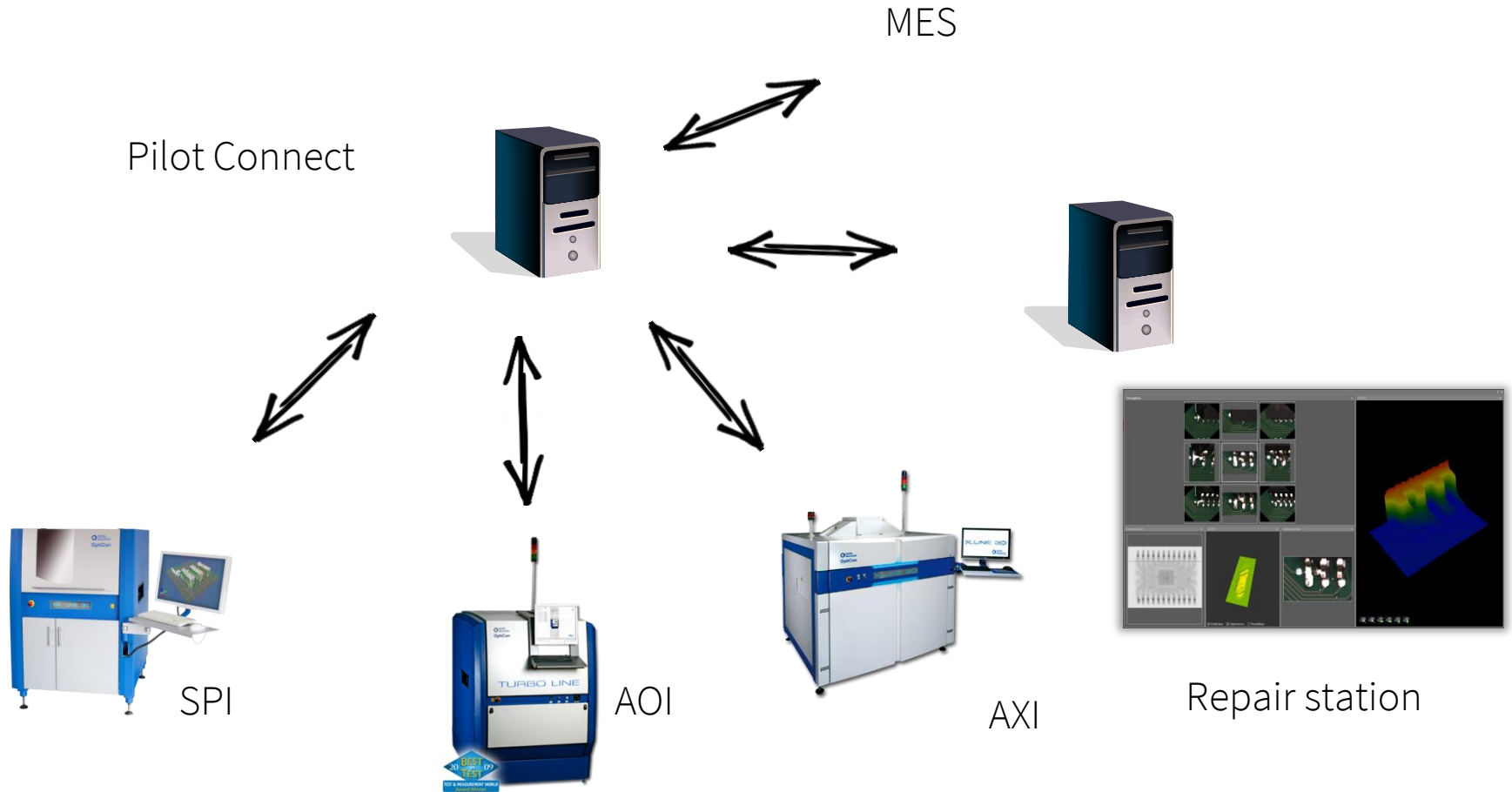
- Reliable measurement of paste



Response of results

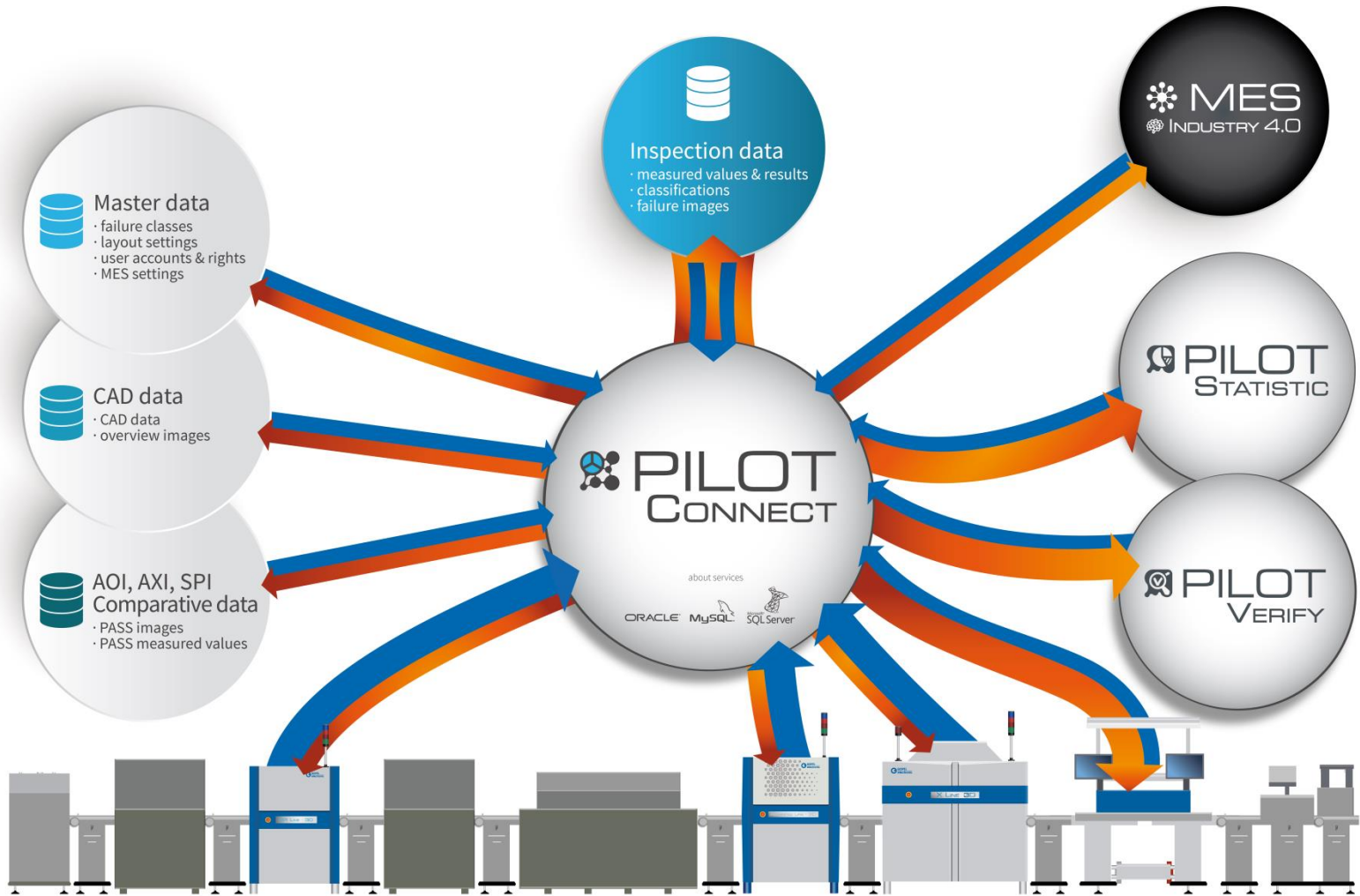
# Process optimization

Many data – one channel / Pilot Connect



# Process optimization

Many data – one channel / Pilot Connect



# Process optimization

Failure visualization on a common repair station



The screenshot displays a software interface for failure visualization on a common repair station. The interface is divided into several panels:

- Logical Tree:** Shows a hierarchical view of components. IC16 is selected, and its failure modes are listed: AOI FAIL [2] 0° Pin [3D], AXI PASS R1, and SPI PASS 24.
- CAD Overview image:** Shows a 3D model of the PCB with a red box highlighting the area of interest (IC16).
- 3D SPI:** Shows a 3D surface plot of the SPI (Surface Mount Inspection) data, with a yellow and red color scale indicating height variations.
- Fail Image AXI:** Shows a grayscale image of the AXI (Automated X-ray Inspection) data, with a green circle highlighting a specific failure point.
- Fail Image AOI:** Shows a grayscale image of the AOI (Automated Optical Inspection) data, with a green circle highlighting a specific failure point.
- Angled View:** Shows a grid of images showing the component from different angles, used for visual inspection.
- 3D AOI:** Shows a 3D surface plot of the AOI data, with a color scale indicating height variations.

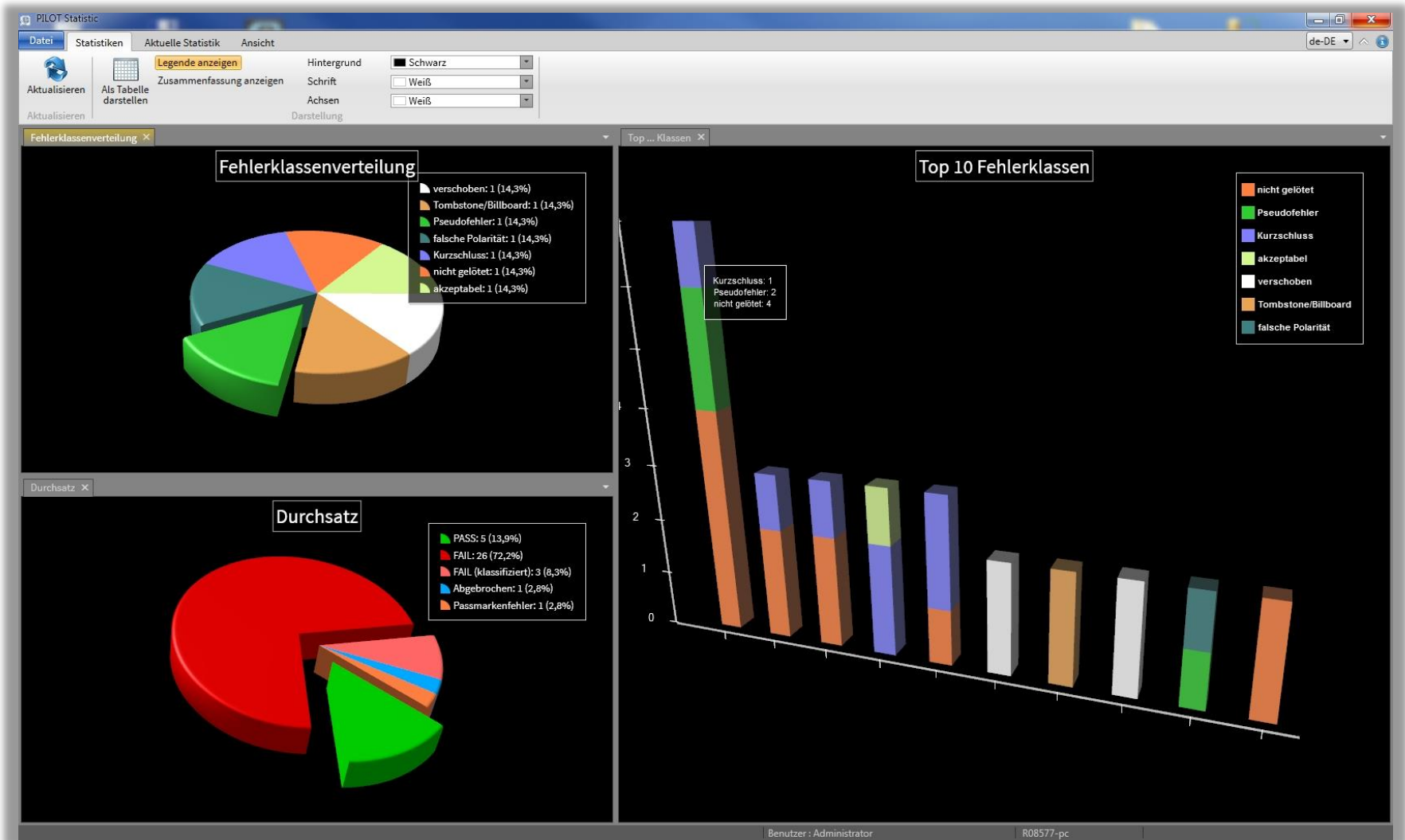
The bottom left panel, titled "Failure Information", provides details for the selected failure mode (Block1 → IC16 → 2):

| Failure Text          | Failure Class Max | Failure Class Use |
|-----------------------|-------------------|-------------------|
| AOI                   |                   |                   |
| Kein Text gefunden... | Unclassified      |                   |
| AXI                   |                   |                   |
| OK                    | Ok                |                   |
| SPI                   |                   |                   |
| Kein Text gefunden... | Pass              |                   |



# Process optimization

## Common statistical evaluation of results





# Summary



- A total test coverage can only be reached with a 3D solder paste inspection.
- Paste defects will be detected with a high precision and high speed.
- The user friendly system concept of the SPI-Line 3D allows a simple line integration.
- The use of SPI-Line 3D offers new possibilities for process optimization and process stability.





Automotive  
Test Solutions

Embedded  
JTAG Solutions

Industrial  
Function Test

Inspection Solutions  
AOI · AXI · SPI · IVS

Thanks for your attention!

[www.goepel.com](http://www.goepel.com)

