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X-Ray Inspection

# Applying X-Ray: Beyond Features and Into Context

Leora E. Lawton, Ph.D.

Knowing the manufacturing context into which x-ray inspection will occur is the key to decision-making.

Ample agreement exists that x-ray inspection for surface-mount components such as ball grid arrays (BGA) is well suited for fine-tuning manufacturing processes.[1,2] Beyond that, debates or assumptions are held on several questions. Should the x-ray capability be in-house or can money and floor-space be saved by outsourcing? Is it better for x-ray equipment to be in-line or off-line? Is it really worth having all the advanced features of systems that cost several hundred thousand dollars or, in the other extreme, can a five-figure machine be part of a high quality manufacturing process?

As in life, manufacturing is a system of trade-offs. In manufacturing, several factors drive the strategy for using x-ray inspection in surface-mount assemblies. X-ray inspection functions well to help develop a high-yield assembly process because it allows examinations of BGA components whose leads are hidden from view underneath the package. By analyzing the error patterns and adjusting the manufacturing environment factors, engineers can refine the process until those errors either vanish or are reduced such that a spot check is sufficient for adequate quality assurance.

Gregory Balas is a manufacturing engineering manager with Kyocera Wireless Corp. (San Diego, CA), a manufacturer of wireless telecommunications equipment. Balas summed up the strategy, "The benefit of x-ray is that we can verify the assembly processes when starting up a new product. We do complete inspection on initial product runs, start-up and process qualification, and we rely on it to test invisible solder joints, etc. After we gain confidence that our defect rates are low, we can then shift to a more sample-oriented plan."

Engineers employ x-ray for purposes beyond BGA inspection. With the shrinking size of components and the assemblies, even magnification can miss some subtleties. "We need x-ray capability because the real estate is so narrow," explained Juan Gamboa, a manufacturing manager at Cisco (Santa Clara, CA), a networking equipment manufacturer.

Phil Yates is vice-president of technology with Nextek Inc. (Madison, AL) a contract manufacturer. He added, "We use x-ray for solder joints, BGA, CSP [chip-scale packaging] and flip chip, on peripheral leaded QFP [quad flat pack] and also for failure analysis."

In addition, some manufacturers use x-ray as they would other kinds of optical inspection: to examine all or a percentage of assembled boards before shipment or before the full system build and functional test.

## In-line or Off-line

The advantage of in-line inspection should theoretically be the advantages of automation and the reduction in steps required in the process. "For very high volumes with repetitive processes, then in-line may very well make sense," said Yates.

However, stand-alone equipment does have advantages. For example, with an off-line configuration, a manufacturer needs fewer x-ray

machines and the surface-mount lines are more flexible. Boards with special features, for example, with placements on the backside, can be handled easily off-line. None of the engineers interviewed for this article reported in-line x-ray inspection in their facilities.

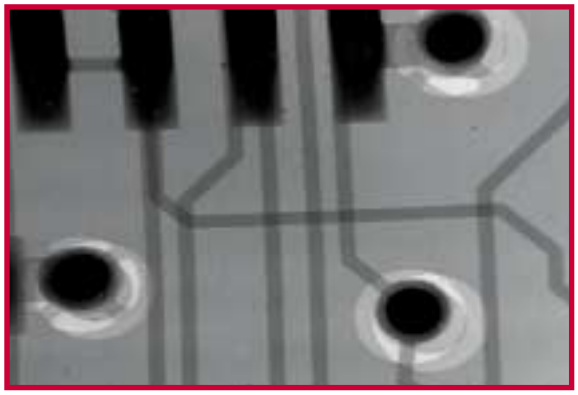
## In-House or Outsource

For some small manufacturers, having an outside vendor perform the x-ray inspection and perhaps analysis is more cost effective. Outsourcing x-ray inspection can reduce costs in terms of headcount, floorspace and capital. Having a committed vendor is a viable strategy for manufacturers with a low mix.

Identifying and costing manufacturing services without the capital expense is also more straightforward. Then, after the process is established, boards can be sent out for rework if they fail in-circuit or functional test. Other manufacturers may scoff at this strategy, but their skepticism may be because this strategy would be disaster in their context of high-mix manufacturing and high reliability or other complex assemblies.

## Low-end or High-end

In the high-tech world, expensive equipment with bells and whistles impresses. The resolution of the images, the results of the statistical process control and more can add a level of capability that some manufacturing establishments require. People regularly evoke the HP5DX (now Agilent) as the standard.



Nextek Inc.

X-ray image of multilayered PCB with misaligned layers.

Balas of Kyocera noted that smaller machines may require a lower level of operator training and may yield quick results with little or no programming. “But it’s not real production line repeatable,” he warned. “A tool like that is very good for debugging circuit board faults.”

One original equipment manufacturer (OEM) engineer derided low-cost machines, saying they were generally incapable of meeting x-ray needs. While ‘you get what you pay for’ and some x-ray machines are ‘pocket change’ compared to the HP5DX, many smaller machines do have a broad range of features. For example, Andrea Dean, training and service engineer with Feinfocus in San Jose, CA, said her company has x-ray equipment that can support three-dimensional (3-D) solder joint portrayal and handle lead-free solder.

High-end snobbery may be an impression borrowed from the semiconductor industry. “They have to take high resolution images, super high contrast, completely and totally magnified,” explained Robert Boardwell, an engineering manager at contract manufacturer SMT Dynamics (Anaheim, CA). “But, in the BGA world, the size of the ball is huge, so there is no comparison to the kind of precision the semiconductor industry needs.” Even with decreasing component size, requirements for detail will not approach those of the semiconductor industry.

Choosing the right x-ray system means recognizing the requirements of the assembly. “Our specific focus of manufacturing makes us unique, so we opted for the high end,” noted Yates of Nextek. “But, if you have a few BGAs on fairly traditional established technology, then you can choose a low-end system and tune it for that spectrum of application.”

X-ray equipment manufacturers recognize that post-sales technical support in the form of staff education and equipment customization is part of their offerings. For example, Nextek collaborated with its x-ray equipment supplier, Xtek, to customize the equipment. Also, websites of x-ray equipment manufacturers typically contain a variety of white papers and other informational materials.

Yates raised another strategic point concerning x-ray equipment: real-time transmission capability as opposed to x-ray laminography (XRL) systems. Laminography solutions require greater engineering expertise, whereas the real-time solutions allow a company to train its operators for non-complex assemblies. Nextek chose Xtek as its x-ray vendor because the machines offer real-time data transmission. “Part of that decision was driven by the fact that XRL is engineering intensive, and, in a high-mix, quick turn contract manufacturer, that doesn’t fit very well,” said Yates.

## Staffing Challenges

A challenge in using x-ray is the expertise level required to interpret the data provided by the inspection. Gamboa of Cisco noted, “The x-ray equipment manufacturers need to improve the algorithms. That is one of the major question marks in the whole process.” Indeed, one commonly raised challenge of x-ray inspection is the difficulty in interpretation and analysis of results and the need to staff inspection teams with an engineer.

One engineering manager also raised the possibility of employee carelessness with x-ray technology. He has seen safety switches of other kinds of equipment turned off for convenience and loathes the thought of safety lapses with x-ray equipment. A stand-alone strategy can mean having fewer machines, fewer employees involved and lower risks for employee safety.

## Customer Focus

Contract manufacturers must also consider customer requirements. In some cases, customers expect the x-ray capability to be in-house, and they may even have requirements about the kind of equipment used. Their expectation is that assemblies including ball grid array components need x-ray inspection. Because of that expectation, customers may use x-ray as a ‘litmus test’ of whether to do business with a contractor.

“We didn’t want to buy it,” explained Boardwell of SMT

Dynamics, "but our customers would take a tour and the first question we would be asked was, 'Do you have an x-ray?' and it was a huge turnoff that we didn't."

Nevertheless, having x-ray capability in-house means not having to rely on yet another vendor's schedule and timely turnaround. With timely delivery a close second to quality for contract manufacturers' requirements, having the edge in time management may be the difference in satisfying one's customers. As with other aspects of outsourcing, feeling in control of the manufacturing process gives manufacturing engineers additional comfort.

## Most Valued Features

Knowing what other engineers value can help guide one's decision about an x-ray purchase. When asked about the top three features they want in x-ray equipment, the engineers interviewed said they look for features offering ease-of-use, which in turn leads to greater throughput and more efficient use of resources. Ease of programmability and interpretation of data is the feature most often desired.

"It's like an art form to interpret what you are seeing on the screen," said Balas of Kyocera. When operators cannot understand the data output, an engineer is required, which is a less than optimal staffing solution.

Being able to rotate or tilt the board and position it in the x-ray was also mentioned by several engineers. With dense placements and fine-pitch components, being able to manipulate the board with different angles, axes and magnifications greatly increases its utility.

Another feature related to data analysis is being able to capture an image and then manipulate it, or save it digitally and send it to another engineer. Yates described the benefits of this capability, "If we have a real-time image, then we can capture it, average images to get rid of background noise…we take the data (pictures) and make it usable information."

Boardwell noted that sending customers a picture of a good placement can give them a feeling of comfort.

## Conclusion

A pattern emerged from speaking with engineers in different manufacturing companies. At one extreme, those who use the higher-end equipment were much more detailed in how they spoke about their use of x-ray equipment. Obviously, these people were immersed in the technology. They worked in facilities where default analysis and perfecting the manufacturing process were a key focus of their companies.

At the other extreme, engineers who stated their strategy with little detail are either outsourcing the inspection or not using the high-end equipment. For them, analytic use of x-ray inspection is not a core competence or a requirement in their manufacturing strategy.

Of the criteria discussed, there is no clear right or wrong, best or worst. Rather, use of x-ray equipment must be tailored to the kind of manufacturing requirements your products and your customers demand. Knowing the manufacturing context in which x-ray inspection occurs is the key to decision-making. ■

## References


1. *Circuits Assembly Online*, www.circuitsassembly.com. Follow links to Top 100 Articles/Test and Inspection.
2. Glenbrook Technologies' website, www.glenbrooktech.com/reports.html. Follow the link for BGA inspection and look for the papers on BGA listed therein.



***Dr. Leora E. Lawton, Ph.D.**, is a freelance writer and founder of TechSociety Research, Berkeley, CA; e-mail: lawton@techsociety.com.*

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