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WHITE PAPER: AUTOMATED LINE CLEARANCE IN MANUFACTURING

Harnessing Edge AI vision system technology

Introducing a groundbreaking automated line clearance system born from the collaboration of industry leaders: Synaptics, Balluff, Arcturus Networks and 42 Technology.

Every minute a production line is idle, costs rise. Yet, before manufacturing can begin, each part of the line must be inspected—an essential but slow and detailed process. ***AI-powered automation is changing that.***

Traditional manual line clearance is critical for ensuring product integrity and regulatory compliance, yet it remains inefficient, labour-intensive and operationally disruptive. Existing automated solutions attempt to address these challenges but often fall short in speed, complexity and cost effectiveness, limiting real world adoption.

A new era of AI driven automation is emerging.


This white paper explores an innovative Edge AI powered line clearance system developed by Synaptics, Balluff, Arcturus Networks and 42 Technology. By combining on-device AI processing, industrial vision systems and deep learning models, this solution eliminates cloud dependencies, accelerates inspection times and reduces reliance on manual verification while offering a scalable, cost effective alternative to current solutions.





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AI is transforming manufacturing

Leading manufacturers are not just keeping pace they are setting new standards. Smarter, real-time automation is now within reach, helping manufacturers boost productivity, strengthen compliance and reduce costs.

This is more than an incremental step forward; this marks a fundamental shift in manufacturing quality control.

Executive summary

Line clearance is a critical step in manufacturing, ensuring product integrity, regulatory compliance and consumer safety.

However, traditional manual inspections are slow, labour-intensive, and prone to human error, leading to costly downtime and operational inefficiencies. While automated vision systems exist, they often suffer from incomplete coverage, cloud dependency, high costs and complex integration requirements.

To address these challenges, Synaptics, 42 Technology, Balluff and Arcturus Networks have developed an advanced, AI-driven automated line clearance solution that leverages Edge AI processing and industrial vision systems. This technology delivers real-time, on-premises data management, eliminating reliance on cloud computing while enhancing accuracy, speed and compliance.

At the core of this solution is the Synaptics Astra SL1680 Edge AI processor, which enables high-speed, on-device AI decision-making. Paired with Balluff's high-performance image acquisition system, this approach offers greater workspace coverage and precise contamination detection. Arcturus Networks' deep learning models provide adaptable, continuously improving AI-driven classification, while 42 Technology's expertise ensures seamless integration into existing manufacturing environments.

A concept demonstrator, initially developed for pharmaceutical applications, validates the system's effectiveness in detecting contaminants, reducing inspection time and ensuring compliance with strict regulatory standards. Its modular, scalable architecture makes it adaptable across multiple industries, including food and general manufacturing.

This cost-effective, high-performance solution redefines automated line clearance by reducing downtime, improving compliance, and minimising reliance on manual verification.

With its first public demonstration at Embedded World in Germany (March 2025), this breakthrough technology marks a significant advancement in AI-powered industrial inspection, setting new standards for efficiency, accuracy and operational excellence.

Introduction

Automated line clearance in manufacturing



Line clearance checks are a critical requirement in manufacturing, ensuring product integrity, regulatory compliance and consumer safety. These inspections verify that production lines are free from residual materials, preventing contamination between batches.

However, traditional manual inspections are slow, labour-intensive and prone to human error. This results in production inefficiencies, costly downtime and increased safety risks.

To address these challenges, Synaptics, 42 Technology, Balluff and Arcturus Networks - four industry leaders in industrial manufacturing, vision systems, Edge AI silicon and software - have developed an advanced AI-enabled automated line clearance solution. This innovative system enhances accuracy, accelerates inspection times and reduces reliance on manual verification, delivering a practical, commercially-viable alternative.

In this white paper, we examine the challenges of manual line clearance, the limitations of existing automation solutions and how this new AI-driven approach delivers a cost-effective, scalable and high-performance solution for manufacturers.

Background

The challenges of line clearance

Manual line clearance remains a major bottleneck in manufacturing, requiring operators to visually inspect and document production areas between batch changes. This process is time-consuming, labour-intensive and highly susceptible to human error, leading to production inefficiencies, costly downtime and potential safety risks.

Each production line presents unique challenges, with different configurations and a variety of potential contaminants, such as raw materials, packaging remnants or residual products, that must be fully removed before the next batch begins. Failure to detect these contaminants can result in substantial plant downtime, product recalls and expensive waste, as contaminated batches often need to be scrapped. Beyond the financial impact, undetected contamination poses serious consumer safety risks, particularly in industries such as pharmaceuticals, where strict regulations govern product integrity.

Regulatory bodies impose stringent line clearance requirements, particularly in pharmaceutical manufacturing, where operators must verify and document every clearance check to ensure traceability. These manual inspections typically take 45 minutes to an hour per batch change, adding significant operational overhead. With the rise of personalised medicine and smaller batch production, line clearance procedures have become more frequent, further driving up costs, increasing downtime and placing a heavier burden on production teams.

Human factors further complicate the process. Many manufacturing facilities operate 24/7, requiring fully staffed teams to maintain production flow. However, staff shortages, fatigue and the repetitive nature of inspections increase the risk of human error, potentially compromising compliance and product safety. These challenges highlight the urgent need for a more efficient, automated approach to line clearance, one that reduces reliance on manual verification while improving accuracy, compliance, and operational efficiency.

Current automated solutions

With advances in machine vision and AI, automated line clearance solutions are beginning to emerge.


These systems use cameras and image-processing algorithms to detect foreign objects and verify that production areas are clear. However, current solutions come with significant limitations that hinder widespread adoption across industries.

One key limitation is incomplete coverage. Many machine vision systems focus on specific areas of the production line but fail to inspect the entire workspace, leaving gaps that require additional manual checks. This partial automation reduces efficiency and does not fully eliminate human error.

Another challenge is reliance on cloud computing. Many AI-powered vision systems require cloud-based processing, which introduces latency issues, data security risks and integration complexities. For regulated industries like pharmaceuticals, where strict compliance and traceability are essential, cloud-based solutions pose a major adoption barrier.

Cost remains a significant hurdle. High-end industrial vision systems often require expensive cameras, AI computing hardware and complex integration, making them prohibitively expensive for large-scale deployment. Installation, calibration and ongoing maintenance add to the total cost of ownership, limiting accessibility for many manufacturers.

Additionally, many AI-driven inspection systems demand extensive model training and customisation, creating additional challenges for adoption. Manufacturers often need to invest heavily in data collection, annotation and continuous model refinement to ensure accurate detection across different production environments. This increases deployment time, cost and operational complexity, making scalable implementation difficult.



Edge AI presents a promising alternative, enabling real-time data processing directly on the factory floor without cloud dependence. However, current Edge AI solutions fall into two categories:

- **High-power Edge AI systems** that deliver strong performance but come at a high cost, making them impractical for large-scale adoption.
- **Low-cost Edge AI devices** that lack the necessary processing power for real-time industrial applications, particularly in high-speed production environments.

For automated line clearance to gain real traction in the industry, manufacturers need a solution that balances performance, cost and scalability.

It must deliver full coverage, real-time AI processing, seamless integration and affordability without the trade-offs of existing solutions.



The collaborative solution

To overcome the limitations of existing automated solutions, Synaptics, Balluff, Arcturus Networks and 42 Technology have collaborated to develop an advanced, cost-effective and scalable line clearance system.

This solution leverages the Synaptics Astra SL1680 Edge AI processing platform and Balluff's image acquisition system, combining high-performance AI with industrial-grade imaging to enable reliable, real-time automated inspections.

At the core of this solution is Edge AI processing, which eliminates the need for cloud-based computing by enabling high-speed, on-device AI decision-making. This approach reduces latency, enhances security and minimises infrastructure costs, making the system easier to integrate into regulated production environments such as pharmaceuticals and food manufacturing.

The system was initially designed for pharmaceutical applications, ensuring it meets strict regulatory compliance requirements. However, its modular and adaptable architecture allows seamless integration into a wide range of manufacturing processes.

42 Technology has played a crucial role in designing the system for seamless integration and scalability. The open development environment, combined with support for industrial communication protocols, makes this solution highly adaptable to different plant infrastructures. Unlike many proprietary systems that lock manufacturers into specific hardware ecosystems, this system removes reliance on restrictive, high-cost AI computing platforms, providing a more flexible, scalable and commercially viable approach to automated line clearance.

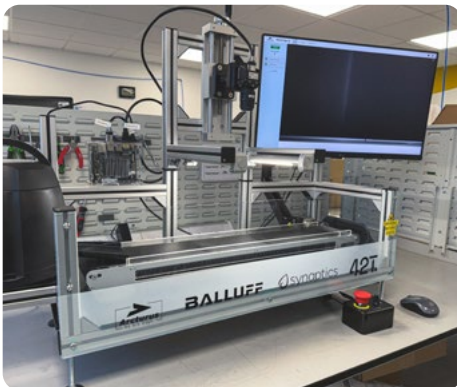
By balancing performance with affordability, this solution delivers a real-world, deployable alternative to conventional high-cost AI vision systems. With its modular, open architecture and proven deep learning capabilities, this solution enables manufacturers to enhance efficiency, improve compliance and reduce reliance on manual inspections, without major operational disruptions.

Concept demonstrator

A collaborative innovation

A critical milestone in the development of this automated line clearance solution was the creation of a concept demonstrator, developed collaboratively by 42 Technology and Arcturus Networks.

Initially designed for pharmaceutical production, this demonstrator showcases how Synaptics' Astra SL1680 Edge AI processor and Balluff's high performance image acquisition system work together to automate line clearance checks with high-speed, real-time AI processing.



The demonstrator is designed to operate in two key modes:

- **Line clearance mode** – Detects any unwanted objects (e.g., stray pills, packaging materials) when the production line should be completely clear, ensuring compliance with stringent regulatory requirements.
- **Normal operation mode** – Identifies and classifies different types of pills during active production, detecting potential defects and providing real-time alerts.

By optimising the vision pipeline for real-time image analysis, the demonstrator ensures precise, high-speed detection of contaminants while reducing reliance on manual inspections.



The integration of Balluff's industrial camera system with Synaptics' Astra SL1680 enables advanced object recognition and classification, enhancing both efficiency and accuracy.

This demonstrator is instrumental in validating the feasibility of a fully automated line clearance system, proving that AI-driven inspections can significantly reduce inspection time, improve reliability, and enhance compliance.

Furthermore, its modular architecture ensures adaptability across pharmaceutical, food and other manufacturing sectors, paving the way for a scalable, cost-effective solution for automated, AI-driven line clearance.

System description

The automated line clearance system is built around the Synaptics Astra SL1680 Edge AI processing device.

The Astra SL1680 is designed to balance the required IoT workloads of AI, compute and input/output acceleration. With this, targeted applications stacks can be efficiently run with room for additional processing. It features a multi-TOPS NPU with dedicated multimedia accelerators, enabling efficient image signal processing without the need for cloud-based computing. The system operates within Synaptics' open development environment, allowing manufacturers to customise and adapt the solution for different production requirements.

At the front end of the system, Balluff's industrial vision cameras and lighting solutions capture high-resolution images of the production line, ensuring precise and reliable detection of contaminants. These rugged, energy-efficient cameras are specifically designed for challenging industrial environments, providing robust imaging performance across a wide range of manufacturing settings.

The AI-driven detection capabilities are powered by Arcturus Networks' deep learning models, optimised for real-world manufacturing applications. Initially tailored for pharmaceutical production, these models are trained to detect, classify and verify objects with minimal false positives, ensuring high accuracy in identifying contamination risks. The system's ability to continuously learn and adapt makes it highly flexible for different manufacturing processes.

42 Technology's industrial expertise ensures seamless integration into existing production environments. The modular architecture supports standard industrial communication protocols, enabling manufacturers to implement the system without major infrastructure overhauls. Additionally, the system is designed for seamless integration into existing automation systems, reducing deployment complexity and maximising compatibility with current manufacturing workflows.

By keeping all data processing local, the system enhances regulatory compliance, supports secure data management, and meets traceability requirements, critical factors for pharmaceutical, food and other highly regulated industries. Its scalability and adaptability make it suitable for deployment across multiple production lines and diverse manufacturing sectors, reinforcing its cost-effectiveness and long-term value.

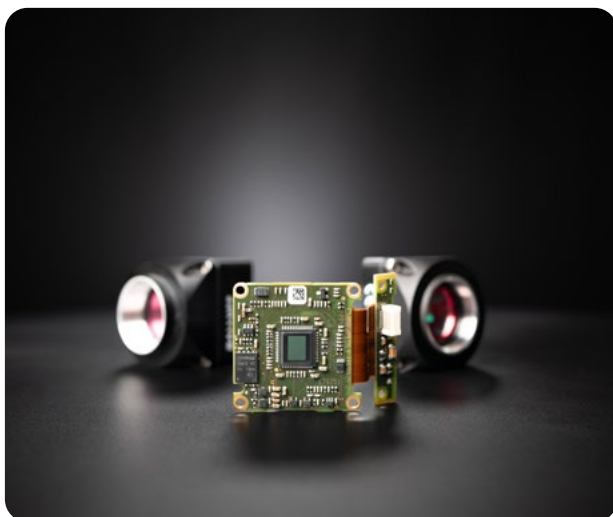
The technology partnership

Collaborative expertise and contributions

This collaborative innovation demonstrates the transformative potential of Edge AI in industrial manufacturing, enabling faster, more accurate and compliant inspection processes.

Synaptics

Developed the Astra SL1680 Edge AI platform, offering an optimal balance of performance, power efficiency and cost-effectiveness. Astra's high-performance neural processing unit (NPU) enables real-time AI inference while maintaining industry-leading performance-per-watt. This makes it an ideal choice for cost-sensitive industrial applications, delivering AI-driven decision-making at a fraction of the power and expense of traditional AI computing solutions.

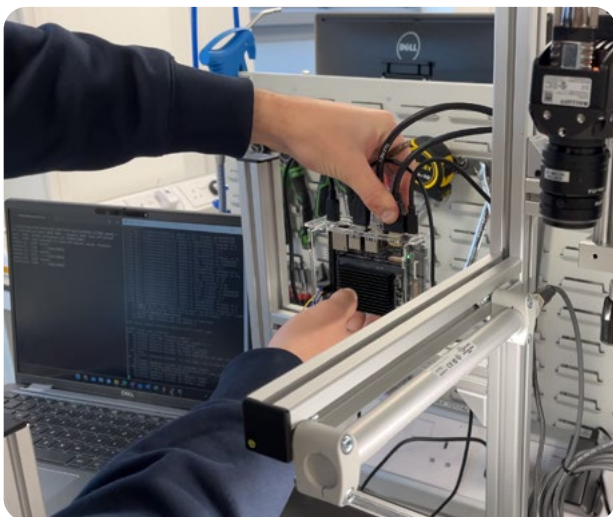


Balluff

Leveraged their extensive expertise in industrial automation to identify and supply high-quality, cost-effective imaging components tailored to the demonstrator's requirements. By providing industrial cameras equipped with advanced CMOS sensors and robust LED lighting solutions, Balluff ensured precise and reliable image capture under various operational conditions.

Arcturus Networks

Engineered the deep learning models and analytics that enable multiple operational modes, Arcturus smart camera software platform demonstrates how users will leverage the real time image streaming, detection, inspection and line clearance process automation.



42 Technology

Conceived the initial concept for the demonstrator and led the overall system design to address the need for automated line clearance. This required deep expertise across multiple domains, ensuring a pragmatic yet detail-focused approach to integrate hardware and software into a unified solution, while maintaining a strategic, solution perspective.

Conclusion

As manufacturing continues to evolve, the demand for faster, more reliable, and cost-effective quality control solutions is growing.

The development of this automated line clearance system represents a significant step forward in boosting process efficiency. It offers a scalable, high-performance alternative to traditional manual inspections while aligning with the broader industry shift toward real-time, on-premises AI-driven automation.

By combining the Synaptics Astra SL1680 Edge AI processor, Balluff's high-performance image acquisition system, Arcturus Networks' deep learning models and 42 Technology's system integration expertise, this innovative solution delivers real-time, on-device AI processing, reducing inspection time while improving accuracy, compliance and operational efficiency.

Looking ahead, the potential for multi-sensor deployment, complete area scanning, and expanded anomaly detection opens the door for even greater scalability and adoption across multiple industries beyond pharmaceuticals.

As manufacturers seek smarter, more adaptive AI solutions, innovations like this will be at the forefront of reshaping industrial inspection standards.

This technology is also a testament to the power of collaboration, bringing together industry leaders in AI processing, machine vision, deep learning and industrial automation to create a cost-effective, highly adaptable solution. The first public demonstration at Embedded World in Germany marks the beginning of its journey toward widespread industry adoption, reinforcing its practicality and impact in real-world manufacturing environments.

By enhancing productivity, reducing operational risks and ensuring product integrity, this collaborative innovation is setting a new standard for deep learning vision systems in pharmaceutical and industrial manufacturing, paving the way for the future of automated, AI-driven quality control.

