Sellafield Ltd

Horizon Scanning

Sellafield Radar: Technology Integration

Scanning the global horizon for breakthrough science and cutting edge technology from the nuclear sector and beyond.

Promote awareness • Inspire future R&D • Invite discussion

Contents

Foreword

Sellafield Ltd's track record of excellence in the operation and decommissioning of legacy nuclear sites has built trust in our organisation, as is evident in the decision by the UK Government to immobilise the UK's inventory of civil separated plutonium at the Sellafield site.

This decision is a huge vote of confidence in us that could not have been made without the world leading expertise and capabilities we possess, which we must now continue to develop as we head into the next industrial epoch of technology integration.

We recently unveiled the inaugural edition of Tech Radar – an episodic publication which explores the future of key markets we will need to engage to deliver the remainder of our mission. The first edition of Tech Radar focussed on the Robotics industry; a diverse domain which is and will continue to have significant impact on all areas of our site across air, land and water. But Robotics is just one element of the broader spectrum of technology we will need, and crucially, we must be able to bring Robotics together with other technologies to amplify their impact; to work together as an integrated system of technologies, rather than a collective of standalone solutions.

In this Technology Integration edition of Tech Radar, we explore some of the other components and enabling technologies, ranging from centralised management of edge AI to immersive visualisations, which will be needed to complete the Technology Integration concept at Sellafield Ltd. These signals show us that moving forwards, different technologies will be able to collect various types of data, share and process this data amongst themselves to inform real-time operational decisions, and then autonomously perform the appropriate tasks, all overseen by our people who we will be able to work in safer environments.

With these insights, we can build on our success and move towards a future where Technology Integration is the primary approach for operations on the Sellafield site. I hope you enjoy reading.

Dr. Robin Ibbotson
Chief Technology Officer, Sellafield Ltd

With a nationally significant mission to solve one of the biggest and most complex environmental restoration challenges in Europe, we at Sellafield Ltd. have placed ourselves at the cutting edge of nuclear science and technology for over 70 years, delivering this mission safely and effectively.

About this report

This report was sponsored by Sellafield Ltd and outlines 18 recent innovations and emerging solutions that could support a greater degree of technology integration. Featured horizon scanning signals were shortlisted from a database of 45 and cover a range of functionalities, relevant applications, and technological readiness levels. For this project, we worked with Outsmart Insight to assemble a multidisciplinary team of 35 pioneering scientists and engineers from universities across the UK. The collaborative efforts culminated in the development of this Technology Radar.

If you have any comments or questions, please let us know at horizon.scanning@sellafieldsites.com.

For more information on how to work with us in future, please visit the Government webpage on **how to do business with Sellafield Ltd**.

Sellafield technology radar

Emerging science and breakthrough innovation for future robotic systems

Analysis and modelling

Scientific Horizon

Engineering Horizon

Business Horizon

FNC Technology (South Korea) Analysis of records from nuclear sites
(See page 31)

Telco Systems (Israel) Edge infrastructure management dashboard
(See page 18)

Zededa (US) Zero-trust edge management platform
(See page 23)

Cribl (US) Security-focused data integration engine
(See page 21)

Unstructured (US) Document standardisation with AI
(See page 19)

Integration and curation

University of Illinois (US) Robot operations simulation environment

Flow Immersive (US) Interactive 3D data visualisation
(See page 30)

Novity (US) Equipment health prediction
(See page 26)

Hula Earth (Germany) Integrated sensor and satellite monitoring

Lume AI (US) No-code integration of disparate data types
(See page 22)

Neo4j (US) Data insight platform based on graph databases
(See page 20)

ETS Montreal (Canada) Combining maintenance logs with numerical sensor data

Fraunhofer Institute for Software and Systems Engineering (Germany) Segmenting industrial data ecosystems

University of Manchester (UK) Autonomous robot fleet control system
(See page 28)

Beyond Limits (US) Auditable AI reasoning platform
(See page 27)

Razor Labs (Australia) Comprehensive predictive maintenance tool

Woodside Energy (Australia) Large-scale digital twin platform

BadVR (US) Immersive collaborative analytics
(See page 29)

Cambridge University (UK) Acoustic data transmission through radiation shielding
(See page 15)

ARX Robotics (Germany) Intelligent ROV collaboration software
(See page 12)

Gecko Robotics (US) Automated inspection data pipeline
(See page 10)
Credit: **Gecko Robotics**

HelixIntel (US) Sensor-driven maintenance automation platform
(See page 26)

SiMA.ai (US) Secure edge AI processing

Nokia (Finland) and SK Broadband (South Korea) Quantum cryptography for critical infrastructure
(See page 10)

Fraunhofer Institute for High Frequency Physics (Germany) Human-sensing robotic skin
(See page 13)

KAERI (South Korea) Edge-processed acoustic monitoring
(See page 14)

ABB (Switzerland) Unified robot control platform
(See page 11)

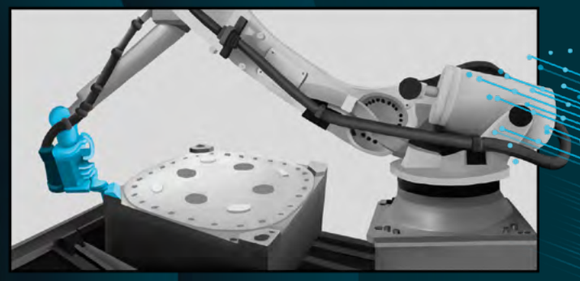
Sensing and control

Future use cases

Today, many cutting-edge sensors, robotics, and other technologies at the Sellafield site operate in isolation.

Data streams between technologies remain fragmented, forcing manual effort to piece together the bigger picture. This slows real-time responses and limits predictive and scenario modelling.

Technology integration brings assets from across the Sellafield site together, to become more than the sum of their parts. Connected sensors track radiation and asset conditions, with initial analysis happening at the edge. Compressed, tagged data is reformatted and fed into immersive real-time visualisations. Autonomous robots tap into multiple data streams, working together seamlessly. Collectively, technology integration should enable smarter, faster, more coordinated operations. This future vision, informed by innovations in this publication, illustrates how technology integration could help make Sellafield Ltd more efficient, more responsive, and potentially safer.

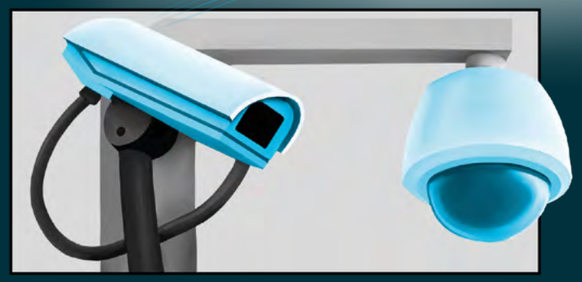


Centrally managed robotic motion

Centralised control software enables robots to operate quickly and safely in close proximity, while artificial 'skin' detects nearby objects and human collaborators.

Information acquired from digital archives

Software automatically converts unstructured historical records into valuable insights that improve predictions and advise maintenance engineers.



Video and audio analysis

Information from distributed networks of cameras and acoustic sensors, initially processed at the edge but then integrated into an overarching model, provides real time event monitoring.

Central command centre

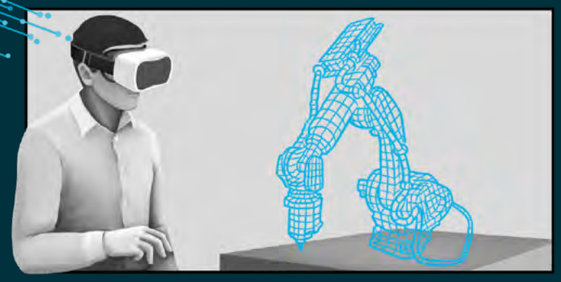
Largely autonomous software tools integrate diverse data streams from technologies across the site, visualise relationships, and make intelligent recommendations.

Edge-AI managed from the cloud

Sensor networks with embedded AI algorithms, managed from a single interface via the cloud, reduce communication bandwidth by processing data locally.

Autonomous vehicles operate collectively

Autonomous drone fleets, processing satellite and local data with edge computing, enable coordinated operations in hazardous environments with minimal human intervention.



Augmented reality visualisations

Information from multiple sources is transformed into immersive 3D visualisations, enabling operatives to quickly assimilate information for rapid decision-making.

Sensing and control

Securely collecting information from sensor networks and distributing instructions to robots and other infrastructure, even if wireless communications are restricted, enables collective responses.

Business Horizon

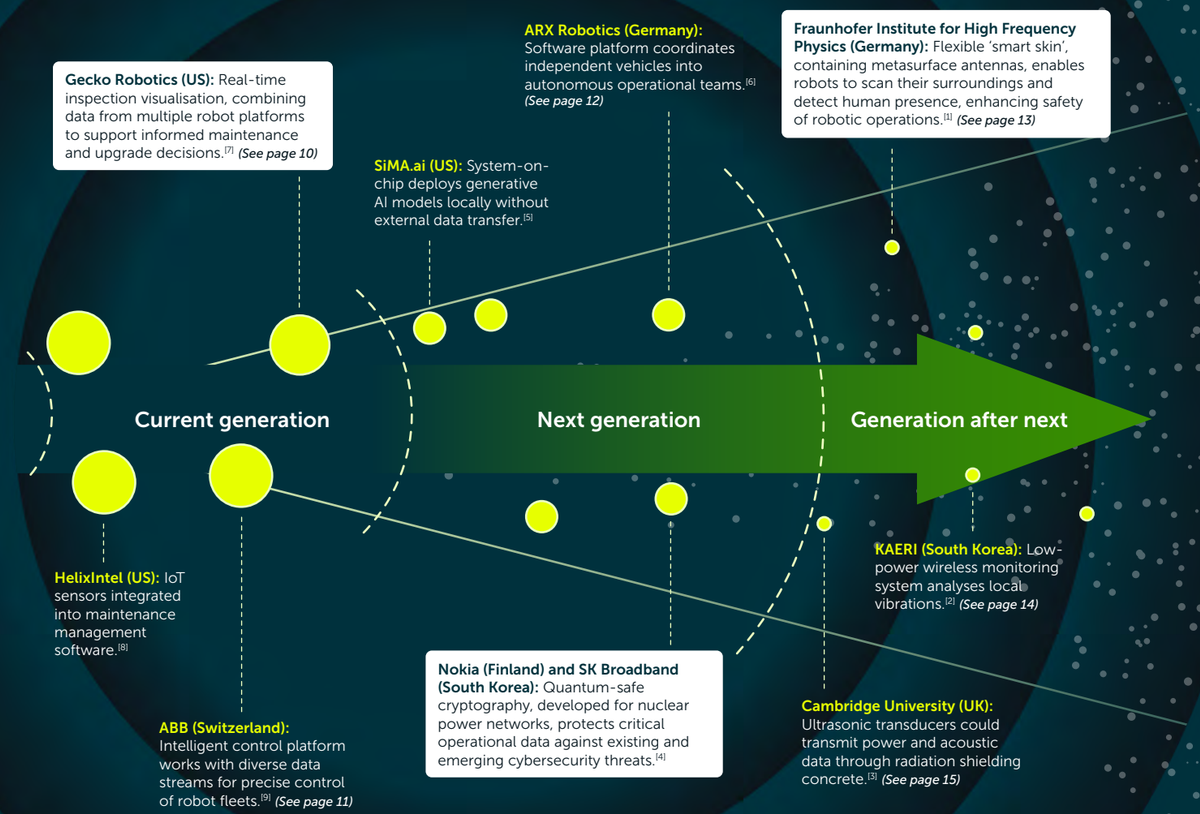
Current-generation technology, established in the market.

Engineering Horizon

Next-generation technology, recently launched or with a clear path to market.

Scientific Horizon

Generation-after-next technology, still in the conceptual or testing phase.



Gecko Robotics (US): Real-time inspection visualisation, combining data from multiple robot platforms to support informed maintenance and upgrade decisions.[7] *(See page 10)*

ARX Robotics (Germany): Software platform coordinates independent vehicles into autonomous operational teams.[6] *(See page 12)*

Fraunhofer Institute for High Frequency Physics (Germany): Flexible 'smart skin', containing metasurface antennas, enables robots to scan their surroundings and detect human presence, enhancing safety of robotic operations.[1] *(See page 13)*

SiMA.ai (US): System-on-chip deploys generative AI models locally without external data transfer.[5]

HelixIntel (US): IoT sensors integrated into maintenance management software.[8]

ABB (Switzerland): Intelligent control platform works with diverse data streams for precise control of robot fleets.[9] *(See page 11)*

Nokia (Finland) and SK Broadband (South Korea): Quantum-safe cryptography, developed for nuclear power networks, protects critical operational data against existing and emerging cybersecurity threats.[4]

KAERI (South Korea): Low-power wireless monitoring system analyses local vibrations.[2] *(See page 14)*

Cambridge University (UK): Ultrasonic transducers could transmit power and acoustic data through radiation shielding concrete.[3] *(See page 15)*

What to look out for?

0–5 years

Centrally managed but comparatively straightforward Edge AI condenses sensor data and cuts bandwidth needs. Robots with varied operating systems feed information into unified management software, fostering efficient collaboration. Combining real-time monitoring with restructured historical records supports more precise predictive maintenance.

5–10 years

Rising computing power, driven by neuromorphic chips and tensor processing units, empowers advanced AI models at the edge. Local video analysis transforms CCTV into an incident monitoring network, issuing automatic alerts. Legacy systems, including vehicles, are digitised, enabling seamless automated sensing and control.

10–20 years

Radiation-shielded areas, previously isolated from wireless communication, are integrated into sensing networks via acoustic transmission. Smart 'skin' enables robots to detect nearby human collaborators. Efficient chips and energy-harvesting systems power fully wireless sensors, running advanced AI agents that autonomously direct other assets.

View source
For sale
Source:
Startup
Origin:
North America

Credit: Gecko Robotics

Combining real-time and historical asset data for superior predictive insights

What's the innovation

Continuous monitoring is essential for industrial assets, enabling problems to be spotted before they arise. Single data streams rarely give the full picture of an asset's long-term health, and it is often the combination of multiple data points, as well as context, that generates real insight. Startup Gecko (US), known for its asset inspection robots (as seen in a previous Tech Radar edition), claims to have developed software that integrates multiple data streams and historical records from similar assets to generate these rich predictive insights.

How it works

- Fixed sensors and inspection robots gather data on the condition of assets, such as tracking fatigue and corrosion.
- The 'Fulcrum' software tool collects and validates the incoming data, then enriches it with historical insights from a pool of 500,000 assets.
- A second software tool, 'Cantilever', integrates these data layers and presents a 3D visual representation of the assets, marking up defects and highlighting where action is needed. AI scenario modelling makes recommendations for changes and repair plans to improve long-term reliability and safety.

Context

- The US Military has already adopted Gecko's software to monitor assets from missile silos to ships, supporting predictive maintenance and precision repair plans.
- A similar approach is being used by Flyability (Switzerland), integrating data from multiple drones, though without historical records.
- The InDePTH consortium, led by BT (UK), is developing a software platform to optimise processing and integration of drone data from surveys of highways and ports, to create digital twins of this infrastructure.

What's next

Gecko is aiming to incorporate process optimisation, and the automatic generation of repair and cleaning schedules into its software suite.

Further reading
Watch an introduction to the software's capabilities

OmniCore: One brain to rule your robots

What's the innovation

As robots take on more tasks, including waste repackaging, transporting materials, and maintenance, there is a need to conduct this orchestra of diverse machines carefully. Industrial robotics manufacturer ABB (Switzerland) has launched OmniCore, a unified control platform that manages the precise control of robot hardware and software in a single system. ABB says this will deliver more flexible, efficient, and sustainable operations.

How it works

- OmniCore's control architecture is modular, and supports all major robotics communications protocols, enabling integration and customisation of a wide range of sensors, cameras, conveyors, and other peripherals at scale.
- The platform supports precise motion control capabilities, with path accuracies of 0.6mm and multiple robots moving at speeds up to 1600mm/s
- Automatic path planning and regenerative braking reduce robots' energy use by up to 20% vs ABB's previous control software, whilst boosting speeds by 25%.

Context

- Alternatives to OmniCore include Siemens' SIMATIC Robot Integrator, which offers a program that can integrate robots from different manufacturers.
- Unified control software is not the only approach. Startup Symbiotic (US) is developing distributed control systems, where groups of robots coordinate their actions through local decision making without relying on a central control point.

What's next

ABB is developing its AppStudio no-code software tool for robot interface programming to make human-machine interactions more efficient.

Further reading
Read more about the OmniCore platform

View source
For sale
Source:
Corporate R&D
Origin:
Europe

Turning legacy vehicles into connected autonomous fleets

What's the innovation

Nuclear facilities host a diverse array of vehicles for tasks encompassing maintenance, safety, waste management, and emergency response. While many new vehicles are remote-controlled or autonomous, offering cost efficiencies and reduced human exposure to hazards, many legacy vehicles

are not. Rather than waiting until these need to be replaced, ARX (Germany) has developed a conversion kit which it says will convert entire legacy fleets into autonomous or remote-controlled vehicles. Whilst initially developed for the military, it has potential for industrial environments.

How it works

- A sensor and control suite are installed on the legacy vehicle, featuring cameras, LIDAR, and GPS for navigation and obstacle avoidance. An AI processor enables remote or autonomous control.
- This integrates directly with electronic steering and braking controls where they already exist. ARX offers tools to retrofit those controls where they don't.
- Remote control and fleet-wide autonomous teaming are then enabled via a digital communications system.

Context

- There are over 5000 accidents, of which 50 are fatal, involving vehicles on industrial sites in the UK each year.
- To maximise safety and efficient site operation, startup SafeAI (US) has created an autonomous management system for converting fleets of heavy industrial vehicles into a single network with intra-fleet awareness.
- Mining company Rio Tinto (UK) has digitised one of its sites in Western Australia, with drilling equipment and haulage trucks controlled remotely from a central hub.

What's next

ARX's robotic systems are being tested by seven European militaries for multirole operations, including surveillance, equipment transportation, and personnel evacuation.

Further reading

Watch an overview of vehicle conversion from ARX

View source

Real-world testing

Source:
Startup

Origin:
Europe

Credit: ARX Robotics

Robotic 'skin' senses people when they get too close

What's the innovation

Industrial robots can struggle to detect objects close to them, including humans working collaboratively, because the antennas and cameras they use are usually optimised for longer distances. Researchers at Fraunhofer FHR (Germany), in collaboration with the EU's FITNESS project, have developed metasurface antennas for robots. Termed 'smart skin', these flat, flexible materials can wrap around the robot and give it an awareness of everything around it (up to 0.5m), while still enabling radio communication at longer distances.

How it works

- The metasurfaces operate like a phased array antenna, where many antennas are connected together. But instead of inefficient mechanical components, they consist of sub-wavelength structures that steer beams in desired directions, both to scan the local environment and communicate with the robot's base station.
- The antennas and associated electronics are integrated into thin, flexible materials which bend and stretch like skin over the robot's contours.
- The robot can monitor its immediate environment and adjust its actions accordingly, enhancing real-time interactions and safety.

Context

- Robot-human incidents account for up to 10% of all workplace accidents, highlighting the need for better safety measures.
- Collaborative robots, especially those based on humanoid forms, are attracting much interest, with startup Figure (US) trialling its robots in a BMW factory.
- Metasurfaces capable of redirecting communications signals are seen as a key component of future high-bandwidth 6G communication networks due to the higher attenuation rate relative to 5G.

What's next

The team is collaborating with the Institute of Applied Polymer Physics (Germany) to synthesise stretchable polymer-based metamaterials based with integrated ceramic particles capable of forming higher frequency electromagnetic beams.

Further reading

Read about the EU's FITNESS program

View source

Laboratory testing

Source:
University lab

Origin:
Europe

View source
Laboratory testing
Source:
Government R&D
Origin:
Asia

Low-power sensors mean fewer battery changes

What's the innovation

Changing sensor batteries can be an onerous task, especially in radioactive environments. Fortunately solutions are in the works, with researchers at the Korea Atomic Energy Research Institute (KAERI) claiming to have developed a low-power wireless acoustic sensor. It can monitor for sounds and vibrations that indicate problems such as leaks, cracks, or steam pressure buildup. Critically, it lasts much longer on battery power than existing ystems, reducing maintenance costs.

How it works

- This sensor is a small, wireless device that listens for unusual sounds in nuclear power plants to spot potential problems.
- It uses low-power microphones to capture sounds, then converts them to lower frequencies to minimise the energy consumption associated with signal processing.
- Instead of sending all data to a central system, it analyses information locally, using Edge AI, and only sends alerts when something seems wrong, saving energy and improving response times.

Context

- Edge AI is increasingly prevalent in industrial monitoring, since it reduces both latency and communications infrastructure compared to centralised data processing.
- The International Data Corporation (US) forecasts that at least 50% of industrial edge computing deployments will involve machine learning (ML) by 2026.
- While energy harvesting technologies, such as indoor photovoltaics and vibration harvesting, can support industrial monitoring where there is an ambient power source, reducing power consumption associated with data processing and signal transmission could extend battery life so that it matches that of the device.

What's next

Future work will involve the team confirming the reliability and efficiency of their data-transmission methodology in industrial environments with electromagnetic pollution.

Further reading

Read the IAEA report about wireless technologies in power plants

Ultrasonic waves can pass sensor data through radiation-shielding concrete

What's the innovation

Gamma radiation shielding in nuclear facilities often means 2m thick concrete walls. While this is great for safety, other types of electromagnetic radiation also struggle to penetrate the concrete, precluding wireless communication. A workaround could come from the Department of Engineering at The University of Cambridge (UK). The team claims to have developed a piezoelectric micromachined ultrasonic transducer (PMUT), which uses ultrasonic vibrations to transfer data through solid materials, and can even transfer low amounts of power. That opens the door to real-time monitoring without compromising shielding integrity.

How it works

- Piezoelectric materials deform in response to an electric field, and create a voltage in response to movement. The PMUT features a piezoelectric film sandwiched between two electrodes and suspended over an acoustic cavity, like a skin stretched over a drum.
- When a current is applied, the film flexes, generating ultrasonic sound waves which propagate through solid materials.
- Those waves can also be directed to create a pressure change in the cavity, which deforms the piezoelectric material to transfer energy and power the device.

Context

- In early biomedical tests, the PMUT transmitted 400nW of power and 50kb/s of data through a substance mimicking human tissue.
- Transferring information through concrete could be more challenging as its composite nature scatters ultrasonic waves. To address this, researchers from the University of Malta (Malta) have developed a PMUT optimised for communicating through concrete but without transferring power.
- An alternative approach, developed by researchers from the Korea Railroad Research Institute (Korea), uses carbon nanotubes embedded within concrete to enable wireless transmission through thicknesses up to 100m.

What's next

The Cambridge team are investigating optimising electrode geometries to improve the quality of data and achieve higher power transmission.

Further reading

Read a review of wireless transmission methods through concrete

View source
Laboratory testing
Source:
University lab
Origin:
Europe

Integration and curation

Increasingly automated data integration and curation will enable information from new and legacy equipment to be combined into unified systems, supporting comprehensive visualisation and analysis.

Business Horizon

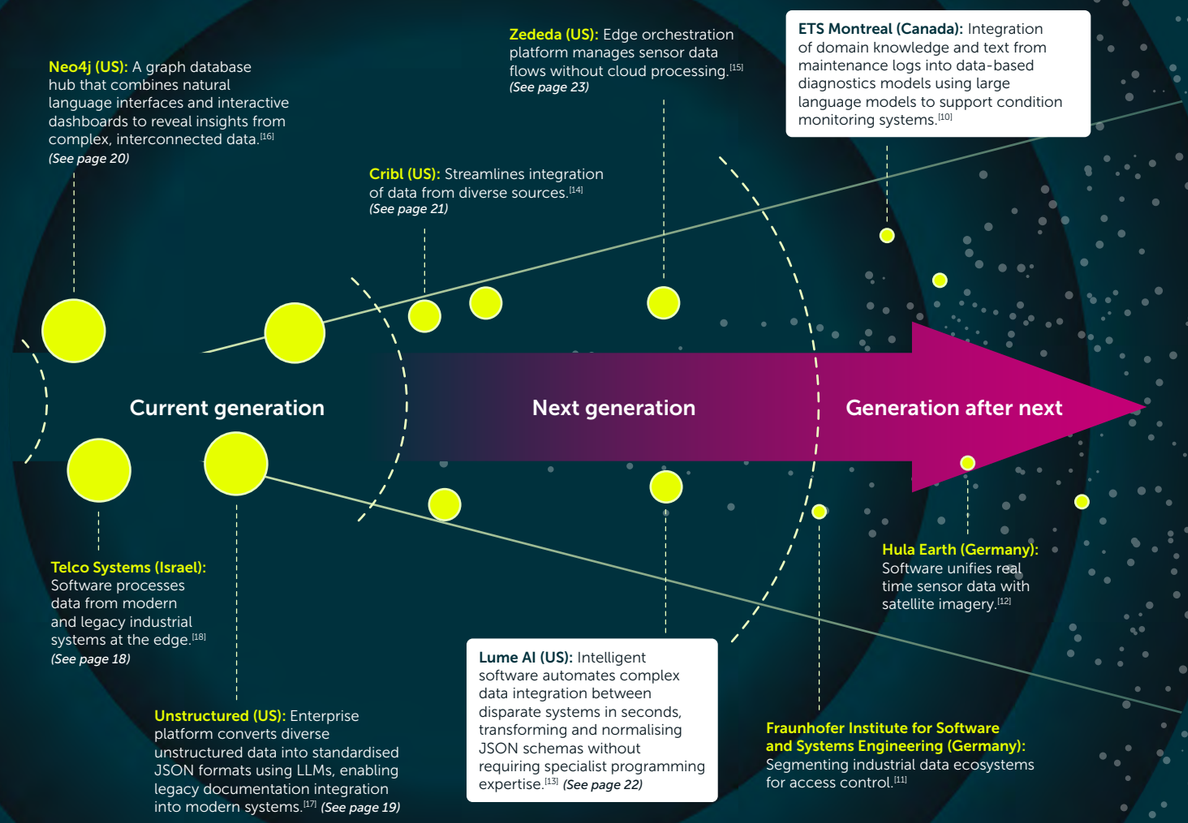
Current-generation technology, established in the market.

Engineering Horizon

Next-generation technology, recently launched or with a clear path to market.

Scientific Horizon

Generation-after-next technology, still in the conceptual or testing phase.



What to look out for?

0–5 years

Modern software platforms begin to break down data silos, allowing historical databases to be searched simultaneously. Intuitive dashboards allow exploration of information from across the site. Insights are extracted directly from sensor data prior to transmission. Generative AI tools provide access to internal records and documents, speeding up information access for operators.

5–10 years

Integration of legacy and modern systems becomes seamless, with automated transformations converting disparate information into comparable formats, reducing the need for data engineers. Centralised systems consolidate insights from distributed sensors and robots, creating a comprehensive view of site activities and enabling self-directed maintenance.

10–20 years

Technology integration extends beyond facility boundaries, with unified platforms merging local sensor networks and satellite data for environmental oversight. Advanced language models blend decades of written records with real-time monitoring. Real-time decision making can now be based on a rich tapestry of internal operations, external conditions, and accumulated institutional knowledge.

View source
For sale
Source:
Corporate R&D
Origin:
Asia

Edge computing platform streamlines large-scale IoT deployment

What's the innovation

Deploying edge computing to devices across industrial networks promises to lower latency and reduce costs of data transmission and storage. But with many diverse connected devices around a site, managing, configuring and upgrading them can be complex. The Edgility software platform from Telco Systems (Israel), in which software is uploaded to devices before installation, claims to make it easier to manage edge computing infrastructure, providing a central interface to manage applications deployed across multiple devices at multiple locations.

How it works

- Edgility OS provides an environment where users can set up a virtual version of any device (based on an Intel or ARM processor), which can be used to remotely control the real device.
- A single dashboard manages the virtual devices, and thus the corresponding physical ones, across multiple sites. This enables oversight and control of real-time data monitoring, troubleshooting and updates.
- The platform supports automatic configuration and deployment of software updates without manual intervention, which is especially valuable for edge devices in hazardous or inaccessible locations.

Context

- Compared to edge device management software ZENEDA, Edgility's more established solution needs to be uploaded before installation. However, it can then be updated remotely.
- Construction material company CEMEX (Mexico) has deployed Edgility across many edge devices, enabling centralised control of multiple applications, including those from other vendors.

What's next

Telco Systems is working to pair Edgility with Adaptiv Network's (Canada) software-defined wide area network (SD-WAN) technology to deliver an easily managed edge-to-cloud connectivity platform for large-scale networks.

Further reading
Read more about Edgility deployment by a construction material company

Turning data into curated text so LLMs can extract insights

What's the innovation

Inspection and maintenance applications, where engineers describe problems in normal language, and receive the exact instructions on how to solve them, promise substantial productivity improvements. Large language models (LLMs) bring this closer, with their ability to process and combine text from instruction manuals and maintenance records. However, the relevant underlying information in company IT systems is often unstructured, making it hard for LLMs to make sense of it. Startup Unstructured (US) has developed a no-code enterprise extract, transform, and load platform that simplifies the conversion of unstructured text-based data into formats well-suited to LLM queries.

How it works

- Data transformation begins by splitting documents into smaller segments for better retrieval precision. Descriptive summaries can be produced for images and tables.
- A process termed 'embedding' converts the text into a structured format that is easier to query using retrieval-augmented generation (RAG) – a type of generative AI that incorporates text from sources such as documents.
- The platform incorporates features for regulatory compliance (SOC 2, HIPAA and GDPR) as well as zero-data retention to ensure privacy.

Context

- Largely unknown as recently as 2023, RAG is now an important capability of many large language models, especially those developed for enterprise knowledge management.
- Some LLMs, such as Perplexity (US), are specifically optimised for RAG, with the ability to quickly retrieve data from vast sets of information rather than relying on the LLM's own knowledge bank.

What's next

Unstructured Technologies Inc. is expanding the platform's vector databases to include Qdrant and AstraDB, among others, as well as introducing a proprietary recommendation tool for data transformation.

Further reading
Read about the performance metrics used in data preparation

View source
For sale
Source:
Startup
Origin:
North America

Building deeper and more meaningful data relationships

What's the innovation

As industrial sensors and robots proliferate, the data they capture must be stored in a database. While relational databases structured around a series of tables are most common, recent years have seen growing popularity of an alternative structure: graph databases. Commonly used by social media platforms to represent networks, these are structured around the contextual relationships between data, making them well suited to representing data from interconnected industrial assets. Graph database provider, Neo4j (US), claims its enhanced cloud data management system makes adoption more user-friendly and scalable, thanks to GenAI-powered natural language queries, no-code dashboards, and enterprise-grade security.

How it works

- The no/low-code dashboard can accept human queries. It can then create maps, graphs, charts, tables, and other easy-to-understand data visualisations, removing the need to learn graph database query languages.
- Neo4j's software is based directly on a graph database, without a translation layer from a traditional relational database, reducing latency and improving reliability.
- The company says its database clusters can read data 15x faster than before the upgrade, making it easier to run large-scale analytics without slowing down performance.

Context

- In 2024, research firm Gartner forecast that graph databases will be the fastest-growing category of database management system (DBMS) category within DBMS, with adoption growing at 25% annually.
- Retrieval augmented generation (RAG), a generative AI technique often used to pull answers from records or technical documents, can be enhanced through knowledge graphs that contain documents and metadata.
- To support the visualisation of graph databases, Cambridge Intelligence (UK) has developed toolsets to build scalable dashboards.

What's next

Neo4j Labs, the R&D division of Neo4j, is looking at integrating their technology with open source libraries to develop new graph-driven GenAI applications.

Further reading

Learn how AuraDB can be used to represent connected datasets

View source
For sale
Source:
Startup
Origin:
North America

Streamlined collection, optimisation, storage, and retrieval of industrial data

What's the innovation

Digitising industrial sites means accumulating networks of wirelessly connected sensors producing vast volumes of data, which all needs processing. Startup Cribl (US) has created a solution for collection, storage, and retrieval of telemetry data that simplifies its handling. It can collect data from any source and route it to any destination, whilst cleaning and enriching it for its intended use. Metadata and statistics offer real-time visibility into data across industrial assets, sites, and systems.

How it works

- Cribl Stream collects data from any source network and routes it to any downstream system, transforming formats if requested. As it does so, it filters out unnecessary fields, ensuring only valuable data is retained.
- The Cribl Lake stores data in open formats, ensuring data integrity and regulatory compliance, whilst allowing easy access and transformation of data formats for different applications.
- The third element, Cribl Search, enables users to find and retrieve data from any point within a data network through a simple query language.

Context

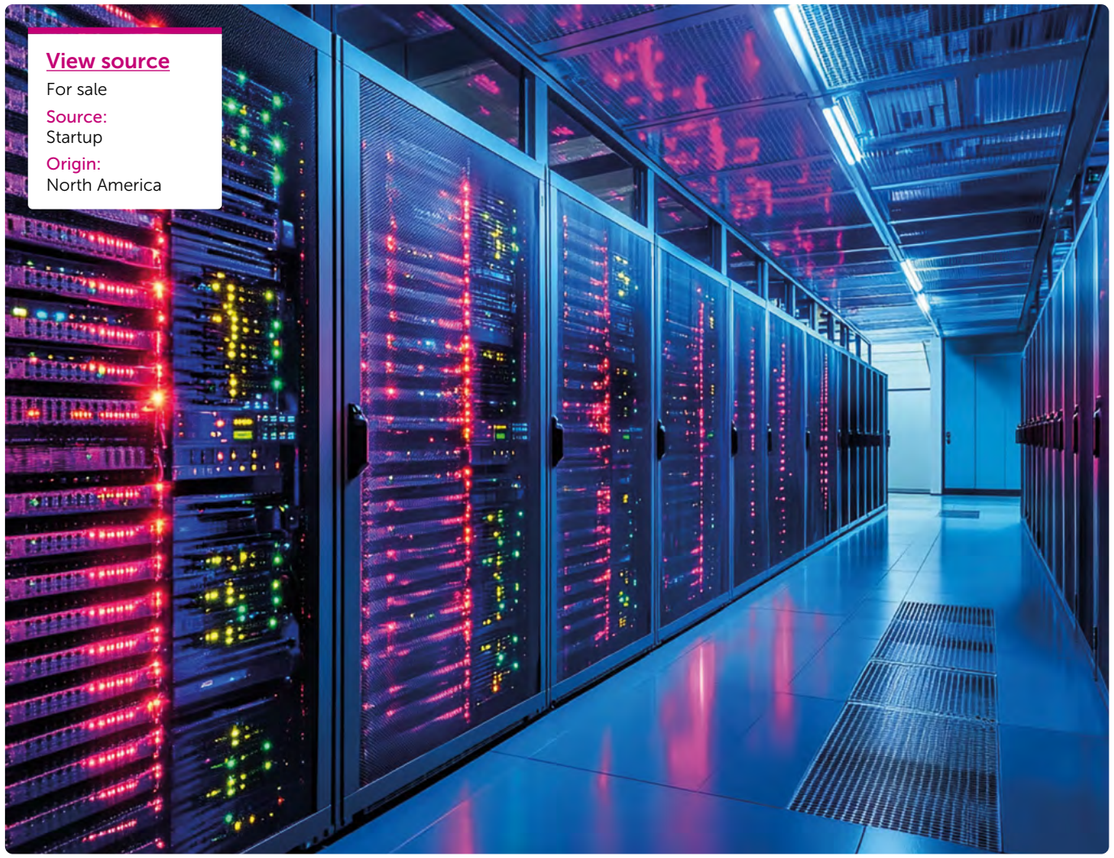
- Cribl's solution has been deployed by companies including Rolls Royce (UK) and Mercedes Benz (Germany), demonstrating applicability to large industrial facilities.
- Like Cribl, startup Mezmo (US) has developed software for efficient telemetry data pipelines, with automatic generation of metadata and statistics.
- Additional functionality is offered by Dynatrace (US), which uses causal AI to provide automatic root-cause prediction and analysis within data pipelines.

What's next

Cribl is expanding its commercial operations globally, growing by 70% last year. It is now offering customers an AI copilot to help them utilise Cribl's suite of solutions more effectively.

Further reading

Watch Cribl's explanation of its data telemetry solution



View source
For sale
Source:
Startup
Origin:
North America

View source
For sale
Source:
Startup
Origin:
North America

Translating diverse industrial data into the same language

What's the innovation

Decades-old infrastructure typically results in disparate data sets that have been collected and stored in different formats over different time periods. Since data analysis software typically requires standardised inputs, considerable effort is often devoted to transforming old data to new formats, with software engineers investing significant time writing complicated algorithms to do so. Now, AI could take away that pain, as startup Lume (US) claims to have developed a no-code AI platform that translates data from disparate sources into consistent formats in seconds.

How it works

- Users select their input data and desired output data structure and Lume analyses both to understand structures and relationships. It then generates mapping logic to transform the source data into the desired output structure.
- Of particular note is its ability to translate complex nested JSON data sets, a format often used for applications such as real-time sensor readings, which can be difficult to convert.
- Data mapping can be reviewed and edited before exporting the final data structure, with data security ensured by advanced encryption and access protocols.

Context

- 90% of large organisations reportedly rely on legacy systems where significant manual input is required to transform data between formats.
- A similar capability is offered by startup Matillion (UK), with code-based and low-code versions of its data integration software, as well as a no-code platform that uses plain-language prompts from the user.

What's next

Lume recently raised $4.2 million, which they claim will be used to further develop their AI research and data infrastructure.

Further reading

Read more about Matillion's software

Industrial edge computing, managed from the cloud

What's the innovation

Connected devices, from monitoring sensors to wirelessly connected pumps and valves, are proliferating on industrial sites, capturing vast amounts of data. Moving all this data to the cloud for analysis increases latency and pressure on communication networks. Edge computing, where analysis is done on the device, is thus increasing in popularity. But this brings the challenge of how to update, monitor and upgrade the combined network of sensors, when they all operate independently. ZEDEDA (US) reportedly addresses this by extending cloud-based computing to the edge, centrally managing edge computing infrastructure across an unlimited number of hardware devices.

How it works

- ZEDEDA uses the open-source Linux-based operating system EVE-OS to run applications within virtual machines on edge devices. More than 75 hardware types (i.e. processors within edge devices) are supported.
- The applications running on the individual devices securely communicate with ZEDEDA's cloud using a zero-trust model. This enables multiple devices to be controlled and monitored via a single access point.
- Unlike some competing approaches, the system can be deployed to edge devices remotely with no physical installation or local configuration required.

Context

- Market research firm Gartner (US) estimates that by 2029, 30% of enterprises will be using edge computing software compared with fewer than 1% in 2023.
- Relative to other edge computing solutions offered by established cloud providers, ZEDEDA offers simplicity and ease of use. For example, a major solar tracker manufacturer was able to reduce overall device provisioning and field installation time by 75% relative to previous approaches.

What's next

ZEDEDA is working to enhance the user experience by allowing users to interact via an LLM-based chatbot. It is also making AI workloads more accessible by supporting NVIDIA Jetson chips that are explicitly designed for edge AI applications.

Further reading

Watch the technology overview of ZEDEDA's approach and its capabilities

View source
For sale
Source:
Startup
Origin:
North America

Analysis and modelling

Analysis of site-wide information, often combining machine learning with physics-based models, will support predictive maintenance and scenario modelling, while immersive visualisation platforms make interpretation more intuitive.

Business Horizon

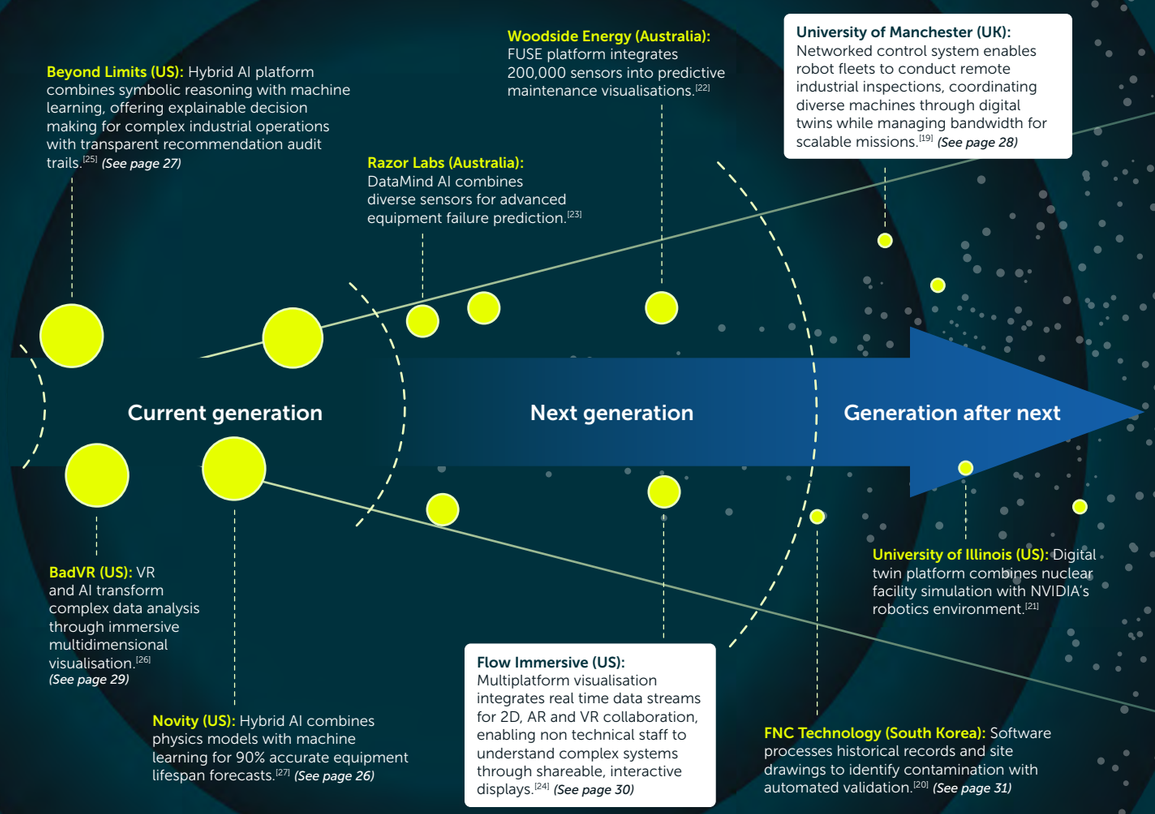
Current-generation technology, established in the market.

Engineering Horizon

Next-generation technology, recently launched or with a clear path to market.

Scientific Horizon

Generation-after-next technology, still in the conceptual or testing phase.



Beyond Limits (US): Hybrid AI platform combines symbolic reasoning with machine learning, offering explainable decision making for complex industrial operations with transparent recommendation audit trails.[25] *(See page 27)*

Woodside Energy (Australia): FUSE platform integrates 200,000 sensors into predictive maintenance visualisations.[22]

Razor Labs (Australia): DataMind AI combines diverse sensors for advanced equipment failure prediction.[23]

University of Manchester (UK): Networked control system enables robot fleets to conduct remote industrial inspections, coordinating diverse machines through digital twins while managing bandwidth for scalable missions.[19] *(See page 28)*

BadVR (US): VR and AI transform complex data analysis through immersive multidimensional visualisation.[26] *(See page 29)*

Novity (US): Hybrid AI combines physics models with machine learning for 90% accurate equipment lifespan forecasts.[27] *(See page 26)*

Flow Immersive (US): Multiplatform visualisation integrates real time data streams for 2D, AR and VR collaboration, enabling non technical staff to understand complex systems through shareable, interactive displays.[24] *(See page 30)*

University of Illinois (US): Digital twin platform combines nuclear facility simulation with NVIDIA's robotics environment.[21]

FNC Technology (South Korea): Software processes historical records and site drawings to identify contamination with automated validation.[20] *(See page 31)*

What to look out for?

0–5 years

Combining generative AI with physical models and analysis of diverse but collated information enables software to forecast equipment failures with over 90% accuracy and recommend solutions, all while providing clear explanations. Virtual and augmented reality tools enable teams to visualise the status of technologies across the site, enhancing situational awareness.

5–10 years

Data from many thousands of sensors is collectively analysed to enhance predictive maintenance and improve scenario modelling. Multi-platform visualisation enables staff to interrogate real-time, historical, and modelled data interactively, assisting with planning complex operations and responding to incidents.

10–20 years

Operations are largely automated, with insights from assets across the site informing both collaborative robot behaviour and high level task assignment. Industry experience from beyond the Sellafield site is integrated into models, enabling accurate predictions of potential radioactive contamination. Virtual testing environments allow mission rehearsals before deployment, reducing operational risks.

View source
For sale
Source:
Corporate R&D
Origin:
North America

Accurately predict an asset's remaining life – no historical data required

What's the innovation

Knowing when pumps, motors, and compressors will fail makes planned maintenance and upgrades far easier. Making such predictions relies on comparing real-time data to high-quality historical data on failures and degradations, which most companies just don't have. To tackle this, startup Novity (US) has developed TruPrognostics. The platform combines machine learning with physics-based models of machinery to make 'remaining useful life' forecasts, which it claims are 90% accurate, with only minimal historical data.

How it works

- Novity deploys a network of sensors to collect data from equipment, such as pressure, temperature, and flow rates. This is then merged with historical data and maintenance requirements of similar equipment.
- The data is analysed using a proprietary combination of machine learning and physics-based models of machine faults and degradation.
- The platform then visualises the history and remaining useful life of each asset, as well as issuing real-time alerts when data drifts outside operating limits.

Context

- Predictive maintenance is estimated to provide up to 40% reductions in maintenance costs, 50% reductions in downtime, and 5% savings on capital investment, compared to scheduled maintenance.
- Integrating human expertise with AI models is a growing trend within asset maintenance. Siemens' Senseye system codifies real-world expertise and combines it with existing and real-time data to generate behaviour models for both machines and maintenance personnel.

What's next

Novity plans to use a 2024 funding round to improve the AI in its predictive maintenance software, and expand its reach across more industries and equipment types.

Further reading

Read more about AI-based predictive maintenance for the nuclear industry

AI makes recommendations on industrial processes, then explains its reasoning

What's the innovation

When AI performs a critical task, like replacing a component or optimising reactor conditions, we need to know that it's making a sound judgment based on credible data. Trusting its advice is easier if its reasoning is explained. Beyond Limits (US) claims to have developed a platform that makes AI process optimisation recommendations, then provides clear explanations for why. The technology, which draws on AI used by NASA (US) for guiding spacecraft, aims to support real-time decisions in complex environments, and provide transparent audit trails.

How it works

- The 'no-to-low-code' platform allows users to capture and encode operator knowledge into a knowledge base, without coding experience.
- An AI digital assistant then applies neuro-symbolic reasoning. This is an AI approach that combines neural networks and logic-based reasoning, and is used to analyse real-time operational data alongside its expert knowledge base. This allows it to balance data-driven insights with human expertise, blending automation and human oversight.
- Crucially, the system then generates human-readable explanations of its recommendations, using Generative AI.

Context

- There is a growing trend to integrate AI decision-making for complex, dynamic environments, but many approaches rely on 'black-box' AI models that don't provide explainable results.
- Startup CognitiveScale (US) has also developed a platform which can be used by non-AI experts to enhance decision-making, along with a hub with tools for developing custom AI solutions.

What's next

Beyond Limits markets its AI platform to sectors including petrochemicals, manufacturing and utilities, with an emphasis on improving asset management and supporting predictive maintenance.

Further reading

Read about how AI is being used in the liquified natural gas (LNG) industry

View source
For sale
Source:
Startup
Origin:
North America

Asset monitoring robots map out their own work environment

What's the innovation

If fleets of inspection and maintenance robots are to one day autonomously navigate nuclear facilities, they will need a way to communicate and coordinate their movements. To help, researchers at the University of Manchester (UK) have developed a new cyber-physical system (CPS), a unique architecture that can be built with off-the-shelf digital and physical components. The system supports robots to map out a digital twin of any industrial environment, then efficiently coordinate their movements with each other via that digital twin.

How it works

- A multi-robot fleet first maps the building, then generates a common 3D map using parameters suited to robotic navigation, and evaluates bandwidth requirements for communications.
- Communication between the fleet happens via the digital twin, and is optimised through data compression, downsampling and dynamic bandwidth management. By filtering the data using a 10cm voxel grid, downsampling alone reduces bandwidth by 95%.
- A human operator can view 3D map streams and visualise data of the unknown environment through the digital twin interface.

Context

- Many investments in cyber-physical systems come from the defence sector, with DARPA (US) regarding them as 'instrumental to supporting unmanned vehicles and weapons systems'.
- Cyber-physical systems with distributed control are especially resilient, since communication and data processing can occur without a centralised control centre issuing commands.

What's next

Future research will include testing the CPS in real-world and industrial settings, along with identifying categories of objects and materials, and ways to verify the state of a facility before humans enter.

Further reading

Read more of this team's previous research

View source

Laboratory testing

Source:
University lab

Origin:
Europe

Gaining rapid situational awareness in virtual reality

What's the innovation

Responding quickly and appropriately to urgent situations, such as communication failures, chemical spills or damaged infrastructure, requires responders to have a clear appreciation of all the available information. Imagine if you could virtually move around the site, assimilating sensor readings and flashing alerts. This is the promise of BadVR, which claims its 3D data visualisation platform allows operators to 'step inside their data', spot hidden problems and opportunities, and make better and faster response decisions.

How it works

- BadVR generates augmented reality visualisations of operational data, using patented data spatialisation and sampling algorithms.
- It presents data within 3D environments, which users wearing virtual reality (VR) headsets can navigate through, allowing them to visualise relationships and patterns more easily. An existing use case involves visualising internet signals throughout a room via a matrix of different sized bubbles corresponding to signal strength.
- The platform enables multiple users to interact with data simultaneously, supporting real-time collaboration within a team.

Context

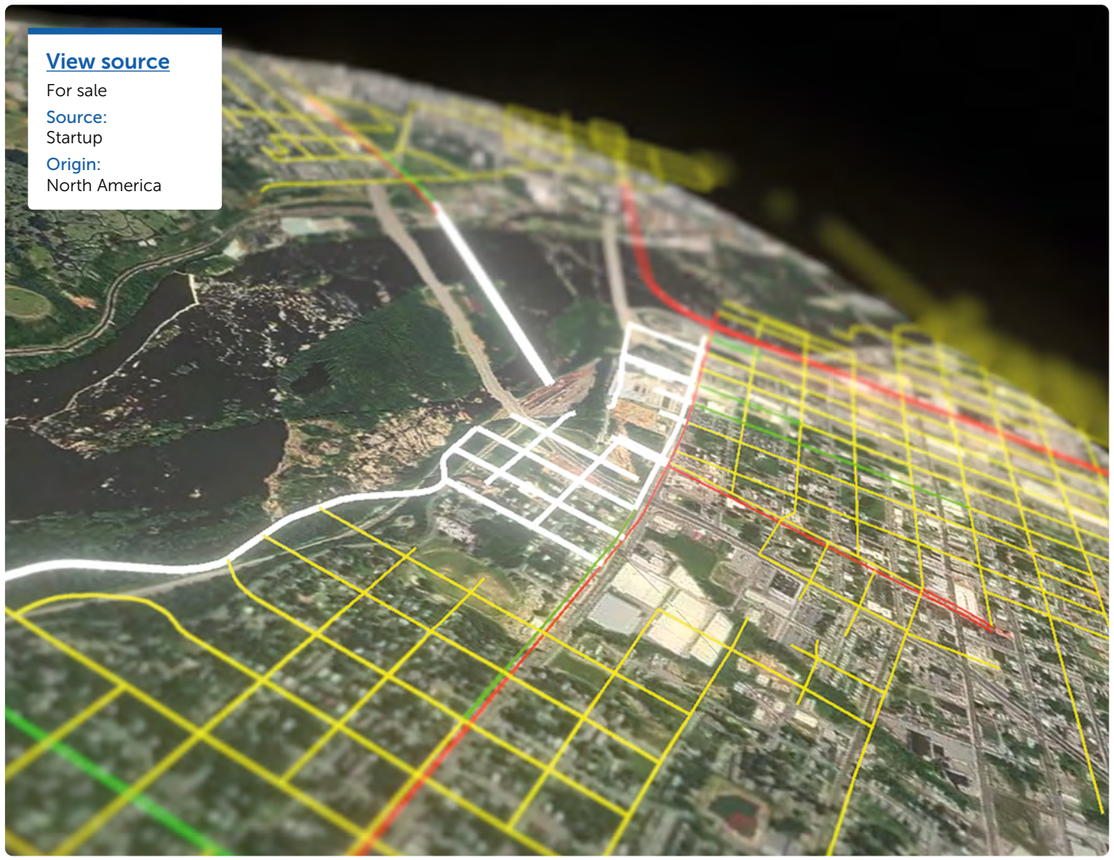
- Competitor 3Data (US) has developed Cloudcom: a data visualisation command centre that integrates AI to support operational decision making. Cloudcom offers synthetic training environments and can create digital twins of real-world assets.
- Similarly, Taqtile (US) has developed Manifest, a mixed VR/AR platform with embedded AI which supports on-the-job training for industry. Users wear headsets to visualise and learn procedures in real time.

What's next

BadVR are working on adding encryption and an application program interface (API) to their data visualisation tools.

Further reading

Read about Taqtile's work AI work assistance platform

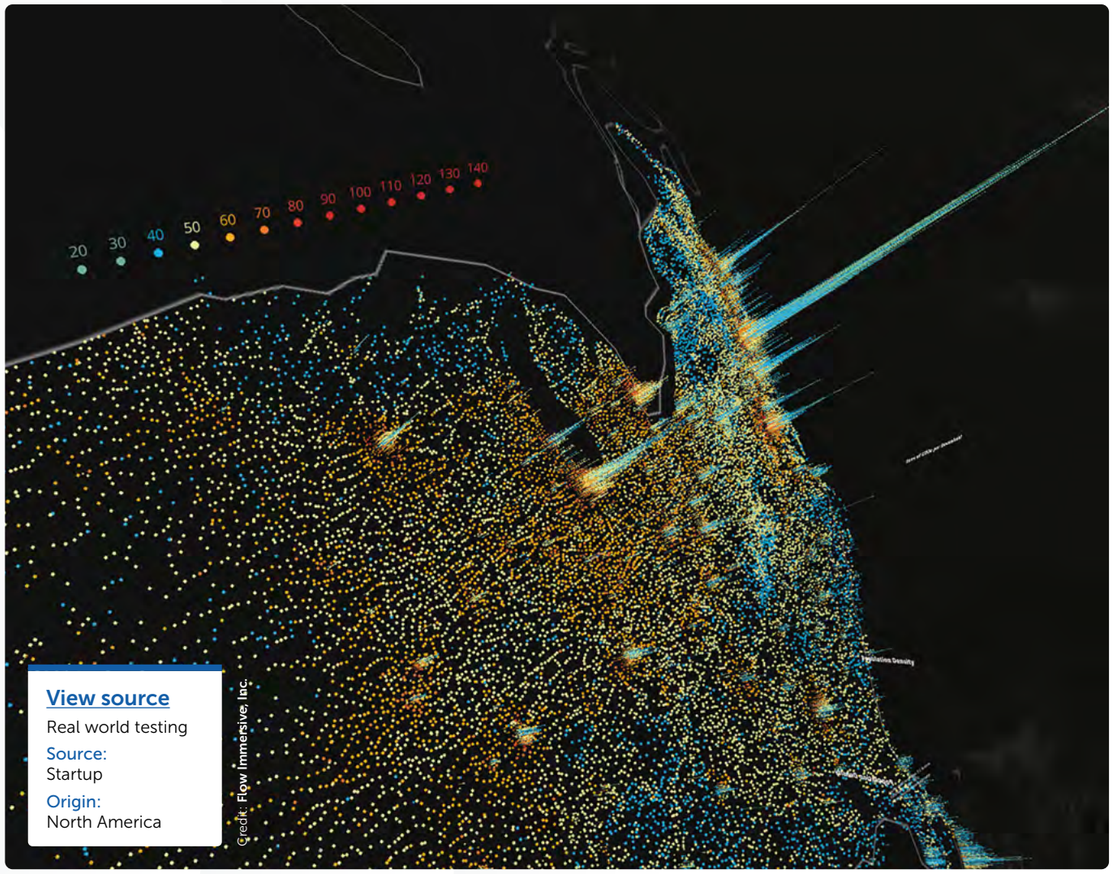


View source

For sale

Source:
Startup

Origin:
North America



View source
Real world testing
Source:
Startup
Origin:
North America

Generative AI and augmented reality make data analysis more immersive

What's the innovation

Finding engaging ways to visualise complex data, such as the changing distribution of radiation exposure over time, helps communicate important trends to non-experts. Augmented reality (AR) and LLMs could now make it easier. Flow Immersive (US) has created a data storytelling platform that it claims presents 3D AR visualisations of multidimensional and multimodal data. The user can move around the visualisations, and make changes and call up contextual information with voice commands. That could make data presentations and discussions more engaging, without oversimplifying data.

How it works

- A no-code visualiser allows anyone to create 3D visualisations from their data.
- Multiple users can collaboratively interact with the same 3D visualisations via headsets, phones or web browsers.
- Thanks to LLM integration, users can use spoken commands to filter content, highlight elements of the data, or change visualisation style. They can even call up additional context from public LLM's knowledge base or their own data stores.

Context

- Neuroscience research has established that the average human mind can only consider 7 pieces of information simultaneously, making it essential to present complex data in a clear and simplified way.
- For organisations using extensive automation, startup Foxglove (US) has created a platform that helps employees extract, manage and visualise data from robots.
- AR is increasingly being adopted to provide information to frontline workers, with startup RealWear (US) offering smart glasses designed for hazardous environments.

What's next

Flow Immersive is collaborating with HTC (Taiwan) to integrate their data visualisation platform into an AR and VR capable device, the HTC Vive Flow.

Further reading
Watch the technology demonstration

Dedicated algorithms sift through historical records to identify contamination zones

What's the innovation

Radiological surveys are essential to nuclear decommissioning sites. A key element involves reviewing historical records and site drawings to identify potential contamination zones. This is a highly regulated and resource-intensive process, relying on expert judgment and extensive data handling. To make things simpler, FNC Technology (South Korea) reports developing COSMOS, AI-powered software that automates the tasks of extracting contamination-related information from historical records, and conducts statistical validation for site clearance.

How it works

- First, a Historical Site Assessment module analyses historical documents and digitised drawings to identify potentially contaminated areas, using AI-based keyword identification and room classification.
- Data from the resulting characterisation surveys is analysed via a Radiation Survey and Site Investigation (RSSI) module, which performs statistical tests to validate compliance with dose or risk-based criteria.
- A data management component coordinates the inputs and outputs from the two modules and supervises the entire RSSI evaluation process.

Context

- Valuable decommissioning records are often hidden within document archives, creating inefficiencies as locations have to be reassessed.
- Existing environmental remediation software, such as RESRAD code developed at Argonne National Laboratory (US), lacks AI-driven contamination identification and automated compliance checking.

What's next

FNC Technology is using COSMOS software to support its suite of nuclear decommissioning services for customers including the Korea Radioactive Waste Agency (KORAD).

Further reading
Read how COSMOS is used in FNC's nuclear decommissioning

View source
Laboratory testing
Source:
Corporate R&D
Origin:
Asia

References

[1] Intelligent skin for more precise communication and near-field sensing in robotics, **2024**, https://www.fhr.fraunhofer.de/en/press-media/press-releases/2024/Intelligent-skin-for-more-precise-communication-and-near-field-sensing-in-robotics.html

[2] Lee, J.-C.; Choi, Y.-R.; et al. Low-Power Wireless Sensor Module for Machine Learning-Based Continuous Monitoring of Nuclear Power Plants. Sensors **2024**, 24, 4209, https://doi.org/10.3390/s24134209

[3] Zhang, T.; Seshia, A. A. Multi-Channel PMUT for Wireless Power Transfer and Data Telemetry. **2025**, https://doi.org/10.17863/CAM.115349

[4] Nokia and SK Broadband deploy quantum secure network to protect Korea Hydro and Nuclear Power's IT infrastructure, **2024**, https://www.nokia.com/about-us/news/releases/2024/12/11/nokia-and-sk-broadband-deploy-quantum-secure-network-to-protect-korea-hydro-and-nuclear-powers-it-infrastructure/

[5] Haley201. An Engineering Deep Dive on SiMa.ai MLSoC Modalix, **2024**, https://sima.ai/an-engineering-deep-dive-on-sima-ai-mlsoc-modalix/

[6] ARX Robotics launches first ever independent AI-based operating system, **2025**, https://www.arx-robotics.com/journal/arx-robotics-launches-first-ever-independent-ai-based-operating-system

[7] Digital Transformation for the Power Industry, **2025**, https://geckorobotics.com/power/

[8] Go From Maintenance to Reliability, **2025**, https://helixintel.com/

[9] OmniCore - ABB's advanced controllers for automation | ABB Robotics, **2025**, https://new.abb.com/products/robotics/controllers/omnicore

[10] Jose, S.; Nguyen, K. T. P.; et al. Advancing Multimodal Diagnostics: Integrating Industrial Textual Data and Domain Knowledge with Large Language Models. Expert Syst. Appl. **2024**, 255, 124603, https://doi.org/10.1016/j.eswa.2024.124603

[11] Möller, F.; Jussen, I.; et al. Industrial Data Ecosystems and Data Spaces. Electron. Mark. **2024**, 34, 41, https://doi.org/10.1007/s12525-024-00724-0

[12] Streamlined Biodiversity Monitoring, **2024**, https://hula.earth/tech

[13] Automate data normalization with AI, **2025**, https://lume.ai/workflows/data-normalization

[14] Cribl Solutions - Revolutionize Manufacturing & Logistics, **2025**, https://cribl.io/solutions/industries/manufacturing-and-logistics/

[15] ZEDEDA Enterprise, **2025**, https://zededa.com/products/enterprise/

[16] Neo4j Transforms Its Cloud Database Portfolio to Accelerate Graph Adoption & GenAI for the Enterprise, **2024**, https://neo4j.com/press-releases/neo4j-aura-update/

[17] Your unstructured data Enterprise AI-ready, **2025**, https://unstructured.io/enterprise

[18] Telco Systems Edge Computing Solutions, **2024**, https://www.telco.com/product-edgility/

[19] Kivrak, H.; Karakusak, M. Z.; et al. Cyber–Physical System Architecture of Autonomous Robot Ecosystem for Industrial Asset Monitoring. Comput. Commun. **2024**, 218, 72–84, https://doi.org/10.1016/j.comcom.2024.02.013

[20] Byun, H.; Park, J. D.; et al. Intelligent Nuclear Decommissioning Solution: Code for Site Characterization and Management of Overall Surveys. Ann. Nucl. Energy **2024**, 196, 110212, https://doi.org/10.1016/j.anucene.2023.110212

[21] A nuclear power plant digital twin for developing robot navigation and interaction, **2024**, https://www.frontiersin.org/journals/energy-research/articles/10.3389/fenrg.2024.1356624/full

[22] Gregory Biegel et al. The Fuse Platform: Integrating Data from IoT and Other Sensors into an Industrial Spatial Digital Twin. Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. **2024**, XLVIII-4–2024, 79–84, https://doi.org/10.5194/isprs-archives-XLVIII-4-2024-79-2024

[23] Labs, R. Razor Labs Launches DataMind AITM V3.1: Unleashing Next-Gen Predictive Maintenance, **2024**, https://www.razor-labs.com/datamind-ai-version-3-1/

[24] Flow Immersive 3D AR Data Visualization, **2025**, https://flowimmersive.com

[25] Beyond Limits AI Products: Tailored Solutions for Enterprise Efficiency, **2025**, https://beyond.ai/enterprise-ai/ai-offerings

[26] BadVR Step Inside Your Data, **2025**, https://badvr.com

[27] Novity - How it Works, **2025**, https://novity.us/how-it-works/

Sellafield Ltd

Outsmart
Insight

Independent delivery partner

Outsmart Insight helps R&D companies and government agencies stay ahead of change and at the forefront of innovation.

Our deep tech research and foresight are powered by crowdsourcing, underpinned by a proprietary global network of scientists, engineers and innovators from world-leading research institutions. Our analysis provides insight into emerging technologies and trends. We achieve this using technology monitoring, partner scouting and long-range forecasting.

Outsmart Insight Ltd

124 City Rd,
London, EC1V 2NX
United Kingdom

T: +44 3330 020 240

www.outsmartinsight.com