Solvay Final Report

Asset Tracking

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ABBREVIATIONS

DCMS	Department for Digital, Culture, Media, and Sport
NCC	National Composites Centre
MAT	Material Asset Tracking
OEE	Overall Equipment Efficiency
BOM	Bill of Materials
IT	Information Technology
OT	Operational Technology
RFID	Radio-frequency identification
ATEX	Explosive Atmosphere *(from French "Atmosphères Explosives")*
PoE+	Power over Ethernet Plus
PoC	Proof of Concept
FLT	Forklift Truck
MES	Manufacturing Execution System
CAPEX	Capital Expenditures
OPEX	Operating Expenses
NIST	National Institute of Standards and Technology
ERP	Enterprise Resource Planning
LIMS	Laboratory Information Management System
TPO	Total Production Optimization
GPIO	General Purpose I/O
SaaS	Software as a Service
GUI	Graphic User Interface
MAT	Material & Assets Tracker
EIRP	Effective Isotropic Radiated Power

EXECUTIVE SUMMARY

5G-Encode is a £9 million collaborative project partially funded by the Department for Digital, Culture, Media, and Sport (DCMS) with the aim of developing clear business cases for 5G applications in the composites manufacturing industry. Solvay was a partner in the industrial use case evaluating asset tracking of time sensitive materials.

The asset tracking evaluation work package was delivered in collaboration with Plataine Ltd which provided the TPO application and the NCC, Bristol which provided the test bed for the private 5G technology evaluation. The NCC test bed was delivered together with Zeetta Networks, Toshiba, Mativision, Plataine, Siemens, Telefonica, Accedian and the High-Performance Networks Group from the University of Bristol as partners.

As a leading supplier of composite materials, Solvay evaluated the potential of the automated asset tracking technology from a material manufacturer perspective. Solvay, based at a site in Wrexham, supplied to the NCC the composite materials required for the evaluation of the automated asset tracking use case from a material manufacturer site to a customer site perspective.

The project highlighted the potential benefits of automated asset tracking in terms of waste reduction and OEE improvement from a composite materials manufacturer perspective. Potential for full automation of currently manual or semi-automatic quality tasks or ERP transactions was also highlighted. Solvay has decided to pursue further the evaluation of automated asset tracking technologies following this project.

At this stage the benefits of, in factory, 5G cellular technology to support an automated asset tracking system deployment at the Solvay, Wrexham site compared to a conventional PoE+ approach remains unclear. Further evaluation would be required before any full deployment of automated asset tracking across the Solvay's multiple Wrexham sites.

INTRODUCTION

Solvay Materials, part of the Solvay Group, is a global supplier of adhesives and composite materials with a strong manufacturing footprint in the UK (Cytec Engineered Materials Ltd). Solvay Materials is currently progressing its digital transformation journey with a strong focus on automation. The Wrexham site, located in North Wales, was selected to explore the potential of automated asset tracking.

The Solvay Wrexham site manufactures prepregs (fibres combined with resin) on multiple reinforcements as well as resin systems for infusion, resin transfer moulding systems, adhesives and potting compounds for the composites Industry. Solvay products manufactured at the Wrexham site are supplied to many industries globally including aerospace, motorsports and high-performance automotive.

Solvay Wrexham site was established in 1982 and has been growing ever since with the addition of the European R&I centre for composites in 2005 and the most recent site expansion with the completion of the European Adhesive manufacturing plant completed in 2015. The Solvay Wrexham site now employs approximately 250 people in production, R&I, technical service, finance, human resources, logistics and procurement.

Solvay was a project partner in the asset tracking work package. Solvay main contribution to this work package was as a material supplier of composites materials, from the factory located in Wrexham, for the case study deployed at the NCC, Bristol. The first Solvay objective was the evaluation of, in factory, automated asset tracking and its potential at the Wrexham manufacturing site. Another objective was the monitoring of the 5G cellular technology being trialled at the NCC to better understand its potential for a full roll out of automated asset tracking across its multiple manufacturing sites. A third objective for Solvay was the evaluation of the potential of automated asset tracking as an enabler for increased vertical integration between composite materials suppliers and composite materials part manufacturers, including potential for in-transit asset tracking.

Project Objectives

- Automated asset tracking within factory

The manufacturing process of composites materials involves the production of multiple intermediates required for the manufacture of the final goods which can bring some

scheduling challenges (see Figure 1). Most of the intermediates as well as most of the final goods are also time and temperature sensitive. This means that they have a maximum time allowed at room temperature to maintain their critical quality attributes. This maximum allowed time is commonly referred to as out-time. When not in use, intermediates must be stored in cold storage, typically in freezer below -18°C. This is to preserve their valuable out-time. However, intermediates must also be fully deforested before being used in secondary operations. This brings extra complexity to the operation planners and production supervisors. The real time and automated tracking of material assets throughout the manufacturing shop floor and freezers is believed to have the potential to optimize production scheduling, preserve valuable material out-time, reduce wastes and maximize overall equipment efficiency (OEE) of production assets.

The first objective of Solvay will be to evaluate RFID technology for automated asset tracking of a selected number of intermediates and final goods to understand the reliability of the technology and how much of the aforementioned benefits can be harvested.

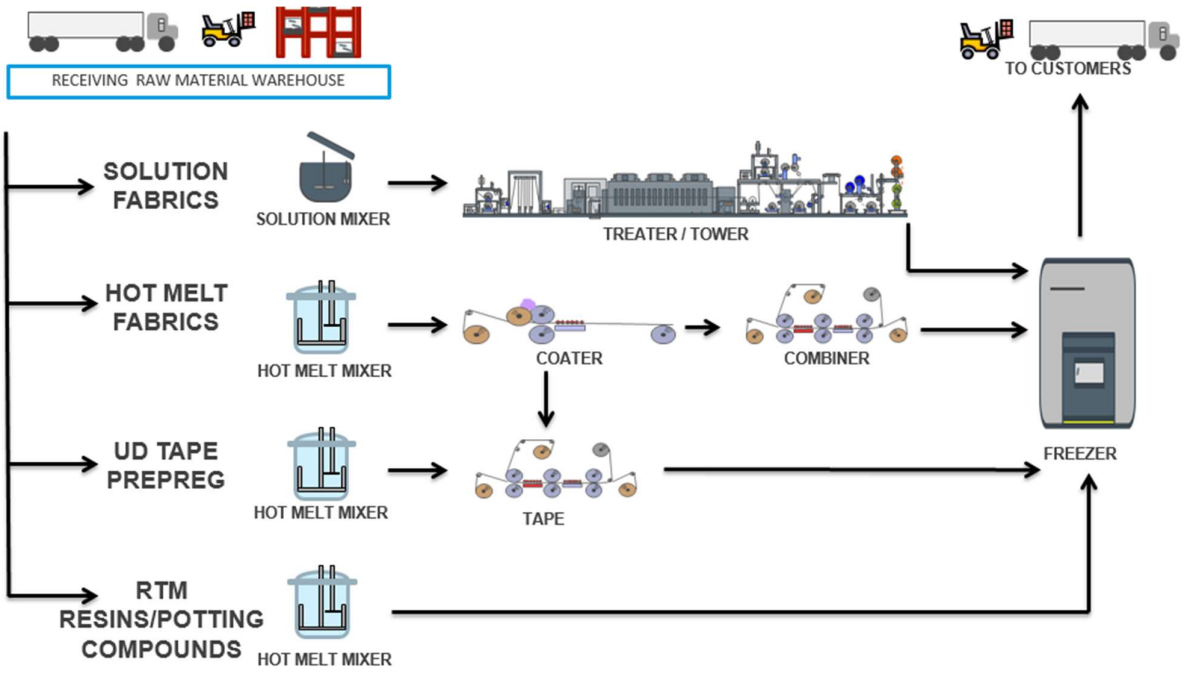

Figure 1: Schematic of manufacturing process.

- Automated out-time tracking within factory

Composite materials and their intermediates are extremely high value products. Any such products which have to be scrapped due to an excessive out-time consumption is extremely costly. By associating the defined locations of the shop floor with their respective physical temperature, the automated tracking of materials can be used to monitor real time their out-

time consumption. For example, when a material asset is detected in the freezer, it is given a temperature of -18°C, or a frozen status. When it is on the production shop floor, it is given a status of defrosted, or room temperature. This automated tracking of out-time can be used to send automatic email warnings to production supervisors in case of unexpected consumption of out-time due to a delay in manufacturing for example. This would allow reduction or elimination of costly waste.

- Paperless and automation of operator tasks

The stringent quality requirements associated with the aerospace industry require operators to perform multiple tasks which are manual or semi-automatic. The automation of the asset tracking and out-time tracking could enable the full automation of BOM consumption, sub-lot pedigree, and out-time recording currently performed by operators.

- Digital material passport and in-transit tracking

The remaining out-time of a material is of great value to the manufacturing department of composites part manufacturer. Within this PoC, both Solvay and the NCC explored the automation of out-time tracking within their factory. Understanding the practical feasibility of automating the out-time tracking not only within a factory but throughout the entirety of the supply chain was also explored.

5G Potential

The installation of 5G cellular technology at Solvay Wrexham site was not part of Solvay's commitment to the work package. The main reasons are as follow:

- Cellular technology is not currently an acquired competency at site level.
- Due to its size and its unique technologies, the Solvay Group could be an attractive target for cyber-attacks. As a result, the Solvay Group has an extremely strict cybersecurity policy on IT and OT networks configuration and management. The deployment of a cellular technology as an OT network at its Wrexham site was not authorized at this stage.
- The Solvay Wrexham site has multiple ATEX-rated (explosive atmosphere) zones where conventional cellular technologies are not allowed unless ATEX compliant. The deployment of an ATEX-rated cellular technology would be prohibitively costly.

However, Solvay is interested in understanding further the potential fit of the 5G cellular technology compared with the PoE+ hardwire network technology selected for this automated asset tracking PoC.

OVERVIEW

System Requirements Development

The requirements for the automated asset tracking system were identified as follow:

- Must be fully transparent to current manufacturing process and not require any additional tasks from operators. (Of course, once the reliability of the system is proven, it must also reduce the complexity of the operators' tasks).
- Must be passive and not require the use of any battery-operated devices.
- Must not require the use of additional tracking device or labels to be added to the product packaging by operators.
- Must survive a high-rate industrial manufacturing environment where FLT's and pedestrian-pallet trucks are used for moving goods around the plant and onto trucks.
- Must survive the full distribution chain cycle from manufacturing, cold storage down to as low as -40°C and transportation by either road, sea or air.
- Low installation costs (CAPEX) and operation/maintenance costs (OPEX).
- Must be compatible with an industrial environment where ATEX-zones are present.
- Must not require a specialized skill set not currently supported within the Solvay Group. Must be easily maintainable.
- Must provide a high reliability and have the capability of self-diagnosis with automated alerts in case of system malfunctions.
- Must have the capability to be incorporated into the MES system once PoC is validated would Solvay decides to do so at a later stage.

Another critical requirement for this PoC was to meet Solvay cybersecurity and NIST 800-171 requirements as well as all export control regulations. For these reasons, a dedicated physical hardwire network was deployed for this PoC. We will refer to this network as the "asset tracking PoC network". This asset tracking PoC network was fully independent and physically separated from other Solvay IT and OT networks. There was no communication between the asset tracking PoC system and Solvay MES, LIMS or any other systems. This PoC was isolated and run in parallel and independently from Solvay operations. The deployment of this system based on hardwire network formed the basis for the evaluation of the relevance and potential of automated asset tracking.

Use Case Architecture

For this automated asset and out-time tracking PoC two roll-to-roll processes typical of a hot melt prepreg manufacturing process were selected as well as the productions freezers used to store the intermediates and final goods. The material assets were tracked all the way to their loading onto the reefer truck ready for dispatch, see Figure 2.

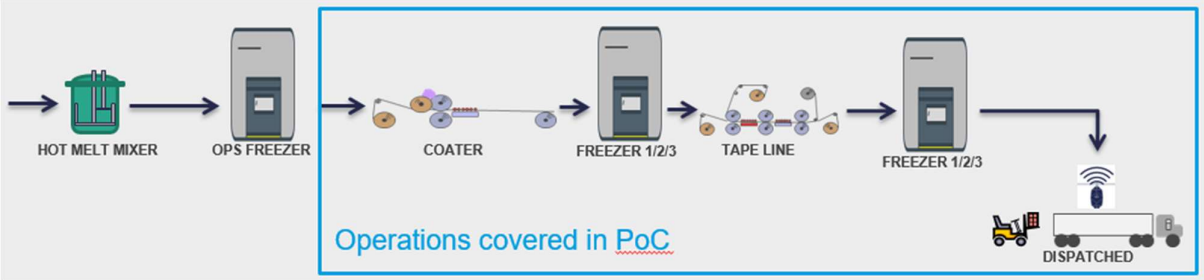

Figure 2: typical hot melt prepreg manufacturing process.

The two selected manufacturing processes and their associated workstation as configured in the Plataine TPO system for the automated asset tracking are:

- Hot melt resin coating, referred to as MSKR workstation in the Plataine TPO. See physical location in Figure 5;
- Hot melt prepreg process, referred to as MST4 workstation in the Plataine TPO. See physical location in Figure 5. An example of nine prepreg rolls boxed up and palletized for dispatched is shown below.

Figure 3: example of 9 boxed up prepreg rolls palletized and loaded by pedestrian-pallet truck for dispatch.

Passive RFID tags from Impinj were selected and laminated into our standard production labels media (see Figure 4). This approach ensured transparency to current production operations and no extra operator tasks, or labels were required.

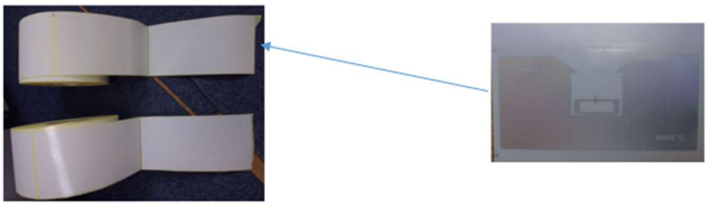

Figure 4: (top) production labels with RFID tag; (bottom) standard production labels without RFID tags.

To detect automatically the movement of the tagged material assets across the shop floor and freezers as well as their loading onto the reefer truck for dispatch, the shop floor was divided in zoned areas. Each zoned area was allocated a fixed temperature status (frozen, being defrosted or defrosted status) in order to allow the use automated location tracking data to compile automated out-time data. Between each of these zoned areas, an RFID gate was installed to detect the movement from one zoned are to another. See Figure 5.

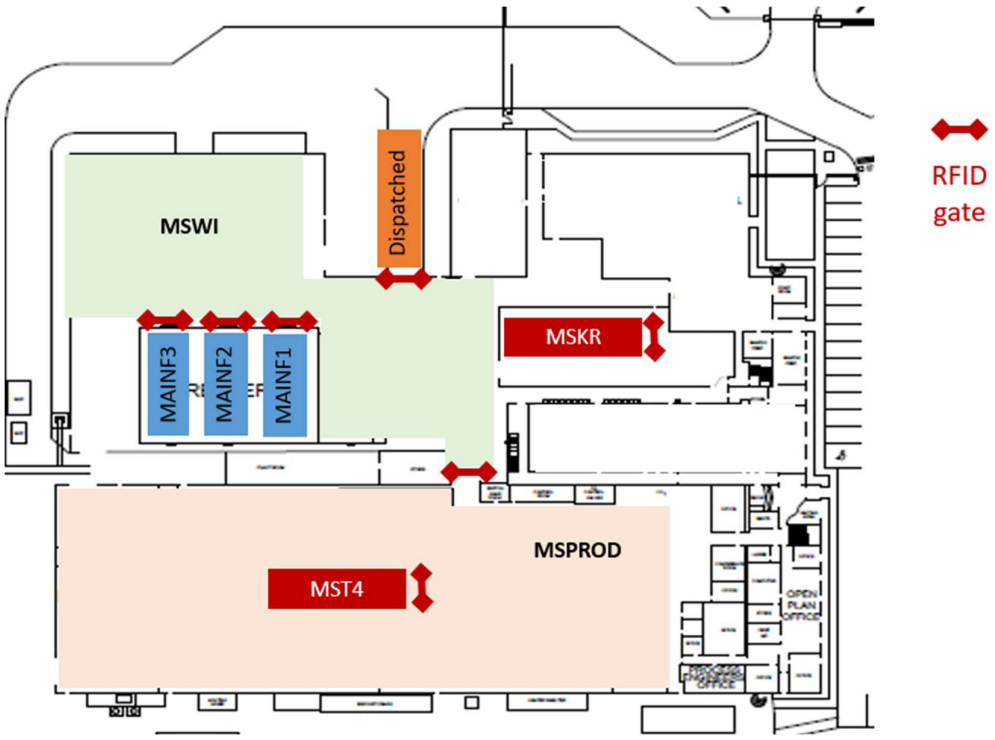

Figure 5: definitions of zoned areas and location of RFID gates for asset tracking PoC.

Each RFID gate is composed of the following elements:

- RFID antennae from Zebra
- Co-axial cables to connect the antennae to the reader
- FX7500 reader from Zebra
- Ethernet data cable
- Power supply (not required in this PoC due to the use of PoE+)

Note that the power supply requirement for the selected FX7500 readers from Zebra is a standard 24VDC but they are also compatible with PoE and PoE+.

The software solution selected to manage the automated material asset and out-time tracking is the Plataine TPO system (see Figure 6). Only the RFID connectivity was used within this PoC as well as the Material & Assets Tracker (MAT) module. Plataine TPO system is a cloud-based system with a SaaS GUI which present the advantage of a very easy deployment. It is already used successfully by multiple composite part manufacturers. Solvay was interested in evaluating this TPO platform for its material manufacturing operations. The configuration of the locations and workstations in Plataine MAT application is presented in Figure 7.

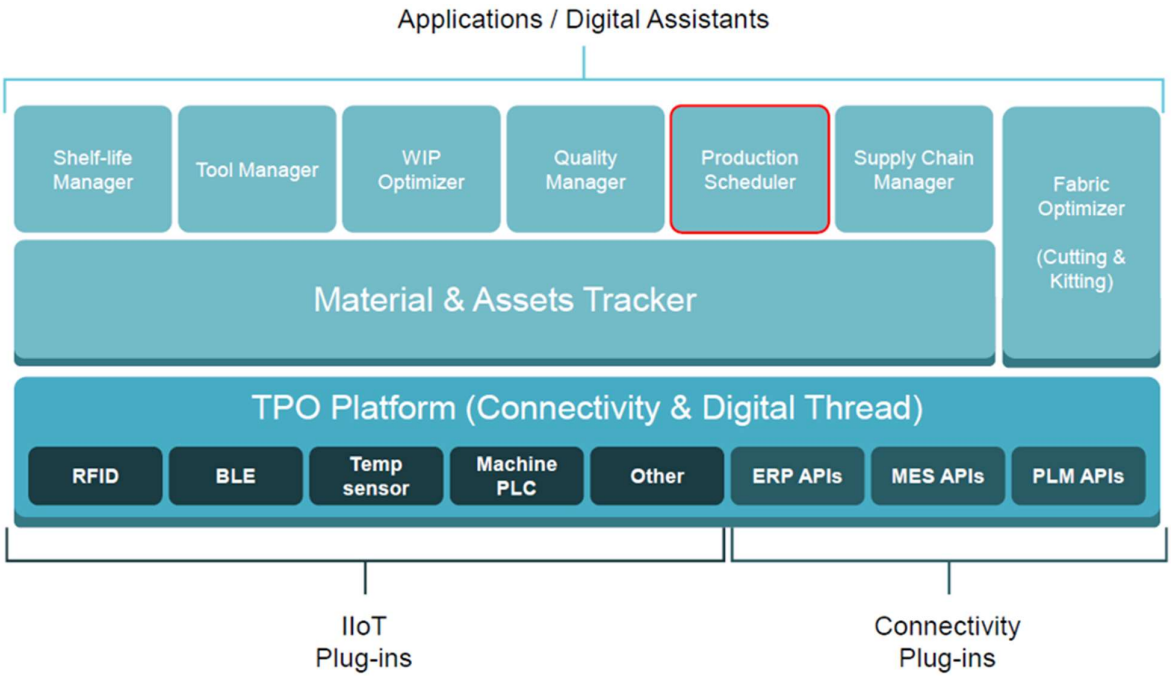

Figure 6: Plataine's TPO suite of applications.

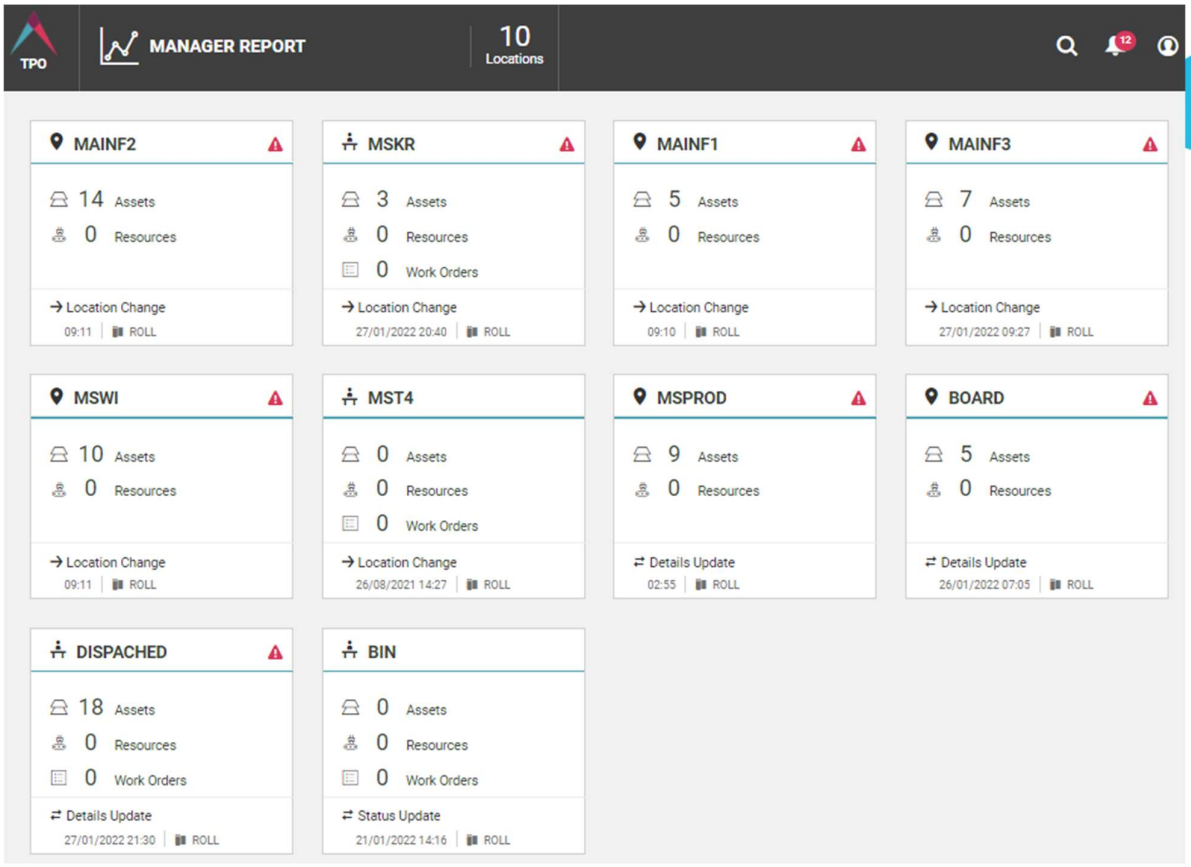

Figure 7: Locations and workstations configured in Plataine TPO for the PoC.

Use Case and Network Benefits

As discussed in the *5G Potential* section above, the deployment of 5G cellular technology at the Solvay Wrexham site was out of scope for Solvay. A more conventional approach has been taken to establish a performance baseline and then evaluate what potential benefits a 5G cellular solution could bring in any future roll out based on NCC, Bristol trials.

In terms of installation cost and safe permit to work in an industrial environment, it is cheaper and easier to install a PoE+ network than power supply lines and associated cellular hardware, etc. Since the Zebra readers were compatible with PoE+ only as power supply while still maintaining adequate GPIO capabilities, it was decided to install a dedicated PoE+ switch board at the centre of the factory. This allowed each of the RFID gates to be reached at a distance less than 90 meters. No additional power supply installation was necessary for the operation of the RFID gates. The centralized PoE+ switch board was linked to the on-premises Plataine edge server following Solvay industrial cybersecurity protocols. The communication between the on-premises and the dedicated cloud-based Plataine server was established following the standard Solvay cybersecurity protocols.

No readily available 5G compatible device able to withstand our cold storage environment could be identified. Furthermore, the 5G public network had limited coverage at the time of the PoC. One of the alternative solutions investigated was the use of a geo-fenced temperature recorder with GPS & 4G capability. Solvay is familiar with this technology which had recently been widely used to track the shipments of high value goods from the UK to the EU during the Brexit disruptions. However, the automation of the whole process would have exceeded the PoC budget so had to be abandoned.

As a compromise, it was agreed with the NCC that the material information required for this PoC will be supplied by Solvay to the NCC after material production. This information was captured in an EXCEL CSV template that was easily imported into the NCC Plataine TPO database to create the material assets to be delivered.

USE CASE DEVELOPMENT AND INVESTIGATION

Use Case Testing

The set-up of the RFID gates is illustrated in the figures below. RFID antennae were placed at fixed height in order to prevent pedestrian obstruction, avoid head collision, and avoid antennae damage from impact with FLT and ped-pallet trucks. After about six months following the installation, still no damages or issues with the antennae have been reported. This demonstrates a good survivability.

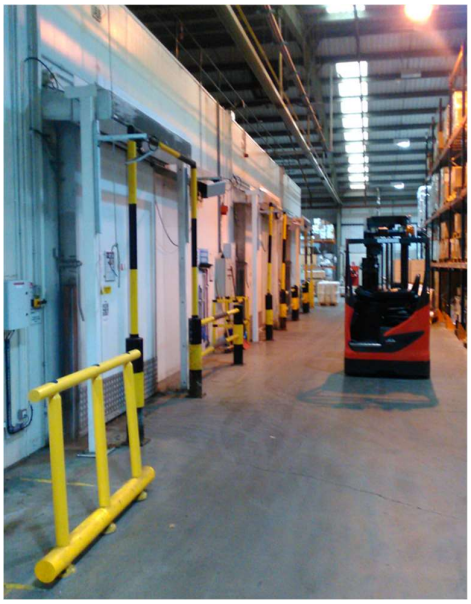

Figure 8: RFID gates at locations of freezers 1 to 3.

Figure 9: RFID gate at the truck loading bay.

Below is an example of a material asset created automatically by the system in Plataine TPO at the time of the asset creation followed by its movement across the shop floor a moment later when taken to the freezer. In this instance, the resin film roll “047010” was created automatically by the RFID system into Plataine TPO at the time of the asset manufacture during a night shift without any manual input from any production operator, see Figure 10. About forty minutes later, the operator took the pallet with the film roll to the freezer number 2. The RFID system detected automatically and in real time the asset movement and updated its status as “IN_FREEZER”, stopping the clock for the out-time consumption. During the next morning shift, the roll was moved from the freezer number 2 to the freezer number 3 to consolidate in the same locations all intermediates for next production order on the tape line. This movement was automatically detected without any loss of out-time.

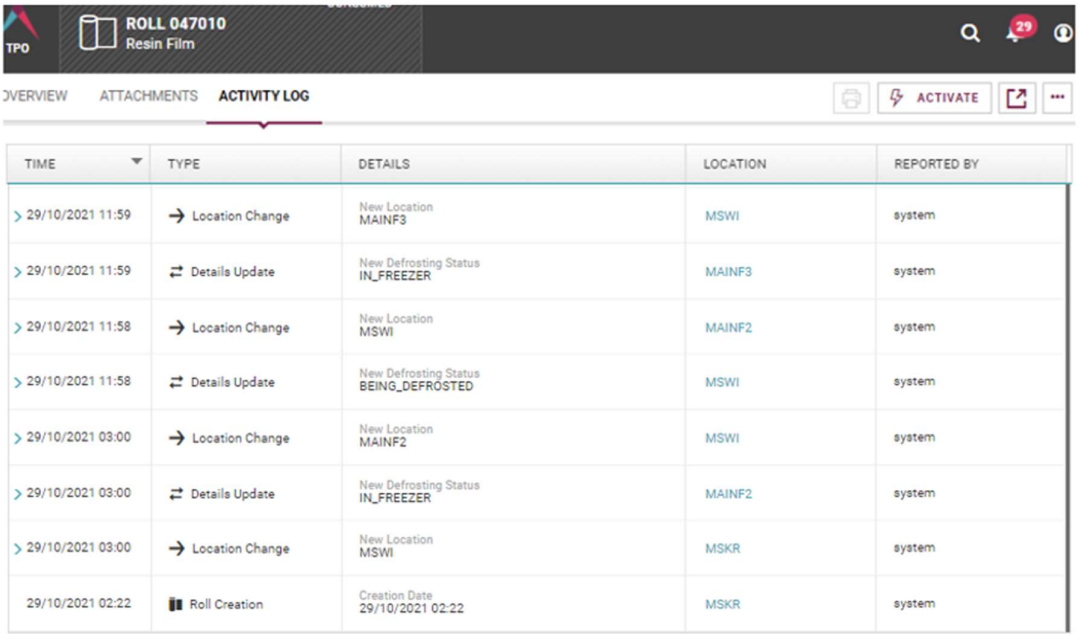

Figure 10: automatic asset creation in Plataine TPO system.

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The figure below illustrates the next manufacturing step. Two days later, the film roll was taken out of the freezer 3 with an FLT driver to defrost the film roll before its consumption on the tape line. This is illustrated in Figure 11. This figure shows that the system is capable of detecting automatically the release of the film roll from the freezer 3 and start the 12-hour defrosting countdown. Once the 12-hour defrosting time was elapsed, the system updated automatically the film roll status from “BEING_DEFROSTED” to “DEFROSTED”. The roll was then consumed within the next five hours. The label was disposed in a bin to deactivate the RFDI tag and the asset was automatically recorded as consumed.

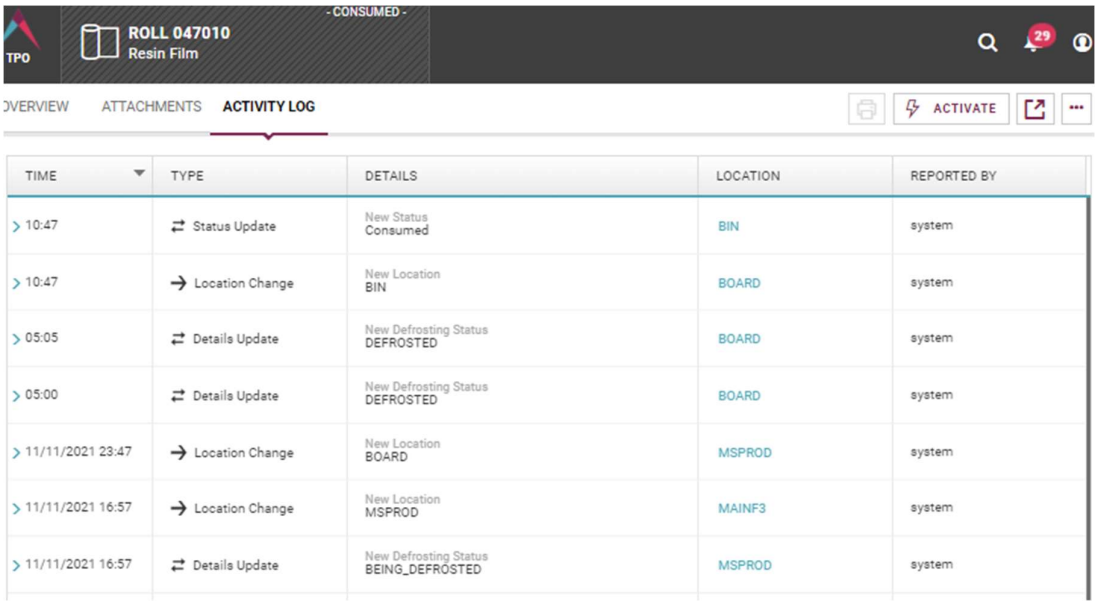

Figure 11: automated asset tracking and defrosting time recording.

Use Case Discussion

Preliminary results from the 2021Q4 trials confirm that the following automated-asset tracking system requirements have been met:

- ✓ Must be fully transparent to current manufacturing process and not require any additional tasks from operators.
- ✓ Must be passive and not require the use of any battery-operated devices.
- ✓ Must not require the use of additional tracker or labels.
- ✓ Must survive a high-rate industrial manufacturing environment with FLT's.
- ✓ Must survive the full distribution chain cycle.
- ✓ Must be compatible with an industrial environment where ATEX-zones are present.

Regarding the last point, none of the gates were positioned within any of the ATEX-rated zones present on site. Furthermore, the EIRP for the RFID installation used in this PoC was calculated as 33dBm maximum, i.e. about 2W. Guidance from the PD CLC/TR 50427:2004 BSI standard regarding the safe distance around a UHF RF transmitter in the 862MHz to 960MHz frequency range from ATEX-rated zones confirmed that there was no ATEX risk associated with the selected RFID installation as deployed.

More detailed considerations will be given in the next paragraph, but it can generally be concluded that the next two requirements below have also been met:

- ✓ Low installation costs and operation/maintenance costs.
- ✓ Must not require the acquisition of a specialized skill set not currently supported within the Solvay Group and be easily maintainable.

The relative breakdown of cost of the deployment of the automated asset and out-time tracking system is given below, excluding Solvay employees labour and overhead costs:

- Software development, deployment, license and support: 59%
- Printers and industrial RFID labelling configuration: 15%
- Network installation including optical fibre, PoE+ switch board and enclosure, fire wall, PoE+ data cables and installation testing: 12%
- RFID hardware (antennae, readers, etc…): 9%
- RFID gates installation: 3%
- RFID labels for 6 months of production on selected assets: 2%

Overall, RFID technology is a reasonably affordable technology to deploy for the automation of asset tracking. A PoE+ network installation is also seen as a reasonably cost-effective approach. If a wireless technology had been deployed, the installation of power supply cables would still have been required. Bearing in mind that 70% of the cost of the network installation is contractor labour, it is expected that the cost of routing power supply cables would have been of a similar order of magnitude.

Deploying a conventional hardwire network meant that no extra IT/OT skills were required. The network and firewall configuration and the Plataine TPO deployment were easily performed with the support of the Solvay Industrial cybersecurity team ensuring all Solvay Industrial cybersecurity protocols and NIST 800-171 requirements were met. The system will also be easily maintained by the Solvay IT/OT teams.

It was found that the weakest point in the physical installation is actually the co-axial cables installation, especially for the antennae mounted in our freezers. These RFID gates can be exposed to rough environment with risk of exposure to blast chiller (see Figure 12). It was found that ensuring a minimum db loss and good signal quality between the RFID antennae and readers required a specific skill set specific to co-axial cable installation and connection.

Figure 12: example of installation survivability testing after exposure to a blast chiller following a maintenance.

Regarding the requirement on high reliability and capability of self-diagnosis, the conclusions are as follow:

- ✓ Plataine TPO has the self-diagnosis capability. Automatic alerts will be raised in the following cases and the duration of the issues will be tracked until resolved:
  - i. As soon as a connection between an antenna and a reader is lost (e.g. due to a damaged co-axial cable or an antenna hit by an FLT). In this case the fixed IP address of the reader as well as the antenna number will be specified.
  - ii. As soon as a reader is disconnected from the on-premises edge server (e.g. a PoE+ data cable is disconnected). In this case the fixed IP address of the reader will be specified.
  - iii. If the connection between the on-premises edge server and the cloud-based server is lost.

- × The required high reliability of the full system for automated asset and out-time tracking was not demonstrated. Over 750 material assets have been created and tracked so far with an estimated reliability of 60% to 80%. This lack of reliability is attributed to the complexity of the industrial environment in which we are operating with large amount of carbon fibre-based materials moving around in palletized boxes by ped-pallet trucks and FLT's. With fine tuning of the RFID antennae to optimize the detection of the RFID labels at the gates, the optimization of some material flow

processes to facilitate automatic consumption and best practices in terms pallets transportation via ped-pallet trucks, it is believed that the detection reliability could be significantly improved. As a result, following the conclusion of this funded project in 2022Q1, Solvay has decided to extend the selected technology to two extra production cells as well as to extend the software license to pursue the evaluation of automated asset tracking throughout 2022 on its own budget.

5G INDUSTRIAL ASSESSMENT

5G Discussion

Solvay joined the asset tracking work package as a material supplier of composite materials with the aim to evaluate the potential of automated asset and out-time tracking both within the factory and ideally in-transit for its manufacturing and logistics operations. A second aim was to understand the relevance and potential of the 5G cellular technology within the context of a full deployment of automated asset and out-time tracking system within a factory and potentially throughout the supply chain.

5G Conclusions

In case of deployment, the automation of asset tracking would likely form part of the OT network which is subject to the strict Solvay industrial cybersecurity policy as well as industrial safety. Currently, cellular technologies are not allowed for process controls and process safety sensors. Since 5G mobile private network in an industrial setting remains a novel technology, it is still unclear at this stage about its potential within an industrial OT network. Further investigation is required to ensure cellular networks can be deployed securely and include local zones to minimise OT network risk. The emerging network slices included in the 5G standards but needs a deeper understanding.

In the particular case of this RFID deployment for automated asset and out-time tracking of time and temperature sensitive materials, a wireless cellular technology would probably compare unfavourably to PoE+ since cellular technology IT skills are not commonly available to deploy the cellular solution efficiently. The complexity of a cellular network deployment needs to reduce such that skills needed for deployment are easier to develop.

REFERENCES

PD CLC/TR 50427:2004: Assessment of inadvertent ignition of flammable atmospheres by radio-frequency radiation. Guide