Outcomes, Insights, and Best Practices from IIC Testbeds: Track and Trace Testbed

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This article gathers information from Industrial Internet Consortium's (IIC) Track and Trace Testbed. The information and insights described in the subsequent paragraphs were captured in an interview conducted by Joseph Fontaine, VP of Testbed Programs at IIC, with Michael Dietz, Product Manager SAP Internet of Things at SAP SE, Andreas Mueller, Product Owner Intralogistics Solutions at Robert Bosch GmbH and Dirk Slama, Vice President at Bosch Software Innovations and Steering Committee Member of the IIC.

TESTBED PROFILE

The Track and Trace Testbed was the first testbed approved by the IIC, kicking off the now-robust testbed program on December 5, 2014. The basic idea of the Track and Trace Testbed was to optimize a number of different Key Performance Indicators (KPIs) for industrial use cases. The initial focus was on manufacturing, in particular, the use of process tools. The testbed has been working with tightening tools, drilling tools, measurement tools, welding, riveting, etc. The KPIs most heavily scrutinized were those related to equipment efficiency on one side, but also process performance, process quality, and other. The original idea behind the testbed was to discover what data could be obtained from different sensors that were already built into tools, or attached externally in a retrofit style, in addition to retrieving tool performance data. The objective was and continues to be to gather data from the sensors or from the tools themselves to help optimize processes.

Sometimes, the data gathering is not straightforward. For example, in the case of an acceleration sensor, this sensor technology can be used to derive information about the usage of the tool. If there is no acceleration, the tool is not used, and vice versa. Sometimes it is necessary to drill deeper and access the native APIs of the tool to obtain information about how the tools were used. In the case of tightening tools, the objective is to achieve a tightening curve that contains a certain top and angle for each tightening process. The testbed team has also deployed specialized sensors that provide information about the localization of the tools and assets in use. Now, the testbed team has expanded this from process tools to include tools used in logistics – i.e., forklifts. The team is also currently analyzing robotic systems for autonomous transports in factories.

To further clarify the primary categories of the Track and Trace Testbed: Tracking is related to localization; Tracing is related to the usage of the tools. The testbed team also evaluates the combination of the two, analyzing data when a tool is being used with a specific configuration and calibration only in a designated area.

Process Tools Use Case - Tracing

The Track and Trace Testbed is solving the problem of finding the tools that are in use, then ensuring their use for the work each is programed to do, in the locale in which each tool is permitted. For example, *Program 87* is installed on a tightening tool, and *Program 87* is designed for tightening a specific type of screw against a specific type of material which creates two car windows. This particular tool, with *Program 87* activated, can only be used in Work Zone Number 3, because Work Zone Number 3 is the only location with a car needing assembly of a car window. All of other work cells are in a different process step.

The Track and Trace Testbed takes it down one level farther: When Track and Trace is combined with the Bosch ActiveAssist (the intelligent workplace – receiving work instructions from a Manufacturing Execution Systems (MES) system), it will activate the specific program on the tool for a given task and will prevent the worker from using the tool in any other position: The system will disable the tightening tool, unless it is being held in the right position related to the work requirements. MES are computerized systems used in manufacturing, to track and document the transformation of raw materials to finished goods – the "production process."

As an example of process optimization, one of the Track and Trace Testbed's first commercial deployments was with an aircraft manufacturer. The worker is required to very quickly perform many tightening actions inside the aircraft body. First of all, process optimization in this example relates to the fact that the worker no longer needs a paper list indicating his or her next task, or which tightening program should be used for a certain situation, etc. All of this is now automated via the tool. Secondly, the tightening tool now has the intelligence to determine that there is a problem, i.e., while the worker is tightening, the screw is breaking. The human eye cannot detect the breaking screw because it is happening inside of the hole. The tightening tool, in the Trace aspect of the testbed, will be able to detect the break and sound an alarm. This allows the start of a sub-process where the worker is able to unwind the screw, instead of being confronted with a broken piece of screw stuck in a hole, needing another tool to remove it or replacing the entire part needing the screw.

This aspect of the Track and Trace Testbed has been deployed by Bosch in its Craftsmen Sector. It has also been deployed with some of their original equipment manufacturing (OEM) customers, who use it in car production.

The initial implementation of the Track and Trace Testbed was a general-purpose implementation, using a standard set of sensors attached to different types of tools. But over time, the team has learned that they need different flavors of Track and Trace for different use cases and different products. So, the advanced version of Track and Trace for tightening tools looks very different from the advanced version for Track and Trace for forklifts, which integrates with SAP Vehicle Insights and SAP Warehouse Management.

Forklift Use Case - Tracking

Bosch is a lead user of technology and this technology is driving growth in their plants. Bosch runs a large manufacturing plant in Traunreut, in Bavaria, operating more than 40 forklifts in both a production environment and a huge warehouse of household appliances. They wanted to improve utilization and optimize the usage of these forklifts but were missing the transparency into the data that would allow them to meet these goals. So, they began to equip a forklift with sensor technology, a solution from a Bosch subsidiary company (view related video). This technology not only provides the localization data, but also provides data about shocks and additional information from the forklift. Bringing this data together, Bosch achieves a much better picture of what is going on in their production.

While Bosch was talking to SAP, they learned of an SAP tool used for external fleet management – expertise outside of the Bosch action plan, but sharing certain logistics principles. The two companies combined their technologies to create an intelligent forklift solution. Bosch's technology was used to retrofit the forklifts to collect the data in the plant. Different data sources are brought together and delivered to SAP where visualization – heat maps, of sort – are created to show the movement of the forklifts and ascertain their loads. This new generation of innovation has an ultrasound sensor attached to the front of the forklift, to detect whether there is a payload on the forklift or not. They now see the paths of the forklifts and avoid crashes, and Bosch also sees which forklifts are moving along empty and which forklifts are moving along with a load – creating business value by providing the data and analysis to optimize forklift loads.

With new data transparency for the forklifts, Bosch gains in process optimization. When managing a large fleet of forklifts, a small process improvement – reduction in efforts of running the forklift; reduction in operating with empty loads – results in noticeable direct savings. They analyze usage, driving time, brake times, and so on. Feedback from this analysis enables Bosch to increase utilization. With detailed understanding of utilization, new insights may result in unexpected recommendations, such as finding it possible to perform the same work with fewer forklifts. Data is easy to capture from connected machines standing in one place, connected to the local area network. For moving assets, such as forklifts, it is more and more difficult to capture real-time data from these moving objects. In a plant, there are many types of forklift and many suppliers of these forklifts. So, integration with different partners was required. Bosch now has the opportunity to perform analyses on data that is often not found in a production environment.

With localization, a primary objective is to mount the data on the forklift. In the case of the forklift, the localization vendor is the camera system. The camera system detects the exact movements of the forklift, using embedded systems to obtain the localization data. That data is collected while the forklift is moving, then is transferred as soon as there is a connection to the local network. The forklifts are usually connected to the wireless network. However, if there is a certain time when they have no connection as they drive behind small buildings, shelves and stacked materials, part of the data – especially the data for safety purposes – is processed on the camera, on the embedded system.

The camera-based system detects certain markers on the shelves and on the floor to obtain the general positioning. The camera algorithms then detect how the forklift is moving by the changing patterns on the floor. This is what is called inertial localization. It uses relative distance that reduces the number of markers needed on the floor.

A laser technology also exists, outside the features of this testbed, which bases the localization on the laser technology, and can be used either/or. There is a testbed and there is a technology which gives forklifts the possibility to move out of the building. Markers could also be used on the floor outside, or use a GPS device, which then uses GPS information for the localization. The localization technology on the device, on the asset, is much more precise, much more accurate and does not depend on line of sight. There are many possibilities for related applications using inertial localization.

IIC Resources and Interactions

When the testbed began, the IIC's Industrial Internet Reference Architecture (IIRA) was in its early stages of drafting. As the IIRA developed, the testbed team engaged in many helpful exchanges with the IIRA authors. The IIRA is a work product of the IIC's Technology Working Group and this testbed team worked closely with the IIRA authors to develop and apply the domain-specific views which convey the fundamental principles of the IIRA. When phase two began, it was much easier to reuse the key concepts that had been developed in the first phase. For example, when onboarding SAP, the testbed team was able to develop a shared language and share the same understanding of the reference architecture. This enabled the collaboration process to move forward much more quickly than if the IIRA had not already been established and accepted as the common architecture framework for developing interoperable IIoT systems.

Another working group of the IIC is the Business Strategy and Solution Lifecycle Working Group, or BSSL WG, of which Dirk Slama is co-chair. This Track and Trace Testbed was used to help shape the key elements of BSSL WG, in particular, the plan-build-run perspective of BSSL WG (See Figure 1, below). Dirk is also the co-author of the book, *Enterprise IoT: Strategies and Best Practices for Connected Products and*

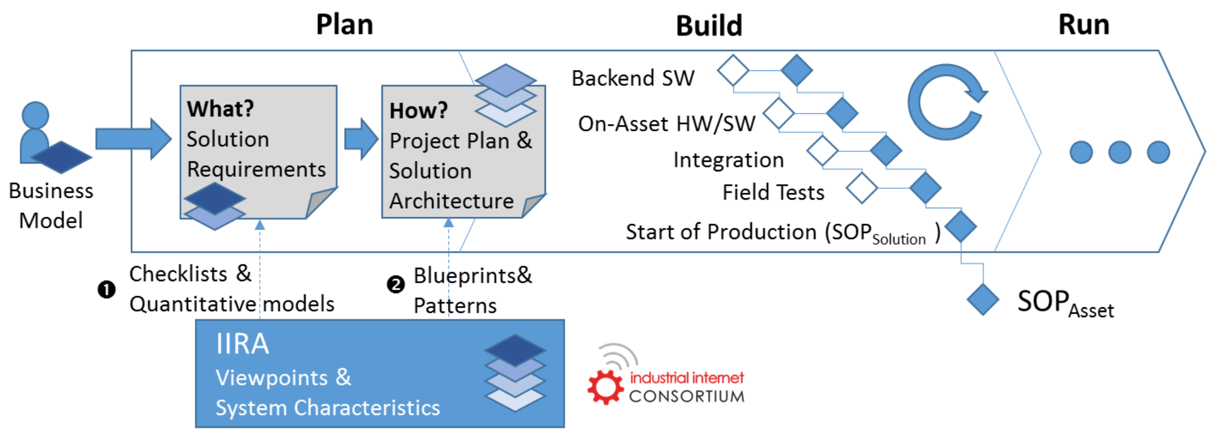

Figure 1: BSSL WG Plan-Build-Run Perspective

Services, [1] which includes a complete summary of the application of the IIRA to the Track and Trace Testbed and an analysis of the testbed from the BSSL WG point of view.

For phase two, the IIC's [Industrial Internet Security Framework] was available to the testbed team and was used as a checklist to assess the cybersecurity of this Industrial Internet system – a critical consideration in manufacturing and supply chain.

established standards. The IIC could then assist in identifying, through its liaison relationships, the standardization bodies with whom the testbed team could work to develop new standards.

Figure 2, below, offers a graphical depiction of these interfaces in a layered approach which also reflects the increasing complexity of a standards stack. The items on the left side reflect the tools and assets being tracked. The elements on the right side reflect the corresponding enterprise system. The arrows in the middle represent the APIs. Three horizontal layers have been identified. One layer, which is completely generic and agnostic, is a general purpose localization API that applies both to forklifts as well as process tools. And here, the Track and Trace Testbed only differentiates between indoor and outdoor, but it can be applied to different kinds of assets, and also different kinds of localization technologies.

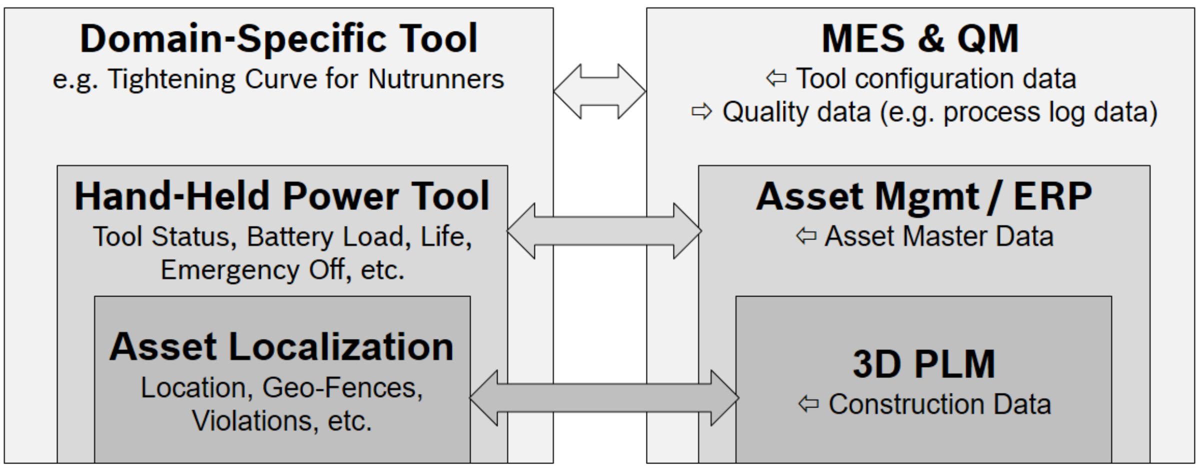

Figure 2: Track & Trace Open Source & Standardization

STANDARDIZATION

From the point of view of standardization, the testbed objectives can best be described with a diagram depicting the correlations between the tools and assets being tracked and the corresponding enterprise systems. The testbed team is trying to extract reusable interfaces that would open this testbed to solution components from different vendors. In analyzing both horizontal and vertical types of interfaces, the testbed team has not found any

The testbed team has discovered there are

[1] www.amazon.com/Enterprise-IoT-Strategies-Practices-Connected/dp/1491924837 & www.Enterprise-IoT.org

many different localization technologies based on cameras, laser, ultra-wide band, Wi-Fi translation, etc. An API provides either a 2-D or 3-D space and, at the end of the day, it reads a position. Users want to be able to bring this positioning to the enterprise software side of things. Moving up the standards stack, it gets a bit more specific. So, the testbed team has tried to identify the general purpose functions of the mobile asset. They discovered there are certain things such as battery load or status on/off which can be generalized.

The team discovered the interface for tightening tools can be generalized because in a tightening curve with torque and angle, it looks the same, whether looking at a Bosch export tool, an Atlas Copco® tool or another. But the tightening functionality is very different from drilling, welding or riveting types of functionalities. So, they began developing sets of interfaces which are more generic, and the same applies to forklifts. There are certain generic characteristics of a forklift, such as load – loading and unloading it. Then there are different classes of forklifts – i.e., electric, gas-powered, hand-powered.

There are many localization technologies but the testbed team could not find a single localization technology that would cover all of their requirements because there is indoor and outdoor localization technology. There is high precision localization technology that only covers a very small range. As examples, it provides precision down to the millimeter, but only within the parameter of two meters. And there is other localization technology that allows one to cover an entire factory hall, but that only provides precision of up to between five and ten meters.

The testbed needed a generalization that allowed the team to plug in different types of localization technology depending on the use case. In some cases, they needed to combine different localization technology, such as combining ultra-wide band localization technology with inertial technology for places where the sensor would not reach because of a production environment. The environments present many metals, shields, and other materials that make any kind of localization very tricky. Striking the right balance between the cost to establish this implementation and managing it within a manufacturing environment, whether indoor or outdoor, was required. Precision was one element requiring experimentation, finding different combinations for different use cases.

In addition, the team needed to explore which interfaces in existing enterprise implementations could be leveraged – what new functionality must be built and how it can be connected to the Track and Trace sensors. For example, the forklifts needed to integrate with SAP Warehouse Management. But also required was something that sits in the middle, taking the data from the warehouse management systems, collecting the information about movements and matching this information. This is where the combination of a Bosch-based solution and SAP Vehicle Insight was introduced in the forklift tracking.

There are a number of localization technologies available, but experimentation was required to determine which ones could be used for certain application areas and then decide how to integrate those through the technology stack. The team also had to employ analytic experimentation throughout the stack to decode the data and apply it in a way that was meaningful for the enterprise. As more and more data is collected, data scientists work with the data, build data models and compute the data. This complex and ongoing effort of the data scientists is not something easily standardized.

An interesting discovery in the midst of this testbed was the importance of a team approach: A team must come together because there is no individual who can solve all of the issues. Technology integration is necessary because more than one technology is essential to fulfill all of the requirements. So technologies are combined on the factory level. The team works together with data scientists, IT experts and process experts to develop the models to interpret the data and deliver the business benefit to the customer. The Track and Trace Testbed is a joint effort with regular meetings conducted with IT scientists from Bosch and SAP, business partners directly from the customer plant and technology partners.

Experimenting to Determine Standards

The Track and Trace Testbed team must experiment at every stage to determine which standards to apply, whether an existing standard need changes and whether their efforts are relevant for the future. This is time consuming and requires careful discussion and evaluation.

There are two standards categories at play within the Track and Trace Testbed: the common data model and the data in communication. For the common data model, there are no currently existing standards.

The Track and Trace Testbed team has developed a data model which has been standardized within SAP. Having a common data model gives flexibility, but it also enables the standardized structure to be applied to other current and future use cases. This standardization has enabled the testbed team to develop a solution quickly.

For data and communications, there are many standards. The data and communication of the testbed is more challenging and is still under discussion. The forklift team may leverage an existing standard and is currently evaluating which data and communications standards will be most useful to the testbed. It is not easy to figure out the best standardized way to exchange data between these two worlds: messages and protocols and within the technology. Communication standards exist and the testbed team is looking into standards (such as MQTT) for communications purposes between devices and the back end, identifying the right standards to apply for the testbed's communications purposes.

There are many standards related to the factory tooling aspect of the testbed, such as CIT, HCT, among others. But a layered perspectives on API standards is currently missing.

When working with standards, there are two steps: first the team applies the data model standard to the solution they have developed. This they sell that solution to the customer, enabling the customer to achieve the benefits of the data model. Then the team considers bringing the newly developed standard to a standards organization to see if this is a data model applicable for general use. In the case of the data model developed for the Track and Trace Testbed, they have not approached a standards organization, to date.

The development of asset vs. backend and localization standards are being driven by the testbed. Recognizing that they will need standards to manage devices from many vendors on the factory floor, the Track and Trace Testbed team is exploring options for standardization of device management with the Object Management Group (OMG, with more than 20 years of experience developing manufacturing standards).

OUTCOMES

At the time of the interview that led to this article, the forklift use case was up and running and the plan was to present collective results to management in June 2017, a milestone culminating from sharing on-going results with management on a weekly basis. The testbed team plans to finalize the data analysis to present the full picture of the business benefits. From there, they will make decisions on how to improve testbed productivity. All of the forklifts and their data are collected and connected. The systems are in place and the data can be analyzed. But to make it *really* productive, it will require another step.

It took a very long time to arrive at the technology decisions and to gather the data about the fleet. The biggest delay came from the integration of technology into the physical process. When the testbed reaches the goal of bringing the implementation to a certain level – to a steady state – the team will move into a pilot implementation.

In reaching this current stage of high productivity, but not yet steady state, the first hurdle to overcome was bringing it to a customer who would allow this productive environment to be set up as a testbed. In this case, the customer was Bosch. Another hurdle was integrating new technology into equipment. This requires more than attaching sensors to the forklift. The testbed team had to arrange with the forklift producers to access the forklift data from the embedded software. The team signed the requisite agreements and asked about safety features, but by using this data, they interfered with the machine itself. And though there were many concerns about safety, which have now been addressed, the need was recognized by the team and the forklift companies that safety is an objective that must be pursued together. They now bring these different data sources together to integrate them into the Bosch IOT environment. The next stage is to bring this data together with SAP and to exchange it in a steady, stable and accurate method.

Business Value

Ultimately, the team seeks to define and achieve the anticipated business value. What is the business value to be provided by this testbed? Can somebody in the warehouse interpret these measurements and realize that this information is exactly what they need? The business value lies in the delivery of knowledge that is of interest to that person: Will these insights make an impact – and how big of an impact? Is this useful – and how useful? Much of this effort is experimenting around the business model itself, not just the technologies.

The testbed team is now evaluating a business model where the customer appreciates the value of the solution and the partners are designing how they will approach the market together. Who do they need as partners in this business? How will their business model change in the future? These business model discussions and realizations run in parallel with the technology solution.

From Bosch's perspective, from inside the plant and from business partners, there is a great deal of interest in this topic. From a business perspective, there appears to be huge potential in the market for this solution. That is why Bosch and SAP are pushing together to bring this solution to the market.

Management's primary focus is commercial interest: Leverage the solution blueprint that emerged from the different installations, multiply this to eventually develop a standard product offering around this solution blueprint and jointly take this to market and expand the sales.

In the Trace side of the testbed, value has certainly been gained, including process improvement, quality improvement, safety and security. The processes the testbed team has planned to enhance through the testbed are often very product-specific. One of the next steps is to quantify the business benefits with the customers.

The Track side of the testbed has received very positive user feedback which has aided in the evolution of the testbed. The main business value derived from this deployment is the increased utilization and the cost savings and increased efficiency derived from this improvement.

This technology works for every piece of moving equipment close to a plant and its surroundings. In related open space environments, such as parking spaces with vehicles moving around in a dedicated environment, geo-transmitting on larger parking spaces may be a potential use case.

Challenges, Innovations and Achievements

One significant challenge for the Track and Trace Testbed was identifying the right localization technologies for the right use cases. Now the team is using the correct range from ultrasound high precision tools for wide-band to inertial technology to ELE and Wi-Fi-based triangulation, and so on. This is a very important element of the testbed – they are now mapping these different variable technologies for different use cases and wrapping them in a generic API to replace different localization technologies. Also of critical importance is the fact that the team was able to very quickly bring together this ecosystem of partners to support these innovations.

In the aircraft manufacturer deployment, the open aircraft body posed another challenge to the factory tools tracking side of the testbed. Wireless communication to the outside of the aircraft was required, yet the aircraft body prevents standard wireless communication through the sides of the plane. To enable multiple tools to be connected inside of the aircraft body, the team developed a peer-to-peer type of communication. There were also numerous challenges related to specific tools: For example, retrieving the data from the tightened tools meant identifying the right interfaces for tracing, requiring the development of specific APIs.

From the customer perspective, the implementation of the testbed has been so successful that it is perceived as a competitive advantage, making them reluctant to go public in describing their successes. Not a bad outcome to report!

Lessons Learned

A Never-Ending Story

In the Track element of the testbed, one important lesson learned is the realization that this is a never-ending story. Once the customer became involved, use cases were quickly added, resulting in specialized sub-solutions, or extensions to support specific combinations of tools – tightening, riveting, welding, etc. Moving a testbed into a production environment as quickly as possible is recommended by the testbed team, as they experienced such great acceleration of their innovations with the help of customers. Without taking this step, and taking it early, a testbed often remains in a theoretical stage and cannot help quite as much in speeding the solution to market.

Customer Involvement

Another key lesson learned is the invaluable feedback received by involving a customer or customers in the early stage of the project – find a way to set up the project in a productive environment; finding a customer willing to support, provide feedback and endure the unforeseen consequences (good and bad).

The users are the very key of the testbed. They were given some initial ideas and now the testbed is pushed forward by the users who were not previously privy to this new technology: They are now asking for more. The users run the tests as they are running the technology and provide feedback to the testbed team on all aspects of the deployment. The users provide very profound information from the utilization of the technology and the ideas provided to them.

IIC Influence

Discussing the project within the IIC assists in finding partners, accelerating those conversations and drawing attention to the implementation of the given technology standards. For the first phase of the testbed, it was very easy for Bosch to connect with Cisco and TechMahindra. Then, a joint IIC and Plattform Industrie 4.0 event triggered a second phase where SAP and Bosch collaborated to accelerate the forklift use case.

The approach taken by this testbed, building a small ecosystem with partners and customers, enabled them to go to market with their solution more rapidly than they had expected. The ecosystem they developed and the resulting management attention is a very powerful combination.

Early Management Involvement

And lastly, in terms of lessons learned and advice to others, involving management as early as possible is of great importance in developing the plan from the user perspective but also from the strategic business perspective. Hosting the testbed with the IIC gave the testbed credibility and caught the attention of the right levels of management within Bosch and their partners.

The testbed team is developing best practices specifically related to Tracking and Tracing in the two use cases, Process Tools and Forklifts. They continue to develop those best practices by experimenting with various combinations of different localization technologies for different use cases and integrate them with the existing enterprise landscape.

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