Wirelessly recorded positioning data of objects and personnel provides invaluable spatial and temporal information for employing the digital twin in Industry 4.0 production models. Flexible, self-organizing manufacturing concepts of the future require the precise and continuously updated mapping of material flows to enhance automation control as well as to improve production visibility, analysis, and optimization. Real-time locating systems (RTLS) technology can provide this information and, by combining different applications in one system, offers a compelling business case for deployment.

Industrial companies are now transitioning to Industry 4.0 production models, assisted by the digitalization of their operations, from front-office administration to plant-floor logistics and production. This transformation is driven by growing competitive pressure and rising customer demands for a wider range of product choices to meet specific needs.

Implementing Industry 4.0 concepts require real-time, deterministic communications networks to run a plant’s operational technology (OT). In contrast to the “best-effort” IT networks in offices, OT networks must ensure control commands can get to machine actuators and other field-level devices precisely when a valve must open or other operations have to be executed. In effect, OT networks provide the digital backbones that industrial enterprises need to control, automate, and optimize their workflows and use of materials. These are key components to engineering flexible, self-organizing manufacturing capabilities.

For years, two types of OT networks have been widely deployed to identify tools, materials, and goods inside plants: Optical identification systems, such as bar-code scanners, and radio frequency identification (RFID) systems. They enable the singular detection of specifically tagged objects as the latter move through the sensing fields of their respective types of readers.
But while these identification systems provide valuable data to plant operators, they are limited in their scope and applications. That’s why, to supplement those systems’ capabilities, Siemens provides SIMATIC Real-Time Locating Systems (RTLS) technology.

Using ultra-wideband (UWB) wireless technology and triangulation techniques, the Siemens SIMATIC RTLS platform can locate objects and workers equipped with UWB transponders to within a few inches or centimeters of their actual positions with latencies of less than 1 second.

UWB, also known as pulse radio, provides “see-through-the-wall” radar-like capabilities, so little or no RF engineering is required to install. That’s because its penetrating signals don’t bounce off metal or get absorbed by liquids as other wireless radio technologies can.

Objects can include tools, material handling containers, mobile robots, automated guided vehicles (AGVs), forklifts, work-in-progress, and finished goods. Workers can have transponders affixed to their attire, hard hats, or security badges.

SIMATIC RTLS technology can also detect and report their motion, acceleration, elevation, and orientation. It can then relay all this positioning data to higher-level systems in real time, making it available for a variety of plant applications. In operation, RTLS continually links the type of object (“What?”) or individual worker (“Who?”) with their location (“Where?”) and time of position localization (“When?”), whether the objects or workers are at rest or in motion.

Siemens SIMATIC RTLS solutions can help plants and logistics operations to achieve several key advantages:

- **Streamline workflows** for greater efficiencies, asset utilization, and production throughputs.
- **Gain greater visibility** into those workflows, by combining RTLS data with other data, and apply advanced analytics to identify process improvement opportunities.
- **Boost worker and overall plant safety**, by knowing where workers are at all times and their status, as well as by restricting worker and vehicle access to accident-prone or inherently dangerous areas.

**Giving digital twins real-time spatial and temporal positioning dimensions**

As industrial operators expand their digitalization efforts within their operations, many are implementing innovative, Industry 4.0 production models that take advantage of the digital twin concept. This is a software-based, 3D virtual proxy for all physical assets, such as tools, materials, and products, used in production.

Digital twins can simulate and monitor end-to-end production processes, from the receipt of raw materials through shipment of finished goods. They can illustrate and animate just about every facet within a plant: from the extremely granular detail of a machine’s components and sub-systems to larger views of the machine itself, the production cells in which the machine will operate, and entire production lines and plants.
With such a comprehensive virtual representation, engineers can conduct a wide range of simulations to evaluate their various automation approaches to find the best one—doing it much earlier in the process. They can then monitor actual performance of all their assets against baseline parameters, either as-designed or as-built. If variances occur, they can investigate the issue and dispatch a maintenance technician before a disruption occurs.

But until RTLS technology debuted in recent years, digital production twins tended to be static models, without a way to incorporate the dynamics of moving objects and personnel. Now, with RTLS, digital production twins can be continually updated with both spatial and temporal dimensions of what and who is where and when.

Simultaneously enabling diverse applications
Siemens SIMATIC RTLS solutions can enable many different industrial applications. Here are some representative use cases:

- **Tracking**: At any one time, plants can have several thousand objects in motion, from material pallets and containers to semi-finished and finished products. With constantly updated tracking and mapping of these material flows, plant operators can better control, analyze, and optimize them. Machine setup processes can start as soon as a specific material arrives. Rarely used resources, such as indoor cranes or temporary storage areas, can be utilized more efficiently, if the goods in circulation at a given time are known. Expensive search and assignment processes can be avoided. (See Figure 1.)

- **Mobile vehicles**: AGV transporters require location information about the vehicle and the objects to be transported to ensure free navigation as well as for loading and unloading. Mobile robots and autonomous forklifts need similar information to do their tasks.

- **Maintenance**: Support processes, such as plant, vehicle, or container maintenance, can benefit from location information by shortening search processes and avoiding errors in maintenance assignments across plant infrastructure, production cells, and tools.

- **Quality assurance**: Plant engineers can design production processes to minimize or even eliminate potential errors, such as workers using tools that are incorrectly positioned. Automatic documentation of tool use on specific products is also made possible.

These examples show how Siemens SIMATIC RTLS technology can enrich digital production twins with real-time positioning information. Importantly, the same RTLS infrastructure can simultaneously enable these and other applications of the technology. This means that the more applications RTLS can support, the more cost-effective it becomes – making the return on investment in a business case for RTLS deployment even more compelling.

How RTLS radiolocation infrastructure operates
The Siemens SIMATIC RTLS platform consists of a wireless hardware transmission and signal-gathering radiolocation infrastructure; a locating server; and the integration of the RTLS information and events to higher-level systems. Specifically, it features these four interworking components:

- **Transponders**: These devices are active UWB transmitters that come in various models and sizes for being fitted to material containers, workpieces, robots, AGVs, forklifts, and people’s work badges or attire. Whether in motion or at rest, they send UWB signals at defined intervals to receivers called anchors. Transponder data is captured every second, with their positions determined in the form of two- or three-dimensional coordinates.

- **Anchors**: These devices are fixed, typically wall-mounted inside plants and warehouses, and record the signals emitted by different transponders. They serve as reference points for the localization calculations and enable the collection and transmission of localization data. At least four anchors mark the transponders’ UWB signals with a fixed position and time stamp, then pass the data to the gateways.

- **Gateways**: These devices, which can also be used as anchors, collect the recorded data and transmit it to the Locating Manager server. Gateways act like anchors, but feature an interface for IT network connection. Localization data and optional application-specific data can be exchanged between the wireless localization network and the localization server via the IT infrastructure.

- **Locating Manager**: This server-based software application calculates the real-time position of individual transponders and relays the data to higher-level systems for use in RTLS-enabled locating applications. With a rules engine as part of the Locating Manager application, it is possible to define specific events and locations and configure higher-level system responses, such as alerts and action commands.
The anchors can only target the transponders, whereas the gateways also provide the interfaces to the SIMATIC Locating Manager software via a plant’s OT or IT networks. The omnidirectional characteristics of their integrated antennas require that the SIMATIC RTLS anchors and gateways be affixed as unobstructed as possible to ensure optimal coverage.

With the Siemens SIMATIC RTLS platform’s Power-over-Ethernet (PoE) feature, one communication cable is enough to operate the gateways, while the anchors only require a voltage feed from a facility’s electrical system.

If additional networking infrastructure is needed, such as wireless local area networks (WLANs), plants and logistics operators can deploy switches, routers, access points, and other devices from the proven Siemens SCALANCE and RUGGEDCOM portfolios. These can provide the basis for the industrial Ethernet and industrial WLAN networking capabilities through which the SIMATIC RTLS gateways can be networked with each other and with the Locating Manager server.

**Two methods of RTLS radiolocation**

Siemens SIMATIC RTLS solutions offer two methods of radiolocation. Each has different advantages and disadvantages depending on the application:

- **Time Difference of Arrival (TDOA).** This radiolocation method involves sending signals between an RTLS transponder and several corresponding anchor points, each in its own fixed position. TDOA calculates the transponder’s position from the differences in the travel times between the different anchors. It is especially advantageous for tracking large transponder populations, processing high measurement rates, and maximizing transponder battery life. TDOA radiolocation scales up well with increasing numbers of transponders – several thousand devices can be measured in just seconds of time. (See Figure 3.) Also, because transponders typically emit short signals, the TDOA minimizes a transponder’s power consumption, ensuring a long battery life over several years.

- **Two Way Ranging (TWR),** also known as Roundtrip Time of Flight (RTOF). This radiolocation method measures the direct distance between an RTLS anchor and a transponder by gauging the time a signal takes to travel to and from the two devices. By measuring the distance of an object’s or worker’s transponder to several anchors, their 2D or 3D positions can be calculated using trilateration and multilateration techniques. This radiolocation method is best for applications that require high accuracy and only a few transponders, such as tool location. Unfortunately, TWR/RTOF radiolocation cannot accommodate large transponder populations because it requires large numbers of communication connections – consuming time, channel capacity, and battery power.
Real-time radiolocation
In RTLS terms, “real-time” describes positioning information – continually updated and available – of all objects and workers equipped with a transponder. The determination of an actual radiolocation measurement depends significantly on an RTLS system’s measuring rate, usually in the range of seconds or minutes. This real-time factor is especially important when the RTLS locating data is used to control production processes as the next section describes.

Interfaces to higher-level systems
With gateways to both OT and IT networks, Siemens SIMATIC RTLS platform can feed precise, real-time positioning data simultaneously to a large number of target systems, including manufacturing execution systems (MES), enterprise resource planning (ERP) systems, and plant safety systems.

Plant operators can configure the SIMATIC Locating Manager to filter locating data for specific production tasks to be performed, based on the object type, such as container, vehicle, tool, or a worker’s access privileges. Some examples:

- **Location data can indicate a process event** – “material reaches machine” – instead of just recording a material container’s x-y-z position. In turn, this can trigger an MES response that sets up or initiates the next production step regarding how the material will be processed.

- **Location data can guide and document tools**, such as an auto-fed, power screwdriver. RTLS can help plant operators identify a specifically tightened screw on the basis of its x-y-z position and the comparison with the product’s 3D digital twin model, then store that data together with relevant tool data (e.g. torque) in a product database.

- **Location data can ensure more efficient resource use** by updating ERP systems with status and position of various materials and goods, so search processes can be minimized or eliminated and local bottlenecks or oversupply situations can be detected more quickly.

- **Location data can enhance plant safety** by controlling access to dangerous areas and, if accidents occur, by improving response times and effectiveness. RTLS can enable the latter by showing plant operators and first responders – before any of them arrive on an accident scene – which workers are affected.

SIMATIC RTLS: Making Industry 4.0 production models more dynamic and precise
Siemens SIMATIC RTLS solutions can help industrial enterprises enact more Industry 4.0 self-organizing concepts in their operations by adding real-time location data of physical objects and workers to their digital production twins. Doing so makes their digital twins much more dynamic and able to reflect current operating conditions inside plants and logistics facilities.

In turn, this enhanced visibility can help operators to better analyze and optimize their workflows to reduce costs and errors, improve product quality, and boost their competitive standing and profitability. With Siemens SIMATIC RTLS technology, they can lay a solid foundation for advanced, end-to-end digitalization that can benefit their operational efficiencies and productivity for years to come.