# Innovative 2D|3D Radar Technology for Scrap Material Volume Measurement & Crane Positioning in challenging Environments

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## INTRODUCTION

This paper explores ground-breaking applications of 2D|3D radar technology for scrap metal volumetric measurement and high-precision crane positioning. Originally coming from a mining context, with numerous installations all over the world, iPosition™ and iStockpile™ are based on industrial-grade and highly robust radar hardware and customized software. Designed to withstand high heat and to penetrate steam, fog and rain/water, solutions have the potential to revolutionize many applications in the steel industry beyond crane positioning and volumetric measurement presented here.

## DISCUSSION

### Crane Tracking & Scrap Metal Volumetric Measurement Motivation

Tracking the movement of cranes in a melt shop has become commonplace throughout North American plants. Crane tracking systems provide several key benefits, including:

- Helps crane operator to improve position accuracy especially for complex operations.
- Analyze usual crane trajectories to optimize operative practices.
- Analyze crane operator operation to spot safety issues (high speed when loaded, etc).
- Display of crane situation in HMI helps coordinate ladle and other loads movements with the melt shop operation.
- Increased safety in cranes movement, avoiding collisions and restricted areas, and improving operative practices.

Currently, the industry knows three crane tracking solutions: Mechanical encoders, RF Triangulation solutions and laser distance measurement, all of which come with significant drawbacks. While mechanicals encoders are high maintenance and require frequent calibration due to slippage, RF Triangulation has acceptable resolution but installation and calibration is difficult. RF also requires constant maintenance and support.

Finally, lasers have problems with steam and fumes and are therefore not suitable for melt shop environments. The illustration below shows the principal difference between radar and laser: While laser works with a mean wavelength of 1 micrometer, radar has a much broader wavelength. Taken into account that collision particles in industrial environments have about the same diameter (2 micrometers) as the laser's wavelength, frequent particle collisions, refractions of laser light and hence erroneous measurements are the result. Radar, on the other hand, avoids these collisions for the vast majority of electromagnetic emissions simply by travelling "around the dust particles". Please see illustration below for more on this issue:

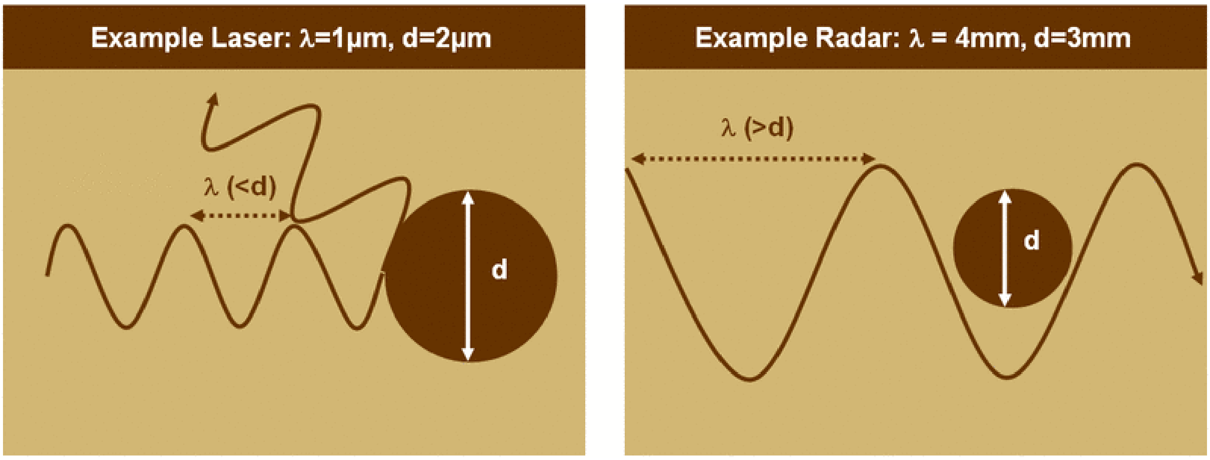


Illustration: Performance of Laser (left) and Radar electromagnetic waves in heavy-dust environments

**Introducing radar-borne positioning & volumetric measurement solutions iPosition™ and iStockpile™**

This paper only focuses on two applications of our original radar technology within a steel context. More applications are currently being adapted to the specific conditions of the steel industry from their original application context in mining and material handling.

In order to avoid the severe drawbacks of laser-based and alternative approaches to crane positioning and inventory control in the steel industry, we have developed highly-robust radar hard- and software. iPosition™ works with a highly focused radar sensor, the iLDR™ (LinearDynamicRadar), which allows to track machinery and distances to molten material surfaces in real-time and with micrometer-precision.

For iStockpile™, the iDRR™ (DualRangeRadar) sensor is used. Typically, the sensors are installed on the infrastructure surrounding a scrap metal yard or holding vessel (silo, dome, etc) to measure the material surface in real-time. The sensors can perform 3D measurements of scrap metal stockyards even from fixed installations.

Alternatively, the same iDRR™ sensors can also be installed on any type of machinery operating the stockyard, such as moving cranes. In this case, the movements of the crane on the rails must also be monitored in real-time by the iLDR™ sensors. In combination with the surface data produced by the iDRR™ sensors, it is possible to generate highly accurate 3D images of the stockyard and volumetric contents.

In any of the above applications, the iRPU™ (RadarProcessingUnit) is the central piece to which all sensors are connected. Here, the complex time-coded calculations are done to process the raw radar data into meaningful process data available on our own HMI iWEB™ and for PLC integration into any interface from 4…20mA via Profibus DP to Modbus.

**Solution 1: iPosition™**

In this specific ongoing project, the customer was trying to find a highly reliable positioning solution for one crane in a steel meltshop. The crane to be equipped with iPosition™ had an approximate width of 80’ (about 24.38 m) and a longtravelling length of 375’ 4’’ (about 114.45 m). The task was to track the position of both crane and crane trolley (with hook) to trigger a warning or alarm whenever the hook hovers above defined areas within the melt shop. Please see excerpt from melt shop plans for more details:

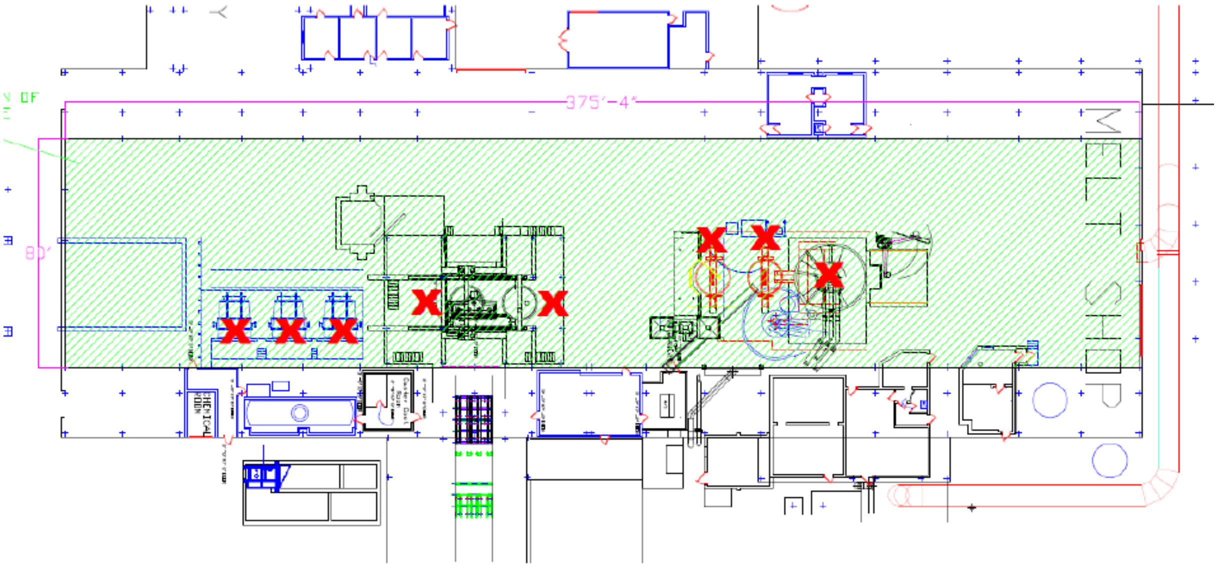



Illustration: View from above Red x represent areas of required alarm if crane moves into/above these

To achieve this end, the following installation was suggested to the customer:

- 1 iLDR™-1 (LinearDynamicRadar) sensor on crane for long travel positioning (x-axis)
- 1 reflector shield-1 installed on infrastructure at end of rails with clear and unobstructed line of sight to iLDR™-1
- 1 iLDR™-2 (LinearDynamicRadar) sensor on crane for trolley travel positioning (y-axis)
- 1 reflector shield-2 installed on crane trolley structure with clear and unobstructed line of sight to iLDR™-2

**iLDR™ (LinearDynamicRadar)**

The iLDR™ radar sensor offers reliable measurement of 1D distances between the radar frontend and any surface capable of reflecting microwaves. The maximum measurement distance is about 400 m (1000’). The iLDR™ offers an extremely high update rate of up to 1000 measurements per second and an accuracy of <1mm (1/32’’). The in-built RadarProcessingUnit (iRPU) offers a basic easy web based management and service interface, visualizing current and historic measured data.


Image: the iLDR™ Crane Positioning and Molten Surface Distance Sensor

How does it work? As can be seen in the illustration below, the time of flight of the radar beams (represented by red dotted arrows) between the iLDR™ sensors (radar signal emitter/recipient) and the full-steel reflector shields installed at the far end of the rails and on the crane trolley (with hook) determines with an accuracy in the micrometer area the exact position of crane and trolley inside the working area. All measurements are in real-time and performed by industrial grade hardware components, which erase the chance of failures due to extreme heat, dust, mechanical shocks or other encroachments that put other technologies out of order.

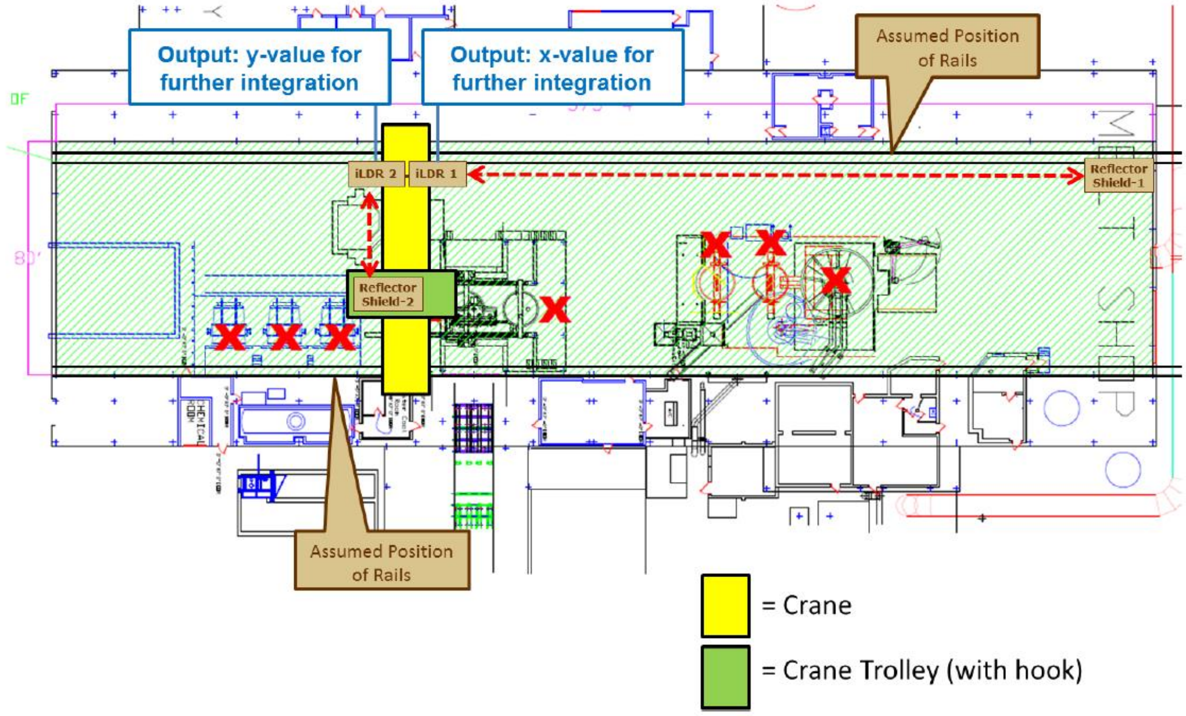



Illustration: View from above, showing all equipment in approximate installation positions + connections.

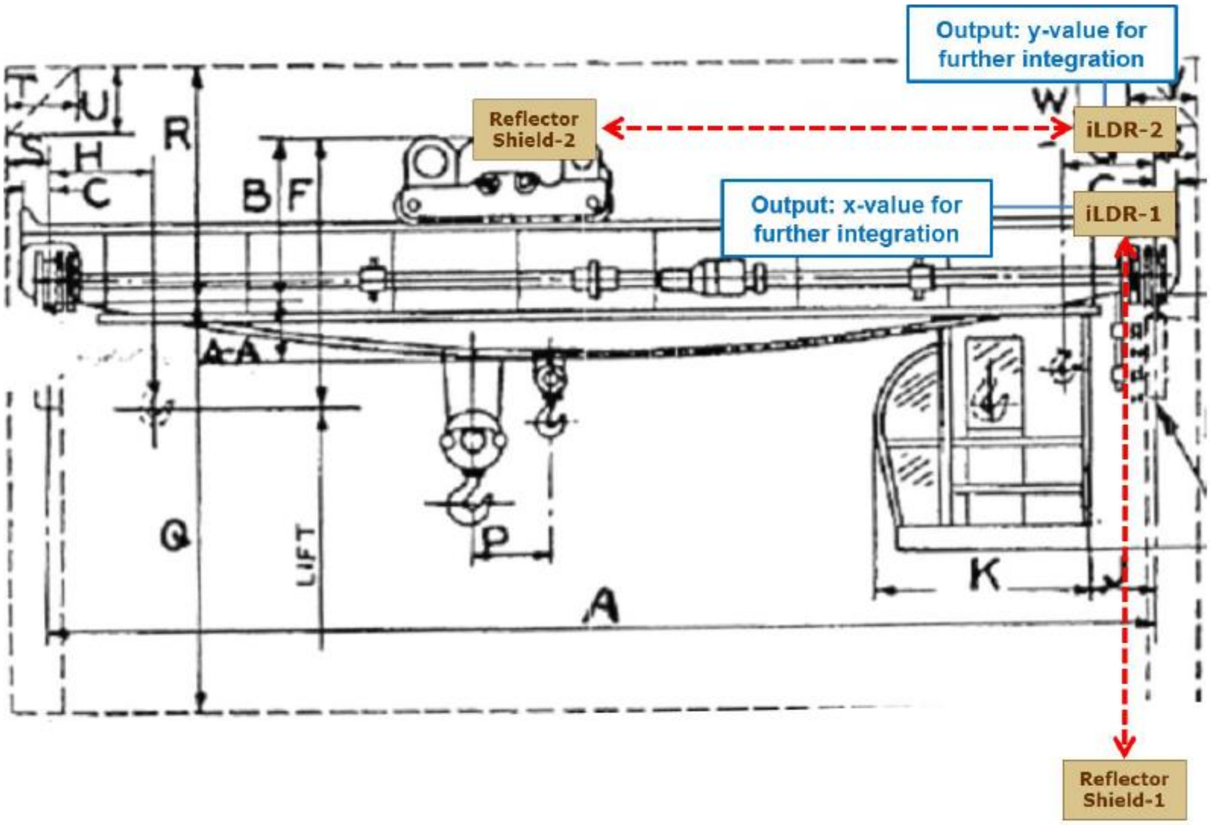



Illustration: Crane with equipment in installation positions + connections.

While this positioning solution is new to the steel industry, it has already seen many successful installations in other industrial environments in South America, Canada, Europe and India. Positioning solution installation example: For one customer in the Netherlands, the position of a moving operators cabin on a crane had to be monitored at any given moment and under all environmental conditions such as snow, heavy rains, dust etc.

For this solution, one iLDR™ and one reflector shield were installed, both looking in each other’s direction parallel to the central crossbeam of the crane structure under which the cabin moves from left to right. The result is a highly resilient and reliable positioning solution, as can be seen in the following illustrations and images of the installation:

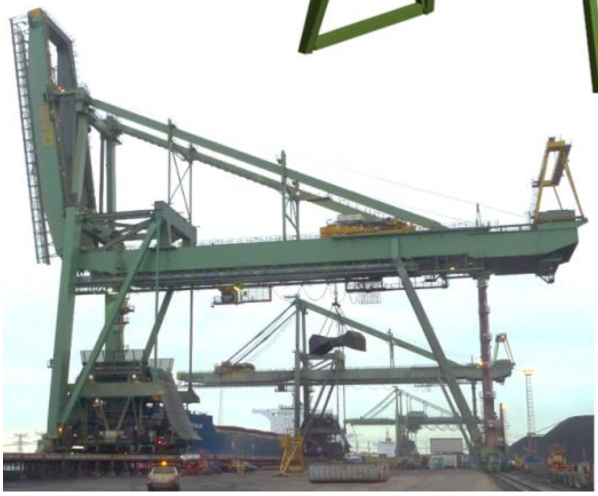
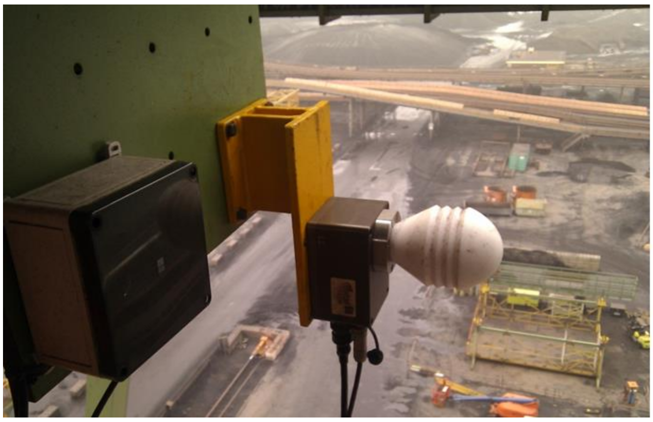



Illustration & Images: For this Dutch customer, the task was to track the position of the cabin at any moment



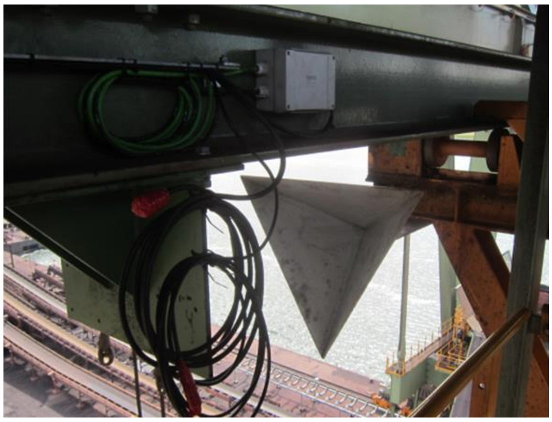


Illustration & Images: This iLDR™ cabin positioning solution with the iLDR™ sensor (left, exposed to sea spray, rain and fog, and in full operation) and the reflector shield (right) which does not need to be powered

**Solution 2: iStockpile™ for scrap metal volumetric measurement**
iStockpile™ was originally developed for permanent and real-time inventory control in large material stockpiles in the mining industry and has seen many installations, predominantly in South America, Australia and India.

How does it work? In a typical installation spot for iStockpile™, the customer has a material stockpile (ores, minerals, metals etc) operated by moving machinery (tripper car, mobile crane, scraper reclaimer). Several DualRangeRadar (iDRR™) sensors are mounted onto this moving machinery in order to scan the surface of the bulk material below.

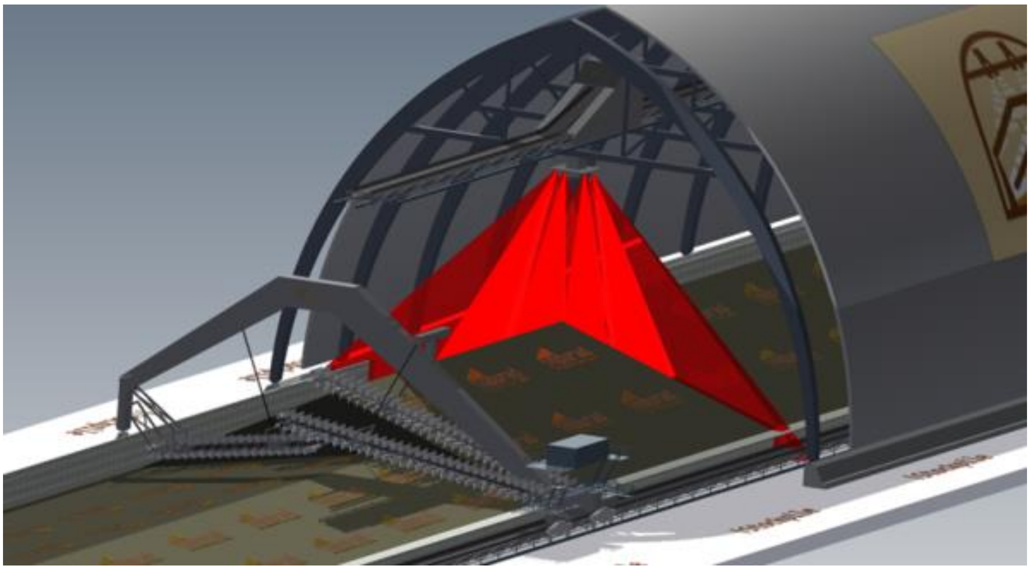


Illustration: Typical iStockpile™ installation environments with radar beams in red

The position of the moving machinery is permanently tracked by the LinearDynamicRadar (iLDR™) with highest precision (therefore, iPosition™ can be seen as a component of iStockpile™). Both types of information (bulk material profile & position) are then fused by the RadarProcessingUnit (iRPU™) in order to create real-time volumetric information and permanently updated 3D images of the bulk material.

**iDRR™ (DualRangeRadar)**
The radar sensor iDRR can be applied in industrial applications for collision avoidance, positioning and volumetric control. It offers reliable measurements of angle, distances and intensities to objects, structures or surfaces in challenging environments. The iDRR™ is a 77°GHz radar with an antenna offering two independent scans, both performed 15x per second. A wide range scan ± 25° in the range of 0.25−30 m and a focus range scan of 16° in the range of 0.25-150 m are available for different tasks and conditions.


Image: the iDRR™ Surface Profile Measurement Sensor

**iRPU™ (RadarProcessingUnit)**
The RadarProcessingUnit is available as an indoor unit for mounting in electrical cabinets, control rooms etc on DIN / T-Rail, and as an outdoor version for local data processing and installation close to the sensors in industrial, unprotected environments. For this reason, the outdoor unit comes with IP 66 and can also be manufactured to meet higher safety requirements.

The indoor unit offers sufficient power to process the data of various sensors at a time. Based on the number of ports (up to 4 ports available),several iDRR™ sensors can be connected on each of the port. The iRPUoutdoor also has sufficient power to process the collected data of several sensors and typically transfers this pre-processed information on to the iRPU™-indoor.

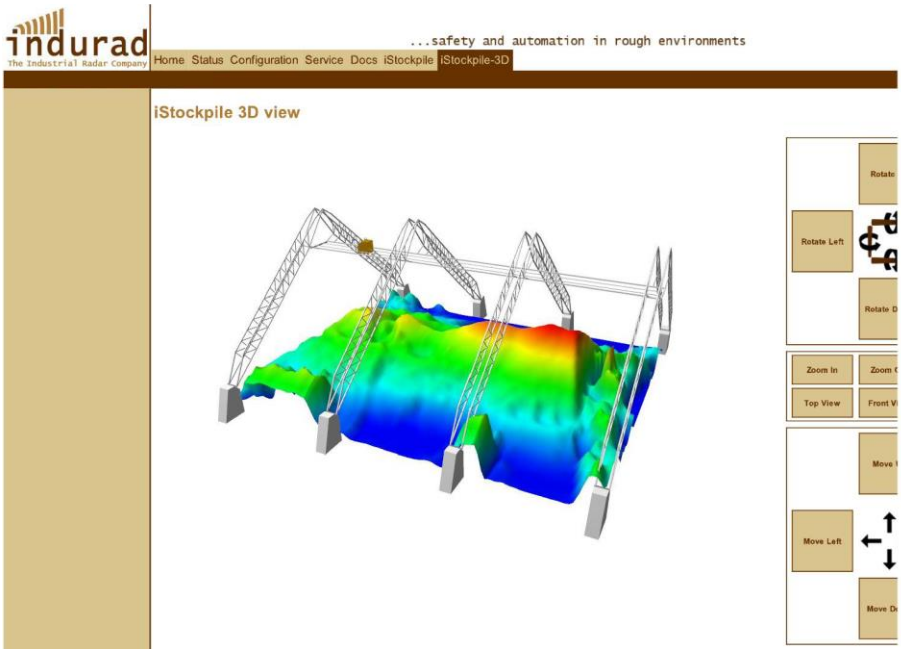
Images: The iRPU™ indoor version (left) and outdoor version (right)

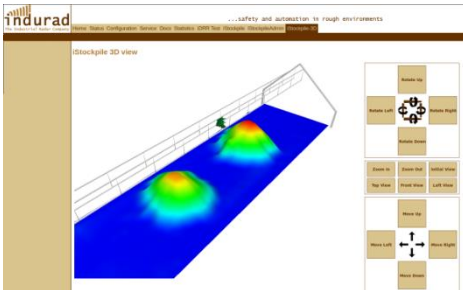

Photographs: iStockpile™ installation example with 4 iStockpile™ iDRR™ sensors installed

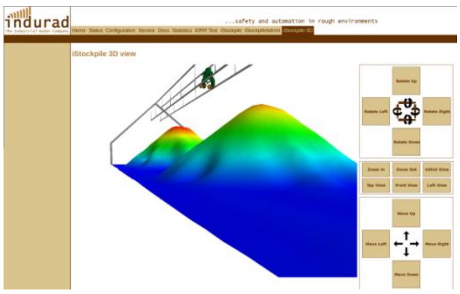
Photograph: Other view of same MLP Tripper Car in Mine Site

**iPosition™ and iStockpile™ Software**

The 3D image and all volumetric information will be displayed in the iWEB™ Webserver in form of a 3D height map to plan and analyze the stacking process as well as the stocked volume. The iStockpile™ software allows to differentiate between different areas of the stockpile (e.g. for different qualities of raw material). The iWEB™ based software allows to define different areas by drag and drop or parameters. Please find more impressions of iStockpile™ 3D software output in iWEB™ below:

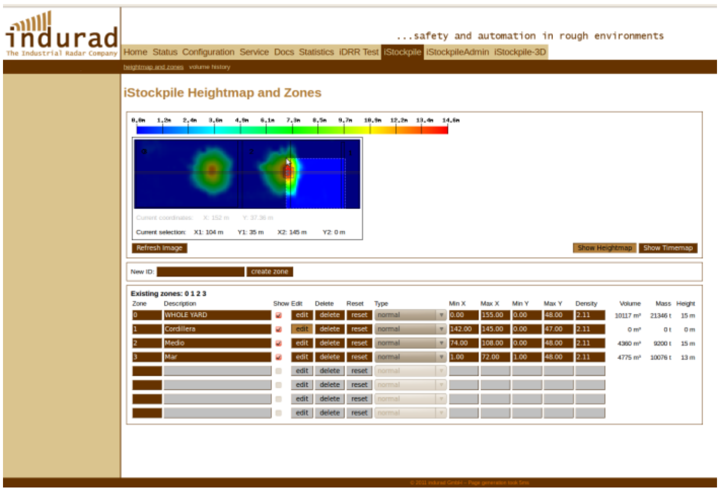


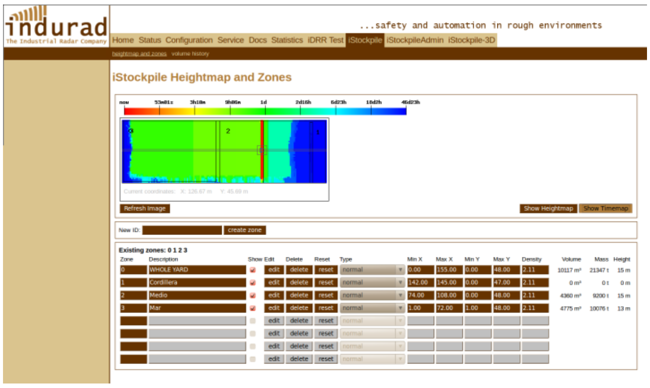

**iStockpile™ Heightmap & Zones**

iStockpile™ Heightmap and Zones allows for intuitive and quick control of the entire stockpile or specific parts therein by the creation of "monitoring zones". As all data comes in real-time, this function contains most valuable information for the planning of processes in production and management. Please see screenshot below:



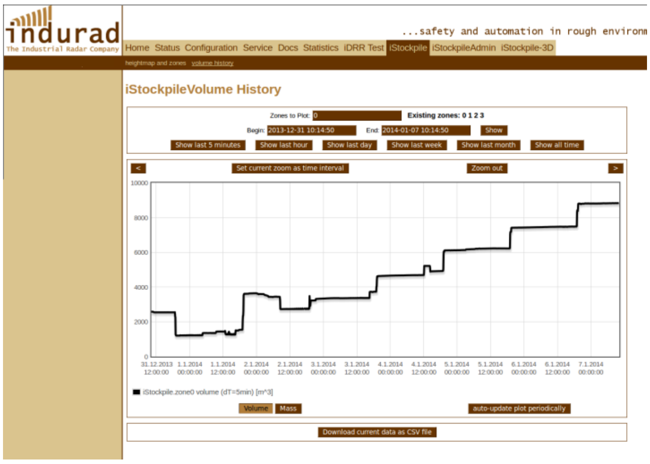
**iStockpile™ Timemap**

iStockpile™ Timemap shows at one click the sensor coverage over time of the entire stockpile or of specific parts therein. The zone function is also included in this feature. The Timemap allows for easy tracking of the sensor update times of the stockpile to determine age of sensor data.




**iStockpile™ Volume History**

Mass flow over time may be tracked by one-click analysis. Logfiles (for example .csv for analysis with Excel), containing volume changes or even radar raw data for expert analysis, may be downloaded as well via mouse click. Specific analysis tools will allow measuring the changes in the stockpile and provide in-depth analysis possibilities.




**iStockpile™ Virtual Silos**

In additon to the color-coded heightmap and timemap, virtual silos can be defined and the volume can be shown on a overview screen. This allows for perfect, to-the-spot control of the volumetric development of subsections of the entire stockpile and represents the first and essential part of a tripper car automation.

**Temperature Challenge & Sensor Protective Casings (High-heat)**

All sensors have an in-built temperature tolerance of 85°C. The typical temperatures inside a steel melt shop, however, exceed these tolerances. Therefore, in order to protect the sensors from the high temperatures, the sensors are installed inside a special protective casing, or armor, which is cooled by purge air. Our sensors were already used inside clinker silos (temperatures up to 200° C) and underground solutions, as can be seen below:

***Images**: Impressions from an actual installation site & design of one purge air sensor casing (in the US)*

## CONCLUSIONS

While iPosition™, iStockpile™ and other indurad solutions are well-known names in the mining industry, their potential for the steel industry must yet be explored. The similarities in environmental conditions (extreme temperatures, fog, dirt) between mining and steel, however, suggest that the results to be expected will mirror their outstanding performance in mines and material handling plants. With their supreme accuracy and volumetric inventory data, both of which hitherto unavailable in steel industry applications in this quality, iPosition™ and iStockpile™ alone have the potential to significantly reduce risks in high-danger situations while raising accessibility, production transparency and comfort for plant operators and managers alike.

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