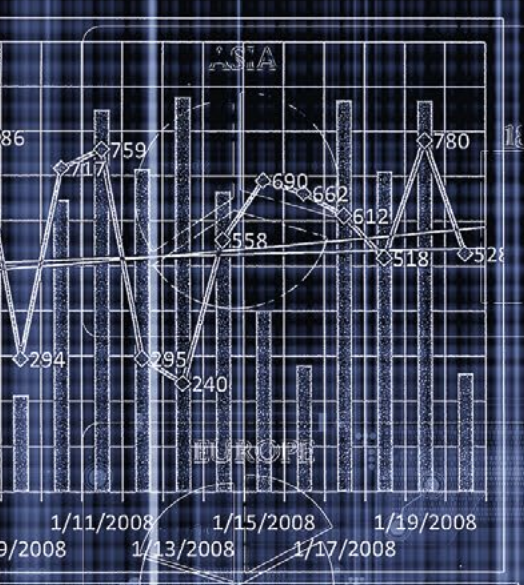
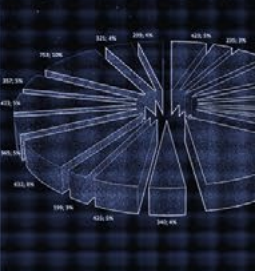
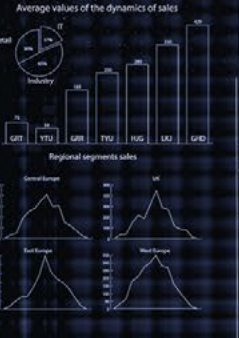
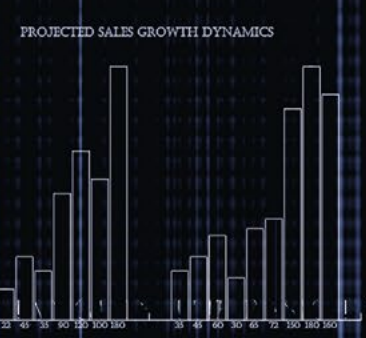


Cotton	\$118.00	\$162.60	37.80%
Flax	\$191.00	\$192.38	0.20%
Textiles	\$208.00	\$244.58	27.20%
Wool	\$217.00	\$244.34	12.60%
Fur	\$199.00	\$216.11	8.60%
Sateen	\$172.00	\$173.03	0.60%
Silk	\$109.00	\$151.07	38.60%



	Sale	Buy	Grow
Gold	\$647.00	\$904.51	39.80%
Platinum	\$381.00	\$509.78	33.80%
Silver	\$774.00	\$1,061.93	37.20%
Copper	\$616.00	\$837.76	36.00%
Steel	\$449.00	\$537.90	19.80%
Beryllium	\$743.00	\$754.89	1.60%
Manganese	\$598.00	\$795.34	33.00%
Aluminum	\$299.00	\$354.61	18.60%
Chrome	\$666.00	\$727.27	9.20%
Nickel	\$421.00	\$453.84	7.80%
Bauxite	\$730.00	\$791.32	8.40%



Cotton	\$162.00	\$196.34	121.20%
Flax	\$172.00	\$182.32	161.00%
Textiles	\$243.00	\$330.48	186.00%
Wool	\$261.00	\$359.68	37.80%
Fur	\$116.00	\$118.55	2.20%
Sateen	\$201.00	\$246.43	22.60%
Silk	\$177.00	\$184.79	4.40%

Oil	\$609.00	\$811.19	33.20%
Electric power	\$578.00	\$808.04	39.80%

# Factory of the Future: Towards zero downtime



Aluminum	\$588.00	\$726.77	23.60%
Chrome	\$351.00	\$442.26	26.00%
Nickel	\$547.00	\$578.01	11.80%
Bauxite	\$583.00	\$753.24	29.20%



**ALTRAN**



## Introduction

With the emergence of the Internet of Things and the wide spread of connectivity in the factories, a complete new set of machines, processes and production organization can be put together to boost manufacturing and more generally industry productivity. This Industrial IoT composes one of the 4 key pillars of the industry of the future, together with Human – Robots collaboration, Virtual Reality and Additive manufacturing.

Based on the actual first deployments of a new connectivity system called SenseForge, the present paper explores how wireless sensors can continuously monitor processes and equipment of all types, including legacy non-born digital machines, and thanks to local computing power, provide breakthrough improvement in efficiency of the industry processes.

Driven by strong Innovation in the semiconductor industry the IoT revolution is impacting all industries, and disrupts many business models. The following graphics illustrate a clear downtrend on hardware cost and data storage prices, together with the rise of embedded computing power. This creates an opportunity to locally compute IoT sensor signals to get a better sense of the environment, a key feature in the industrial arena.

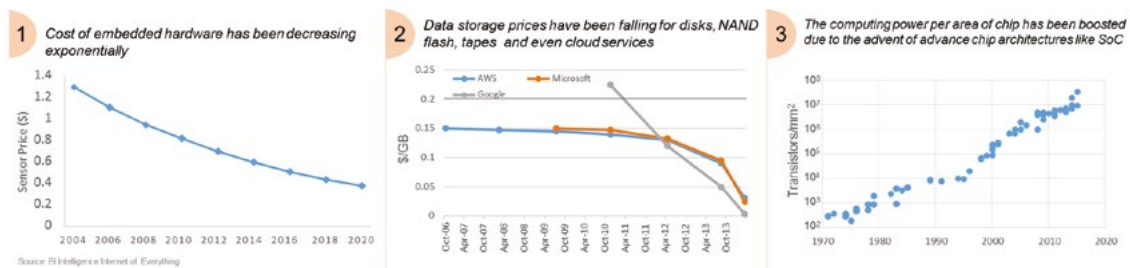


FIG 1:

## TRENDS ON EMBEDDED DEVICES COMPUTING POWER AND COST

It has become clear that the Industrial Internet Of Things (IIoT) will enable an end to end ability to aggregate and analyze process data in near real-time. This new insight will allow executives to discover trends and take decisions to achieve the best operational performance and reduce downtime. The IIoT use cases are as unlimited as the types of resources that sensors can monitor.

There is however a price to this revolution : IIoT needs a mindset shift. It's surprising that, in many industries, automation only receives an average of 4% of the total facility investment. So, going for the full IIoT promise, where machine driven data is collected systematically and exhaustively, and then shared with third parties which analyse and optimize the operations of the manufacturer is rather a distant dream requiring a profound mindset mutation.

Fortunately there are intermediary steps on this path, which anyone can take. The aforementioned cost reduction of wireless sensor technology, plus the increased computing capabilities of the IoT components, recently opened opportunities for what CISCO called "Fog Computing" or "Edge computing" ie. A new generation of distributed architectures where data can be computed locally. Machine driven data can then be used locally to boost production awareness, and therefore, overall performance.

But first of all let's have an overview of key factors threatening factory performance, and how IIoT can help cope with them.

## 1.1. HOW TO SECURE AND ENHANCE KNOWLEDGE & TRAINING WITH AGING WORKFORCES

Many technically skilled workers take invaluable experience and expertise with them into retirement. As organizations digitize and leverage the Industrial Internet of Things (IIoT), they can tap machine learning and cognitive analytics to deal with this. Using smart connected devices will help to solve those challenges by creating a digital culture on the floor plant.

Whereas sensors can be upgraded to "digital senses", building cognitive biofeedback on a new kind of portable HMI, Kaizen-like investigation & innovation approaches need to be implemented and relevant personnel be trained. Obviously floor managers will benefit from this approach to keep the knowledge alive and shared. All this happens on top of the changes from discrete industrial sensor systems to IIoT cognitive sensors, which can be illustrated as below.

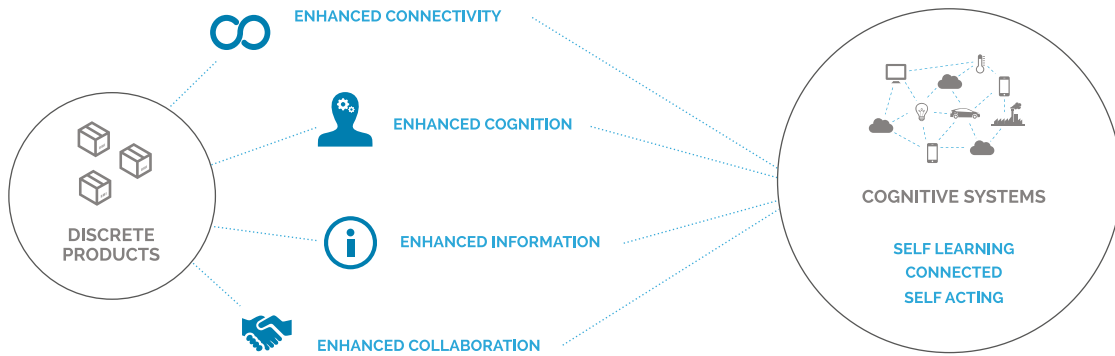


FIG 2:  
ROADMAP FOR IIOT AS BUILDING BLOCK FOR A COOPERATIVE PROCESS  
AUTOMATION SYSTEM (CPAS)

## 1.2. AVOIDING PARTIAL BLINDNESS

Performance culprits often hide in places where no sensor nor metrics exist. There are many reasons for this, like aging machinery that is difficult to replace, warranty/maintenance contracts that prohibit any tampering of the site, internal built tooling devices with no sensing, excessive uncontrolled pooling, and many other apparently simple items which play a role on unplanned downtime and performance loss.

Intelligent IIoT can now cover these blind spots and "digitalize" legacy machinery or any fixed or moving resource. Indirect metrics will then be calculated to avoid tampering or wiring the machine when harvesting operational state metrics.

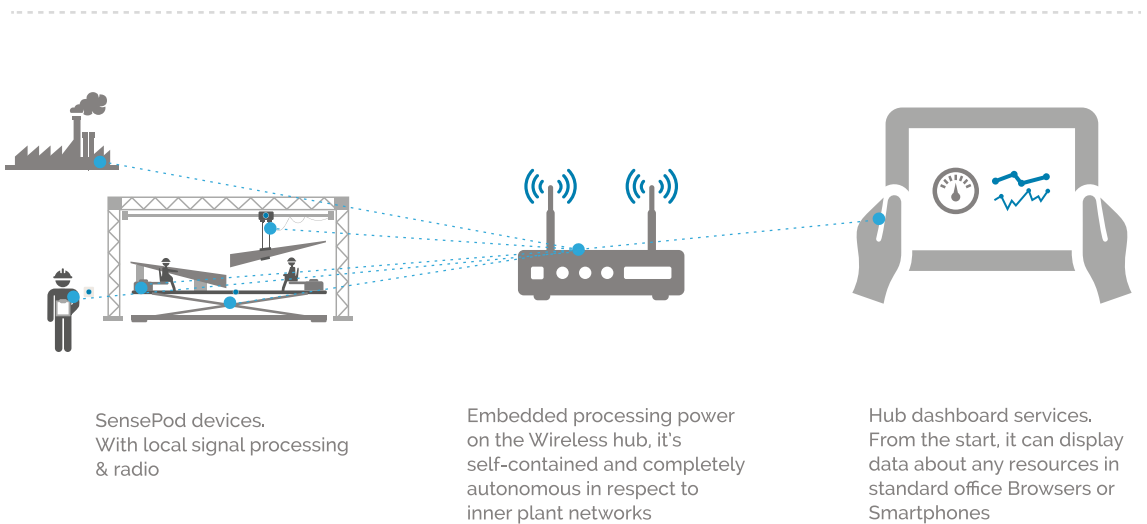


FIG 3:  
A QUICK GLANCE AT OUR 1<sup>ST</sup> STAGE SYSTEM SETUP

This is now possible thanks to programmable, flexible and intelligent devices with multiple sensors. This enables detection of the operational status, using sensor signal footprint, which tags each state with a signature instance, and display them as real-time series. All of these outputs are then used as input variables for machine learning algorithms, which are detailed further in this document.

This data feed is also intended to be used as augmented reality graphs to show contextualized Key Performance Indicators (KPI's) and build awareness for shop floor people, using a dedicated application. This effectively creates a kind of "bio-feedback" sense on the workers, by repeatedly showing localized data indicators. To achieve this, augmented Human Machine Interfaces (HMI) can be designed, thanks to new AR display techniques.

### 1.3. AUGMENTED SENSES AND KAIZEN REWARDS

Kaizen (continuous improvement) encourages experimenting and rewards shop floor people, even on small failures. If people visualize a wisely chosen graphical summary of IIOT & SCADA data feeds, they create "graphical biofeedback senses". Shortly a boost on proposed improvements due to intuitive process awareness will be obtained.

Anything that moves the floor closer to achieving permanent gains is a win. Efficiency comes from awareness, and helps when ramping up the output capability, without losing quality on the go.

IIoT lets a shop floor manager receive, measure, and reward achievements on the go. In the process, shop floor workers will come to see that performance isn't just a corporate mandate but a shared goal that comes with shared rewards. And that IIOT came to help on this, and to encourage improvement.

Experience proved that giving easy graphical access to synthesized KPI concepts on the plant creates a "6th augmented sense". This was done by using indoor location awareness on common commercial devices to display and reveal machine operational data using already existing AR techniques. Just by pointing the camera to a device code tag, a graphical KPI dashboard with key data is shown, containing a set of real-time updated gauges and graphs. This only requires common smartphones, tablets, or digital glasses. A plain PC can use a "device pin code" to access it as well.

This augmented sensing tool was accepted by people really fast, the overall result was a gain in awareness and, therefore, performance gains. Human brain exhibits a superb capability to "feel changes" and is able to tell that "something isn't like yesterday" or "this machine doesn't look like that twin over there". People only need to get access to an easy way to harvest and share "subjective" performance indexes. They get used to values, graph bars and colours, detecting any minor changes and establishing mental normality barriers and intuitive relations.

But the best is that providing digital media metrics about processes, promotes plant knowledge and KPI awareness, and builds a culture to be used, shared and taught. This is perfect for a Kaizen – Lean approach to a superb performance roadmap, and stops knowledge losses.

### 2.1. OBJECTIVES OF THE PROJECT: PERFORMANCE, QUALITY AND KPI VISIBILITY

The first and dominant goal is merely **line performance**, that is, remove bottlenecks, reduce downtime and increase availability.

On the same level of priority, the intent is to maintain and improve product **quality** by lowering scrap rates and getting **better quality metrics**, covering every aspect with a zero deploy interference. This has to be true even on 40 year's old machinery with poor or no documentation at all.

As a prove of concept, existing data from SCADA Distributed Control Systems, was used for Process Automation Monitoring evaluation on a selected site. It was shortly demonstrated that comprehensive "End to End" awareness was needed for Process Automation Analytics to succeed. This led to build a new breed of autonomous programmable IIoT Sensors, capable to be deployed easily with no machine tampering and low installation requirements.

Low cost wireless sensors introduced by the Internet of Things (IoT), were chosen to continuously monitor processes and equipment of all types. This IIoT solution makes possible to know environment states in real time, and programm them remotely. If **local machine learning & statistics** is added to this setup, the equation can dramatically change, and switch from plain sensors to **algorithmic "senses"**, that can be deployed virtually everywhere.

To exercise a valid proof of concept, a set of industrial facilities were selected, and a limited number of wireless devices were deployed and connected to a new breed of autonomous IIoT hub with embedded machine learning engines. Each device was called SensePod and loaded with a new kind of Operating System for IIoT which was called "SenseForge" illustrating the intent to give a new kind of "digital sense" to the machine, through the ability to run algorithms locally. The hub device has its own servers and processing power to provide a dashboard engine and independent connectivity to act as a standalone unit. The system is designed to be totally self-contained.

In the SensePod design, lots of sensor kinds were embedded inside in order to get many input metrics; positional, vibrational, magnetic, temperature, and humidity, to name a few. But the real difference here was the set of processing capabilities and algorithms embedded into the devices, and the way they can be programmed to repurpose sensors at will. Furthermore, the devices were planned to wirelessly dialog between them to form a "differential sensing mesh". And due to the low cost of each unit, the fast no-wires installation, and the ability to run even on batteries, the application possibilities were really endless.

This answered the goals: Easy **performance metrics, quality indexes and real-time visibility**.



## 2.2. THE KEY FACTOR: IIOT WITH EMBEDDED MACHINE LEARNING AND STATISTICS INSIDE

Essentially all started from very small and low powered silicon devices, coupled with a set of micro-sized standard sensors like accelerometers, gyroscopes, thermopiles, and so on. The challenge was then to perform signal processing in such constrained processors. For example: how to perform vibrational frequency analytics (FFT) on the device itself, in near real-time? Mechanical vibration is a common testing procedure for non-intrusive diagnostics, because it reflects machine states due to the signal footprints coming from motors, gears and metal to metal friction.

(See Figure 4 below, showing plots of several machine states and associated vibration spectrums)

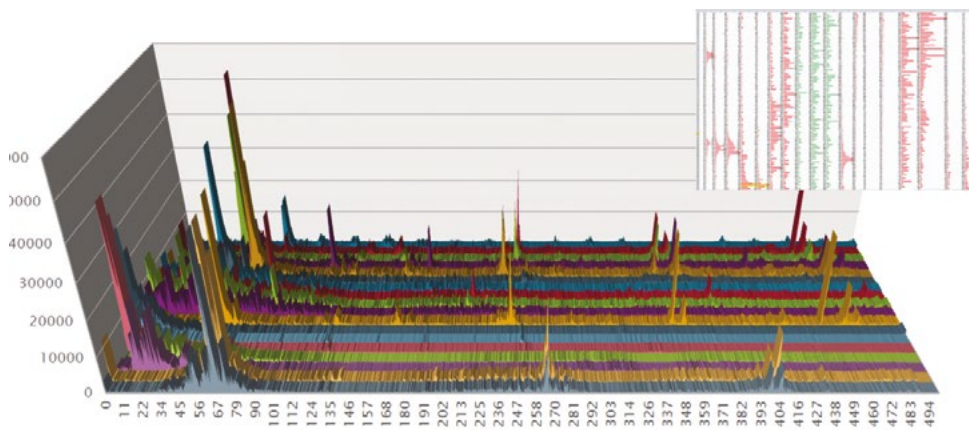


FIG 4:  
EVERY PROCESS ITEM (COLOR/DEPTH) ORIGINATES SPECIFIC  
FREQUENCY SIGNAL FOOTPRINTS TO DETECT ITS BEHAVIOR

Consider all the above as inputs to a statistical algorithm defined as: "frequent pattern recognition and classification engine". Now let's put the obtained pattern time series on a graphical dashboard and, what will be the result? Please welcome our "machine state learning system", capable of recording footprint pattern **states**, instead of plain signals. Now shop floor management people just had to tag the "spectral words" learnt in this "dictionary" with human readable naming for the states and go on toward further knowledge.

After that moment, shop floor management teams will have a fairly good insight about the environment and its behavioral states. Every start, stop, subtle hiccup or pace change, will be there to build the appropriate KPI's on top of them. Plant end to end digitalization is now possible in a matter of days instead of months, with no complex wiring, and a very low footprint.

The roadmap is simple. Just "pour" SensePod devices in every suspected corner and start sensing any production line, logistics ops, people around, hand tools, in almost no time. But it doesn't stop here; continue reading for more gains in maintenance using **remote condition sensing**.

By its sensing nature, "out-of-the-box", the described system is actually a **continuous condition based maintenance (CBM) network**. If correctly deployed, it will detect **mechanical wear as signal drifting and as event sequence degradation**; a must-have to plan ahead and avoid downtime and scrapped materials. Coupled with predictive analytics engines, it's the key component in a technology roadmap to ultimate performance, that is: **toward zero unplanned downtime**.

## 2.3. REAL LIFE EXAMPLE AND RESULTS

After months of testing and development, the first version started to show meaningful real-time data from pilot production installations. On the HMI part, a programmable dashboard system was built with capabilities to display and process data locally, showing machine operating states and mechanical analytics. Nothing more is required beyond SenseForge Pods & Hub, everything comes inside the hub server and included on the devices. Furthermore, the hub supports most kinds of connectivity onboard: 4G, WiFi and plain Ethernet cable. Just scan the QR/URL sticker on the casing, use a common browser, set up security and go. Call it, "plug & sense".

In less than a day, this new "machine driven data feed" enabled many indexes that never existed before, for every resource involved. After some weeks of data harvesting and event tagging, the dashboard showed machinery performance/state and tooling wear indexes, like:

- 01. ESTIMATED REMAINING LIFETIME OF FUNGIBLE MATERIALS
- 02. WORK/STOP KPI, IDLE TIME CHARTS
- 03. TOP TEN STOPS CHART, RELIABILITY KPI AND A RISK INDEX
- 04. NON MAINTENANCE RELATED MECHANICAL SIGNAL DRIFTING / CYCLES = "AGING/HEALTH INDEX"
- 05. MACHINE OPERATIONAL STATES AND ACTUAL OPERATION ADJUSTMENTS (FREQUENCY FOOTPRINTS)

You will find below the full description and results of the first ever deployment of SenseForge in an automotive parts manufacturer.

### 2.3.1. CUT & WELD ROBOTIC / SEMIAUTOMATIC MACHINES

→ **THE SITUATION WAS:** The machine consumed abrasive discs to cut an extruded profile composed of different densities of rubber and metal cores. The disc wear was very variable for various "unknown/known" reasons, and there was a significant amount of unavoidable downtime due to lifetime uncertainty. Add lots of scrapped materials to the problem, to get an overall idea.

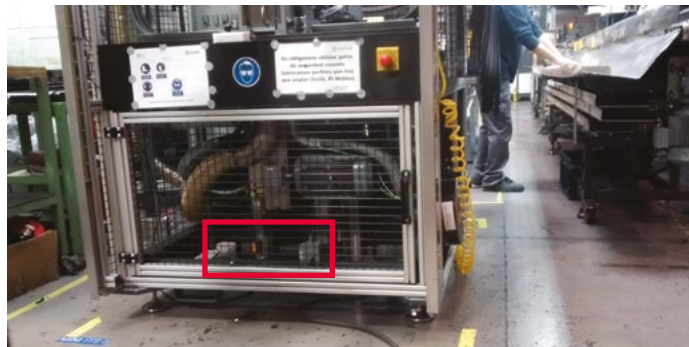


FIG 5:  
RADIAL CUT & WELD UNIT

→ **NOW THE SITUATION IS:** VueForge SensePods were installed easily in just an hour inside the cage, near the motors. From that moment a stream of data was ingested on the provided standalone SenseHub, and vibrational analysis detected a "cycled amplitude drifting" on the main rotational signals (5000rpm @83Hz), this was clearly related to the nature of works performed. After adding more insight, several frequencies were found to "disappear" near the end of life of the discs. The resulting technical dashboard, showing one interesting event is this:



FIG 6:  
DASHBOARD - TECHNICAL VIEW PAGE

Illustrated above are the amplitude signals coming from the disc rotation over time (in blue). As can be clearly seen, there's amplitude variation, and some operational changes over that day. The key fact here is that the slope of the signal corresponds to the disc footprint changing, and that this **indicates a short remaining lifetime**. The discs were replaced around 12:00, after that operation, a clear signal level change can be seen.

In the second blue graph below, the one showing a 3 day span, the dented slope at the right is the compressed version of the first one, and clearly indicates the disc change. Cycle detection & prediction was relatively easy to model on top of that.

The maintenance dashboard it is shown below, providing some KPI's, along other metrics. The algorithm computes the relation with previous cycles and a computed overall risk probability KPI is offered. That single SensePod instance provided a perfectly controlled machine maintenance lifecycle, with @90% lower unplanned downtime than before.



FIG 7:  
DASHBOARD - OPERATIONAL VIEW PAGE

### 2.3.2. MULTIPLE HEADS, HIGH PRESSURE, RUBBER/METAL EXTRUSION MACHINE

This is a proprietary machine, one of a kind, with many years of knowledge embedded inside and great operational complexity. Many obscure settings are still not clearly understood, and every mold setup is a try-and-error procedure. This, of course, means that any subtle drifting has consequences on the final product quality.

→ **THE SITUATION WAS:** The machine applies a great deal of pressure from 300 to 500 atmospheres to a preheated rubber continuous band. Several pieces of different densities and metal bones are joined in a continuous extruded profile. This profile is used as seal in the automotive industry (Ex:doors).

Due to the custom made nature of the machine, many inner sensor readings were not planned, nor instrumented in the building stage, and risking a crucial piece of machinery for a business is not a game to be played with frivolity.

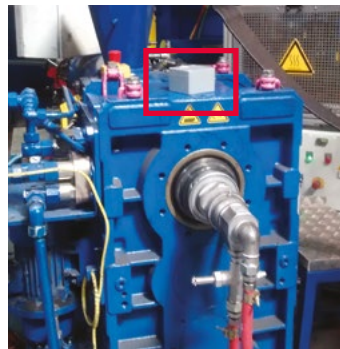


FIG 8:  
EXTRUSION HEAD

→ **NOW THE SITUATION IS:** Again, just one VueForge SensePod attached on top of the machine was able to see all mechanical signals from the head unit. Main motor, gears, refrigerant pump and other vibrations from the extrusion process were there waiting to be picked. A signal footprint pattern, unique for every profile model and machine operation state, was detected. Drifting leading thermal and jamming issues was registered too. The net result was more information about the machine adjustments and better understanding of the conditions needed to set it up for new models. Performance was enhanced in just some months of system usage. Now several calculated KPI's are being integrated in the existing SCADA system.

The actual plan is to obtain even more insight from the data streams, using Advanced Machine Learning techniques from VueForge solutions and Big Data Analytics in the next stages.

### 2.3.3. MOTORS, PULLEYS AND ROLLERS

Often the downtime is not caused by complex systems, but from fairly simple ones. The hot extruded rubber is extremely delicate. Several pulleys maintain the continuous conveyor belts of the production system at constant speed inside the oven. What happens if a belt breaks or a pulley skids? The outcome is a lot of scrapped material and a race against time to fix it before the intermediate pools exhausts, and all the systems must be shut down.

→ **THE SITUATION WAS:** Uncontrollable downtime events that can happen anytime, this facility works 7d x 22h meaning that a maintenance team was to be ready at all times, "just in case". But the worst effect was downtime, scrap and people stress.



FIG 9:  
ROLLER PULLEY

→ **NOW THE SITUATION IS:** The VueForge SensePod does local vibrational analysis and extracts constant frequencies when the system operates. Before the breakage event, pulley began to skid, and some frequencies were picked up hours before failures. Furthermore, the included thermopile infrared reader was used to read belt heating. This solution was implemented using the included "uncommon pattern detector", after some repetitions the relation was established, and a KPI was created from that finding. This risk index provided a way to plan ahead, almost no uncertainty remained and more items are being instrumented.

Advanced Machine Learning techniques including all the signals harvested in this deployment were also ingested in Big Data solutions for further investigation, in order to find other possible gains in performance or reliability from other simple mechanical items like blower fans, pumps, gears and cardan joints, to name a few. The overall outcome looks promising and more plant installations were planned over 2017.

## Conclusion

These deployments are fantastic examples of the way that smart technologies can affect the operations of traditional manufacturing sites and improve overall performance of our industries. Low cost sensors can be used to upgrade legacy equipment into digital connected, sensible machines, which can sense, collect, compute data and make decisions locally. This results in a dramatic potential of productivity increase for all industries.

With connectivity becoming a commodity, the question is no longer on who will embrace this digital transformation, but who will be first! As pointed out by Charles Darwin "It is not the strongest leaders that survive, nor the most intelligent; instead it is the ones that are the most responsive to change".

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## About the author

### Francisco Herrador

Francisco is an it architect with expertise in several technologies and business areas. He has over 30 years' experience in technology innovation and research. He created early artificial vision technologies for automotive manufacturing process automation in the 90's. He has recently been involved in Smartphone and IoT Solutions development for Altran digital solutions sensing technologies, creating user behavior analysis algorithms for intelligent system's VueForge® solutions suite. He now works as expertise leader for the factory of future solutions developed by the Altran World Class Center Advanced Manufacturing. "Entropy is a close friend of innovation, therefore don't expect to innovate if you always stick to what you know".

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## About Altran

As a global leader in innovation and high-tech engineering consulting, Altran offers its clients a new way to innovate, by developing the products and services of tomorrow. Altran works alongside its clients on every link in the value chain of their project, from conception to industrialization. For over thirty years, the Group has provided its expertise to key players in the Aerospace, Automotive, Defense, Energy, Finance, Life Sciences, Railway, and Telecoms sectors, among others. In 2016, the Altran group generated revenues of € 2.120 bn. With a headcount of more than 30.000 employees, Altran is present in more than 20 countries.



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