Realizing the Industrial Internet Opportunity: How GE's Predix Delivers Value Today and into the Future

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Abstract

The promised savings and new opportunities embodied in the Industrial Internet may seem to many companies more aspirational than possible. The theory behind using sensor data, predictive analytics, new user experiences, and the cloud to dramatically change operations and costs across a wide range of industrial companies is indisputable. But the question of how companies can move towards realizing these gains without massive disruptions and costs has injected a dose of harsh reality into many companies' plans.

These concerns are beginning to be answered, and recent developments in the technology and functionality of the Industrial Internet, led by GE and its partners, are pointing towards an incremental, cost-effective way to start down the road to achieving these goals. Powered by Predix, GE's cloud platform for the Industrial Internet, new solutions are helping industrial companies realize genuine savings and operationalize new opportunities. This isn't theoretical – it's a reality.

Over the last few years, GE has been able to show how manufacturing companies can reap significant savings in the energy footprint of key industrial assets – from individual compressors, turbines, and milling machines to entire factories and wind farms. In a factory setting, these savings extend to all consumables – electrical power and gases used in the plant for specific processes – as well as to heating, ventilation, and cooling systems. In wind farms or in airline fleets, valuable assets such as massive power turbines and aircraft engines can be monitored and managed to not only lower their maintenance costs, but also to allow the utilities and airline companies that use these assets to provide better levels of service to their customers. These are a few of the many examples where the potential of the Industrial Internet are being realized today.

While the journey to the full realization of the Industrial Internet is still a long one, these early successes point to real value today, value that can be realized in many cases without a massive replacement of equipment and technology. This ability to provide an incremental path to the full potential of the Industrial Internet is a core reason why GE has come out with its Predix Industrial Internet platform and related technologies.

1 The Path to the Industrial Internet: Technology and Process

The seeds of the Industrial Internet were sown many years ago, when sensors, controllers, and other digitizing technologies began to be found inside shop floor machinery, power-generating turbines, or valuable assets such as aircraft engines and locomotives.

For the most part, these different "smart" devices and assets lived in highly proscribed data and analytical environments, with little to no ability to do the kind of analysis and operational optimization that we now think of when we talk about the Industrial Internet. Rather, these different assets and devices, with their unique data footprints, communications protocols, and localized analytical and operational models, ran in isolation from the rest of the plant, power grid, or aircraft fleet, as well as the enterprise back offices that depended on the functionality of these assets and devices in order to actually run a profitable business.

Over time these historical assets have been augmented, and in many cases supplanted, by new, even more intelligent assets and devices. As a result, in many industrial companies, a hybrid environment exists, made up of highly advanced, state-of-the-art technology working alongside assets and devices that are literally decades old. As Industrial Internet pioneers and visionaries began to envision the future of operational and industrial analysis and control, it became apparent that the platform that would set the stage for the *Power of One Percent Better* would have to take into account the need for analyzing vastly different data types, formats, and frequencies as a pre-condition for delivering advanced analytics and operation optimization. In order to advance the business processes needed to realize the *Power of One Percent Better*, a new platform was needed.

This realization became a core foundation for the development of Predix. In order to support these new analytics and processes, Predix needed to be able to collect data of any kind, in particular sensor-based time series and historian data, and make it available to a wide range of predictive and operational analytics.

Creating and managing a data lake at industrial scale meant that Predix needed to support data collection and analysis across time and space in very unique ways. Industrial operational excellence requires data collection and analysis to take into account different requirements for the quantity, quality, and time sensitivity of operation being analyzed and optimized. For example, an aircraft engine must be able to understand and react instantaneously to changes that might affect the airworthiness of a plane in flight. That instantaneous analysis and response requires different data and analysis than what is needed to predict the optimal time for a preventive maintenance procedure. And looking at fleet-wide usage patterns in order to optimize spare parts procurement requires a different level of data acquisition and analysis as well.

This multi-dimensional data management and analytical capability is a core feature of Predix and its data approach, and of course provides the foundation for the other components of Predix: advanced predictive analytics, advanced user experiences, and security, all available in a cloud-based system. Importantly, Predix is designed to adapt to the different realties on the ground, in the air, or even underground, by allowing older industrial assets and devices to be used alongside state-of-the-art technology, and enabling the data from all of them to improve operations across a wide range of industrial processes.

This allows companies to connect their assets with a unified platform and to adopt or build apps to do different kinds of analysis, from analyzing how a single asset, such as an individual aircraft engine or milling machine is operating, to optimizing an aircraft fleet or manufacturing plant, and even doing broad-based analysis across multiple fleets or plants.

At each level of analysis different data types are needed at different frequencies, and different analytical tools and technologies are needed to provide the required analysis. This is why GE created Predix.

2 Net Savings and New Opportunities

While Predix itself will continue to evolve and learn from new data challenges, the concepts behind Predix and the possibility for real operational gains are far from theoretical. GE's own efforts at operationalizing the concepts underlying Predix have already begun to yield impressive gains in wide range of industrial domains. Three examples are presented here: Energy management in manufacturing, asset maintenance in aviation, and operations management in power generation.

2.1 Managing Power Use in a Smart Factory: Real-time Data meets Historical Analysis

The ways in which GE is able to manage a factory's use of electric power in both production and product testing offers an excellent example of how measurable gains from Industrial Internet concepts can be realized at the factory level without a massive equipment upgrade. The key is to use existing data and physical assets to power a new set of analytics that can drive new efficiencies within well-established processes.

How GE was able to improve power usage for HVAC systems in one of its plants is an excellent case in point. Ambient plant temperature is a core variable in the manufacturing process in many plants: many of the materials used in manufacturing turbines and other valuable assets have a very limited acceptable temperature range – a few degrees one way or the other can deform a part sufficiently so as to make it unusable.

The plant in question had relatively old HVAC systems, and it was recommended that the plant upgrade its HVAC systems by adding new intelligent controls that would theoretically provide overall energy savings from 25-30%. But the projected cost was over $1 million, and so a pilot project was initiated to see if those savings were realistic.

A single rooftop unit was upgraded to include the new controls, and then, as the new controls were put in place, usage data was downloaded from the newly upgraded unit as well as a unit that had not been upgraded. By comparing these two data sources, a usage model for the entire plant was built that predicted a reduction of energy use of over 50%, with a year one savings of $1 million. Based on that analysis, the plant upgraded a total of 100 rooftop units.

When the first year of operation was over, the actual savings from the 100 upgraded units came to $987,000, proving not only that this was a good business decision, but that the model guiding the decision was exceptionally accurate. More importantly, this project showed the value of making relatively small, incremental changes in existing plants and equipment. Subsequent studies showed that this kind of analysis – analyzing and modeling the use of energy in factories – can yield important benefits, all without a massive retrofitting of expensive assets.

In-plant testing was another place where GE put Predix to work. Testing expensive assets like electric turbines involves enormous amounts of energy. In some plants testing a $25 million turbine can cost an average of $200,000. Managing a cost of that magnitude is important: electric rates can fluctuate dramatically, and the cost of a kilowatt-hour has historically varied from five cents to one dollar in a single day. Needless to say, planning when a test takes place can have a huge impact on the profitability of an individual turbine.

In order to better monitor these costs and provide better visibility into the optimal time and day for a test, GE built an analytical model that combined historical data on energy usage for testing with pricing data from the utility that supplied the plant. This in turn allowed GE to improve the timing of its product testing to coincide with lower energy prices, thus lowering costs and improving its profit margins. This kind of analysis can also allow GE to improve overall factory operations by adding important information regarding optimal testing windows to the ERP system's production plans, and, ultimately, to the service-level guarantees in a particular contract.

The combination of historical and real-time energy usage analysis can also impact the maintenance costs of expensive machinery, such as the lasers used in additive manufacturing (3D printing) processes. Many of these lasers are extremely sensitive to voltage fluctuations that come down the line from the utility, which guarantees a standard voltage range that could still damage the plant's lasers. By analyzing historical data, GE was able to find potential external events – weather related, for example – that could trigger voltage spikes. Based on that analysis, GE was able to predict potential spikes and take the lasers off line or otherwise protect them from harm. Importantly, the analysis and subsequent action took place without a major retooling of factory assets.

2.2 Optimizing an Aircraft Engine's "Time on Wing": Improving Predictive Maintenance Models

The management of aviation assets is another area in which GE has been able to demonstrate the value of the concepts behind its Predix platform, particularly in optimizing the "time on wing" of an individual aircraft engine.

Time on wing, or the number of hours during which an engine is in use, as opposed to in the shop being maintained, is the primary key performance indicator for aircraft engines. One of the best indicators of performance, and a pending maintenance requirement, is the exhaust temperature of the engine: particulate matter enters an engine during normal usage, and as the particulates build up, the engine begins to run hotter. Monitoring engine temperature and understanding what the changes in temperature mean in terms of maintenance requirements are key analytical requirements for optimizing time on wing.

GE monitors exhaust temperature of the engines it manufactures at variable rates: some of the data is transmitted to GE's flight support center during flight, other data is transmitted in "batch" when the aircraft lands. From these two kinds of data, a comprehensive exhaust temperature curve for a given engine is developed, and then compared to a temperature curve based on predicted normal use.

Deltas between the two curves are then investigated to determine whether the engine's temperature curve indicates the need for maintenance or not. The process for analysis is complex: engine wear varies not only from aircraft to aircraft, but from airline to airline as well. Key factors such as the city pairs flown by a particular engine come into bearing – pollution and ambient particulates vary from region to region – and the maintenance record of the engine, including the provenance of the parts used in maintenance, are also analyzed. The results of the analysis are then used by GE's flight support engineers to determine if preventive maintenance, such as an engine wash, is in order. GE also monitors the engine post-maintenance in order to determine if the maintenance was successful or not. The result is more time on wing, lower potential maintenance costs, and increased customer satisfaction – a win/win for GE and its customers.

The use of these types of data can also drive important refinements to the maintenance process. A maintenance order can also include an order in the maintenance company's supply chain system for a just-in-time parts delivery and an order in the human resources management system to deploy the maintenance personnel in a just-in-time manner.

2.3 Wind Farm Efficiency: More Power, Less Cost

The modern wind farm is as much about the information flow between wind turbines and the operator as it is about the power flowing into the grid. That information flow is a perfect example of the different data and analytical requirements – and their time sensitivity – that go into operating, and optimizing, complex assets like wind turbines.

There are a total of three primary use cases for the data generated by a wind turbine, each one has its own requirements in terms of data quantity and timeliness, and each can be used to generate vastly different, but equally valuable, operational analyses. Supporting this data and analytical complexity makes a strong case for a platform like Predix, which has been designed specifically to manage use cases as different as those found in a wind farm.

One level of analysis is at the turbine itself – data regarding speed, torque, and other factors is analyzed in real time and used to make corrections in the position or angle of the turbine that can prevent damage to the turbine or optimize its energy output. Speed of analysis and response is of the utmost importance – millisecond response times are needed – and as such the data is analyzed in the turbine itself and used to make real-time changes to prevent damage.

Another important analysis can be done at the wind farm level to determine how the energy is to be used by the operator, in particular whether it is released to the grid immediately or stored in the wind farm's local batteries for later use. This kind of analysis attempts to optimize the value of the energy being generated by looking at demand and pricing on the grid and calculating whether the energy could fetch a better price at a later time while still keeping the operator in compliance with its contractual obligations. While speed is also important, the analysis and response time are measured in seconds, not milliseconds.

A third level of analysis is at the "fleet" level. In this case GE monitors all the turbines of a particular model and revision and checks for anomalies that could indicate the need for preventive maintenance. The data collection for this level of analysis can be up to once per hour, depending on the use case and the algorithm being used.

GE's PowerUp software system delivers this kind of analytical and operational support, and the results from its use reflect the value of these new approaches. In one use case, PowerUp was able to drive a 5% improvement in power output at a wind farm, which in turn resulted in a 20% increase in profit for the operator. When deployed at scale, systems like PowerUp can have an enormous impact. Another operator, working with GE, plans to install PowerUp across a network of wind farms containing over 400 turbines. The wind farm operator and GE estimate that PowerUp could improve output by 420,000 megawatt-hours across the operators' wind farms.

3 Conclusion: The Predix Journey Starts Now

These real world examples of how the concepts behind Predix are already yielding results demonstrate that the Industrial Internet and the *Power of One Percent Better* aren't just interesting concepts, but rather sign posts that can lead industrial companies toward a future that is more efficient, more profitable, and provides better service to customers and partners alike.

Importantly, these opportunities aren't restricted to green-field plants and net-new operations. The Predix platform is designed to leverage the full complement of digitized industrial assets: from 20-year-old shop floor controllers to the sensors in an advanced GE GEnx aircraft engine. By tying industrial assets together into a single platform, the full power of Predix's data management, analytics, and user experience capabilities can be brought to bear in virtually any industrial environment. *The Power of One Percent Better* starts now.