Smart Systems, Asset Performance Management and Digital Innovation in the Chemical Industry

To stay competitive, chemical manufacturers will need to sustain global economic momentum while developing new digital and Industrial Internet of Things (IIoT) capabilities and operating models. What growth themes and technology trends will the chemical industry seize to drive differentiation?

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Smart Systems, the Fourth Industrial Revolution and digital technology in general represent a new generation of computing systems and information architecture that when combined with artificial intelligence, machine learning and Industrial Internet of Things (IIoT) technologies is breaking away from today's information, computing, telecom and control paradigms to enable intelligent real-world physical systems to be integrated onto networks and the data from machines, sensors, video streams, maps, people, news feeds and more to become an integral part of all information systems. This new paradigm is driving all information systems and, more importantly, their interactions towards real-time, context-sensitive capabilities that will integrate people, processes, physical equipment and knowledge to enable collective awareness and better decision making. The chemicals industry represents a major contributor as well as a major benefactor of new digital technologies. Many core innovations enabling new smart systems are informed by chemistry and innovations such as touch screens, rechargeable batteries in portable devices, organic light-emitting diodes in flexible electronics and lightweight materials used to build drones and other aircraft. There is ample evidence that many leading companies are working hard to define and implement new strategies where digital and Smart Systems plays a fundamental role. The chemical industry, as a whole, is quickly waking up to many and diverse benefits of these new technologies.

TABLE OF CONTENTS

EXHIBITS

Chemicals Industry Growth Themes

The chemicals universe encompasses a wide range of companies that develop and supply the inputs that other manufacturers incorporate into their products. The impact of chemical manufacturers on the global economy cannot be overstated. The breadth of products that require chemicals demonstrates the importance of these inputs to everyday life. From consumer electronics and household cleaners, to batteries that power cars and drones and the processors and fiber optics that power the world's computing and Internet infrastructure, chemicals are a part of nearly everything.

This paper identifies new forces acting on players and markets and key growth themes that tie closely to future chemical manufacturer competitiveness which, in turn, are tied to several technology developments that we believe will enable new solutions and new non-traditional growth opportunities.

All aspects of chemical manufacturing will be affected by new smart systems technologies that promise to drive unimagined new value for manufacturers and their customers.

Digitization and the continued evolution of Smart Systems technologies will impact virtually every dimension of any chemical manufacturer's growth strategy and operating model and will likely make the business look and feel very different in the coming years. By exploiting the convergence between operational and information technologies, these companies are connecting their enterprises internally and externally throughout their supply chain. This both requires and supports new business models and processes.

Intelligent connected products and manufacturing assets, along with network communications, software, and advanced data management and analytics are allowing companies to re-define their approaches to business and operational processes, including product development and product life cycle management, asset performance management and supply chain and customer interaction management. Thanks to new Smart Systems and digital technologies, chemical companies are realizing new advantages across their enterprises:

» Chemical formulation processes combined with new product life cycle management systems are moving toward closed-loop product and chemical formulations and recipes to support continuous product improvement;

» Asset and related data management systems are radically improving predictive and prescriptive maintenance processes to reduce unplanned downtime, costs, and risks;

» Supply chain management processes are being deployed to support digital omni-channel go-to-market systems that integrate and improve chemical supply chains and customer purchasing and support experiences.

CHEMICALS MANUFACTURERS FACE DRAMATIC CHANGES

While it is difficult to generalize, most chemical manufacturers are undergoing dramatic change due to broader forces at work in the marketplace but also because of the impacts driven by digital and Internet of Things technologies. The advent of connectivity for intelligent equipment and machines is enabling asset monitoring and tracking to ensure uptime, performance, availability, software version control, and location analysis for a wide range of applications. As networks continue to invade the physical world of sensors and machines, many chemicals suppliers have come to understand the significant value created from extracting and leveraging the machine data and usage information from their equipment and processes to drive process optimization, compliance, safety and more.

As the chemicals arena evolves past the last several turbulent years, multiple forces [such as global economic expansion] are starting to contribute to positive growth in the short to moderate term. The overall health of the global economy and global gross domestic product (GDP) growth historically ties closely to the growth of chemicals usage. For leadership teams within chemical manufacturers, identifying and understanding key forces and trends and their potential impacts on their specific products, processes or customers will be critical to sustaining growth and performance in the long run. Management in these companies will face tough trade-off decisions related to new technology and innovation investments as well as rapidly evolving business and operating models.

Technologies, markets, customer needs and competitors are all changing rapidly. Consider just a selection of the many forces at work in the marketplace today:

» As the economy has evolved to a more service-oriented and increasingly digital state, the importance of speed and agility as well as building new skills has increased dramatically.

» Capital is increasingly available and abundant. The scale of financial assets is now roughly 8-10 times global GDP, making unique skills and new innovation concepts far more important than capital formation, and also the true constraint on a chemicals supplier's ability to drive new growth.

» Industries are consolidating into a "winner-takes-all" mode and chemicals is no exception. Both bulk and specialty chemical segments are continuing to consolidate creating globally dominant leaders that collectively earn an ever higher percentage of the available profit pool.

» Relatively lower oil and gas prices, particularly in North America, have had a major impact on the industry, since both are key feed stocks for specialty and bulk chemical production and provide much of the energy (either directly or indirectly) for these resource-hungry sectors.

» The impact of shale oil and gas has created a new wave of activity in both greenfield and capacity expansion projects in North America for specialty chemicals as well as for bulk chemicals.

» There has been continued trend in investments in state-of-the-art, global-scale chemical production facilities in China and India due to cost advantages and in Saudi Arabia due to feed stock advantages.

» While the scale and complexity of bulk chemical manufacturing appears to be increasing; specialty chemical manufacturers, particularly in Europe, are exploring increased modularization of production assets. This includes the development of new modular "micro" production plants that can be easily located close to either feed stocks or end customers to reduce logistics costs.

» Government regulations and mandates to increase safety and reduce potentially harmful emissions continue globally which, in turn, drive increased investment in automation and Industrial Internet of Things technologies that reduce costs and compensate for the growing skills shortage.

» Increased digitization across the value chain is a rapidly expanding investment focus for chemical industry participants.

We would describe all of the above trends as "classic." What we mean is the relationship of these trends to a chemical manufacturer's core business is predictable. For manufacturers to succeed in their core businesses they will need to continue to carefully set priorities and investments to address prevailing trends in the marketplace. Innovation for the core business and operational model is, for the most part, sustained, incremental and continuous. Performance measurement, repeatability, risk management, continuous improvement and financial discipline are the minimum requirements to create a continuing cycle of improved costs and higher levels of customer support.

However, we believe new digital and Smart Systems technologies will have an out-sized impact on chemical manufacturer strategy and begin to turn long held beliefs upside down. For example, many managers believe that you can be big and low cost, or you can be focused and differentiated—but not both. Today's Smart Systems and IoT technologies are enabling new modes of product and services delivery and creating new opportunities with data and analytics capabilities that either significantly reduce, if not eliminate, this classic strategic trade-off. This, we believe, is but one example of the extraordinary effects new systems technology will have on chemical manufacturers.

EVOLVING CHEMICALS INDUSTRY GROWTH THEMES DEFINED

The business environment for chemical manufacturers has entered a new chapter with new challenges and unfamiliar technologies impacting virtually all of the diverse players

and segments across the chemicals arena. Because of its breadth and diversity, it's difficult to generalize how players in specific segments should think about and respond to new unpredictable forces in the market. Even though the journey forward will differ from company to company, we believe leadership teams in chemical manufacturers should be focusing on the following growth themes that are enabled by new digital and Smart Systems technologies:

» **Smart Systems Supply Chain and Operations Innovation and Optimization:** new digital and IoT technologies will drive a multi-year wave of growth based on the convergence of innovations in embedded software, machine intelligence and data and information architectures integrated with more powerful sensors, actuators and client devices connected to higher performance personal, local and wide-area networks. These technologies will work together in unprecedented ways to solve more complex business problems than previous generations of automation, control and computing technologies. These new capabilities will revolve around real-time situational awareness and automated analysis of "states" and operations. As a result, technology moves beyond just proposing task solutions — such as executing a work order or a sales order — to sensing what is happening in the world around it, analyzing that information for risks and alternatives, and recommending action.

New business models and systems enabled by intelligent, connected assets, people and processes are being developed to help chemicals manufacturers increase competitive differentiation, profit margins, and customer satisfaction.

» **New Business Models, Skills and Organization Designs:** The technical innovation driven by digital and IoT technologies coupled with diverse and changing relationships between and among complementary players will likely lead to changes in market structure, shifts in the sources of profit and value creation and thus, new business and operating models. Identifying and designing new business models along with developing the new skills, capabilities, systems and organizational relationships they require will be critical to success.

It is this last growth theme focused on new business models that stands out for us. The influence and disruptiveness of platform companies affect much of the business world these days. Platforms can come in many types, including a de facto standard such as Cisco's network operating system or Microsoft's Windows, or Facebook's immense user base. Platform business models that creatively combine elements of dis-intermediation, shifting profit pools, new recurring services, customer transparency or other maneuvers are all disrupting existing business and operating models - and it does not stop here - just think about supply chain and freight logistics, travel, order management, customer relationship management software, consumer lending and payments, to name a few. New platform business models are cropping up everywhere leading to the question, how should chemicals manufacturers respond?

Perhaps the most important perspective we have come to is about the relationship between technology architectures and business models and the "role" that platforms and ecosystems play in enabling a whole new level of differentiation. Our evolving "thesis" points to the complexity of smart connected systems and, as the number and diversity of stakeholders expands (users, sellers, supporters, benefactors, etc.), and the volume and nature of their interactions grows, the systems or "technology architecture" will become more and more tightly coupled to the "business [model] architecture" and, in turn, the so-called platform becomes the central organizing mechanism required to deliver new data and information-driven services. Platform development decisions must align with the corresponding business and revenue models these technologies will inform. These two "architectures" must be viewed in close proximity. Technology architectures and business architectures need to be mutually supportive without inhibiting one or the other.

However, trying to coordinate and leverage the respective roles of technology and business architectures often creates contention. Many of the participants in this emerging arena that we speak with are coming to see the continuously evolving relationship between these two dimensions as fertile ground for innovation. They need to be interwoven and mutually supportive; success in either - technology architecture and business architecture - increasingly goes to the company that effectively utilizes the combined potential of both.

The Age of Smart Systems, Assets and Services

The emergence of Digital and Internet of Things is unleashing an age of "always-on" connectivity and collaboration. We have entered an era where people, businesses and social organizations are beginning to understand the profound impacts that awareness, collaboration, and intelligence will bring. In the not too distant future, hundreds of millions, then billions, of individuals and businesses, with billions, then trillions, of smart, communication devices, will stretch the boundaries of today's business and social systems and create the potential to change the way we work, learn, entertain and innovate.

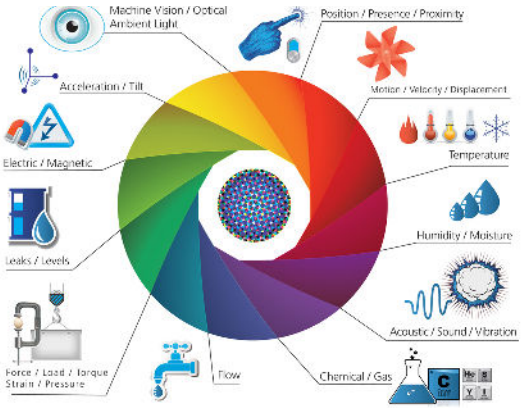
As suppliers, customers and users have become more familiar with digital and IoT capabilities, they are realizing these technology innovations will push the boundaries of how products, systems and equipment are used and managed within their operations. Chemical manufacturers in particular stand to gain significant operational productivity and drive closer customer relationships with the use of these technologies. Success, however, requires working closely with OEMs, other suppliers and end customers. As a result, specification and adoption of digital and IoT enabled equipment and systems is beginning to shift towards a "shared" set of roles between end customers and their suppliers.

What's required is a true shift in thinking about how data from devices, machines, people and physical systems will integrate and interact. We need an approach that is not about leveraging aging IT, telecom or automation technology into a new context; its about looking forward to a single, unified approach for integrating the many interactions that these systems will foster.

How will this shift effect chemical manufacturers? How should leadership in these companies think about the impacts of evolving digital technologies on their strategy, operating models and customer value creation?

Exhibit 1: Smart Systems and the IIoT Are Enabled By Sensors, Connectivity and Data

SENSORS AND ACTUATORS COMBINE WITH...



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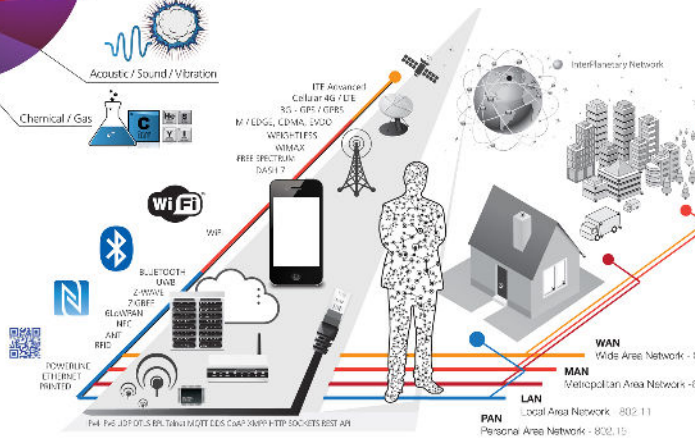
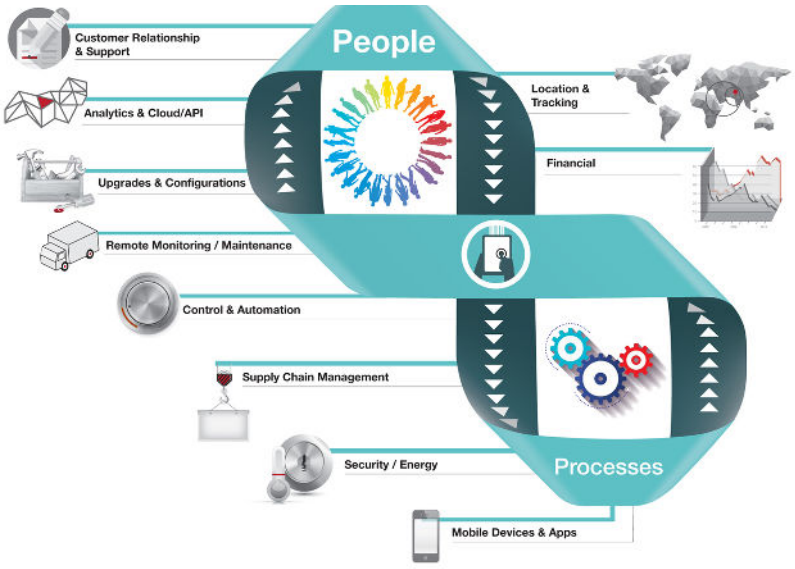


.....DATA, PEOPLE AND PROCESSES



SMART SYSTEMS within CHEMICALS MANUFACTURING

Traditional operations and maintenance practices are being compromised due to the absence of people or systems to manage them. All of this is exacerbated by the relentless drive to reduce costs and increase the productivity of manufacturing assets. Industry players cannot expect to compete effectively in the next cycle in the marketplace without aggressive investments in operational improvements and efficiencies, particularly those investments that leverage new information and decision support tools to improve asset performance tracking and visibility.

The continuing push to reduce production costs and increase total product quality and flexibility is a driving force for Smart Systems adoption. Any plant not lean enough and not flexible enough to deal with this reality faces the threat of eroding market share. With growing complexity in the design of new plants and upgrade programs for existing operations, the key factors are process precision and flexibility, which dictate the reliability of the actual process and ultimately its quality. More importantly, the current practice of reactive and break-fix maintenance rather than a predictive maintenance strategy is costing valuable uptime and hurting chemical manufacturers' ability to deliver quality products predictably.

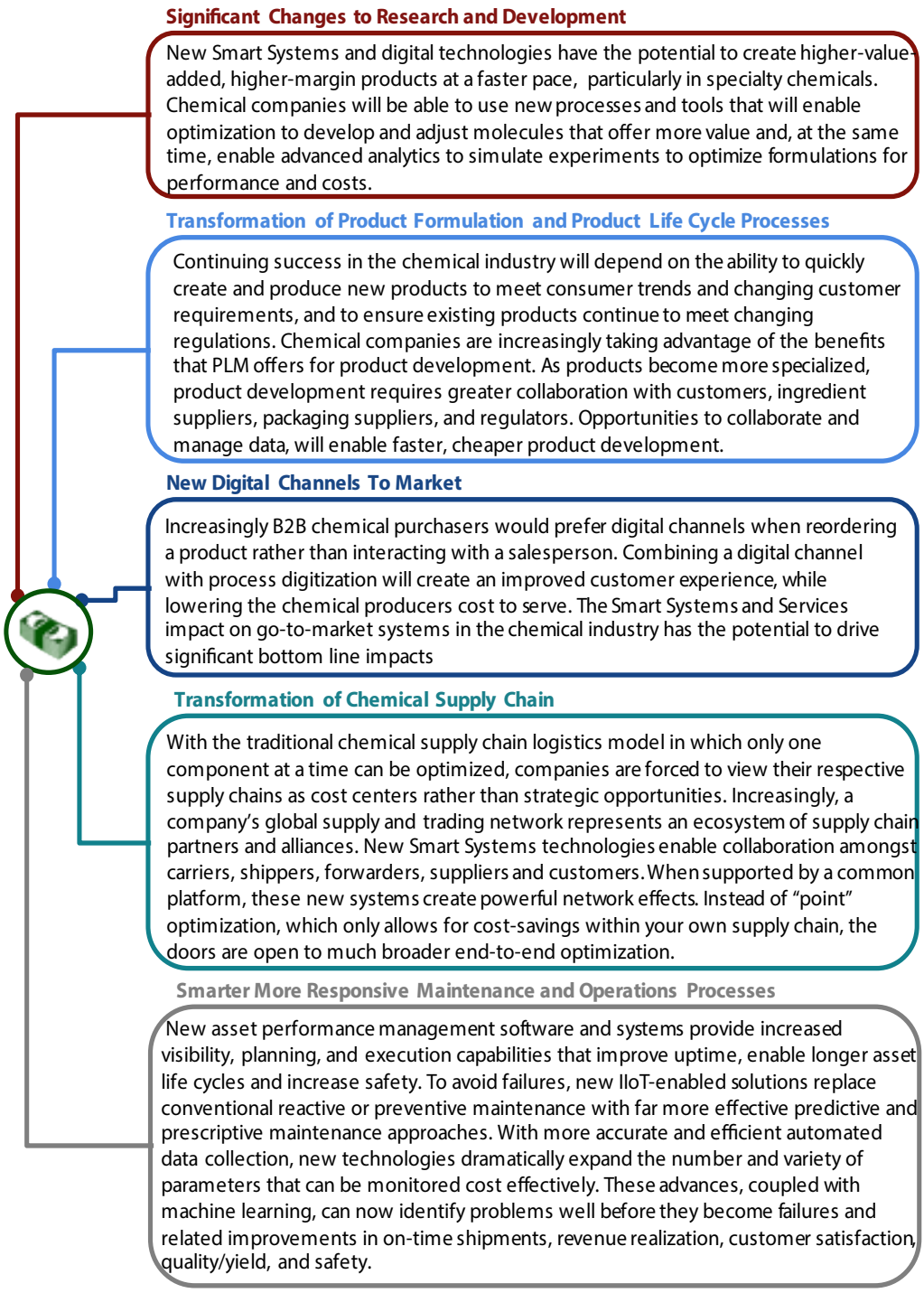
Sadly, the IT systems that run most operations today were in all likelihood designed and implemented in much the same way as when they came to market twenty to thirty-plus years ago. Further, industrial concerns have followed the path of enterprises, going off to implement ERP, asset performance management systems and other enterprise-oriented offerings. This accomplishes the management of complex business functions such as order entry, inventory management, sales and finances, but these expensive enterprise systems all have a common limitation: while precise in their collection of data about when particular components were purchased and for how much, these systems take nothing into account with regard to the behavior or performance of the process-producing outputs. In other words, ERP systems stop at inventory level, which is not actually a technical level. That the technical condition of a component or its specific technological use could have an effect on the overall profitability of the company is something the ERP system in its present state has no way of knowing.

There are many opportunities to leverage smart systems within chemicals manufacturing, from R&D, through supply chain and production to go-to-market and product delivery. Production reliability is a significant priority, but other operational levers are important to consider.

By elevating these critical problems up from the "wrench-turners" to progressively higher levels of management, a more comprehensive operations and maintenance strategy can be attained, with critical, real-time information on the performance of machines and process dynamics. However, senior leadership in today's environment typically do not get intimately involved with the daily operations and the particulars of servicing equipment and machines. Fortunately, this oversight is rapidly changing: executives in today's chemicals arena are just beginning to see operations as a critical component for increasing

shareholder value and new technology investment as a way forward to more productive businesses. Core investments in new technical capabilities are focused on the areas detailed in Exhibit 2.

Exhibit 2: Key Investment Strategies For Chemical Manufacturers To Consider



The goal of asset optimization is near-zero downtime for manufacturing operations equipment and processes based on the ability to model optimal machine performance and monitor real-world performance degradation using sensor data already available (but underutilized) on most state-of-the-art equipment. This requires the development of software systems to share this information over networks and the use of networked devices to schedule predictive maintenance before failure occurs. Ultimately, it means the creation of machines that learn, self-optimize, and even repair themselves—converting emergency repair visits into routine service.

When smart process control equipment is networked and remotely monitored, and when device data is modeled and continually analyzed with sophisticated systems, it is possible to go beyond mere "predictive maintenance" to systems "prognostics", the process of pinpointing exactly which components of a machine are likely to fail and when. When the "health" of production and control equipment is almost perfectly visible, a chemical company can plan intelligently rather than being blindsided by failure.

Internal operations-focused use cases of Smart Systems technologies for chemical manufacturers, while important in driving efficiency and productivity, are only meant to drive greater margins for the producer. To achieve top line growth, chemical manufacturers will have to consider new modes of collaboration and interaction with their customers that create new value above and beyond the simple sale of products.

COLLABORATION TECHNOLOGIES WILL BE CRITICAL TO ADDRESSING END CUSTOMERS

We believe the shift in product and systems specification is driven by end customers wanting to integrate data from diverse suppliers of devices, machines, chemicals, materials and production systems in their operations.

Peer-to-peer information and network integration are combining to create new modes of collaboration and sources of value between suppliers and customers. Networks are integrating knowledge, people and things into systems that enable awareness, creativity, better decision making, and ultimately, higher value solutions.

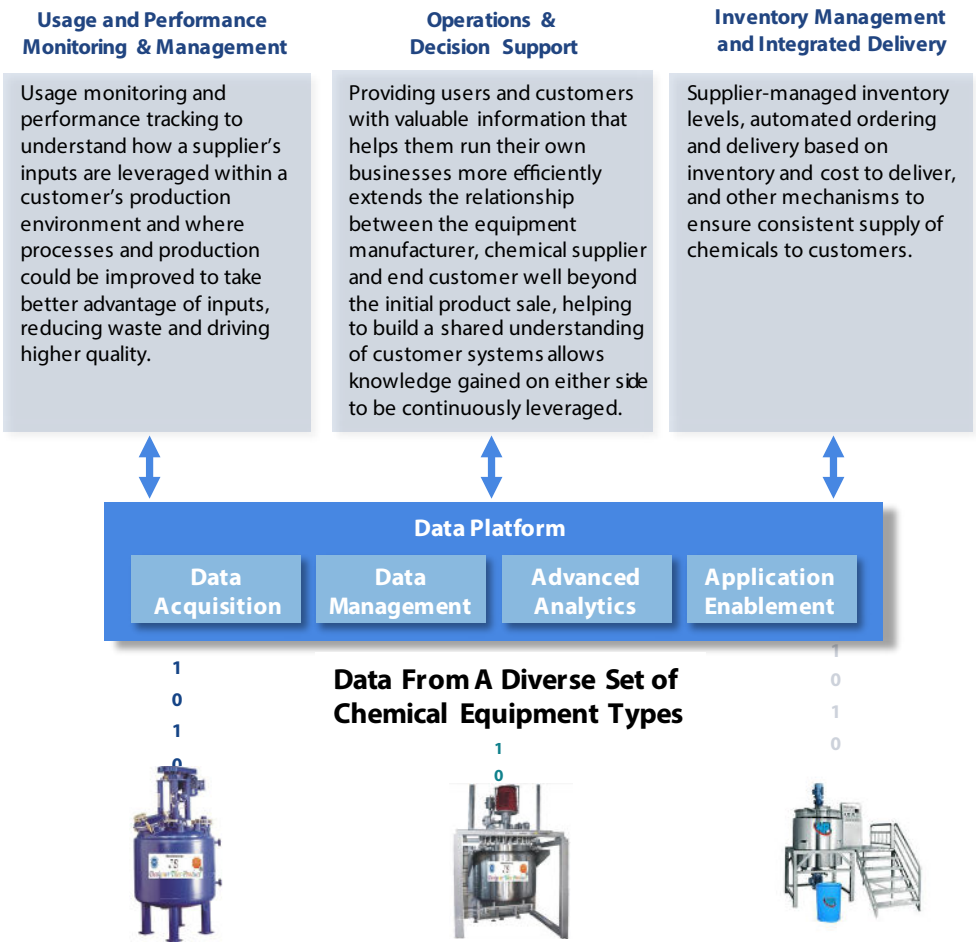
The intersection of cloud computing, big data and intelligent device connectivity creates new value across the business and public systems spectrum. Cloud computing services and large-scale data management infrastructure services will increasingly dominate ICT systems and services development. Coupled with the maturing of IoT technologies, these collective trends are beginning to transform industrial sector systems and have the potential to create unimagined value.

This convergence informs significant new modes of service delivery and customer value creation, and reflects the increasing importance of three critical elements: end-to-

end solutions; a new generation of real-time, "state-based" platforms; and large-scale ecosystem collaboration. All three drive businesses towards a fundamental shift in their business models to address the myriad of opportunities arising from services wrapped around connected products. This phenomenon has far-reaching effects the likes of which have never before been seen in business or our everyday lives. It is no longer enough for a company to offer services; it will have to provide Smart Services. For chemical manufacturers, these include internal and external applications, including usage and performance management, operations decision support, and inventory management and integrated delivery, among many others.

Smart assets, systems and services can be applied to product delivery and customer processes to create new collaboration opportunities and drive closer relationships with greater engagement.

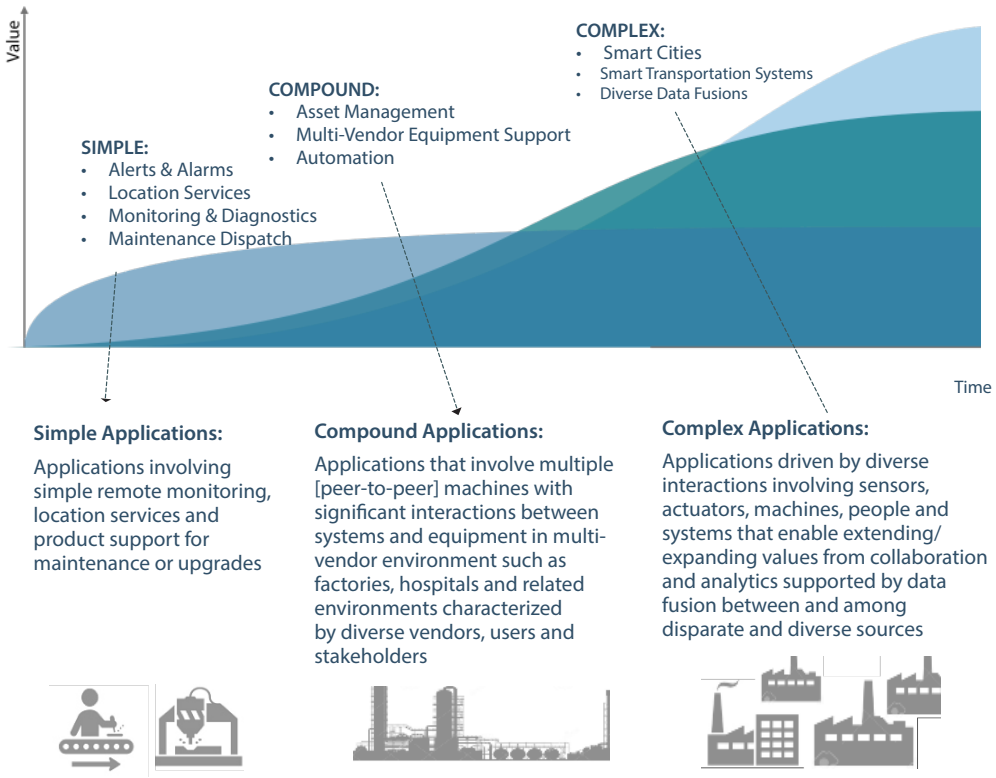
Exhibit 3: Data Platforms Enable New Smart Services Opportunities



In a unified network environment, information becomes currency, and can be shared and utilized collaboratively. When machines and equipment become networked, the environment in which they are utilized shifts to a much more "aware," and responsive support environment. Eventually, this environment helps suppliers and customers alike to optimize their processes, save money, and become significantly more efficient.

For a chemical manufacturer, integrating internal efficiency and productivity-driving technologies and external customer-facing information-based services can create compound values that are worth more than the sum of their parts.

Exhibit 4: The Journey From Simple To Compound To Complex Applications



ACHIEVING COMPOUND VALUE from SMART SYSTEMS

The true potential of Smart Systems, Manufacturing Assets and Services lies in the integration of diverse machines, information systems and people—its ability to connect billions upon billions of smart sensors, devices, and ordinary products into a "digital nervous system" that will smoothly interact with individuals and the physical world. The nature of compound and complex smart system applications is just beginning to be understood where the information value generated by these capabilities opens up new opportunities for value capture and creation for chemical manufacturers, including:

» Managing and automating suppliers and the entire supply chain, including production inputs, spare parts inventory and service delivery chain for maintenance processes providing vastly improved levels of service, increasing responsiveness, and reducing inventory levels;

» Providing first line support staff, the equipment manufacturers' service technicians and other third party support personnel with complete access to a unified machine maintenance record that captures all of the machine's performance data, history and knowledge about the status of the equipment enabling faster and more effective maintenance processes;

» Analyzing the history of the equipment in use against diverse data sources such as weather patterns and peak usage requirements to optimize its performance; and,

» Providing entirely new services to chemicals customers such as collaborative product development, automatic ordering, just-in-time delivery, and more as managed services.

Taken one step further, applications that drive interactions between devices, sub-systems, machines and people across operational and enterprise systems will potentially catalyze an expanded value-set from third party collaboration and large scale data integration and analytics that, while complex, will be the greatest opportunity for smart systems and manufacturing assets.

The Implications for Chemicals Manufacturers

Combining sophisticated sensors, real-time connectivity, and massive computing power to leverage the data from these operational systems, can equip chemical manufacturers with a higher level of optimization across virtually all aspects of their supply chain, production, and delivery.

To achieve real compound value in smart systems and asset applications, chemical manufacturers will need to think and act differently. A renewed focus on developing ecosystems and critical relationships that will drive value is key to success.

PARTNERSHIPS and ECOSYSTEMS

The next great step in IT and OT development—completely fluid information and fully inter-operating devices, people and systems—requires a new generation of data and application integration platform technology that will make information itself truly portable in both physical and information space, and among any conceivable smart information devices and machines.

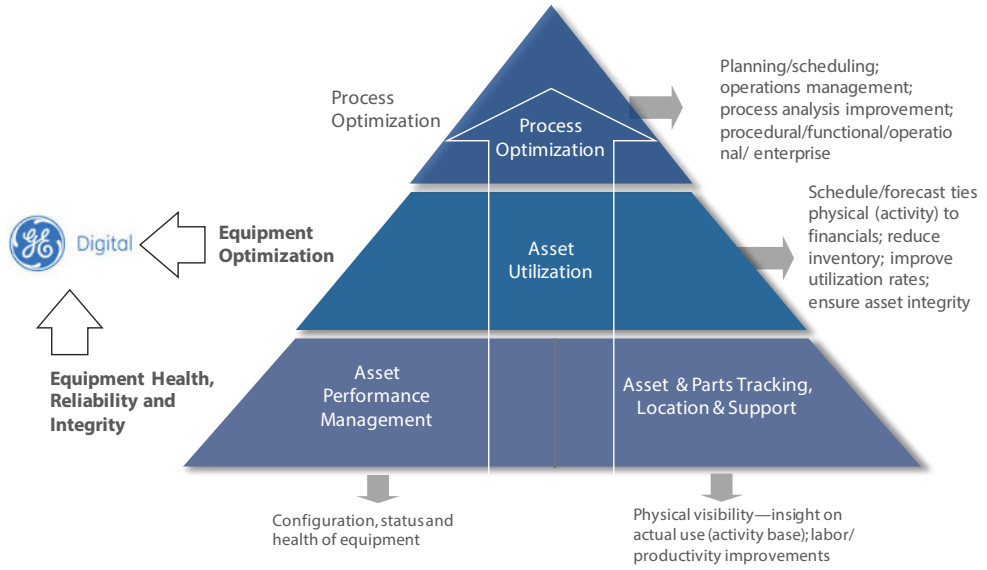
Technology advancements need to engender new system elements and services. Correctly balanced, technology, operations and service delivery modes can help chemicals suppliers and their customers reach their goals of increased operating efficiency, reduced costs, automated system upgrades, and more efficient operations. Achieving this critical balance is the challenge that GE Digital's Predix platform is aimed squarely at solving.

Creative combinations of technologies, applications, systems and partners are key to capturing the smart systems opportunity.

You cannot do this alone.

GE's platform is intended to reduce a significant percentage of the complexities of application development, systems management and application delivery. The challenges of networking smart devices, developing connected product applications, integrating complex IT systems and unifying services delivery in a coherent and cost-effective manner have been big hurdles to adoption that new platform technologies are finally addressing.

Exhibit 5: GE's Value Proposition Lies in its Platform Modularity and Ease-of-Use



Integrating physical and virtual systems will require expert application knowledge as well as a deep understanding how these systems will work. Choosing the right partner, one that fully understands the different elements involved and has industry domain and equipment knowledge, and correctly aligned with delivery infrastructure partners will be critical to successful deployments. Working with a technology and solution provider that has a deep rooted understanding of the complexities of large global deployments will ensure that the solution is successfully delivered. A new chapter in the story of smart systems and manufacturing assets, OT, IT and Telco partnerships has begun that will inform new value in the converged Internet of Things and People.

ENDPOINTS and NEXT STEPS

Manufacturers and thought leaders alike now see that digital manufacturing technologies will transform every link in the manufacturing value chain, from research and development, supply chain and plant operations to marketing, sales and service. We see an increasing awareness of these new approaches and technologies as adoption, particularly in highly mission critical segments, picks up. There are, however, several reasons that adoption has been relatively uneven across the industrial landscape.

Many managers feel that they do not have enough data, the right data or reliable data to make accurate business decisions. Even information that seems common, such as accurate profit and cost information, often proves to be elusive. Some reasons for this are siloed and inaccessible storage processes for data, unclear understanding of how to extract value from data and the absence of data that is not being collected. This has often prevented industrial firms from successfully leveraging the data flowing from their equipment and operations.

Senior leadership, on the whole, has a very diverse and uneven understanding of value of data from these systems. Executives in today's industrial arena are just beginning to see that data and analytics can unlock new shareholder value. As a result, the chemicals industry has invested substantially more in direct process innovation and automation than it has in extracting and leveraging information from operations and maintenance. Investment in wireless technologies for mobile and distributed monitoring, for low-cost data extraction and for device and system connectivity has been spotty.

Radical new thinking about connected assets, operations and product delivery technology must begin at the most basic levels, future proofing their innovations by making the fewest possible assumptions about the nature of networked objects and the data they produce, carry or process - the company takes a much broader, all-encompassing view of information. Ultimately, this type of platform solution will alter traditional business models and how new applications are realized.

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