SMART SYSTEMS and INTERNET OF THINGS PLATFORMS

Overview of Research and Analysis and Summary Findings

Current computer science operates with models of information, networking, and database schemas that were conceived in the mainframe and client server eras and cannot serve the needs of a truly connected world.
Smart Connected Systems really means the future of networked computing and information. It will require a remarkably agile global network that could comfortably scale to trillions of nodes—some of them hardware, some software, some purely data, many of them coming into and out of existence or changing location constantly. Obviously, such a network system cannot be “designed” in any ordinary sense. Certainly, it cannot be designed “top-down.” And yet the Internet of Things must be designed in some sense. The tools we are working with today to make products “smart” were not designed to handle the diversity of devices, the scope of interactions and the massive volume of data-points generated from devices. Each new device requires too much customization and maintenance just to perform the same basic tasks. These challenges are diluting the ability of organizations to efficiently and effectively manage development. Today, platforms for the Internet of Things are still a collection of yesterday’s technology and architectures that do not address the most basic development challenges.
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INTRODUCTION

For quite a few years now, Harbor Research has focused most of its research and consulting on what we call “Smart Systems”—the convergence of pervasive or embedded computing with the packet-switching “network of networks” called the Internet.

These days, many people refer to this phenomenon as “the Internet of Things (IoT).” We prefer “Smart Systems” over other terms in common use because it captures the profound enormity of the phenomenon—something much greater in scope than just machine connectivity.

Whatever we chose to call it—“Smart Systems” or “Pervasive Computing” or “The Internet of Things”—we are referring to digital microprocessors and sensors embedded in everyday objects. But even this makes too many assumptions about what the smart systems phenomenon will be. Encoded information in physical objects is also smart—even without intrinsic computing ability. Seen in this way, a printed bar code, a house key, or even the pages of a technical manual can have the status of an “information device” on a network. For that matter, all of these characterizations do not even begin to address the human-machine dimension of collaboration.

But very few people are thinking about smart connected systems on that level. Current technologists are operating with outdated models of data, networking and information management that were conceived in the mainframe and client-server eras and cannot serve the needs of a truly connected world. “Smart Systems” should automatically be understood as “real-time networked information” but it isn’t.

We have now entered the age when everyday objects will communicate with, and control, other objects over a global data network—24/7/365. It’s not “the future,” it’s now—this year, next year—and thus it is vitally important that business leaders understand this phenomenon, its effects on their business, and what they should do right now to position themselves for opportunities that are literally just around the corner.

When telephones first came into existence, all calls were routed through switchboards and had to be connected by a live operator. It was long ago forecast that if telephone traffic continued to grow in this way, soon everybody in the world would have to be a switchboard operator. Of course that did not happen because automation was built into the systems to handle common tasks like connecting calls.

We are quickly approaching analogous circumstances in the IoT arena with the proliferation of connected devices. The tools we are working with today to make products “smart” were not designed to handle the diversity of devices, the scope of interactions and the massive volume of data-points generated from devices. Each new device requires too much customization and development resources just to perform the same basic tasks efficiently and effectively.
Today, platforms for the Internet of Things are still a kludgy collection of yesterday’s technology and architectures that do not address the most basic development challenges. Even though many companies are telling fantastic IoT marketing stories about what their solutions can do, you wouldn’t know it from today’s fragmented collection of incomplete platforms, narrow point-solutions, and software incompatibility.

The IT, telecom and automation sectors have failed to keep pace with advancing technology and its potential impact on their constituents. In the course of the last two decades, the world has become so dependent upon the existing ways computing, telephony and automation systems are organized that most people cannot bring themselves to think about the evolution of these technologies with any critical detachment. Even in sophisticated discussions, today’s key enabling information, automation and control technologies are usually viewed as utterly inevitable and unquestionable.

The client-server model underlying today’s computing systems greatly compounds the problem. Regardless of data-structure, information in today’s computing systems is machine-centric because its life is tied to the life of a physical machine and can easily become extinct. With today’s IoT platforms information is not free and fluid. In fact, thanks to today’s platforms and information architectures, it’s not free to easily merge with other information and enable any kind of systemic intelligence.

All of this adds up to a huge collection of information-islands whether on your servers, your service provider’s servers or anywhere else. Assuming the islands remain in existence reliably, they are still fundamentally incapable of truly interoperating with
other information-islands. This is the issue with all so-called IoT platforms that have flooded the market – they are really “data traps” and information islands. We can create bridges between them, but islands they remain, because that’s how they were designed.

The next cycle of technology and systems development in the smart connected systems arena is supposed to be setting the stage for a multi-year wave of growth based on the convergence of innovations in software architectures; back-room data center operations; wireless and broadband communications; and smaller, more powerful client devices connected to personal, local and wide-area networks. But is it?

This report is about an important new perspective on smart systems and services and the technology integration and development platforms that play a critical role enabling these new solutions. This perspective does not just come from our own thinking. It is from the diverse group of people who are thinking about the scope and on the scale that Smart Systems deserves. It is because this community of technologists and business developers is so fragmented that we believe a new approach is required. This is why we believe a new “architecture” is required to begin to integrate and bind these disparate views of the future of information technology.

What do we plan to address in this report?

» The required architecture and technologies to inform a radically new view of information services; and,

» The corresponding emerging business models these technologies will inform.

Most importantly, we plan to demonstrate that for the first time in the evolution of networked businesses, these two “architectures” must be viewed in close proximity. The two thrusts need to be mutually supportive without inhibiting one or the other. However, trying to coordinate and leverage the respective roles of technology architecture and business architecture often creates contention. Many of the participants in this emerging arena 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. In fact, from our own direct consulting experiences, we believe success in either increasingly goes to the company that effectively utilizes the combined potential of both.

In our years of work on the Internet of Things phenomenon and its real-world effects on business, we have not encountered very many compelling visions about the complete integration of things, people, systems and real-time real-world inputs. The world today, for the most part, lacks a group of coordinated innovators that understand that the tools we are working with to make products “smart” on networks were not designed to handle the scope and diversity of interactions they are being enabled to accomplish.
WHAT ARE SMART SYSTEMS?

Peer-to-peer information, social networking and pervasive computing are combining to create new modes of collaboration and decision making. People, information, and technology are becoming more connected, distributed and pervasive enabling the convergence of physical and virtual worlds. Social networking technologies are moving to the enterprise and will be embraced and experienced differently than in the consumer space. Network awareness will include knowledge, people and things.

These forces are informing a new trend we call “Smart Systems.” In its simplest form, Smart Systems is a new generation of computing systems and information architecture that when combined with artificial intelligence, machine learning and Internet of Things technologies are breaking away from today’s information, computing and telecom (ICT) 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, state-based, context-sensitive capabilities that integrate people, processes, physical equipment and knowledge to enable collective awareness and better decision making -- thus, Smart Systems.

The foundation of Smart Systems is based on leveraging embedded computing, software and networking technology to deliver smart, remotely monitored goods that will support entirely new modes of customer-device interaction and service delivery. The core platforms that inform Smart Systems combine new innovations in software and information architectures with data collection, aggregation, integration and management tools. These “data” technologies will work together in unprecedented ways to solve more complex business problems than previous generations of computing.

Since the beginning of computing there have essentially been three waves of technology and architecture: mainframe computing, personal computing, and network computing. This next generation of “Smart Systems” technology will add significant new capabilities to computing and network systems. These new capabilities will revolve around real-time situational awareness and automated analysis. 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 new information for exceptions, risks and alternatives, and taking actions.

The three previous waves of technology each have had significant impacts on productivity and efficiencies; mainframes standardized transactions; personal computing placed processing power into the hands of professionals; and, networked systems enabled business process automation. What is important about this next wave of Smart Systems is the combined impact of these innovation cycles.
SMART SYSTEMS ARE BASED ON HORIZONTAL ARCHITECTURES

As networks have invaded the “physical” world, traditionally unique components and interfaces between and among electronic as well as mechanical elements are becoming more and more standardized. Connectivity and integration will become universal as components, platforms and systems become ever more standardized, open and readily integrated.

The implications of these trends are enormous. No product development organization or its suppliers of components and sub-systems will be able to ignore these forces -- product and service design will increasingly be influenced by common components and sub-systems. Vertically defined, stand-alone products and application markets will increasingly become a part of a larger “horizontal” set of standards for hardware, software and communications.

As it becomes easier and easier to design and develop smart systems, competitive differentiation will shift away from unique, vertically focused product features towards how the product is actually used and how the product fosters interactions between and among users in a networked context. The opportunities this opens up to forward thinking product and service organizations are nearly infinite. Businesses can begin to explore many new possibilities for system solutions unthinkable just a few years ago.

Once a device becomes networked and is monitored for the primary purposes of device status, usage tracking, and consumables replenishment, it will also serve the larger business purpose of being a key driver for the vertical customization of services in general. For example, “asset management” is an important service that incorporates a number of different variables and systems (diagnostics for equipment health monitoring, location services for maintenance and spare parts planning, etc.).

Application service providers need to organize the devices and system capabilities they offer configured for the environment in which they operate—factory, office, hospital, and elsewhere. A product inventory program will have a much different configuration in a factory than it will in an office building. More than ever before, the drivers, needs, and environmental conditions will determine the way technology is implemented. Ultimately, all devices and services, like asset management, will be highly configurable to match the needs of a particular venue, industry segment or even of a particular end-user.

Technology developers and related services providers will realize revenue streams within this new market model in multiple ways that align to the so-called “tech stack” in the following categories:

» Enablement: the communications capabilities attached to or embedded in each machine to be connected;
» **Network Services**: the wireless or wireline communication medium used to receive/send machine data including configuration and provisioning, network service charges, and support services;

» **System [platform] Applications**: the integration software that most people today refer to as “middleware” or “platform” software for the IoT which, in some cases, will also provide tools for application development; and,

» **Value-Added Application Services**: which include the [managed] services delivery for vertically-focused value added applications.

### Exhibit 2: Common Architecture Across Physical and Digital Systems

<table>
<thead>
<tr>
<th>Systems Applications</th>
<th>Services &amp; Applications</th>
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<tr>
<td>Carrier &amp; Network Services</td>
<td>Tools &amp; Infrastructure</td>
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<tr>
<td>Software Tools, Middleware</td>
<td>Mobile Telephony, IT Terminals &amp; Tools</td>
</tr>
<tr>
<td>Network Infrastructure &amp; Connectivity</td>
<td></td>
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</tbody>
</table>

Mobile Equipment

- SmartPhones
- Tablets
- Terminals
- Diagnostic Tools
- Aerospace
- Vehicles
- Marine
- Rail
- On-Road
- Off-Road

Fixed Equipment

- Complex Systemic Equipment
- Standard Machines & Equipment
- Facility Systems & Equipment
- Facility Infrastructure Components & Sub-Systems

Facility Systems & Equipment

- Electrical Sub-Systems & Components
- Mechanical Sub-Systems & Components
- Fluid & Pneumatic Sub-Systems & Components
- Electronic Interconnect
- Semiconductors & Micro-Electronics
- Power & Control Systems
- Machine/Device Sub-Systems, Assemblies, Modules & Components
- Embedded Electronics

Within these four “stack” segments, one of the most critical “foundation” elements are “systems applications” described above. When we refer to system apps and platform functions we mean a set of state-based application functions that are horizontal in nature and often characterized in a general sense as “middleware” that are not seen by the end user (we do not like the term middleware as it risks generalizing capabilities that are unique to Smart Systems and IoT applications).
In its most basic and practical form, our concept of “Systems Applications” is based on “connectivity and device management services integrated with data aggregation and management functions. But that’s not as simple as it sounds. Capturing the real value of Internet-connected devices goes much further than providing connectivity, a transport scheme and databasing. For example, real pervasive managed services will allow networked, intelligent devices to execute remote applications as if those applications were part of the internal operating system. This type of enablement, or distributed processing, can bring extraordinary value to the growing population of networked devices with increasing amounts of embedded intelligence.

System application functions are relatively general in nature and include the following:

- **Monitoring & State**: Status applications capture and report on the operation, performance, and usage of a device, or the environment that the device is monitoring. Diagnostics applications allow for remote monitoring, troubleshooting, repair, and maintenance of networked devices.

- **Location & Tracking**: Profiling and behavior-tracking applications are used to monitor variations in geography, culture, performance, usage, and sales of a device. These applications can also be used to create a more customized or predictive response to end-users of a device.

- **Device Management & Connectivity Services**: Device management functions improve or augment the performance or features of a device. They can prevent
problems with identity management, version control, technology obsolescence, and device failure. This kind of program makes site visits to upgrade products unnecessary and eliminates the need to keep track of what has been upgraded and when, thus saving time and money.

» **Automation, Analytics and Data Management:** Analytics and automation applications coordinate device data to enable a sequenced pattern of behavior based on data filtering, normalization, transformation and analytics, such as predictive analytics, pattern recognition or machine learning algorithms.

A key characteristic of Systems Applications will be the importance of how their basic functions can be combined to provide vertically focused solutions -- the bulk of which will increasingly be delivered as a managed or value-added service. In conceptualizing how platforms would support Value-Added Applications Services, system-level applications would be called upon and integrated in differing configurations to provide vertical value-added applications. For example, a combination of monitoring, data logging, control and tracking functions could be configured to provide basic functionality required to enable an energy management application.

These value added application services are solutions that integrate people, business processes and assets and are and will be delivered largely as managed services. Examples
of value-added applications services include the following:

» Asset management and optimization
» Supply chain integration & business process management
» Customer support
» Energy management
» Security management

Players will create solutions that combine elements of industry-specialized hardware devices, vertical industry software, and industry-focused wireless/wired networks with data management tools to optimize business processes and performance both operationally as well as financially.

Smart Systems technologies and applications will help organizations address the key challenge of optimizing the value of their balance sheets, allowing them to move beyond financial assets and liabilities to their physical assets and liabilities (like electric grids or hospitals) and then to their intangible assets and liabilities (like a skilled workforce or brand). Assets and liabilities tend to be very industry-specific, even more so than processes that may be common across industries. And the task of optimizing the value of these assets and liabilities is vertically focused because optimization requirements vary dramatically from industry to industry.

THE FAILURE OF IoT PLATFORMS

The term “convergence” implies unification, but you wouldn’t know it from today’s rapidly evolving “Internet of Things” market—a fragmented landscape full of incomplete platforms, narrow point-solutions, and software incompatibility seemingly all based on the premise of some outsized dependency on big data and the cloud.

The Internet of Things really means the convergence of information, control and the cyber elements of physical systems. It will require a remarkably agile network that could comfortably scale to billions or more nodes—some of them hardware, some software, some purely data, many of them coming into and out of existence or some in obscure physical locations or changing location constantly. Obviously, such a network cannot be “designed” in any ordinary sense. Certainly, it cannot be designed “top-down.”

And yet the Internet of Things must be designed in some sense. Some basic design principles must be put in place to guide the growth of a vast, distributed technological organism that must remain organized as it evolves according to a logic all its own. It demands that we design not only devices and networks but also information itself in ways not addressed by current IT.

Artificial intelligence, machine learning and the Internet of Things are all in some way trying to break from today’s computing paradigms to enable real-world physical systems,
but these promising technologies need to be viewed as applications that will work with this next generation IoT architecture that provides near seamless access to data of all types seamlessly to these applications. Said another way, it will not be feasible to re-invent the underlying infrastructure for each new application. Instead, these applications need to integrate easily with an appropriate networking and data management foundation.

We have seen that we can make a computer capable of beating the reigning genius of chess, but yet we can’t make a robot capable of walking across the street as well as any normal two-year-old child. The real world is not a strictly regulated, closed system like a chess game. Sensing a player’s moves on a wired chessboard and responding quickly and intelligently based on “knowable” algorithms is one thing. Sensing and responding to physical systems and states – is a fundamentally different challenge. To achieve the intelligent solutions envisioned by the IoT requires an entirely new approach that can leverage common platforms and data models across diverse devices, data and domains.

The fact that a wide range of sensors, machines and equipment can transmit information about status, performance and usage, and can interact with people and other devices anywhere in real time points to the increasingly complex role of data in IoT systems. This only compounds when we consider the billions or more of networked devices that many observers are forecasting will be deployed and the scale of data they will produce.

The tools we are working with today to make products “smart” on networks were not designed to handle the scope of new functional capabilities, the diversity of devices and the massive volume of data-points generated from device interactions.

REPORT SCOPE and COVERAGE

The report covers the evolving core technologies that enable data platforms, the key trends and forces impacting adoption of new Smart System platforms including evolving market structure, the critical requirements for a new generation of platforms, the players developing truly next generation innovations for platforms as well as the new business models these capabilities can inform.

Forecasts for Smart Systems and IoT platform technology or, what we define as Systems Applications, are presented in this report as a part of four macro levels - Enablement (embedded and module level connectivity), Network Services, Systems [platform] Applications and Value-Added Applications and Services. All forecasts are presented worldwide and broken down by region.
SUMMARY FINDINGS

Through our firm’s consulting work with OEMs and services providers adopting new platforms and related technology, we have found many of our clients and others we speak with in the marketplace very confused about what actually is the definition of a so-called IoT platform and what capabilities and needs must be addressed by developers of platform technology.

The number of developers that have been funded to bring new IoT platform technology to market over the last five years is staggering. IT systems suppliers and wireless carriers have compounded the confusion by also introducing a variety of “platform” ... “gateway”... “software” ... etc... IoT offerings.

We decided we needed to analyze user needs and requirements more closely and then analyze the broad, diverse and confusing array of offerings in this context. As a result, Harbor Research screened over 200 software infrastructure and platform players to better understand each supplier’s core functions, enabling technologies as well the applications, use cases and markets served.

We do strongly believe that the Pervasive Internet and Smart Systems market opportunity is reaching a new level of maturity; there is now substantially greater recognition of the technological capabilities and the potential benefits of connecting and integrating machines and devices to the Internet. This represents a whole new generation of technology innovation and, if history repeats because certain conditions repeat, we expect to see a significant and expanding wave of growth in Smart Systems and Services.

Summary points from our analysis addressing the scope and scale of the opportunity:

» ICT investment is expected to reach 3.5 trillion dollars in 2017, with Smart Systems investment comprising approximately 10-15% of ICT spending;

» Our analysis indicates the rate of investment in smart systems will be measurably higher than in maturing IT and network infrastructure technologies; Smart Systems growth expected to reach 3-4X the compounded rate of traditional ICT;

» As investment in Smart Systems continues to move to a more sustained cycle, the growth in new classes of sensors, hardware interface devices, wearables and related mobile IT support terminals will also rise significantly.

» Growth in System Applications (i.e. IoT platforms) will be driven by customer demand for more advanced platform functions in two critical areas: data/information architecture to enable scaleability, and data management and transformation tools to support analytics and machine learning applications. These functions are a minimum requirement to enable new business and revenue models.
The Smart Systems, Services and Internet of Things platform market potential represents as much as $75 billion today growing to as much as a $300 billion potential market by 2023.

While the range of current year revenues for new entrants supplying platforms is estimated between $480 - $540 million which does not include monitoring, maintaining or upgrading existing installed systems including SCADA and related machine and equipment control monitoring systems as well as similar systems utilized today for a wide variety of commercial applications such as monitoring of HVAC systems, refrigeration equipment, power distribution systems, lighting systems to name a few instances.

Exhibit 5: System Applications and Platform Opportunity by Venue, Billions, 2017-2023

In this context, our analysis also points to several broader market development challenges in realizing the full value of IoT platforms:

» Challenges in adopting new business and revenue models;
» Complex services delivery ecosystems that require new and different relationships;
» Anticipation of service and systems innovation modes not widely adopted today;
» Fragmented IoT vendor landscape not yet well aligned with the larger IT players;
» Requirement for vertically-focused solutions from “horizontal” technologies.

The potential scale of the Smart Systems and IoT platform opportunity is utterly dependent on new platform innovation. Without it, we would expect much lower adoption rates and corresponding market scale.
As more devices continue to be brought online, expect exponential growth of data from sensors, machines and other equipment which, when properly leveraged, brings new, unique value to users and customers. To harness this value adopters have been turning to a new class of software or “platform” (historically referred to as middleware) to integrate and manage devices, connectivity services and data aggregation and a new generation of state-based applications.

What the evolving digital and IoT market needs is a platform that anticipates developers’ and users’ toughest challenges—from interoperability and latency to database dependency and user complexity—as a group of problems that can be addressed by a single, unified, scalable software solution.

Summary points from our analysis of user requirements for platforms that enable new connected machine and device applications highlights four critical needs:

» A fully configurable software platform architecture that enables both peer-to-peer and client-server distribution of services;

» A platform that can simultaneously and asynchronously act on any type of information from any device, storage or streaming source;

» Enabling real-time temporal, spatial and state-based contextual processing; and,

» A platform that provides tools for development of real-time, stateful applications.

Demand for these types of capabilities is hardly new, but as they converge, these technologies need to be interwoven and mutually supportive. We believe success will only go to players who effectively leverage their combined potential.

Based on direct interviews with market participants and thought leaders, next generation IoT and Smart Systems platform architecture will need to address the following:

» Advanced, high value applications and use cases enabling systemic awareness, visibility and collaboration can be achieved using today’s technology, however, significant time and money is required to integrate and manage the variety of tools from numerous vendors.

» A new generation of systems architecture is required – one that can align with and “form fit” to the physical world; embedded computing with software tools that are easy to use and address a broad range of real-time, and historical data analytics requirements – ideally a single unified framework to design and build solutions that can interoperates across diverse data environments and under widely differing usage scenarios.
» Systems will require a true distributed software architecture that can process and create value from device data locally at the node – in remote sites, buildings, equipment rooms and telecom closets, while enabling higher level applications that generate value from portfolio-wide data. We have been lead to believe that the only way to get value from IoT data is to bring all of it to the cloud. It is not possible, cost effective or desirable to transmit every piece of data from IoT devices to the cloud in order to gain value from them. Numerous critical applications will require processing and analysis of data locally to support user needs and to automatically filter and semantically enrich that data before delivering it to higher levels of the architecture for other application needs.

» Users needs and requirements emphasize the need for software that can enable easy integration of any combination of inputs and data types - message - feed - stream - data - in real-time with stream processing that provides complete independence from traditional rigid database technologies; software designed without the bias and dependencies of a single product or service application that will cause integration pain when attempted to be used beyond its original scope.

» Ultimately, software and tools that allow users to easily and quickly build their own applications integrated into a truly scalable software architecture and data models/architecture with no constraints on where it gets deployed – whether on a chip, device, server, cloud, or hybrid system; yet able to provide extensibility with common features and functions at each level of the architecture.

The rigid and fragmented nature of software offerings available today make it extremely difficult and expensive to develop effective Smart Systems and IoT applications. Feedback from developers, adopters and users suggests we are reaching a critical juncture in market development where organizations will expect their invested resources to develop new data-centric IoT applications can be easily re-used again and again. We believe this situation underscores the need for fresh new thinking about computing, information management and networking that demonstrates it is possible to migrate gracefully to scalable architectures truly designed for the era of pervasive computing.

Based on our analysis of over 200 platform and software infrastructure developers, Smart Systems and IoT platform offerings can be segmented into four broad groups:

» Players that offer basic device management functions and services;

» Players offering device management and connectivity services;

» Specialist players developing focused capabilities in areas such data management/transformation, analytics tools, vertically focused applications and related; and,

» A distinct minority of players who are addressing next generation adaptable software
platforms that become the integration and digital fabric for ubiquitous connectivity & distributed intelligence. Four examples of this group of players include niolabs and Fathym, both general platform players as well as SkyFoundry and Glassbeam, two significant data management-focused players (see our analysis in the Chapter 4 of this report).

Customers expect evolving software tools to be functional, ubiquitous, and easy-to-use. Within this construct, however, the first two expectations run counter to the third. In order to achieve all three, a new approach is required.

The next great step in the convergence of IT and OT—completely fluid information and fully interoperating devices, data, people and systems—requires an equally simple, flexible, and universal abstraction that will make information itself truly portable in both physical and information space, and among any conceivable information devices.

**Evolving Platform Player Ecosystems**

After displaying signs of relative indifference for so many years, traditional players within established segments such as IT systems, enterprise software, telecom and network equipment have finally awakened over the last three or so years. Meanwhile, the world of Smart Systems and Services has continued to evolve, particularly in the emergent player communities serving this opportunity. In this new cycle, physical assets and devices are being connected and enabled with sensors on a daily basis. Recognizing this scenario, technology suppliers around the world are now devoting major resources to addressing the opportunities associated with Smart Systems, but are, for the most part, failing to bring any new fundamental innovations.

For most IT and telco equipment vendors, selling existing servers, PCs, storage devices, and enterprise applications will be a recipe for shrinking revenues, given the impacts of new architectures on these markets and applications. But demand for these purchased technologies will not disappear. A few vendors that focus on being the consolidators of these shrinking but still large product markets will be able to survive.

The functional requirements of new digital and IoT platforms increases with the complexity of the use cases as well as the scope of assets to be targeted; the IoT is not a simple environment to navigate. High value use cases enabling widespread visibility and collaboration can be achieved using today’s technology, however, significant time and money is required to integrate and manage the variety of tools from numerous vendors.

Who will be the winners and who will lose as the Smart Systems Platform opportunity develops? In the much larger and more complex world of business-to-business technology, there is no vendor that has the clear leadership position. While the “Internet of Things” platform opportunity represents a market of vast potential,
technology suppliers must be aware of the current competitive dynamics if they are to successfully navigate the market. How well will various supplier groups align with the Smart Systems opportunity as it develops?

Players like HPE Dell/EMC, Lenovo and other peer legacy IT systems players are all still in the horizontal IT tech space and have been slow to embrace Smart Systems in a meaningful manner beyond “point” maneuvers such as introducing gateways.

IBM should have a leading position but needs to overcome its consulting services bias and improve edge capabilities along with driving its Watson strategy to a meaningful and functioning capability beyond what the consulting organization can deliver with it.

SAP is trying to get unstuck in many ways. Like Oracle, SAP has both the apps and the analytics capabilities to put into Smart Systems solutions. However, its platform story lags behind Amazon’s and Microsoft’s. SAP, of course, understands that balance sheet issues do matter, and its product suite can be, and has been, used to address these issues in some industries.
Amazon has come out of the backfield and become a significant force in modern information and computing systems. Its maneuvers to create a significant ecosystem of partners coupled with focused “specialist” IoT acquisitions have positioned the company to be a formidable competitor.

In many ways, Microsoft has been the clever player leveraging its legacy strengths from critical horizontal enterprise technologies in infrastructure with its shift to Azure. Coupled with its re-structuring into vertical solution delivery business segments, Microsoft has positioned itself into an enviable position.

What will be required of the technology developer and supply community? Here are the success factors:

» **Smart Systems Platforms With Real Data Management Capabilities Are Fundamental To Success.** With more players focusing on the Smart Systems opportunity the competition for customers is heating up. New entrants are quickly realizing that in order to be profitable it will be necessary to connect large volumes of devices to scale revenue opportunities and, as a result, seeking new ways to differentiate their services beyond simple device enablement and connectivity services. Beyond this, enabling complex use cases requires advanced data management, integration and collaboration tools as well as machine learning-enabled analytics.
Alliances Are Key To Success: The dynamics surrounding the Smart Systems and Services are incredibly complex. Basic enablement, network connectivity, device and machine integration into platforms and providing new services, value-added applications, and other device management functions are all needs that generally must be addressed when customers seek to connect intelligent machines and devices. Given all of the aspects that must be addressed from the customer standpoint, alliances represent the best available means to address the challenges facing an OEM or the end customer and also create maximum value for all parties involved.

Exhibit 8: Larger Computing and Infrastructure Players

Alliances Between Infrastructure and Platform Innovators. Players that understand “current versus future” generation architecture (meaning players understanding future data and information architecture) are entering the market to deliver a broad and diverse scope of data management tools and solutions, representing an architectural shift that will significantly impact future competitive market structure. Players like niolabs, Fathym SkyFoundry and Glassbeam are all changing the competitive landscape. While players like ThingWorx and Xively meet current requirements, players such as niolabs represent a forward-looking, emerging technology architecture that reduce the time and cost of providing complex, high-value applications. Longer term services disruption and expansion
requires new architectural foundations and developments, including tools for easier application development that can manage diverse data types as well as time series data, “embedded” system development tools & reference designs that are well integrated with control and IT device management and analytics and an entirely new information architecture. These capabilities must be deployable in the cloud, on premise and at the edge to meet the requirements of various customer.

» **Data, Analytics and Vertical Expertise:** For vendors that pursue vertical industry solutions, balancing horizontal infrastructure elements such as platforms and systems applications, asset management and systems management will be key. Successful vendors will need to have analysis tools and skills, and the ability to design systems to create awareness of asset status, transform and structure the analysis of this data, define rules and work flows, and identify the right application elements. Further, for those vendors that pursue a vertical industry strategy, choosing which verticals to go after will be a key success factor. Because operations technology applications tend to be unique to an industry, crafting the right combination of Smart System elements to address these challenges requires deep understanding of that industry and those challenges.

» **Systems Integration:** Ability to pull together the hardware, software, and network elements of Smart Systems. These solutions will not work if they are a collection of separate hardware, software, and network products from different vendors unless, and until, there are clear standards and protocols that define how each part works with the others. Those standards and protocols for interoperability, security, and performance will mature in time. But, for now, vendors that can provide all the elements of a full solution, and can do so as a product that can be sold to many clients, will have the edge.

» **Managing the Contention Between Horizontal and Vertical Opportunities:** In this evolving arena, despite what observers say about the “vertical intensity” of application solutions, horizontal core technologies will make up the bulk of purchases. Technology suppliers looking to be the players with dominant shares and scale economies from horizontal technologies will need to manage the “creative contention” this will create with vertical solution deployment and delivery.

This requires new technology innovations and new relationships between and among large players and small specialist players serving new vertical niches. All participants will need to carefully pick the horizontal technologies that they want to master and/or the verticals that they want to dominate and give up the others. Sadly, this does not appear to be the current state of affairs in the collective digital and IoT arena, particularly as it relates to next generation platform development. Witness the number and diversity of misguided platform acquisitions over the last few years. Larger IT and equipment manufacturers acquiring platform players with a diverse range of intended business
models that, for the most part, do not align themselves will with their new parent company’s strategic intent.

**Exhibit 9: Platform Player Segments Are Many and Diverse**

<table>
<thead>
<tr>
<th>Analytics</th>
<th>Prescriptive</th>
<th>Predictive</th>
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<tr>
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<td></td>
<td>Edges Processing/Analytics</td>
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**Data Management**
Integration and automation services that simplify development of new apps and conversion of legacy apps into IoT applications, regardless of issues with differing information architecture or communication processes.

**Device Management**
Management tasks and decisions surrounding the ingestion, annotation, cataloging, storage, and distribution of devices.

**Data Acquisition**
The process of retrieving and processing data from physical assets and converting them into digital formats. Data types which may be collected include: unstructured, structured or semi-structured.

**PLATFORM INNOVATORS**

After reviewing and analyzing over 200 so-called IoT and related data and analytics platforms, we have found that there is a distinct minority of true platform innovators in the marketplace. Leading and innovative examples of players working on next generation platforms include:

» niolabs

» Fathym

» GlassBeam

» Skyfoundry
Fathym and niolabs are both general, relatively horizontally focused platforms for integration, data management and application development. SkyFoundry and Glassbeam are largely focused on data management, transformation and the analytics that these functions enable. All are exemplary in their grasp of the architectural requirements to inform next generation systems.

It is clear from our analysis that the community of technologists and business developers that truly understand future Smart Systems and IoT platform requirements is fragmented and quite dispersed. Further, there are many developers working on focused aspects of next generation platforms but mostly in isolation. This is why we believe a new “architecture” community needs to be developed and is required to begin to integrate and bind these disparate views of the future of information technology.

The capabilities these next generation platform developers are focusing on include an architecture where there are no artificial barriers between diverse data types, and that facilitates free flowing data discovery, data fusion and collaborative application development. Acceptance of this reality is essential to the effective design of platforms, including their data management and analytics functions and capabilities. Related drivers of their platform designs for Smart Systems and IoT platforms includes the following:
Interoperable for universal compatibility
Linear scalability for unrestricted volume
P2P & client server for adaptable architectures
Distributed computing with true distributed intelligence
Asynchronous for heterogeneous signal capture
Semantic stream processing enabling temporal, spatial and state context in real time
Database independence to break away from the restrictive client server architectures

Longer term services disruption and expansion requires:

New architectural foundations, including tools for easier application development that can manage diverse data types as well as time series data;

“Embedded” system development tools & reference designs that are well integrated with control, networked and IT device management and analytics

Below we characterize the work of these three platform innovators and highlight elements of their development work.

FUTURE PERFECT

A platform vision that enables a more universal means to integrate and manage disparate data, to which anyone can contribute, and which liberates information by abandoning traditional relational databasing and the client-server computing models that have us so deceptively “trapped” today are critical to market development.

These broader functional needs are driving several important development requirements, including:

The rapidly rising need for smart products to be interoperable with a growing array of applications, systems and people.

The need for new development protocols and what we call information automation to address the growing complexity of new device data driven systems and the sheer scale of development required to bring these systems to market.

The ability to aggregate, fuse and manage structured, semi-structured, unstructured and time series data and the maturation of radically new information models and architectures that can more readily integrate classical IT capabilities with real-time, state-based devices and systems.
These critical developments will directly impact the growth and scale of the Smart Systems and Services market opportunity, particularly new software tools that address the needs of users, developers, OEMs and third party value adders, including:

» An architecture that can align with and “form fit” to the physical world and its embedded and distributed computing architecture.

» Integrate multiple data acquisition protocols, to enable simultaneous management and analysis of data from a wide variety of sources via a diverse assortment of communication connectors.

» Software tools that are easy to use, particularly by users and evolving developer communities; a unified family of tools to develop smart connected devices.

» An architecture that addresses a broad range of real-time and historical data analytics requirements – ideally a single unified framework to design and build solutions that can interoperate across diverse data environments and under widely differing usage scenarios.

» A true distributed software architecture that can process and create value from device data locally, while enabling higher-level applications that generate value from enterprise or portfolio-wide data.

» Software that can enable easy integration of any combination of inputs and data types - message, feed, and streaming data - in real-time that’s independent from traditional rigid database technologies and can blend and manage diverse datasets – any type of information from any device, whether historical batch data or streaming source combining a number of non-relational techniques in order to accept, store, normalize and analyze diverse data sets.

» Software designed without the bias and dependencies of a single product or service application that will cause integration pain when attempted to be used beyond its original scope.

» Truly scalable software architecture, data models, tools and functions with no constraints on where it gets deployed – chip, device, server, cloud, or hybrid system-and provides extensibility with common features and functions at each level of the architecture and embraces the non-hierarchical nature of the IoT with a single scalable software architecture that brings the analytics processing “to the data” enabling high speed continuous analysis of data.

Next generation platforms will need to enable easy ways to find patterns and transform data, yet if the process required to create and present data analysis results to the user entails significant costs, complexity, long lead times and lack of re-use, the potential benefits will not be realized.
NEW RELATIONSHIPS and M&A WILL DRIVE MARKET DEVELOPMENT

We believe that successful market development will also require established players focusing on developing new relationships, what we like to call deliberately seeking out “strange bedfellows” and radical innovators. This re-newed focus on developers, ecosystems and the potential positive synergy of new relationships will be required to drive value.

Because of the uniqueness of Smart Systems and IoT platform development, we believe many larger IT, infrastructure and software players will turn to acquisitions as a path to off-set development complexity and time to market. Depending on how you define IoT, there have been over $100B in IoT-related M&A activity over the last two years. Platform M&A has reached as much 40+ billion over the last two years.

We are now witnessing the discontinuities driven by Smart Systems and IoT development which is, in turn, accelerating strategic maneuvers by several larger players positioning themselves to take advantage of the significant potential of IoT. In the end, no larger player wants to be left behind. It is important to note that the structure of this market is still forming. Startups will continue to bring new offerings to market making these smaller development organizations a natural target for larger players.
BUSINESS MODEL DESIGN and DEVELOPMENT

Thinking about the business opportunity associated with a connected product is a highly creative process. Often there are no cut-and-dried markets to identify and size. Rather, there are entirely new markets that might develop as networked products and systems are brought to market.

We believe business model design needs to transcend discrete product or service innovation. Assuming that the role of business design is only about making existing products or services more attractive no longer works. Business developers need to creatively imagine fully developed systems and whole marketplaces. Companies must to envision the design role as one that can address product, service, user experience and cumulative system value.

Today, with the emergence of connected products and information-based services, even more complexity has arisen in the design of the systems and the services as well as in the core of the products and elements within the core system. Additionally, because networks add yet more complexity to the process and because just about everything will get connected, we strongly believe business developers need to address multiple interrelated dimensions in order to fully address the nature and scope of the resulting business opportunities.

To move from thinking to research to real-world solutions, you will go through a process of synthesis and interpretation that needs to begin with a discovery phase that can help organizations connect better with the customers they serve. Done properly, discovery sets the stage to drive new concepts and innovation potential and help organizations to see tangible new opportunities.

The intersection of the six dimensions above is where discovery of business models begins. This discovery phase is where organizations can identify a “business model design challenge.” The foundation of Smart Systems business model development is identifying a concise design challenge.

The process begins by discovering and identifying challenges customers are facing or leveraging opportunities your organization has identified and is interested in exploring. The goal is to narrow feedback and inputs from the discovery process down to one specific business system and model design challenge. This challenge will guide the queries and questions you will ask customers during field research and the opportunities and solutions you will develop later in the process.

Once addressed, the diverse perspectives developed during discovery can help feed a more structured process that addresses the tasks that need to be undertaken to define and develop new Smart Systems businesses.
Inevitably, companies will fail to understand the disruptive threat inherent in the Internet of Things and connected products, but a merely defensive justification to network a product or machine may not succeed in creating sustained competitive differentiation.

Many companies will be hampered in their thinking by a tendency to assume that the company after networking and Smart Systems will be the same company and in the same business as before networking. This is almost never a safe assumption.

The first fact about a networked product, which is so obvious that no one needs to be told, is that it will capture and convey valuable data. The second fact, not quite so obvious, is that this new data become a core asset. The third fact, an obscure leap for many managers, is that information as an asset makes for fundamental changes in a
company's business. The fourth fact, which makes things simple but by no means easy, is that most changes brought about when information becomes central have the effect of moving a company toward an entirely new service business model.

We say this is simple but not easy, because while the fact that service moves to the fore is not hard to grasp, in practice service is a paradigm so foreign to manufacturers that they cannot understand, let alone implement, the changes necessary to make the shift successfully.

Many companies have already seen some of the challenges inherent in shifting to a services-driven business. In fact, the phrase “shift to services-driven business,” though accurate, can be dangerously misleading as it can make the required corporate culture and business model changes sound almost tame. They are not. The era of near-perfect, real-time information about physical assets and customer behaviors is looming like a tanker coming out of the fog. Any degree of complacency – even from those who consider themselves “advanced” – will be deadly.

The Internet of Things and People will depend on managing, understanding and responding to massive amounts of user and machine-generated data in real time. With more users and sensors feeding more applications and platforms, innovators and developers will be able to tackle serious real-world problems. Radically new platform technologies with new data management, application development tools supported by a real information architecture are the key innovations that will enable the Smart Systems and Services opportunity to move from growing arithmetically to growing exponentially.
WHAT ARE SMART SYSTEMS?
A new generation of computing systems and information architecture that when combined with artificial intelligence, machine learning and Internet of Things technologies are breaking away from today’s information, computing and telecom (ICT) 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, state-based, context-sensitive capabilities that integrate people, processes, physical equipment and knowledge to enable collective awareness and better decision making.

ABOUT HARBOR RESEARCH
An internationally recognized research, technology, and business development consulting firm, Harbor Research has predicted, tracked, and driven the development of the Internet of Things since our inception in 1984. While our history is long, our strategy is simple: capture and create value by combining accurate data discovery and analysis with creative systems-thinking. It is this mindset that has given us the privilege of working with some of the greatest companies in the world. Today, we continue to work with C-level executives and top management of some of the world’s most consistently successful companies and innovative startups. In the same way that the market has flexed and grown over the years, our services and experience have grown to make us the premier service organization you see today. We work with clients in a variety of ways including consulting, advisory, research and content development, thought leadership and workshop facilitation.

THOUGHT LEADERSHIP
We provide our clients with rigorous analysis and insight to support critical new business design and development decisions. Our research, content and modeling provides an ideal context for discovery, ideation and planning.

UNIQUE PROCESSES
As much as we would like to say there is a simple “linear” process to drive new smart systems innovation, the nature and complexity of the Internet of Things, there is no one best way to design an innovation process to design new systems.

VIBRANT COMMUNITY
Building new ventures for the Internet of Things requires new and very different modes of design and development – organizations will need to push the boundaries of collaboration to include many new and unfamiliar participants.

If you or your colleagues would like to learn more:

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