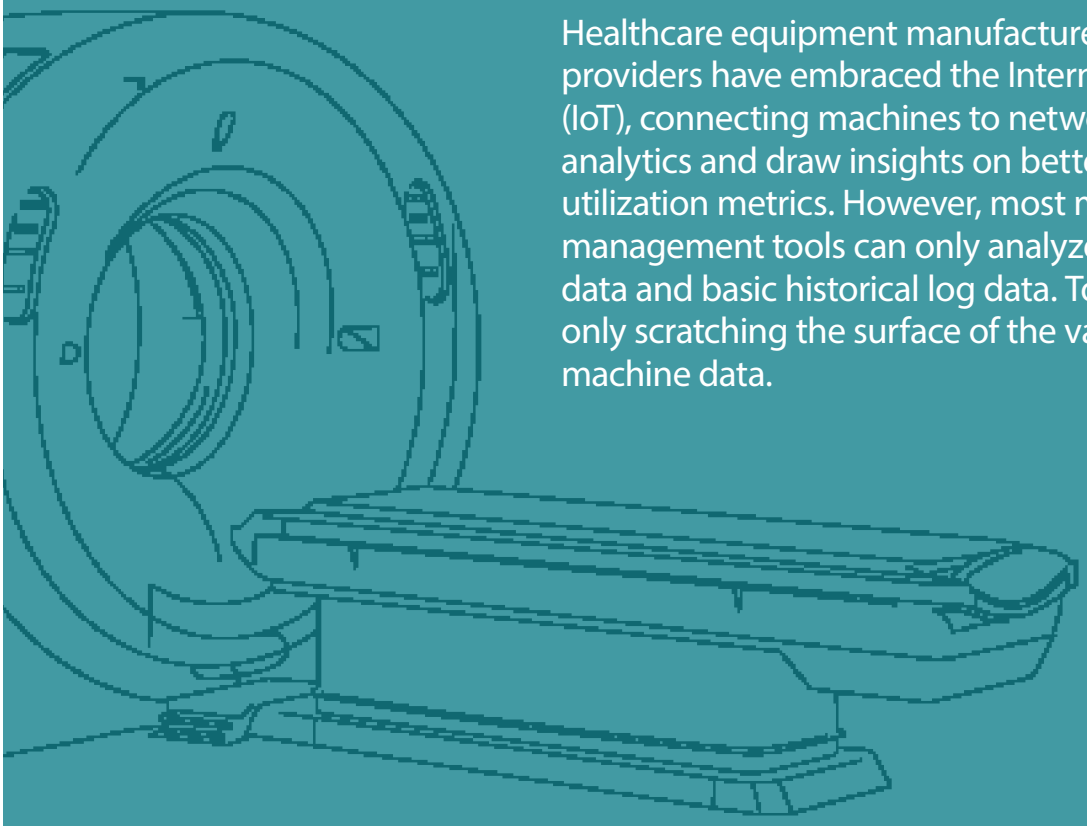
Machine Data Analytics Drives Innovation in Healthcare Market



Healthcare equipment manufacturers and providers have embraced the Internet of Things (IoT), connecting machines to networks to enable analytics and draw insights on better support and utilization metrics. However, most machine data management tools can only analyze simple sensor data and basic historical log data. Today's tools are only scratching the surface of the value of complex machine data.

smart systems design | Harbor Research

The fact that a wide range of healthcare equipment can transmit information about status, performance and usage and can interact with doctors, nurses, technical staff and other enabled devices in real time points to the increasingly complex role of data in healthcare delivery. This only compounds when we consider the many networked devices that are being deployed in health delivery systems and the scale of data they will produce. Healthcare needs new tools to enable actionable intelligence from real time machine data collected from their assets, combining transaction information from legacy information systems, in days, not months, and at a fraction of the cost. The challenge lies in the fact that data transformation and management solutions today can analyze some, but not all data, and mostly just simple sensor and historical log data. Today's medical equipment systems are increasingly producing complex machine data that require more advanced data transformation solutions to enable root cause analysis, predictive analytics, machine learning and other high value support applications. Without advanced data management and transformation tools, users, equipment manufacturers and third party service providers will not realize the true value of their machine data. This report explores how new machine data transformation and analytics solutions enable the true potential of complex machine data.

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, newsfeeds 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.

TABLE OF CONTENTS

EXHIBITS

HEALTHCARE MARKET IS RIPE FOR DISRUPTION

If ever a sector of the economy needed smarter systems to enable optimization of business and operations processes, it's healthcare. The healthcare arena offers untold opportunities to apply IoT and Smart Systems technologies to increase awareness, knowledge, efficiencies and actions. According to several sources, global healthcare expenditures expanded to over $8 trillion dollars in 2016; capital expenditures for machines, devices and equipment totaled over $350 billion.

Healthcare delivery organizations are discovering the many and diverse opportunities that networks, sensors, intelligent machines and transactional software like CMMS (Computerized Maintenance Management System) create. The healthcare sector has put significant investment and resources into new technologies for automated diagnostics, remote patient monitoring, medical equipment monitoring and drug and supply chain tracking.

Today, the average 200+ bed hospital has over 250 brands of equipment and devices, and the typical hospital patient comes into contact and interacts with over 75 devices per day. The speed and scale at which manufacturers are integrating automation and data analytics into healthcare equipment systems is staggering. These innovations are aimed at revolutionizing the quality, consistency and efficiency of equipment and devices in support of patient care. But are users realizing the maximum benefits from these new tools? We think not; but why?

Today the healthcare sector has one of the highest rates of adoption for connecting machines. However, connectivity alone may help the manufacturer of the machine provide more efficient service and support, but it does not allow the healthcare provider to leverage much intelligence across diverse systems with multiple brands of machines. This is due to several factors, including technical integration complexities, networking standards and differing approaches to embedding intelligence in machines.

Existing technology has proven cumbersome and costly to apply with many conflicting protocols and incomplete component-based solutions. The challenges of gathering machine data and integrating diverse data types have been big adoption hurdles for healthcare industry customers wanting to analyze the data from their machines and systems.

If what we're speaking about could be summed up in a word, it would be 'optimization', but you cannot optimize anything or any system without addressing the whole system. So, how should users and manufacturers of medical equipment and devices be thinking about automation and optimization of healthcare systems?

DATA IS THE CORE ENABLER OF SMART SYSTEMS AND IoT IN HEALTHCARE

Even though we have been steadily designing devices and machines with more and more intelligence, the data and information they produce has gone largely unleveraged and unharvested. This may seem surprising to some observers, but it has only been in the last few years that the world has come to understand the value of device and machine data in the healthcare arena.

Machine data can offer extraordinary business advantages to the companies that manufacture, deliver and service machines, especially in terms of customer value creation and relationships. It can also revolutionize healthcare providers to offer better patient care at far lower operating costs and unprecedented visibility into the utilization of their entire fleet of medical machines. The ability to detect patterns and build AI and machine learning models from large scale machine data is the "Holy Grail" of smart systems. Machine data analytics, often thought of as part of the evolving Big Data story, allows not only data patterns, but a much higher order of intelligence to emerge from large collections of ordinary machine and device data.

Embedded machine technologies are combining with new innovations in data and information architectures to work together in unprecedented ways to solve more complex services and support challenges.

WHAT IS MACHINE DATA?

Machine data includes all data generated by equipment, devices and sensors, including:

» Medical device readings for human health parameters

» Temperature, pressure and related sensor readings from diagnostics devices

» Location data such as RFID readings and GPS system outputs

» Computer network, and other equipment logs

DON'T WE ALREADY HAVE BIG DATA IN HEALTHCARE?

Before delving into the new thinking that makes all this possible, let's talk about why it's necessary at all. Don't we already have Big Data and analytics tools? Aren't these tools helping us to manage patient care and analyze all the intelligent medical device data we keep hearing about?

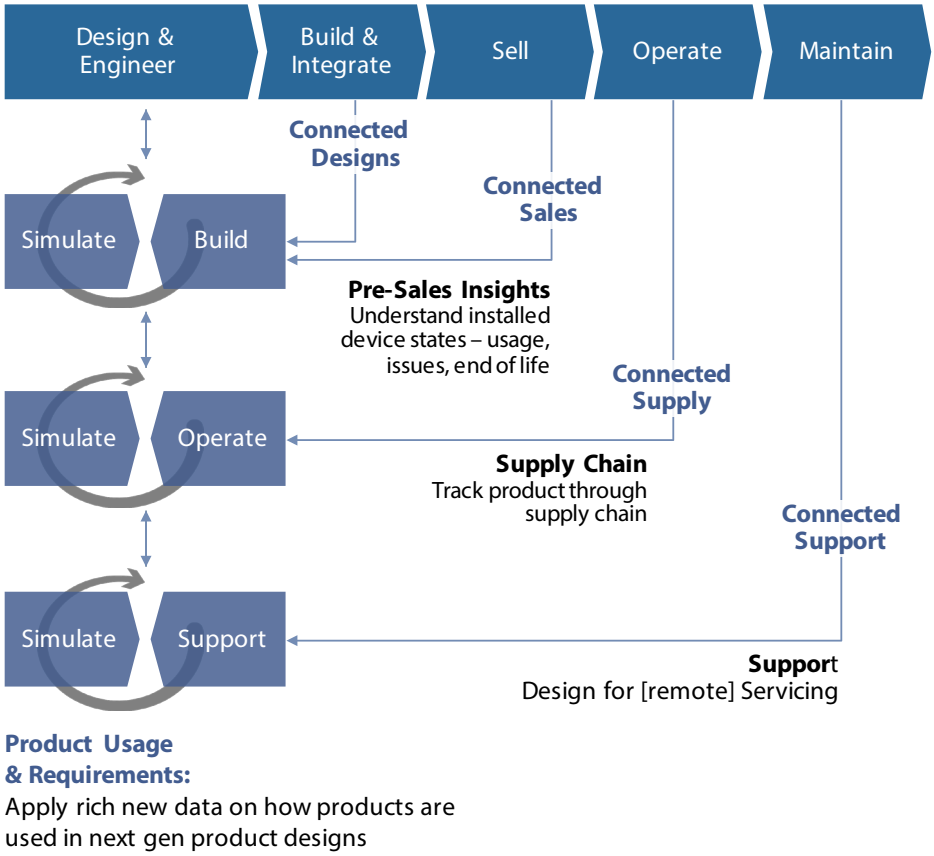
Almost everyone will answer with a resounding "Yes!" But consider this analogy from Buckminster Fuller: Suppose you are traveling on an ocean liner that suddenly begins to sink. If you rip the lid off the grand piano in the ballroom, throw it overboard, and jump on it, the floating piano lid may well save your life. But if, under normal circumstances, you set about to design the best possible life preserver, are you going to come up with the lid of a grand piano?

Today's so-called data management and analytics tools are like that piano lid. In a period of great change and tumult, it's been working—in the sense that it kept us afloat. But that does not make it the best possible design, or qualify it to be something that we should plan to live with forever.

A networked machine generates information value over its entire lifespan. Machine builders and equipment manufacturers can know where the device is located,

when it was installed, critical specifications, diagnostics, availability of spare parts, usage patterns, support status and so on. However, to realize the value of data and analytics, OEMs and providers will need to re-think the whole relationship of devices, machines and people to business systems and processes. It must be built upon true, across-the-board digital automation enabled by a whole new generation of information tools for managing rich streams of machine data.

Exhibit 1: Connectivity Produces Data Value Across a Machine Builders Entire Value Chain

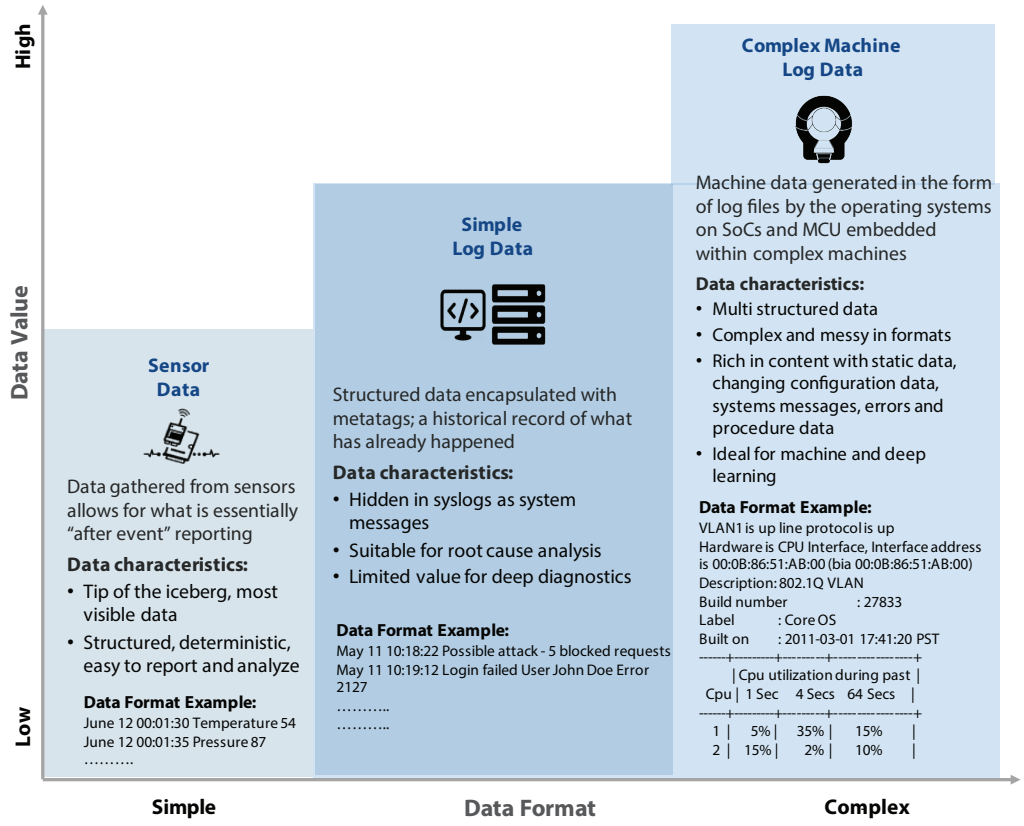


Unfortunately, while there's a rapidly growing number of software players who tell a great story about data and analytics tools that can be applied to any data, anytime, anywhere to create new insights, most of the available tools that providers and OEMs are working with today were not designed to handle the diversity of data types and the massive volume of data generated from real-time networked machines and equipment. These challenges are diluting the ability of technical support staff within healthcare OEMs and hospital networks to efficiently and effectively organize the data to model it and analyze it.

NOT ALL MACHINE DATA IS CREATED EQUAL OR IS EVEN THE SAME

The "Achilles Heel" of data management tools for smart machines does not originate in their data collection or aggregation capabilities, or even in the analysis tools. Those inventions are not necessarily ideal, but they are useful enough today, and they can be replaced over time with better alternatives. Rather, the primary weakness lies with data management—in particular, the lack of effective data transformation and modeling tools—and the restrictions, without these tools, that get placed upon organizing and utilizing machine data to conduct analytics.

Exhibit 2: Not All Machine Data Is Created Equal - IoT Data Comes In Many Forms



Historically, computing systems have stored information in one of two basic ways: completely structured or utterly unstructured. At the unstructured end of the spectrum are static Web pages, blog postings, emails, etc., which are free-form and lack any fundamental identity. At the other end of the spectrum are very structured relational databases that are not at all flexible and make rigid assumptions about the meaning and context of the data they store.

WHAT IS DATA MANAGEMENT and TRANSFORMATION?

Data transformation is a high value step in the data management process that involves sifting through multi-structured data and identifying logical boundaries that assign meaning to previously indistinguishable values. These processes can include the following:

DATA QUALITY PROCESSING
Cleansing
Filtering
De-duplication

SYNTAX TRANSFORMATION
Format normalization
Data normalization

SEMANTIC TRANSFORMATION
Semantics assignment
Context injection

GOVERNANCE
Ownership assignment
Anonymization
Protection

PARSING
Syntax analysis
Data structure

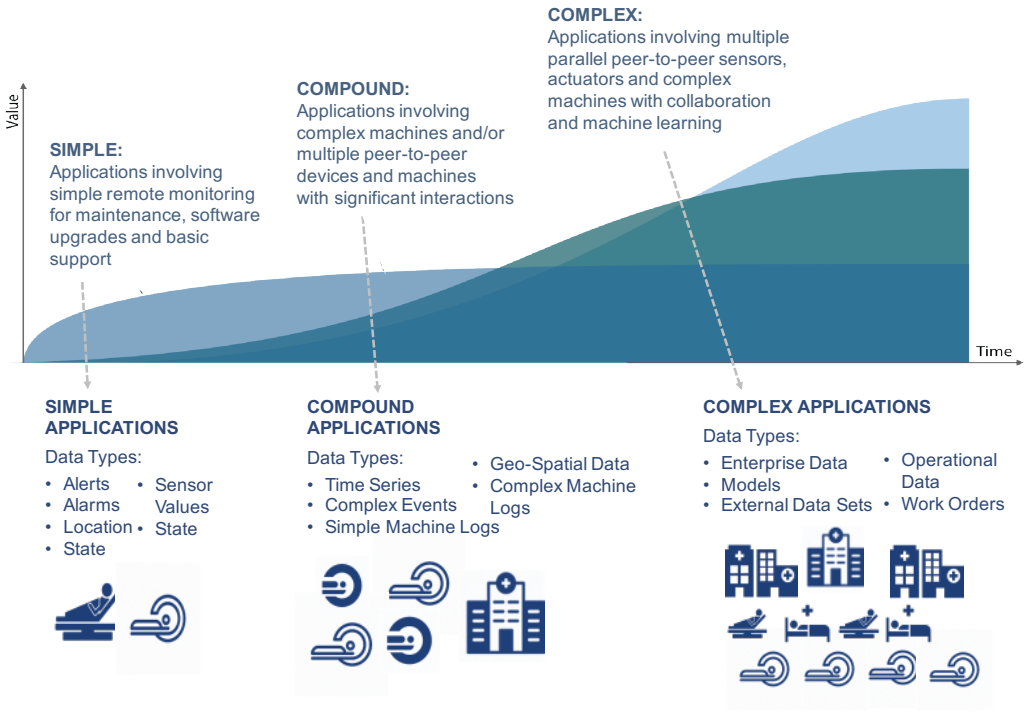
EXTRACT, TRANSFORM, LOAD (ETL)
Data reading
Data converting
Data writing

Between these opposite extremes, intelligent machines on networks are now producing a vast array of semi-structured data types, including machine logs, data streams, sensor values, control signals and more. Sensor data and simple historical log data comprise the vast majority of data gathered from machines today. These simple data types comprise only a fraction of all potential data value, and on their own, cannot enable more advanced use cases such as root cause analysis to support predictive maintenance on an MRI machine. Furthermore, basic machine data cannot effectively be leveraged for advanced machine learning capabilities. In many ways, data transformation and management is the most critical step in the machine data analytics value chain, but it's also the least organized and automated.

THE FUTURE OF MACHINE INTELLIGENCE IN HEALTHCARE

Today, most networked machines in healthcare market are limited to "simple" applications such as remote monitoring to enable basic alerts and alarms as well as tracking and location services.

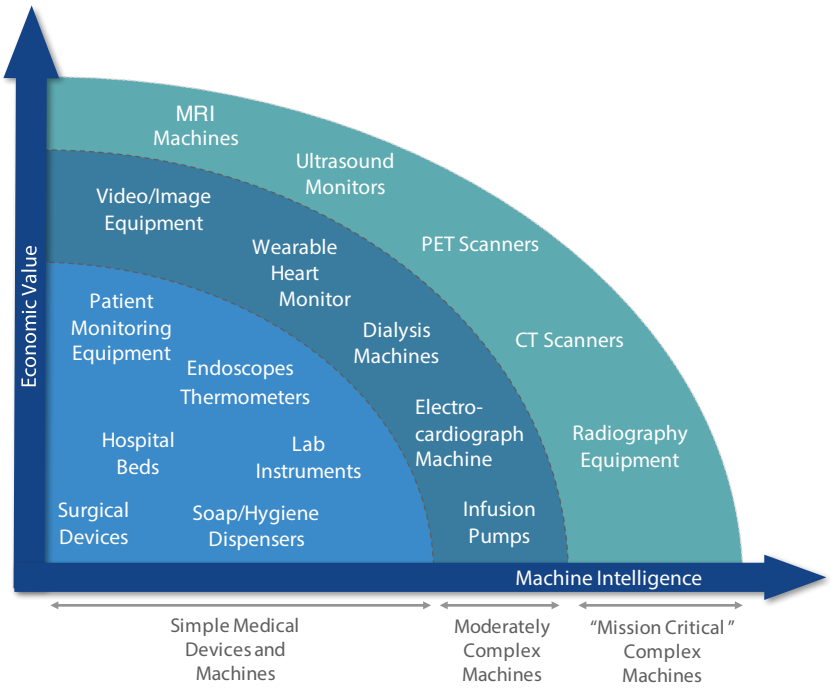
Exhibit 3: Evolving From Simple to Compound Application Value



Return from simple applications, while extremely valuable, is limited primarily to the manufacturer's service delivery efficiency. Contrary to what current market

offerings depict however, the value of connectivity does not have to end with simple applications focused on a single class of device. Moving from "simple" to "compound" applications involves multiple collaborating machines and systems with significant interactions between and among devices, data, systems and people. No longer is the focus solely on the machine builder's ability to deliver support for their product efficiently. Rather, value is created for the customer by analyzing the entire fleet of multiple modalities from various manufacturers, along with the automation of business and operations processes, and systems optimization.

Exhibit 4: Healthcare Machine Intelligence Evolution



As technologies mature, machines will continue to evolve to higher levels of intelligence that will enable new compound applications. However, as medical devices become more complex, so too will the challenge of extracting intelligence from machine data. Higher-end medical devices that have significantly more embedded computing power and sophisticated software are producing an expanding diversity of data types and structures, particularly complex "machine logs." A major driver of the need for new data transformation and management tools is both the diversity of data types and the complexity of the machine logs. While there are many factors that contribute to the challenges of analyzing complex machine data, the most underestimated and significant hurdle is data transformation.

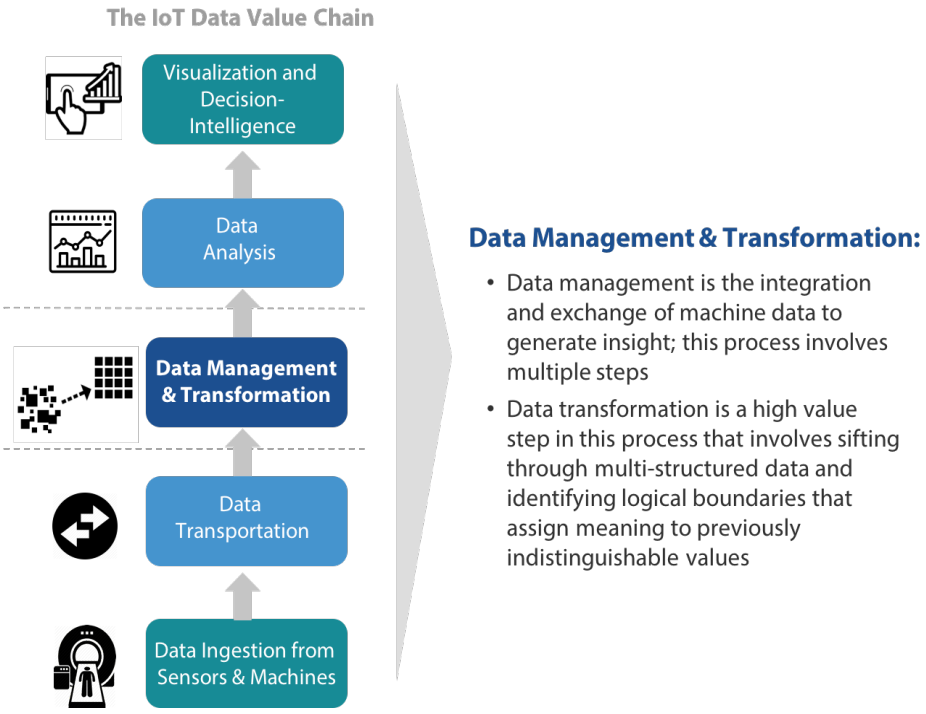
Unfortunately, this is a topic that has been confusing and misunderstood for too long. Many healthcare delivery organizations know that machine data is a critical

enabler of more effective and efficient support, but are often frustrated because they are not getting the value they expect from connected medical devices and machines. The vast majority of IoT data solutions currently on the market can only address sensor and simple log data; these solutions are not able to address the growing amount of complex, multi-structured log data produced by today's equipment.

MACHINE DATA MANAGEMENT CHALLENGES ARE COSTLY AND TIME CONSUMING

Most of the software tools available today for data transformation have two principle failings. First, they cannot provide a holistic view of diverse machine data types because they are direct descendants of the last generation of IT-centric data analytics tools. And second, not only are most of these tools outdated but they are very fragmented, "cobbled together" solutions.

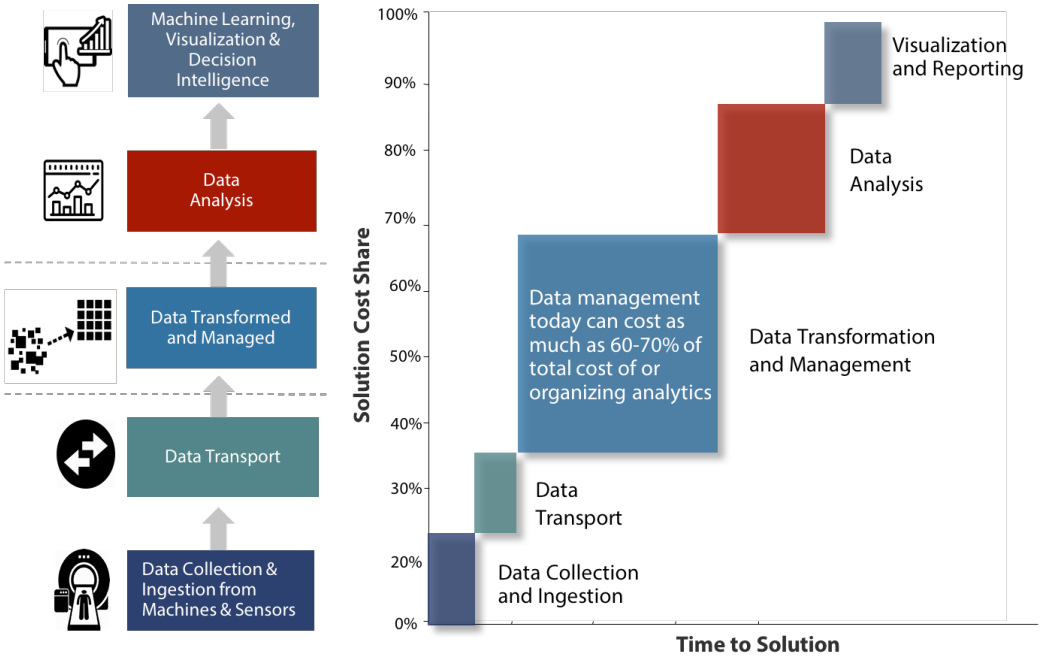
Exhibit 5: The Scope of Data Management and Transformation



Today's approaches for data transformation are costly, time consuming and often difficult to get tangible results from. For example, analyzing why an X-ray tube has failed in a CAT Scanner that is now losing $3,000 or more per hour of downtime, requires investigation of the patterns and hidden signs within complex machine log

data. Doing this on an ad-hoc and reactive basis implies thousands of dollars of lost revenue for the provider over multiple days and an irritated customer for the OEM. Only complex machine log data with proactive and predictive automation can be used to truly uncover and address the root cause of the failure. Complex logs provide a much richer context than sensor data and simple log data. Sensors provide simple values such as a temperature or pressure readings, while analysis of complex machine logs can provide insight into how a given application might be under-performing or provide information that helps users understand differing usage patterns and suggest operational improvements.

Exhibit 6: Data Transformation is Critical to Analyzing Complex Machine Data



Very few machine OEMs or providers understand how costly and challenging data transformation truly is. To support development of this report, Harbor Research interviewed several OEM and healthcare users to understand their challenges with organizing and conducting machine data-focused analytics projects. We examined total project budgets and the distribution of time and costs in each step of the IoT data analytics value delivery chain.

Our interviews and research found that the data transformation and management phase of connected machine analytics projects was the most expensive and time

consuming step in the process. Across the dozen or so interviews we conducted, data transformation accounts for approximately 60-70% of overall machine data analytics project costs.

Many hospitals have some kind of monitoring solution in place; they have basic alerts, but beyond monitoring if equipment managers want to create true value such as conducting root cause analytics or equipment maintenance forecasting, they need to collect and analyze the actual machine data

Third Party Equipment Maintenance Services Manager

Tools to manage complex machine data are evolving to enable more robust analysis capabilities to address valuable [compound] applications and use cases. New applications will involve more complex machines (such as predictive maintenance for medical imaging machines) as well as significant interactions between and among many simple and complex machines and data sets (combining, for example, service history data from CMMS systems and financial data from scheduling applications), creating new collaborative business model opportunities that have the potential to drive much greater value for the user and customer.

DIMENSIONING THE OPPORTUNITIES FOR MACHINE DATA, ANALYTICS and APPLICATIONS

The impacts driven by new data transformation and management tools within the healthcare equipment markets will be substantial. Technology developers, healthcare equipment OEMs and related equipment support services providers will realize revenue streams from smart connected systems in two broad segments of the so-called "tech stack."

These two areas are: 1) enablement and connectivity (the communications capabilities attached to or embedded in each machine) along with the network services this enables; and, 2) System and Value-Added Applications (which include the integration platform and managed services for the vertical applications such as asset management).

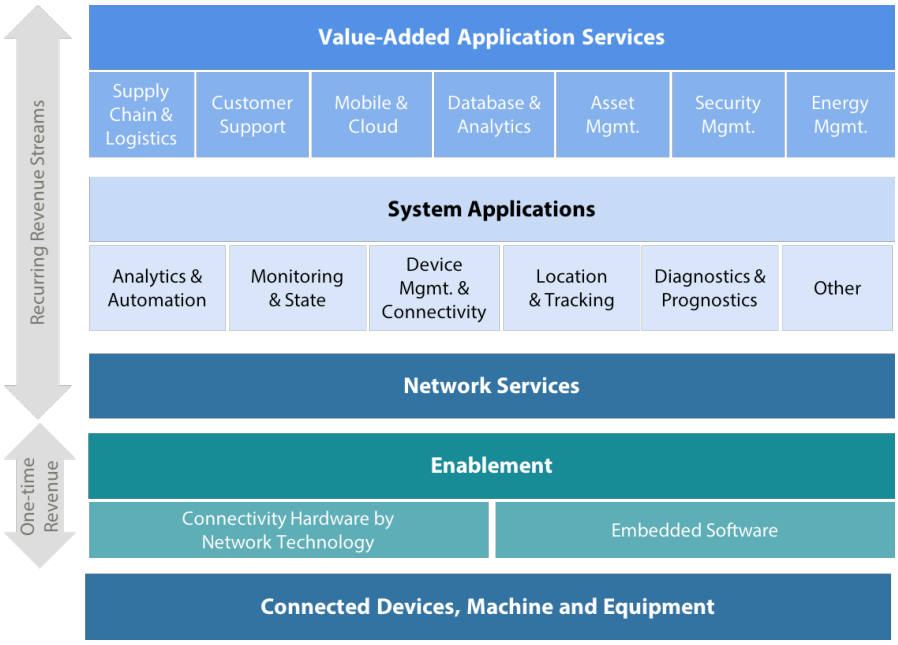
The lower two layers of the stack - connectivity/enablement and network services have, for the most part, become relatively stable and mostly mature elements in IoT solutions offered in the market today. The value in these systems is rapidly shifting away from connectivity and simple monitoring to valuable applications informed by machine data. Hence the real value creation opportunities in Smart Systems lies in the upper two layers -- Systems Applications and Value-Added Application Services.

One of the most critical "foundation" elements are "systems applications" described above. Many people on the marketplace today describe system applications as "platforms" or just as often as "middleware," but whatever we choose to call these functions what we mean is a set of state-based application functions that are

horizontal in nature and include device Management, Provisioning, Connectivity Services, monitoring, location and data collection.

A key characteristic of Systems [platform] 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 asset management application.

Exhibit 7: Smart Systems and IoT Revenue Segmentation



Within the healthcare sector, System Application services will integrate data from machines, people, systems and business processes to provide vertically focused Value Added Application services to automate customer support, supply chain functions and asset management overall.

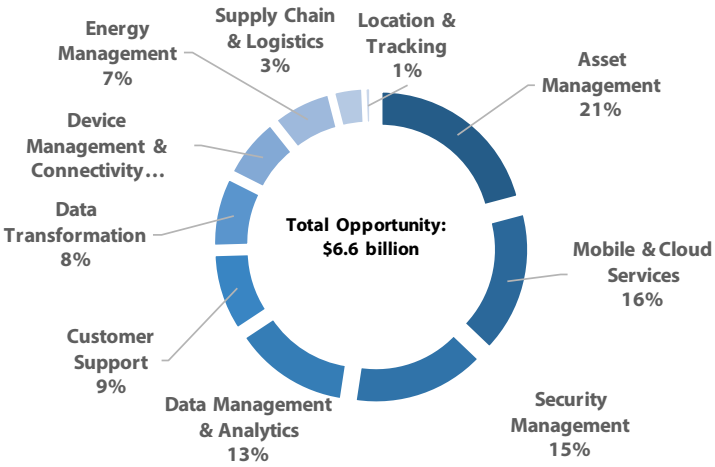
Today a diverse range of software vendors are touting their solutions for various aspects of IoT and Smart Systems. In many ways, it is a very confusing landscape of players present in the market, some who are addressing data transformation and management in a focused manner and many more who are claiming to do a variety

of data related functions as a part of other adjacent capabilities such as application development platforms, device management and monitoring platforms and so on and so forth.

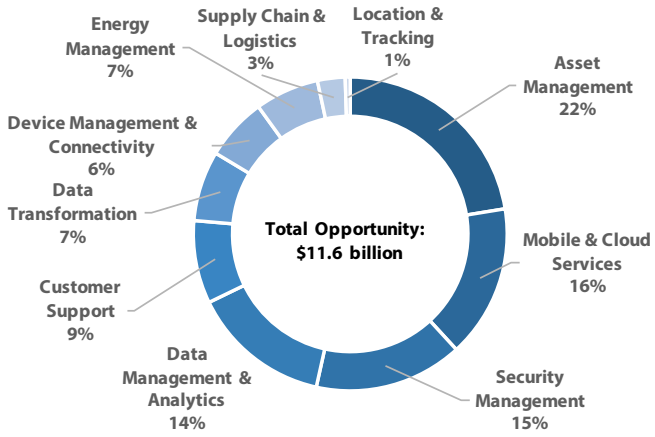
What's important to keep in mind is that System Applications offer limited value when used on a stand-alone basis. Underlying functions, particularly data transformation and management as well as application development tools, are required to unlock the real value of System Applications.

Exhibit 8: Market for Healthcare Data Management, Platforms and Applications

2017 Healthcare Connected Equipment Data, Analytics and Software Market Opportunity



2022 Healthcare Connected Equipment Data, Analytics and Software Market Opportunity



It's also important to understand the vast majority of today's IoT data solutions can only address sensor and simple log data; these solutions are not able to address the rapidly growing amount of complex, multi-structured log data produced by today's

advanced machines. The challenge is that data transformation and management is part of this larger group of IoT platform functions we refer to as Systems Applications.

SERVICE AND UTILIZATION CHALLENGES FOR HEALTHCARE PROVIDERS

For health delivery organizations, achieving effective and responsive services and support can be very challenging. The pressure to deliver better patient care at an ever-lower cost runs right up against the high cost of OEM service contracts. The cost of a service contract for an MRI machine or CT Scanner is directly proportional to the cost of the machine. A new MRI machine can cost anywhere from a few hundred thousand dollars to several million dollars with the maintenance and support contract running as much as $80,000 per year with machine life cycles now getting stretched to as much as 8-12 years of use.

Efficient and effective use of these machines is a primary goal for hospitals and networks with multiple locations and multiple machines. Any issues or unplanned downtime can add up to significant lost revenues and the associated high cost of repairs and service. Medical imaging equipment typically has 8-15 downtime events per year which can lead to as much as 6+ hours of lost usage per incident. All of this adds up to substantial losses.

> A major provider of imaging machines installed in our network has no data management and analytics processes in place to predict support requirements and potential failures
>
> Hospital Chain Administrator

To put these support costs into perspective, the average maintenance contract for medical imaging equipment is 3-5 times higher, relative to hardware cost, than support contracts on today's IT systems and equipment. With such high values, it's no wonder healthcare delivery organizations implementing these systems are demanding significant productivity improvements and much higher levels of support in order to realize a reasonable return on their investment.

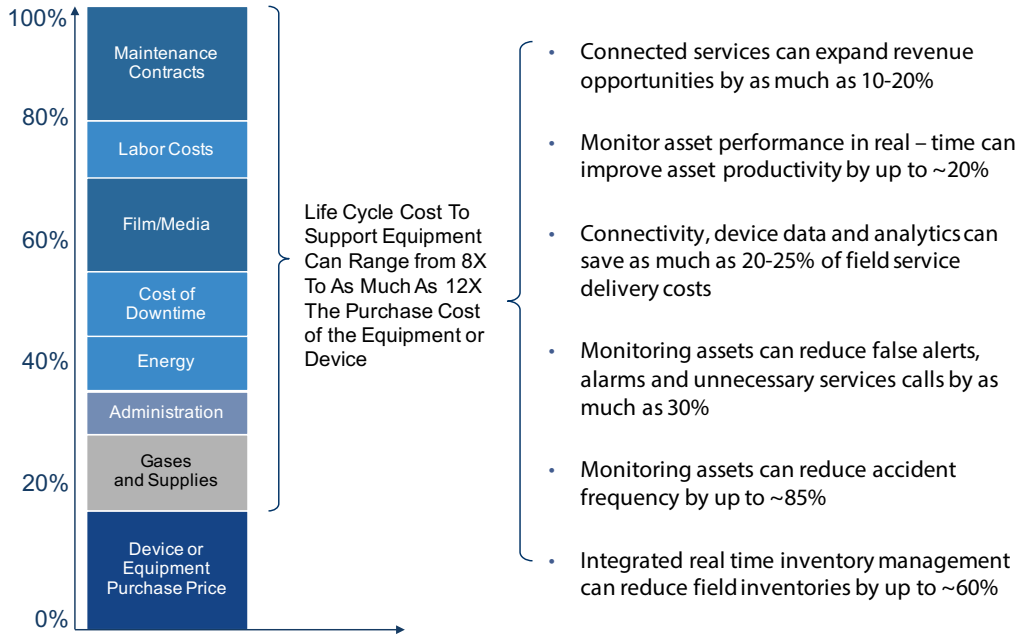
One significant trend currently unfolding in the market involves a growing number of hospital networks looking for new and less expensive ways to support their installed equipment to avoid paying expensive OEM service contracts. This has, in turn, lead to the growth in third party independent services organizations (ISO) that are providing equipment support expertise on a more regional and local basis to hospitals. One of the evolving values that third-party service providers bring is the ability to support multiple equipment manufacturers for a single hospital network and do so through a single unified contract. However, ISOs still lack the analytics and software capabilities to bring all disparate information from machine logs and transaction systems into one holistic application.

BUSINESS MODEL AND DATA CHALLENGES ARE SIGNIFICANT FOR EQUIPMENT OEMs

As devices and machines becomes more intelligent and networked, competitive differentiation for healthcare equipment OEMs will shift away from unique product features towards how the product is actually used, how the product fosters interactions between and among users in a networked context, and most importantly, how the data from the product will inform higher levels of awareness and new insights to improve support.

Medical device and equipment manufacturers have been challenged by networked business models, as many health organizations now expect more responsiveness from OEM service contracts. Unfortunately, the builders of complex machines such as MRIs and CT scanners have yet to provide software solutions that can deliver on these expectations. This has left many hospitals frustrated due to unexpected downtime and the lack of overall asset visibility across an entire hospital network.

Exhibit 9: Healthcare Imaging Life Cycle Costs



Putting machines onto networks essentially connects the OEM, quite literally, directly to the user of the equipment in a continuous relationship through the life cycle of the machine. This, in turn, forces a value shift in the OEM's business model towards services and away from a product-centric business model and a "break-fix" support mode. Even though most OEMs will never openly admit it, they

are often very uncomfortable acting in a new "smarter services" mode and do not fully appreciate that the core enabler of these new networked services is advanced analytics focused on complex machine data.

Moving beyond an industry specific context, OEMs want to extend relationships with their end customers by providing services, but many OEMs have become complacent with the traditional "aftermarket" view of the services opportunity. Complex machine data will play a major role in driving new services for OEMs.

For OEMs, data transformation and analytics platforms will open new connected services and value adding opportunities to capitalize on and help to grow the overall services opportunity because it appeals to customers who previously did not see the value in a services contract. Evolving services opportunities will drive new revenues by as much as 10-20% increase over traditional support sales for OEMs.

Healthcare equipment providers are just now beginning to understand that leveraging data and really embracing analytics is a significant step beyond just simple monitoring of machines and systems

Regional Services Manager
Healthcare Equipment OEM

Examples of new customer values created by new services offerings include:

» **Building Aggressive Customer Retention Capabilities:** Many OEMs further along the maturity curve of data analytics have come to recognize that the cost of acquiring new customers pales in comparison to the cost of retaining customers, meaning that ongoing machine data analytics helps accomplish better customer retention by providing customers with continued product intelligence.

» **Driving Recurring Revenue Opportunities:** Although it is still early in the life cycle of new services driven by advanced data management and analytics, many OEMs see the shift away from reactive, transactional services towards a more predictive and managed services stance (larger established OEMs are all approaching attach rates for services contracts in the 90+% range).

» **Capitalizing on Cross- & Up-Sell Opportunities for Equipment & Services:** OEMs are recognizing that as they increase their understanding of systems and support performance through better analytics, they have the ability to focus this data on service performance to enhance their ability to sell that performance as part of their offerings. Further, comprehensive discovery and inventory tools allow customers and OEM partners to see more clearly where systems require updated hardware and support and where equipment is either not supported or at the end of its support life.

» **Improving Business Mix and Profitability:** Many OEMs are coming to believe these systems will help grow new services revenues, drive revenue mix and larger contribution margin. While it is still early from a quantification standpoint, the most aggressive partners are seeing huge performance impacts on their business as a result of adopting advanced data management and analytics solutions.

The rise of the IoT is transforming machine OEMs into value-added service companies. Manufacturers are learning that by putting products on networks they are essentially placing themselves into continuous contact with their customers, thereby enabling them to better understand their customers' needs and act appropriately. The intersection of these trends creates an opportunity for product OEMs to evolve their business model and drive competitive differentiation through new collaborative product and service offerings.

Data transformation is the bridge between connectivity and the applied value of data and analytics - it's the true enabler of new machine data capabilities

Head of Development
Analytics Software Tool Provider

We believe that as this ecosystem trend continues to play out, virtually all of the constituents involved and interacting with healthcare equipment will come to see the need to leverage machine data and analytics to re-design business processes by automating a wide range of devices, machines and equipment systems for greater efficiency, safety and validated compliance.

The overarching goal of future digital healthcare delivery should be to seamlessly integrate the processes used to diagnose, monitor, treat, and rehabilitate patients with all of the data from sensors, machines, people and systems leveraging new analytic tools to re-define how we deliver healthcare.

THE BUILD VERSUS BUY DILEMMA

Service organizations within hospitals and health delivery companies are working to cut costs by reducing the amount of spending on OEM and third party service contracts and conducting more asset services in-house. While this may seem pragmatic, many organizations are discovering that the technological skills and know-how required to develop data management and analytics capabilities is beyond their core capabilities.

Organizations that develop in-house data management and analytics solutions typically run into several major challenges:

» First, they spend significant amounts of time and resources building systems from scratch, but what these organizations do not realize is data transformation and management can take up to 70% of all data analytics cost and time; therefore, these in-house systems are quickly overwhelmed by the volume,

velocity and variety of data coming from their assets.

» Second, services and support for these "Frankenstein" systems is a major challenge, as organizations find their own internal IT teams troubleshooting and working to upgrade these systems much more frequently than expected in order to keep up with increasing levels of data complexity from today's advanced assets.

» Third, many in-house solutions are built as one-off, point solutions that cannot be easily scaled beyond the specific use case or asset that the solution was originally designed for. This leads to the need for creation of additional one-off systems in other parts of the organization and the creation of data silos—making it impossible to glean an enterprise-wide view of asset performance.

Due to all of these reasons, organizations who develop their own in-house solutions quickly become bogged down by unexpected challenges and fail to reach the true value potential from their data.

ENTER GLASSBEAM

As Smart Systems move beyond the first base of connectivity, the service delivery story becomes critical to deriving new levels of value from gathered data. The need to manage and transform complex data for analysis becomes paramount, and the complexity of building this sort of solution in-house becomes unrealistic. Unfortunately, customers who opt to go with OEM service contracts are spending huge dollars and getting little value in return. This is why an increasing number of companies, both OEMs and providers, who are looking for new levels of data value from their advanced machines are turning to Glassbeam; they realize that other offerings cannot address complex machine log data in the manner that Glassbeam is able to.

> Many hospital equipment service organizations are very far behind the curve using data and analytics; often organizations are using software built decades ago with very limited features
>
> Healthcare Industry Data and Analytics Consultant

Glassbeam's key differentiators include:

» Ability to ingest, parse and analyze multi-structured, complex log data from advanced assets by integrating machine logs with the service history of CMMS data; the Glassbeam solution goes beyond the simple value provided by only analyzing sensor or historical data.

» Much faster time to deployment, which also leads to significantly reduced cost (rapid deployment and reduced man hours). Overall, Glassbeam can deliver 10x the functionality in 1/10th the time at half the cost of other solutions.

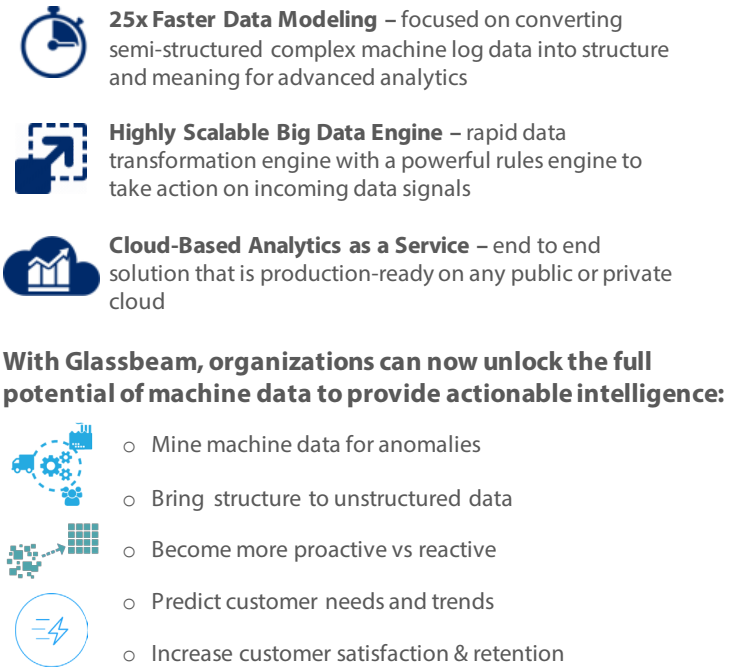
» Much more granular development of Rules & Alerts when compared to competitors. Complex log data management uncovers many more variables for analysis than traditional solutions can.

» Integration of multiple data types to enable increasingly complex applications.

» Enablement of machine learning and predictive analytics on complex log data.

» Ease of use and role-based access for multiple user personas with different data needs.

Exhibit 10: Glassbeam Technology Benefits



Glassbeam's patented technology capabilities that drive differentiation:

» SCALAR Platform and Semiotic Parsing Language (SPL): SCALAR is a purpose-built machine data management and analytics solution; the platform leverages Glassbeam's SPL to combine data parsing, ETL and Rules/Actions into a single processing element (ability to address both unstructured and structured data in one single development step).

» Rules & Alerts Engine: Complex event processing technologies that model and capture threshold and anomalous conditions, then send alerts when pre-defined conditions are met.

Glassbeam is well positioned to address complex machine data produced by advanced assets in the healthcare industry. Compared to traditional solutions, Glassbeam can deliver ten times the functionality, in 1/10th of the time, at half the cost of other solutions.

Exhibit 11: Before and After Comparison With Glassbeam Technology

	Without Glassbeam	With Glassbeam
Cost	• **Expensive OEM contracts at $150K+** per machine per year • **ISOs are 15-20% cheaper** cost that claim to provide same value as OEM contract	• **Glassbeam charges less than 10%** of OEM or ISO cost per asset per year • **Reduced overall budgetary spend** for a provider by providing software driven predictive analytics
Use Cases	• **Proactive monitoring** on key indicators such as magnet pressure, helium levels, Cold head temperature etc.	• **Predictive analysis** such as X-ray tube failure in CT Scanners • **Anomaly Detection** per asset based on thresholds established through machine learning algorithms over historical data • **Asset utilization** providing insights into machine usage with patient and procedure throughput
Assets Monitored	• **OEMs specific** modalities only • **ISOs are more OEM neutral** and provide single stop shop for different kinds of assets	• **Multi modality multi manufacturer** views into entire fleet in single dashboard with drill downs • **Rich roadmap** rich to cover Ultrasound, X-Rays, Mamography, Cathlabs, Patient Monitors, etc
Data Analysis Speed	• **Several hours** to react to system and part failures	• **Seconds to alert** key personnel over emails leveraging automated and customizable Rules & Alerts Engine

When applied to the Healthcare market, Glassbeam's functionalities enable the solution to significantly out-perform competing 3rd party solutions and those developed in-house by machine OEMs or end-customers. For example, many hospitals today use remote asset monitoring & support solutions from machine OEMs, which do not provide the breadth or depth of analysis that can be accomplished with Glassbeam. Beyond enabling significant cost and time savings, Glassbeam also works with healthcare OEMs and end-customers to enable new

Exhibit 12: Complex Data Management Impacts in Healthcare

Harbor Research interviewed several healthcare providers and ISOs (Independent Service Organizations) to synthesize user challenges, desired solutions and business impact statements (if the desired solutions are implemented).

The analysis made it clear that although complex data challenges are numerous across all industries, they can be most clearly seen within the healthcare sector. Clearly healthcare organizations strive to minimize asset downtime and expenses while also providing a better experience for patients. The research reinforces that this can only be accomplished by conducting analysis on complex machine log data from diverse medical assets such as medical imaging systems.

Environmental Monitoring

Challenge: Proper room temperature and other environmental considerations are critical for MRI machines to function optimally. Power fluctuations or malfunctioning chiller units can bring down the MRI or CT Scanners unexpectedly, leading to significant downtime.

Solution: Glassbeam is working on integrating environmental data from imaging rooms (temperature, humidity, etc) and feeding that into its Rules & Alerts Engine to proactively alert clinical engineers with instant email alerts when, for example, room temperature begins to fluctuate out of required range.

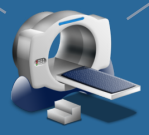
Impact: Significant recovery on revenues that are otherwise lost due to equipment downtime.

Asset Utilization

Challenge: A hospital network spends 4-6 man hours per week across all its 10 facilities to assimilate machine utilization data from scheduling and other transactional system. End result is an adhoc report that is not 100% accurate full of redundant information.

Solution: Analyzing machine logs with Glassbeam can allow the hospital to understand asset utilization rates of its imaging fleet across the entire hospital network, on a real time dashboard, by type of manufacturer (GE or Siemens), procedure type, patient throughput - anytime, anywhere, anyplace

Impact: Effective capex decisions based on actual machine utilization per facility



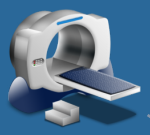
Enabling advanced healthcare use cases by leveraging complex machine data is a valuable opportunity, but few software suppliers have the technical ability to address this challenge.

Glassbeam's Semiotic Parsing Language (SPL) and Rules and Alerts Engine can transform and analyze complex machine data from healthcare imaging equipment with much more depth and efficiency than solutions developed in-house by OEMs or software solutions from competitors.

Exhibit 12: Complex Data Management Impacts in Healthcare

As healthcare organizations begin to transition away from sorely outdated software solutions, leveraging advanced data management and transformation solutions is a key building block for success. Glassbeam has played this role within many healthcare organizations that are looking to get real value from their asset data. The solution is able to quickly parse complex machine log data and provide advanced analytics that were not previously available. The Glassbeam solution can:

- Quickly transform and analyze complex log data from a wide variety of assets produced by any OEM;
- Enable a wide variety of use cases that were not previously possible, including real-time data visibility, predictive maintenance, and environmental monitoring;
- Allow hospital maintenance staff to reduce downtime by proactively predicting machine failures and alerting staff to order new parts much faster than is possible when using OEM monitoring solutions.



Operator Training

Challenge: Task completion time by ultrasound machine operators is several times inconsistent across a hospital network, and the hospital management always desires to identify which operators need more training to complete tasks more efficiently.

Solution: Complex machine log data from ultrasound machines can be used by Glassbeam to identify how long each task takes for individual machine operators. Operators taking too long can be identified for additional training.

Impacts: 15-20% increase in operator efficiency after training.

Remote Services & Maintenance

Challenge: ISOs take on full service contracts for the entire fleet of CT and MRI machines but have no incident-based automated alerting solution in place, and thus have to rely on customers reporting on problems or physically doing unproductive trips to hospital sites to catch potential failures.

Solution: Analyzing machine logs using Glassbeam, ISO's field engineering staff can get proactive and predictive notifications on potential issues before they turn into catastrophic machine failures. Part replacement trips can also be optimized.

Impact: Reduced MTTR, MTBF, and FTR metrics, saving thousands of dollars on service contracts.

Harbor Research projects that leveraging complex machine data from healthcare imaging equipment will produce over $11 billion of potential revenue value by 2022. Glassbeam's capabilities directly address the bulk of this opportunity.

use cases, such as AI and machine learning applications, that were previously not possible when using simple sensor data and legacy data transformation solutions.

Glassbeam is a data transformation and management solution that is actively used in the healthcare sector today. All healthcare organizations strive to minimize asset downtime and expenses while also providing a better experience for patients. Glassbeam is an end-to-end technology solution that works across multiple market segments that utilize compute-intensive machines that produce complex multi-structured log data. Healthcare is an extremely complicated market, and Glassbeam has been able to enter this market and overcome challenges that in-house solutions and OEM solutions simply cannot address.

Implementation of an advanced data transformation and analytics solution from Glassbeam can drive competitive differentiation for a wide variety of customers, including OEMs, end customers and third party service providers. There is huge promise in the value of conducting data management and analytics for multi-structured machine log data. However, many customers underestimate the importance of data management and transformation, and do not understand that the full value of this complex log data can only be realized through advanced data solutions. Glassbeam is purpose-built to address these challenges, allowing end-users to realize new levels of value from data, while also achieving significant cost and time savings.

SUMMARY - DATA TRANSFORMATION DRIVES VALUE IN SMART HEALTHCARE SYSTEMS

The nature of compound and complex Smart Systems applications in healthcare is just beginning to be understood. The information value generated by these capabilities positions players to take on significant additional tasks for the customer, such as:

» Managing and automating a customer's spare parts inventory and service delivery chain for maintenance processes, providing vastly improved levels of service and responsiveness;

» Providing the customer's first line support staff, the machine builders' service technicians and other third party support personnel with complete access to a unified machine maintenance record;

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

» Providing entirely new services to the customer such as "security-as-a-service", where security and privacy for all devices, machines, networks and data is provided as a managed service.

Health delivery organizations are looking to equipment manufacturers not just for high-quality equipment, but also for help in optimizing their ability to supply consistent and high-quality services for patient care. Taken one step further, this evolution will allow medical equipment manufacturers to tie their revenue and pricing models directly to the value and related benefits they provide.

ABOUT HARBOR RESEARCH

Founded in 1984, Harbor Research Inc. has more than thirty years of experience in providing strategic consulting and research services that enable our clients to understand and capitalize on emergent and disruptive opportunities driven by information and communications technology. The firm has established a unique competence in developing business models and strategy for the convergence of pervasive computing, global networking and smart systems.

ADDENDUM: COMPLEX HEALTHCARE MACHINE DATA MANAGEMENT OPPORTUNITY

Enabling advanced healthcare use cases by leveraging complex machine data is a valuable opportunity, but few software suppliers have the technical ability to address this challenge. Solutions are required that can transform and analyze complex machine data from healthcare imaging equipment with much more depth and efficiency than solutions development in-house by OEMs or software solutions from other competitors.

Exhibit 14: Data Management and Applications Revenue Potential

Revenue Category	Glassbeam Offering Capabilities	Overall Complex Machine Opportunity 2017	Overall Complex Machine Opportunity 2022	'17 - '22 CAGR
Mobile & Cloud Services		$1.1 B	$1.8 B	10.4%
Supply Chain & Logistics		$220.7 M	$329.1 M	8.3%
Energy Management		$441.3 M	$761.7 M	11.5%
Security Management		$1.1 B	$1.8 B	10.4%
Asset Management		$1.4 B	$2.6 B	13.2%
Customer Support		$584.8 M	$988.4 M	11.1%
Data Management & Analytics		$879.1 M	$1.7 B	14.1%
Location & Tracking		$45.4 M	$59.6 M	5.6%
Data Transformation		$520.6 M	$836.8 M	10.4%
Device Management & Connectivity		$454.7 M	$745.1 M	10.4%
Total Opportunity		**$6.6 B** [1]	**$11.6 B** [1]	**10.1%**
Total Glassbeam Primary/ Secondary Opportunity	Glassbeam can address 56% of the total market in 2022	**$2.7 B** [1]	**$4.8 B** [1]	**12.2%**

[1] Includes 'Other' Category within System Applications

Addressed by Glassbeam Core Capabilities
Partially Addressed by Glassbeam Core Capabilities
Not Addressed by Glassbeam Core Capabilities

Solutions than can address these functionalities have the ability to address a large amount of the healthcare data management and analytics market. Key capabilities and use cases required in the healthcare space range from transforming complex

data from healthcare imaging machines to addressing a variety of use cases, including predictive and preventative maintenance, asset utilization, operator training, uptime assurance, environmental monitoring, and others. Harbor Research projects that leveraging complex machine data from healthcare imaging equipment will produce $11.6 billion of potential revenue value by 2022.

Exhibit 15: Data Management and Applications Revenue Segment Definitions

Revenue Category	Definition
Mobile & Cloud Services	Services providing a means for device data to be transmitted through the network and be used for further platforms or applications at the edge or on a private/public cloud
Supply Chain & Logistics	The movement and logistics of raw and finished materials from point of extraction/creation through wholesale distribution to re-distribution through retail and ultimate end use
Energy Management	The monitoring of systems to provide information on energy production and/or consumption, and the control of those systems to optimize energy usage
Security Management	A series of policies, processes, and systems to manage the risk of information assets and ensure no unauthorized party interacts with equipment, systems or environments
Asset Management	The aggregation, correlation and analysis of real-time, state-based, and historical equipment and system data to inform predictive maintenance, reliability management, overall equipment effectiveness optimization and other asset-based applications
Customer Support	Connectivity and data enable increased efficiency, effectiveness and availability of customer support functions that drive value for all parties involved
Data Management & Analytics	Processing and storing data with functions including data aggregation and storage, data integration, analytics tools, and data presentation
Location & Tracking	Location and Tracking applications are used to monitor variations in geography and movement of equipment, devices or people
Data Transformation	Process of sifting through data and identifying logical boundaries that assign meaning to previously indistinguishable values
Device Management & Connectivity	Makes devices available as logical things or systems and enables users to control device functions. Functions include a range of capabilities for device provisioning, remote access, configuration, administration, software management, device monitoring, etc.