Fast and Reliable Systems for Highly Accurate Predictive Maintenance and Quality (PMQ)

Sponsored by IBM

Srini Chari, Ph.D., MBA mailto:chari@cabotpartners.com
September, 2015

Cabot Partners Group, Inc. 100 Woodcrest Lane, Danbury CT 06810, www.cabotpartners.com

Executive Summary

The economic value of Predictive Maintenance and Quality (PMQ) is immense across the enterprise. For plant floor and maintenance managers, the primary benefit is to improve equipment/asset performance, minimize unplanned downtime and increase reliability and quality while lowering maintenance costs. Manufacturing executives can optimize all operations across multiple plants and the supply chain for better utilization of all resources – equipment, inventories and human. For the C-Suite, PMQ improves enterprise performance and profits.

PMQ solutions leverage recent remarkable advances in Information Technology (IT) – Internet of Things (IoT) aggregating data from pervasive sensors, advanced analytics, enterprise social collaboration and mobility, cloud computing and fast and reliable enterprise-grade systems.

Based on a layered IT architecture, the IBM PMQ solution helps operators detect impending problems early, provides greater control of operations, avoids costly breakdowns, reduces the number of expensive in-person inspections and mitigates the needless replacement of properly functioning parts dictated by preventive maintenance schedules. For this, fast, reliable and accurate Predictive Analytics is critical.

Using highly-accurate customized data-driven predictive analytics models of asset performance, the IBM PMQ solution constantly monitors production assets in real time and detects and isolates abnormal behavior. It then posts these incidents and provides exception-based notifications of impending problems to users with specific scored "next best actions".

But the sheer volume, velocity and variety of data could cause performance bottlenecks with commodity systems particularly as PMQ adoption grows across the enterprise and in the supply chain. To meet these challenges, organizations must deploy a cost-effective, high-performance, reliable and enterprise-grade IT infrastructure. This is the goal of IBM's Power and Storage Systems.

These IBM systems could also lower the total cost of ownership (TCO) while improving utilization and reliability. Additionally, IBM offers industry-leading financing and leasing programs that make it easy to acquire these systems and the associated IBM PMQ solution.

Cabot Partners
Optimizing Business Value

Predictive Maintenance and Quality (PMQ) provides 10X ROI to the enterprise

Predictive Maintenance and Quality for Better Business Outcomes

There is a revolution brewing in manufacturing. Products once solely composed of electrical and mechanical parts have become complex systems networked in numerous ways with servers, sensors, software and data. These smart connected products help manufacturers and their supply chains improve quality, reliability, time-to-market and profits.

Maintenance, once considered a necessary cost center relegated to the bowels of the plant floor, is getting the attention of the C-Suite. The economic advantages of Predictive Maintenance enabled by low-cost sensors, advanced analytics and the Internet of Things (IoT) are staggering: 10X return on investment, 25–35% deduction in maintenance costs, 70–75% fewer breakdowns, 35–45% reduction in downtime and 20–25% increase in production.[1]

But operators challenged with data overload and lack of customization

Heavy equipment production assets operating on the manufacturing plant floor or on oil platforms or at construction sites are monitored continuously to detect the probability of equipment failure. Continuous active monitoring is necessary since 89%[2] of equipment failures occur randomly. However, many operators grapple with problems associated with data overload and lack customizable actionable intelligence to prevent surprises.

While no technology can prevent normal equipment wear or the need for maintenance, Predictive Maintenance and Quality solutions (based on Information Technology – IT) are helping operators detect imminent and potential problems early. This provides greater control of operations, avoids costly breakdowns, reduces the number of expensive in-person inspections and mitigates the needless replacement of properly functioning parts dictated by preventive maintenance schedules. For this, fast, reliable and accurate Predictive Analytics is critical. And this requires reliable, enterprise-grade high-performance systems.

Managing Maintenance and Repair against Cost – the P-F Curve[3]

Maintenance professionals have historically used the P-F curve as a visual operating guide. Figure 1 depicts the substantial lead time and cost advantages of PMQ solutions.

PMQ provides larger lead times, avoids costly breakdowns while reducing expensive in-person inspections

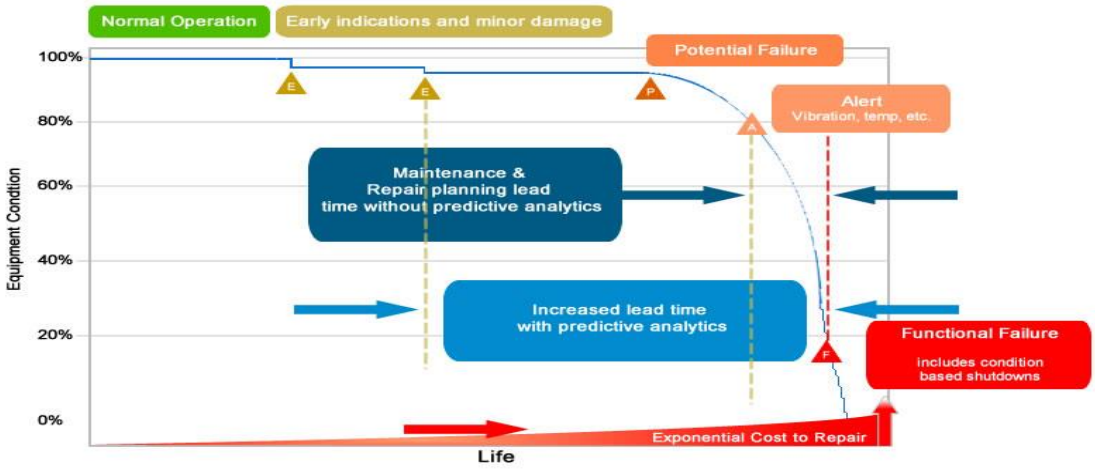

Figure 1: P-F Curve Depicting Increased Maintenance Lead Time Possible with Predictive Analytics

[1] "Operations & Maintenance Best Practices: A Guide to Achieving Operational Efficiency", U.S. Department of Energy Federal Energy Management Program, August 2010, http://www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf
[2] Mike Gehloff, "P-F Curve 101 – Keeping is Simple", http://www.maintenancephoenix.com/2013/10/02/pf-curve-101-keeping-it-simple/
[3] Steve Tonissen, "Winning the race against equipment failure".

PMQ better than Reactive, Preventive or Condition Monitoring-based maintenance approaches

Key points on the curve are "Potential Failure" (**P**) and "Functional Failure" (**F**). **P** occurs when events lead to component damage that needs repair. **F** occurs when equipment performance no longer meets design conditions and must be shut down for repair.

Traditional approaches used by manufacturers are:

- Reactive or Breakdown: Service or replace equipment after it fails.
- Preventive: Service or replace equipment per manufacturer's suggested schedule, or the amount of time it has been in service, or based on operational observations.
- Condition Monitoring-based: Service or replace equipment based on monitoring performed to regularly assess its current condition.

The problem with these traditional approaches is their high cost. Waiting until a component fails results in lost production time and revenue. In-person inspections are expensive and can lead to replacing parts unnecessarily, based only on the inspector's best guess. Following the manufacturer's recommended maintenance schedule saves on inspection costs but often results in replacing parts that are still functioning well and could continue to do so.

More accurate assessment of asset health with earlier warning

PMQ solutions differ considerably from the traditional approaches. They provide a more accurate assessment of the condition of each individual piece of equipment and earlier warning of developing issues. Operators benefit from extended lead time enabling them to fix small problems before they grow large or catastrophic. Figure 2 summarizes how PMQ solutions Model, Monitor and Act.

PMQ Solutions: Model, Monitor and Act

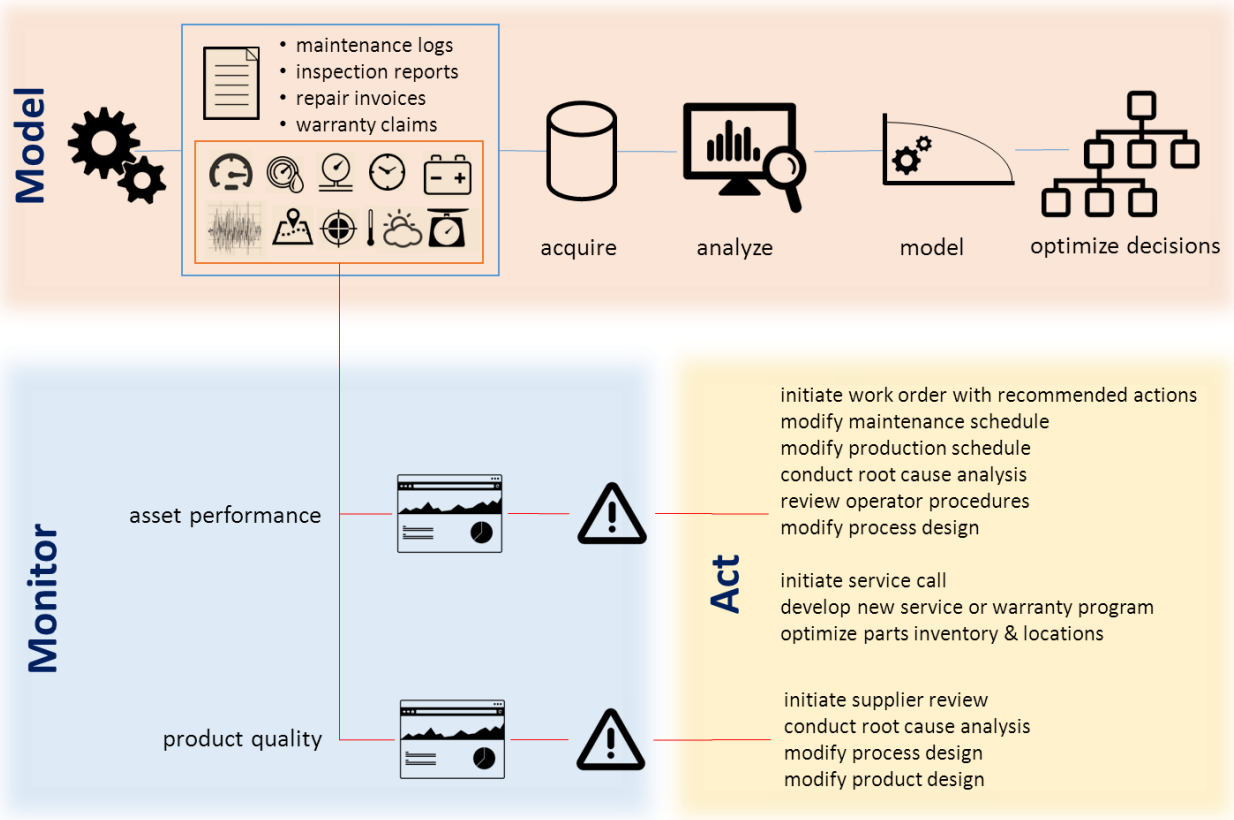

Figure 2: PMQ Solutions: Model, Monitor and Act

How PMQ Solutions Work[4] - Monitor, Model and Act

Constant monitoring crucial as failures are very random

PMQ solutions constantly **monitor** and analyze each production asset's condition to assess its fitness for continued operation. Repairs or alerts are initiated only as and when determined by the underlying predictive mathematical model customized to the asset. This is hard to do.

Even two seemingly identical pieces of equipment that were manufactured on different days under dissimilar conditions, possess different operating characteristics, have distinct maintenance histories especially if they have been functioning under different ambient conditions, loads and operating contexts.

Unique accurate data-driven customized near real-time predictive models provide next best actions

Unique Predictive Models are built for every production asset. This **Model** calibrates the individual equipment across all known loads, ambient conditions and operating contexts. It calculates the proper operational relationships among all relevant parameters, such as loads, temperatures, pressures, vibration readings, ambient conditions and more. It then takes actual real-time sensor readings and compares them to that particular machine's normal response.

Based upon the differences between real time and normal, along with their persistence, the PMQ solution detects and isolates abnormal behavior, in the context of operating conditions. It then posts these incidents and provides exception-based notifications of developing problems to users. It does this automatically, continuously and constantly, 24 hours a day.

Some leading PMQ solutions, such as the IBM PMQ Solution, go one step further and help an organization **act** and optimize its maintenance program by developing a set of prioritized actionable recommendations when specific changes in asset health are identified. Today, early adopters include companies in the manufacturing, energy, transportation, and IT sectors.

Fast, Enterprise-grade Systems Crucial as PMQ Adoption Grows

IoT, Analytics, Cloud and Enterprise Social Collaboration and Mobility key to spur broader PMQ adoption

Several fast-growing intertwined technology trends – Cloud, Social, Mobile, Internet of Things (IoT) and Big Data Analytics will enable deeper collaboration between companies and their ecosystems and spur the broader adoption of PMQ solutions.

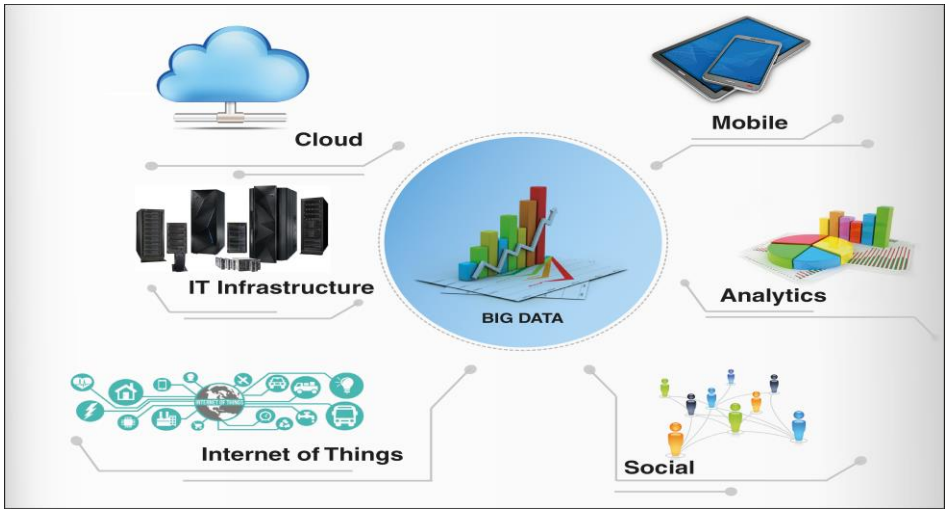

Figure 3: Intertwined Technologies of Cloud, Social, Mobile, IoT and Analytics Spur PMQ Growth

[4] Steve Tonissen, "Winning the race against equipment failure".

Traditional commodity systems are limiting to address the PMQ data challenges

As the appeal of PMQ grows, companies are challenged with the complexities of managing exploding volumes, velocities and varieties of data. To extract actionable insights and value, companies must deploy IT solutions that ensure data veracity and reduce vulnerability. The ability to virtualize and visualize data is also crucial to implement effective PMQ solutions.

But traditional commodity systems are limiting. Technical obstacles include slow data loading and querying, large network latencies, low system reliability and utilization, and the costs and complexities of managing distributed infrastructure. Fast, enterprise-grade systems provide an agile foundation for PMQ solutions to model, monitor and act in real-time.

The enterprise-grade IBM Predictive Maintenance and Quality solution includes robust Reliability-Availability-Serviceability (RAS), deployment, security and governance processes anchored on the IBM Analytics Platform built on IBM Power Systems and IBM Storage.

The IBM Predictive Maintenance and Quality Solution[5]

The IBM PMQ solution anchored on IBM Systems is fast, reliable and highly-accurate

The IBM Predictive Maintenance and Quality solution helps monitor, analyze, and report on information gathered from devices and recommend appropriate maintenance activities to:

- Predict the failure of a monitored asset to fix it and avoid costly downtime
- Optimize asset maintenance schedules by incorporating predictive insights and forecasts
- Learn which equipment-specific parameters (measurement types) best predict failure
- Conduct Statistical Process Control (SPC) analysis on different asset operating parameters
- Interactively analyze frequency distribution histograms based on different asset parameters
- Combine the predictive powers of multiple predictive models, each tapping a variety of equipment and maintenance data in structured and unstructured formats
- Find answers and take corrective actions faster by performing a connected and interactive RCA (Root Cause Analysis) using advanced visualization and predictive analytic techniques, and without the need to switch across multiple systems, thus reducing the time to value for identifying the problem, locating its causes and the root cause, and taking corrective action
- Provide better early warning signals for accelerated failure rates discovered during inspection of production batches
- Provide early warning signals of increasing replacement or wear rates for parts under warranty. Analyze the reasons for the observed rapid replacement or wear, across reasons related to changes in service conditions, anomalies during manufacturing, and sub-optimal sourcing
- Compute customized health score for all equipment using advanced models to predict the patterns in sensor data that may lead to equipment failure.

Provides early warning with best actions to avoid costly downtime and needless expensive replacements

Figure 4 depicts the IBM PMQ layered solution architecture along with key components.

Layer 5: Analytics: The analytics layer is supported by IBM SPSS Modeler, IBM SPSS Decision Management, and IBM SPSS Collaboration and Deployment Services. The analytics layer uses models based on historical information and other inputs. These models produce scores to predict the future of a given asset and any associated maintenance recommendations.

[5] IBM Predictive Maintenance and Quality 2.0 Technical Overview, May 2015

A customized layered architecture built on industry-leading software and systems components

Layers: Analytics, Integration, Reporting, Data and Systems with automated installation scripts

IBM Systems provide fast, secure and reliable foundation across all layers

Layer 4: Integration Bus: The integration bus layer is supported using IBM Integration Bus and connects the internal and external components of the solution. This layer:

- Transforms external events (received from monitored devices) into the solution's format
- Integrates with the solution's predictive-model training and scoring services to obtain the most optimal predictive scores from the most recently trained predictive models. This way, the recommended maintenance actions are based on the latest received events.

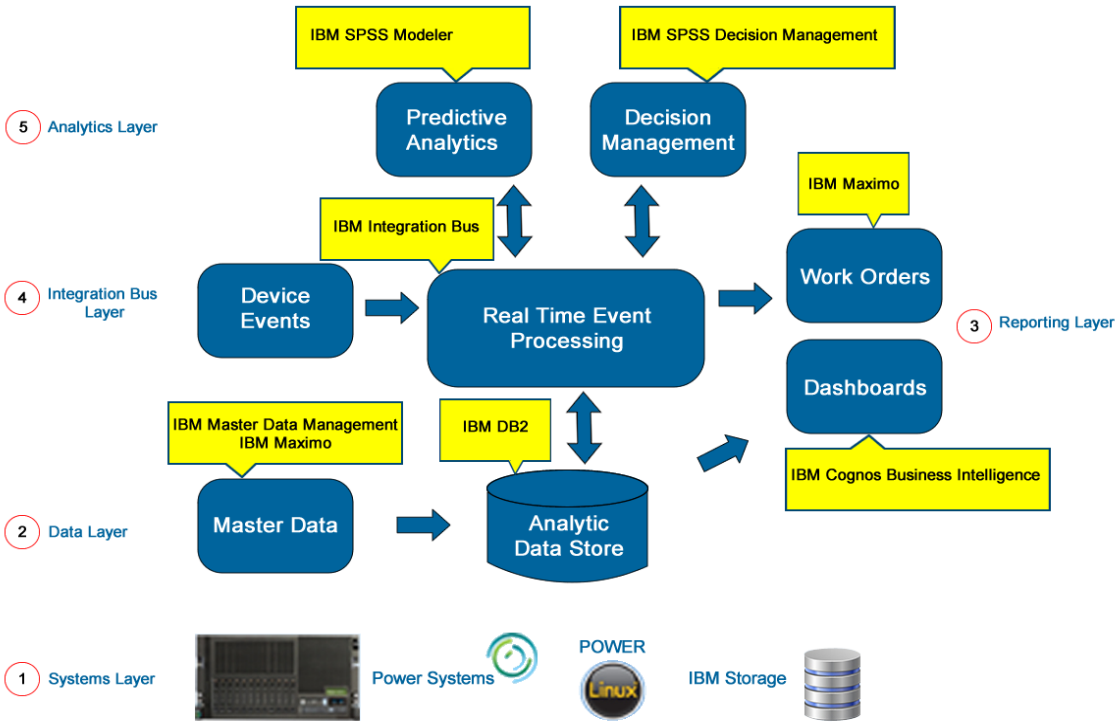

Figure 4: IBM Predictive Maintenance and Quality High Level Contextual Layered Architecture

Layer 3: Reporting: IBM Cognos Business Intelligence provides a set of live dashboards and reports showing the information captured in the analytic data store. Example reports include a Site Overview report and an Equipment report.

Layer 2: Data: The data layer contains the solution's analytic data store, an IBM DB2 repository for received device events and any recommended maintenance activities that stem from those events. The data layer also stores critical master data about devices being monitored. Master data can be loaded into the analytic data store through the integration bus layer and can be received from an external source or IBM Master Data Management.

Layer 1: Systems: The IT infrastructure matters[6] and provides the foundation to ingest, store, easily access, combine, and analyze large data sets. IBM Power Systems and IBM Storage are optimized to support real time analytics on growing volumes of streaming and at rest data. Compared to commodity alternatives, these IBM systems provide reliable, secure, high-performance in-memory processing so that users get timely access to the relevant information for more informed decisions.

[6] http://www.ibm.com/systems/infrastructure/us/en/it-infrastructure-matters/it-infrastructure-report.html

Fast and Reliable Systems for Predictive Maintenance and Quality

The IBM Systems architecture is designed and optimized for PMQ

As data volumes grow exponentially, the costs of moving the data in and out of a central processor becomes prohibitive. To move 1 byte from storage to the central processor, it could cost 3-10 times the cost of one floating point operation (flop).[7] So why not move data less by running workloads where the data resides? This requires "computing" at all levels of the system stack including network, memory and storage. This is, in essence, IBM's Fast, Enterprise-grade Systems approach (Figure 4) with the following architectural principles:[8]

1. **Minimize data motion** by providing hardware and software to support and enable compute in data and schedule workloads to run where they run best.
2. **Enable compute in all levels of the systems hierarchy** with "active" system elements throughout the stack including network, memory, storage, etc.
3. **Build Modularity** with a balanced, composable architecture that is scalable from a sub-rack to hundreds of racks.
4. **Optimize for PMQ** by using real workloads/workflows to drive design points optimized for client business value.
5. **Leverage the OpenPOWER Foundation**[9] to accelerate innovation and provide clients flexibility and choice to deploy well-integrated, best-of-breed solution components.

The modular architecture minimizes data motion and enables computing at all levels in the hierarchy

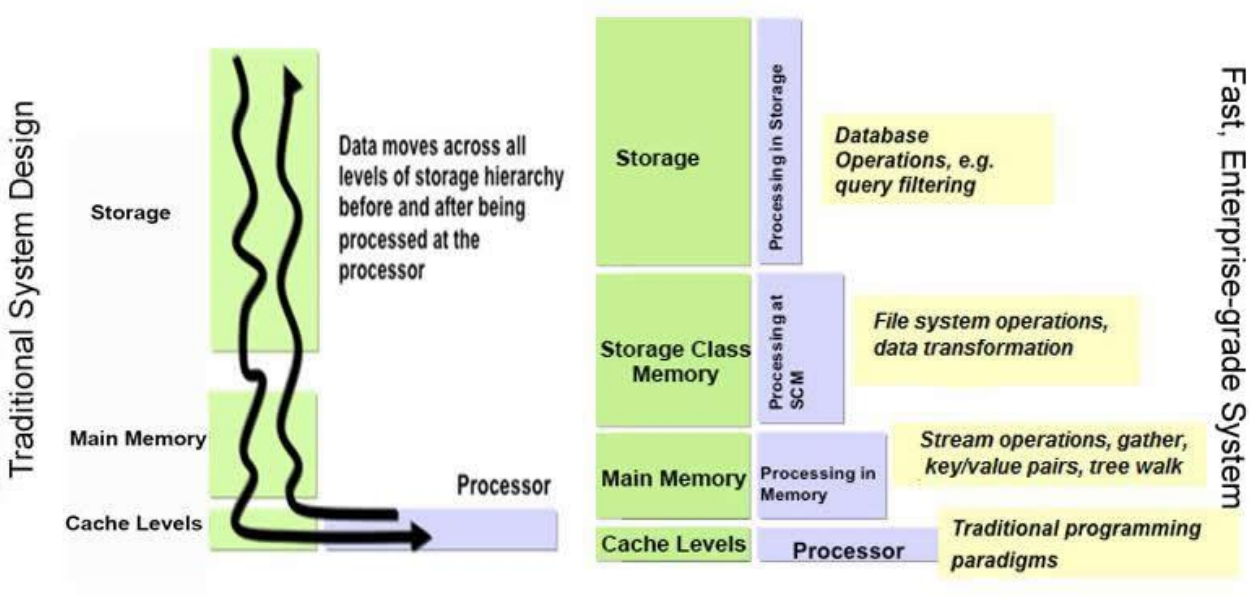

Figure 5: Traditional and Fast, Enterprise-grade System Designs

IBM offers a wide array of IT Systems with industry leading financing and leasing programs

IBM offers a wide array of IT infrastructure solutions including fast, reliable systems, and software and cloud services. Featured systems include: IBM Power Systems and IBM System Storage on Linux and IBM AIX. Key software includes a high-performance shared-disk clustered file system – IBM Spectrum Scale. Additionally, IBM offers industry-leading financing and leasing programs that make it easy to acquire software, systems and solutions.

[7] https://www.nersc.gov/assets/NERSC-Staff-Publications/2010/ShalfVecpar2010.pdf
[8] Tilak Agerwala and M. Perrone, "Data Centric Systems: The Next Paradigm in Computing", http://icpp.cs.umn.edu/agerwala.pdf , 2014.
[9] http://openpowerfoundation.org/

IBM Systems deliver higher performance, greater bandwidth and better integration and economics

IBM Systems (POWER8 processors and Storage) offer a tightly-integrated and performance-optimized infrastructure for PMQ workloads with enduring economics:

1. **Massive Threads:** Each POWER8 core is capable of handling eight hardware threads simultaneously for a total of 96 threads executed simultaneously on a 12-core chip.
2. **Large Bandwidth:** Very large amounts of on- and off-chip eDRAM caches and on-chip memory controllers enable very high bandwidth to memory and system I/O.
3. **Higher Performance:** POWER8 is capable of clock speeds around 4.15GHz, with a Thermal Design Power (TDP) in the neighborhood of 250 watts.
4. **Agile Integration and Better Economics:** IBM FlashSystems deliver more scalable performance, enduring economics, and agile integration.
5. **Excellent RAS:** Many studies[10,11] across a range of enterprises have indicated that IBM Power systems perform better than x86 systems in Reliability, Availability and Serviceability (RAS), performance, TCO, security and overall satisfaction.

Game-changing systems innovation with CAPI and OpenPOWER

6. **Game-Changing Performance with Coherent Accelerator Processor Interface (CAPI):** CAPI, a direct link into the CPU, allows peripherals and coprocessors to communicate directly with the CPU, substantially bypassing operating system and driver overheads. In the case of flash memory attached via CAPI, the overhead is reduced by a factor of 24:1. More importantly though, CAPI can be used to attach coprocessors — directly to the POWER8 CPU for significant PMQ workload-specific performance boosts.
7. **Innovation with the OpenPOWER Foundation:** IBM has opened up the technology in Power Systems architecture offerings, such as processor specifications, firmware and software. The Foundation – with over 120 global technology leaders and growing – was founded by NVIDIA, Mellanox, IBM, Google and Tyan.

   There are several real world examples of innovations and performance enhancements resulting from the OpenPOWER Foundation and these span the business spectrum ranging from Monte Carlo financial risk modeling, Big Data and Java acceleration, NoSQL acceleration, Key Value Store (KVS) acceleration and so on – all key to PMQ.

PMQ Components Optimized on IBM Systems include:

PMQ software components optimized on IBM Systems

1. **The IBM BLU Acceleration Solution** – a next generation in-memory IBM DB2 database technology for real time analytics.
2. **IBM Solution for Analytics and Reporting** – enables rapid deployment of business and predictive analytics using SPSS and Cognos.

These optimized components provide high levels of performance even when reading tens of millions of records and/or scoring actions with petabytes of data volumes.

As a result, IBM Systems are more likely to perform better than comparable x86 server configurations. This is especially important for quickly providing the "next best action" that is critical for fast, reliable highly-accurate Maintenance and Quality.

[10] Edison Group, " Better Performance, Lower Costs The Advantages of IBM PowerLinux 7R2 with PowerVM versus HP DL380p G8 with vSphere 5.1, http://public.dhe.ibm.com/common/ssi/ecm/en/pol03161usen/POL03161USEN.PDF

[11] Solitaire Interglobal, "Power Boost Your Big Data Analytics Strategy", http://www.ibm.com/systems/power/solutions/assets/bigdata-analytics.html

For Fast, Accurate and Reliable PMQ across Multiple Industries…

IBM PMQ has been customized to enhance business value and quality across several industries

The IBM PMQ solution has been customized and delivered to enhance business value across multiple industries. Here are just a few illustrative examples:

Aerospace: Commercial plane manufacturers can improve safety and quality by predicting when specific tools need calibrating. This prevents the need for costly and time-consuming rework and keeps customer deliveries on schedule.

Manufacturers can automatically capture, store and analyze aircraft sensor data. This provides an at-a-glance view of the health of aircraft fleets and schedules condition-based maintenance management service to maximize asset availability. It also provides alerts when aircraft conditions necessitate unscheduled maintenance and creates data-driven preventive maintenance schedules to avoid unneeded maintenance downtime.

Key Industries: Aerospace, Automotive, Heavy Industry, Oil and Gas and Others

Automotive: A premium car maker can gather real-time data from vehicles, repair operations and factories worldwide, which could then be structured and analyzed to identify relations between product/process metrics and their effects on quality. This holistic approach provides new (previously not available) actionable insights that lead to design improvements.

A luxury car maker can analyze the many factors that influence the quality of the painting processes and minimize quality-control issues. The solution also helps eliminate the factors that cause secondary paint scratches during the assembly process; improving paint yields, reducing costs and improving the luxury brand's image of high-quality.

Oil and Gas: Analyzing sensor-data, an Oil and Gas firm can identify a seismic anomaly and immediately alert the operator to shut down the injection process before the well collapses. This averts expensive major problems while promoting safe and efficient oil extraction.

… IT Infrastructure Matters

With the ever increasing volume, velocity and variety of data and the need to support near real time "next best actions", companies implementing PMQ should consider IBM Power Systems and IBM Storage for their IT Infrastructure:

IBM Systems accelerate PMQ, lower TCO and integrate easily

- Accelerates analytics tasks many fold and minimizes costly data-motion across PMQ layers.
- Lowers total cost of ownership (TCO) with fewer servers with improved utilization, lower PMQ operational costs and less storage and data bottlenecks because of consolidation, fewer redundant copies, novel compression algorithms and efficient data-aware scheduling.
- Many businesses already run mission-critical Data Warehouses and Business Intelligence Applications on Power Systems and IBM Storage with excellent RAS and performance. By deploying PMQ on this infrastructure, current IT investments in people, processes, platforms and applications are protected, while having a seamless and cost-effective path to scale.

Cabot Partners is a collaborative consultancy and an independent IT analyst firm. We specialize in advising technology companies and their clients on how to build and grow a customer base, how to achieve desired revenue and profitability results, and how to make effective use of emerging technologies including HPC, Cloud Computing, and Analytics. To find out more, please go to www.cabotpartners.com.