Enterprise Asset Management

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Enterprise Asset Management - Abstract

Enterprise Asset Management (EAM) in capital intensive industries is a major opportunity for improving equipment availability, operating performance and financial performance. Effective EAM addresses all elements of the equipment lifecycle from conceptual design, manufacture / construction, commissioning, operations & maintenance to decommissioning & retirement. EAM includes the computerized systems and associated databases needed to support total lifecycle management of assets. Also included are the associated business processes and key metrics needed to support and sustain the entire program. EAM is a comprehensive program that encompasses all parts of an organization.

EAM as a program with its associated strategy and tactics have been evolving for more than two decades to the point where best practices and results in different industry sectors can be identified and replicated. This presentation outlines key elements of a comprehensive EAM program, including: Design for Integrity & (same) Reliability, Reliability Engineering, Maintenance Work Control (e.g., work approval & prioritization, planning & scheduling) Materials Management, and Computerized Maintenance Management Systems support. Each of these elements and their support business systems will be discussed in sufficient detail with examples to allow the conference attendees to complete a mini-diagnostic in order to compare their current program against global best practices.
Organizational change is an important part of a successful EAM implementation and needed for sustaining the improvement into the future. Change management strategy and tactics will be interwoven into the discussion.

(Paper)

There is an old adage that says “if we don’t know where we are going any road will get us there.” Or as the author Steven Covey said: “Begin with the End in Mind.” Both of these statements are true for an Enterprise Asset Management (EAM) Program. Organizations that have effective EAM programs have taken the time to define, document and communicate them across the organization and implement them successfully.

The place to begin is with a definition of what we are trying to achieve. Enterprise Asset Management is defined as the management of physical assets of an organization over the entire lifecycle. It includes design, manufacture / construction, commissioning, operations, maintenance and decommissioning / replacement of equipment and facilities. EAM includes the computerized systems and associated databases needed to support total lifecycle management of assets. Also included are associated business processes and key metrics needed to support and sustain the entire program. EAM is a comprehensive program that encompasses all parts of an organization.

There are two other views of EAM that should be mentioned here. Organizations in the Oil & Gas, Chemicals and Petrochemicals industries often refer to this total lifecycle approach to asset management in terms of integrity - Asset Integrity Management. The three elements of this view are: 1) Design integrity; 2) Technical integrity; and 3) Operating integrity (Figure 1). Another view is that published by the British Standards Institution, known as Publicly Available Standard 55 (PAS 55). This approach provides a framework and a 28-point requirements checklist of good practices in physical asset management. The standard was originally produced in 2004 by a number of organizations under the leadership of the Institute of Asset Management. It was substantially revised and released in December 2008 as PAS 55:2008 and is in the process of becoming an ISO standard.

An EAM implementation and improvement is driven by business needs. Recently a study was done by the ARC Advisory Group to assess the business drivers for an EAM program. Ten business drivers were documented (Figure 2). There were, however, four primary drivers: 1) Improve Uptime; 2) Reduced cost for maintenance labor and parts; 3) Extend asset longevity, and 4) Safety and Risk Management. A common term heard in many organizations today from the Chief Financial Officer (CFO) is “squeeze the assets.” These CFOs are trying to maximize return on investments, preserve precious capital and keep investment
at the lowest practical level to achieve desired output while effectively managing safety and risk.

Over the past decade or so the area of Operating Integrity has become increasingly important, received a great deal of focus and a number of good practices have developed across all industrial sectors. Therefore the main focus of this paper will be in this area while briefly mentioning Design and Technical integrity.

There are a number of essential elements to Design Integrity. The first is to define and document a clear scope. This answers the question: what is the intended purpose of this asset and in what operating context will it be required to perform? This is the foundation for all future design decisions. Another key element is to define the functions the asset will be required to perform in order to fulfill its mission or purpose. In recent years Reliability Engineers (RE) have come to play an important role in this stage of design by helping the project team “design for reliability.” This RE activity involves understanding failure mechanisms, failure modes, probability of failure, failure consequences and maintainability considerations in order to create a design that will produce higher reliability over the asset’s useful life. A simple example is the monitoring device designed into modern automobiles to monitor the condition of engine oil. This design change informs drivers immediately and conveniently when engine oil condition has fallen below acceptable parameters and a preventive maintenance visit to change the oil must be scheduled to preserve highest reliability. Another important aspect of understanding failures and their consequences is to develop maintenance programs with specific tasks to prevent or predict failures that will eventually occur. Another good practice during design is to have a member of the maintenance team from the plant that will operate and maintain the asset be a member of the design team. These individuals bring the practical aspects of daily maintenance into the design process. This practice is sometimes known as “design for maintainability.” This cross-functional and cross-organizational membership on the design team also helps mitigate another common issue – fixation on lowest purchase price. The objective during design should be to design for lowest total lifecycle cost.

There are a number of other proven techniques available during design that are well understood and will only be mentioned. One is RAM (Reliability, Availability and Maintainability) Analysis. This tool has been standard practice in safety critical industries such as aerospace and nuclear for some time. However, it is increasingly being adopted in the process industries such as Oil & Gas, Power Generation and Petrochemicals. Another design tool is Hazard Identification (HAZID). Hazard Identification is a process used to identify all possible situations where people may be exposed to injury, illness or disease, the type of injury or illness that may result from these and the way in which work is organized and
managed. It is the first step in developing a risk management strategy. Finally a technical integrity strategy needs to be taken into account during design.

Technical Integrity and Process Safety Management combine to reduce the likelihood of occupational incidents (e.g. slips, trips and falls) and major accident events (e.g. fire, explosion, structural failure, loss of containment, loss of buoyancy, pollution etc.). Technical Integrity is not just about the physical asset condition. It must also take into account the ability of systems to operate correctly under abnormal or emergency scenarios, or a combination of both; as well as the competence of personnel to react to atypical conditions to prevent the situation escalating into an unpredictable or uncontrollable event. A robust Technical Integrity program will reduce the risks from loss of containment and provide assurance that structures can withstand environmental and accidental events throughout their lifetime. It is a critical component of Total Lifecycle Management.

Comprehensive technical integrity programs include three core elements: systems, people and processes. The “systems” element encompasses the equipment assets, emergency and safety systems, design verifications and project quality management during construction, commissioning certification and start-up in accordance with specifications, standards, applicable regulations and codes, a reliability and maintenance program, and inspection & testing to ensure continuing fitness for purpose in the final operating context. The “people” element concerns itself with knowledge, skills, education, experience, competency, training and compliance. Role definition, competency testing and role-based training are well established in many industry sectors. A best practice is to have a training syllabus for each role and a tracking system to ensure that all personnel are competent and current. The aviation industry is one of the most advanced in this area. Pilots are required to demonstrate competency by flying a “check ride” for a specific type of aircraft with a Certified Flight Examiner before being allowed to operate the aircraft independently. In addition, pilots are required to undergo recurrent training in the equipment they are flying at specified intervals. The “processes” element deals with the business processes and tasks that must be properly executed to ensure technical integrity during operations. These include: in-service inspections (e.g. risk-based inspections), control of ignition sources, ensure integrity of protection systems (e.g. process trips, pressure relief devices), detection systems testing, shutdown systems like Pressurized Shutdown (PSD) and Emergency Shutdown (ESD) testing, mechanical integrity verification, asset management of change process and root cause analysis for continuous asset integrity improvement.

From this point forward this paper will focus on Operating Integrity. As industry CFOs require “squeezing the assets” it is in this area where there is significant opportunity for reliability and financial leverage. Technology has been continuously improving and some good practices have developed. The key elements of Operating Integrity are as follows (Figure 3).
Operations Assurance & Maintenance
Capital Projects Management
Turnarounds / Shutdowns
Computerized Maintenance Management System (CMMS)
Reliability Engineering
Work Management
Planning & Scheduling
Spare Parts Program
Metrics & Performance Improvement
Maintenance & Reliability Strategy
Change Management

Two of the elements – capital projects and turnarounds and shutdowns – will not be addressed here. Some aspects of project work have already been discussed in the Design Integrity section and the Turnarounds / Shutdowns process is well established among the industries represented at this conference.

One of the foundations of an EAM program is a comprehensive, streamlined and up-to-date Operations Maintenance program. The core of this program is a criticality analysis and a criticality ranking for all assets. As mentioned earlier “if we don’t know where we are going any road will get us there.” The analogy here is: without a criticality ranking asset criticality is simply a matter of opinion - and everyone will have an opinion on this subject, particularly when equipment in their area has failed. The Quality and Safety groups will also want to weigh in. The fundamental business reason for asset criticality ranking is that physical assets should be maintained with different levels of maintenance hours, preventive maintenance (PM) intensity & frequency, spare parts support, Original Equipment Manufacturer support, etc.

Another core element is the Proactive Maintenance Program. Several studies over the past four decades have established that 80-90% of all equipment failures are not related to equipment age. ‘Age-related use’ includes stress fatigue failures (e.g. shafts breaking, springs breaking, boiler tubes leaking), erosion / corrosion failures (e.g. material erosion, metal corrosion), wear-out failures (e.g. car tire tread wear, packed gland leaks) and other such failures where the length of operating time contributes to the eventual failure. Therefore time-based maintenance is pointless in most cases. This situation coupled with good equipment history from CMMS and advances in Predictive Maintenance (PdM) technology have helped leading-edge firms in several industry sectors to adopt Condition Monitoring methodologies and tools to improve reliability by monitoring equipment condition in service and applying maintenance tasks accordingly. Predictive technologies (e.g. vibration monitoring) can be online, on-stream or static. Some software tools can now generate a work order when a condition monitoring program indicates a need for maintenance. In addition, the
concept of Total Productive Maintenance (TPM) or Operator Care as it is known in some industries has provided a mechanism for Operations / Production and Maintenance personnel to collaborate in detecting failures in sufficient time to plan and execute necessary maintenance before a failure occurs.

Leading-edge maintenance programs have an ongoing PM optimization program to manage the quality and effectiveness of the proactive maintenance program. PM programs are built and proliferate in a variety of ways. Naturally, OEMs want all of their recommendations included in the program and often make warranties contingent on executing their program. Another PM building block is failures. When a failure happens a natural tendency is to add a PM or increase the frequency “just to make sure that failure does not happen again.” (Spare Parts can be involved in this scenario also – more on that later). A regulatory issue or quality issues can often lead to more PMs or increased frequencies for the same reason just mentioned. Another difficulty with PM is the way they are written. In many cases the tasks on the PM are not linked to a failure mode. So, a logical question is: “if a task is not being done to prevent a failure or detect a failure, why is it being done?” In addition, PM tasks are often written with very general instructions such as “inspect,” “check,” “verify,” etc. This is usually done because the author is in a hurry to write a PM (we are all busy) and the expectation is that experienced maintenance technicians “will know what to do.” The problem is that technicians have different experience levels and even experienced technicians will execute maintenance tasks (e.g. “inspect” a belt) differently - we are human and we have our preferences. The net effect is to introduce variation into the maintenance process because of the way PMs are written and then executed. So, bottom line: after 5 -7 years the following scenario often exists:

- All OEM recommended PMs are still being done (some tasks not linked to failure modes and some tasks no longer required)
- A large percentage of tasks are time-based – not condition-based
- Some equipment is being “over PMed” just to make sure that some failure or incident from long-ago does not happen again
- Some equipment has been removed from service and the PMs are still in the system and are being generated every month or quarter – this is quite common
- Many PM tasks contain a significant number of general tasks like “check” and “inspect”
- Many “general” PMs that may not be applicable or effective for a specific equipment type

One “key indicator” to look for to diagnose the health of the proactive maintenance program is to analyze when PMs are being done. If PM close-outs are concentrated at the end of the week or in the last few days of the month there
is cause for concern. Another metric useful to measure PdM effectiveness is: Work Order (WO) hours generated as a result of a PM – there is really no universal “target” number, but the point is that the program should be predicting potential failures.

An ongoing PM Optimization program periodically evaluates all PMs and associated tasks are “value-added.” That means tasks are linked to failure modes, PMs do not exist for obsolete equipment, PM tasks are very specific and clearly written to ensure consistency no matter who completes the work, the latest available PdM technology is being deployed in a cost-effective way and that operators are involved in the condition monitoring program with clear roles and responsibilities defined. PM optimization can be accomplished in different ways. For example, a Kaizen event could be scheduled to bring key stakeholders together for a week to optimize a part of the PM program (perhaps a subset of site assets or a few classes of assets). Another approach could be to organize a team of key stakeholders led by a Reliability Engineer to optimize a percentage of the PM program each quarter until complete. Still another approach is use outside experienced REs to work with site resources to very quickly optimize the PM program. Each approach has advantages and disadvantages. As one business process redesign Guru once said: “everyone wants it done fast, right, cheap and easy. The trouble is that it is not possible to have all four – three, yes, but not four.” Results from a PM optimization effort can be impressive. If one has never been done it is not unusual to remove 20 – 25% of the PM hours in the program. This additional maintenance labor capacity can be used to reduce outside contract labor or provide a growth opportunity for maintenance techs by training and certifying them on predictive technologies.

Another foundation element of an EAM program is the Computerized Maintenance Management System (CMMS). There are a variety of systems in use but there a few market notables for the purposes of this paper.

- Maximo – about 19% share of global market. Used in all industrial & Government sectors
- SAP PM - about 11% share of global market. Used in all industrial & Government sectors
- Oracle - about 19% share of global market. Used in all industrial & Government sectors
- AMOS – used by marine and maritime industry including FPOs and FPSOs.

A well designed, implemented and configured CMMS can greatly enhance a reliability and maintenance program. A poorly designed, implemented and configured CMMS can have the opposite effect. Key components of an effective CMMS are as follows. The system must be user friendly – easy to use. This
attribute derives both from design and configuration. A well designed system can be implemented poorly. Effective implementation requires that core maintenance processes (i.e. how work gets done) be fully understood, and streamlined as much as possible using cross-industry good practices as a reference. This is done by interviews with those doing the work. Also, those processes need to be fully documented and to the greatest extent possible the CMMS is configured to enable the existing processes to be well executed. Some compromises are inevitable but systems today are highly configurable. If the CMMS was not well implemented all is not lost. It is possible to do some remediation by revisiting the business processes and doing some system reconfigurations. When choosing this path it is important to work with an experienced person who understands maintenance and knows what questions to ask to make the adjustments to workflows.

There are several other attributes of an effective CMMS. One is a well designed equipment hierarchy with components identified to the appropriate level of detail. The standard definition across industry sectors is “to the maintainable component level.” Also, leading CMMS packages allow asset structures to be configured both by location and system. This is especially advantageous when Lock Out / Tag Out is required for maintenance (e.g. an air cylinder is part of the compressed air system and locking out that system, or part of it, will have broader impact). Planners and Schedulers will especially appreciate this feature (more on Planning & Scheduling later). Another attribute of a well implemented CMMS will be equipment criticality identified for each asset. The rationale was discussed earlier. Still another very important aspect is a Work Priority system so that all work orders can be scheduled appropriately. Without a defined and implemented Work Priority system there will be many opinions on work priority with the resulting inefficiencies. The combination of asset criticality and work priority can be combined into a best practice tool called RIME (Ranking Index for Maintenance Expenditures) which will be discussed in the Planning & Scheduling section of this paper. Another important attribute of an effective CMMS is the ability to integrate with handheld technology. These devices come in many forms and can have very sophisticated functionality. They enable maintenance technicians to use some or all of the capability of the CMMS anywhere in the plant, platform, vessel or site. Supporting WiFi is needed and configuration is required but neither have been barriers in many industries in the current environment.

One of the most significant leverage points in an EAM program is Reliability Engineering. Reliability Engineering is a field that deals with the study, evaluation, and the ability of a system or component to perform its required functions under stated conditions for a specified period of time. Successful reliability programs almost always have a dedicated Reliability Engineering function with a dedicated Reliability Engineer / Reliability Engineering Specialist. Less than effective programs usually try and designate a Maintenance Engineer

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or Process Engineer to do part-time reliability engineering. This approach is usually suboptimal because the “crisis de jour” in production / operations or maintenance always takes priority. Reliability Engineering requires time to gather data and do analysis without constant interruption. It also requires diagnostic, detective and “soft” or people skills along with a certain mindset and broad experience from other engineering disciplines. Not all engineers are suited for it.

Key roles and responsibilities for the Reliability Engineering function are well defined. The RE is functionally responsible for the function and all of its supporting businesses processes along with metrics to track and trend reliability performance. The critical components are as follows:

- Criticality Ranking
- Reliability Data Analysis (Bad Actor Analysis)
- Root Cause Analysis (RCA)
- Failure Modes and Effects Analysis (FMEA)
- PM Optimization (PMO)
- Condition-based Maintenance Program (Predictive Technology)
- Calibration Optimization
- Lubrication Program
- Equipment Configuration Management in the CMMS

Two of the responsibilities in the above list are especially critical. They are: Failure Modes and Effects Analysis (FMEA) and Root Cause Analysis (RCA). The FMEA process involves the following: identifying the failure mode at the equipment level / system level / subsystem level or component level, identifying root cause(s), determining frequency of failure, identifying failure consequences, and then ranking the failures based on a composite score of the factors. The final step is to put in place adequate safeguards or barriers by implementing better designs, materials, construction, redundancies, better maintenance practices, etc. to achieve higher equipment reliability. Implementing better maintenance practices includes: an evaluation of the existing maintenance program, evaluation of the existing spare parts program and recommendations to move toward conditioning, monitoring and operator care tasks, is in essence the asset care strategy over its lifecycle.

Comprehensive FMEAs should be developed for all critical assets and become “living documents” that guide asset management for as long as the asset is in service. When failures occur they should be updated and PMs optimized to improve reliability. The RCA process should be a part of the site “culture.” That means that when a critical asset fails – assuming a criticality analysis has been done – everyone knows how to engage in the RCA process to determine root cause and put in place a CAPA (Corrective Action Preventive Action) to ensure that failure does not happen again. Note: this does not necessarily mean adding
a PM. One of the most common documentation approaches for RCA is the Ishakawa Diagram (sometimes called the Fishbone diagram). This approach segments the root causes into four or six primary causes with many possible root causes listed under each primary cause. Fault tree analysis is another approach commonly used. This is a deductive approach to analyzing a system in terms of failures that could happen. A basic 5-Whys approach will also serve fine in some situations. The objective is to have a defined RCA process that is used to improve reliability through the use of deductive and inductive reasoning. The capability to lead this process is one of the reasons why not all engineers are suited to be Reliability Engineers.

Effective EAM programs measure the effectiveness of the Reliability Engineering process. One important metric is the number of unplanned outage hours (downtimes cost or number of events are also sometimes used) attributed to “Bad Actors.” A bad actor is defined as a critical asset that has a repetitive failure pattern. Two other important metrics often used are: 1. Availability % for critical assets, and 2. Uptime % for critical assets. In a growing number of industries a metric called OEE (Overall Equipment Effectiveness) is being used. OEE is defined as: Asset Availability (%) x Throughput relative to Target (%) x First Pass Quality (%). In some cases the first two OEE metrics are combined to create what is termed an “asset efficiency” metric.

The maintenance Work Management element of EAM includes the process of work identification, work analysis, Planning & Scheduling, work execution and follow-up. To be effective these processes must be well defined with clear roles and responsibilities and supported by a training and development program. As mentioned earlier, these workflows are loaded into the CMMS and easy to execute in the system. A critical component of work management is the plant work priority system. These schemes range from simple (4 or 5 priorities) to complex (10 or more priorities) but the purpose is the same – to differentiate true “emergency or urgent” work from work that can be planned and scheduled. The work priority is then recorded on the work request and later on the work order and used throughout the planning, scheduling and execution phases.

Work identification occurs in three different ways. For emergency / breakdown maintenance, naturally individuals closest to the asset (Operator or Supervisor) will identify the work. Proactive EAM organizations make every effort to create a work request and work order immediately. This ensures that all maintenance work becomes part of maintenance history. Creating work orders after maintenance is done (assuming that they are created at all) is one sign of a reactive organization. A second work order (WO) generation process is the PM / PdM program. These WOs are generated by the CMMS according to a schedule and executed accordingly. These WOs should be part of the Annual Plan, Monthly Plan and Weekly plan maintained by the Planners & Schedulers. A good
Practice is to have a PM library of reoccurring PMs that are preplanned and can quickly be issued when they are to be executed. The third WO generation process is for turnarounds / shutdowns / outages. Effective organizations have a well defined process for these events including a lockdown date for a final schedule, robust project management during the event and a post event review for lessons learned and continuous improvement. Naturally all work is recorded on work orders including outside contractor work and parts used. Finally, in all cases all work orders require Operations / Production approval before any work is done. One additional process is part of an effective EAM – work order audits. There should be an audit process in place to ensure that technician work on Corrective WOs and PM / PdM WOs is done according to specific standards. Normally a periodic random sample of work performed is sufficient. Ideally this is a maintenance supervisory function but in some cases it is done by the planner who then communicates with the maintenance supervisor.

Planning & Scheduling in EAM is a very well defined process. It begins with a designated function. Some organizations separate the Planning & Scheduling roles while others combine them. To be highly effective the planner must be experienced with the assets in the plant. Also an experienced planner will quickly gain the respect and trust of the maintenance technicians which is essential to getting higher wrench time from the planning effort. The planning workflow should be defined with specific duties for each day of the week. Normally Monday and Thursday are key days. On Monday a review is held to verify schedule compliance from last week and correct any deficiencies. On Thursday Operations / Production and Maintenance jointly creates a draft on the next week's maintenance plan with the maintenance hours clearly identified in the production schedule. One other aspect of effective maintenance planning is “field time” for the planner. A good target is 20% of planner hours should be spent in the field while work is going on. This is necessary to get feedback on planning effectiveness, continue to learn about the equipment and maintain a close working relationship with crafts.

A useful tool for the Planning and Scheduling function is known as RIME (Ranking Index for Maintenance Expenditures). See Figure 4. The method of ranking maintenance expenditures is based on an index that combines both the "work classification" ranking and "asset criticality" ranking, to produce a single “RIME” number that is then used by Planners, Schedulers, and Materials Management in concert with Production / Operations to prioritize the weekly workload. In the example in Figure 4 there are 10 classifications used. Some organizations limit the number to 5 -7. The objective is to have a disciplined method to set maintenance work priorities that everyone has agreed to so that scheduled maintenance gets done.
There some key metrics that help measure planning and scheduling effectiveness. They are as follows:

- **Ratio of Proactive maintenance hours / Reactive maintenance hours.** Leading edge organizations have a ratio of 80% or more proactive work.
- **Percent of maintenance craft work hours captured in the CMMS – leading edge EAM organizations at are 100%.**
- **Maintenance Ready Backlog** – defined as work that is planned and ready to execute. The target is 2 - 3 weeks.
- **Schedule Compliance** – measured as a %. Defined as number of maintenance hours per week completed as scheduled. The target >90%.

An effective job closeout process has three steps. The first is that the technician completing the work completes the WO fully. This will include designating a problem code, cause code, remedy code, etc. and comments if necessary. Note that different CMMSs use different coding schemes but the idea is to describe the failure, what caused it and what was done to remedy the situation. A description of work completed and any parts used are also required. The second step is for Operations / Production to formally accept the asset is put back in service after verifying that the work done was satisfactory. Finally the Planner closes the WO and ensures that all relevant information is included on the WO so it can become part of the equipment history. At this point the Planner may also make suggestions to the Reliability Engineer on improvement or changes to the PM / PdM program.

The **Spare Parts Program** is another significant leverage point in an effective EAM program. In some cases this aspect of EAM is referred to as MRO (Materials & Operating Supplier) and also as Materials Management. An effective spare parts inventory is based on asset criticality. It will also be based on Bills of Materials for equipment assets loaded into the CMMS and on the spare parts lists that reside in the PMs. The parts should have standard naming conventions with clear descriptions that are easy to understand. Leading-edge multi-site organizations have standardized naming conventions across the enterprise to facilitate inventory management, sharing critical spares, etc. Spare parts will be designated and managed in several different categories. Typical designations are as follows:

- Insurance spares – critical, long lead time or very expensive parts
- Critical spares – similar definition as above but based on a reliability analysis
- Standard Replacement Parts
- Fasteners and Fittings
- Special tools
Spare parts management should include a number of critical elements. Business processes such as receiving, stocking, issuing, etc., should be documented and a training program in place to ensure compliance. Inventory management should be executed based on an ABC analysis with control increasing based on value. Storeroom layout and stocking strategy should be based on a XYZ analysis including a free-issue strategy for low-value items such as fasteners. Cycle counting is used to preserve inventory integrity. Stores personnel work closely with the planning & scheduling function to execute the Kitting and pre-staging activity to help maximize technician wrench time. The CMMS functionality (e.g. criticality designations, parts reservation, etc.) should be fully utilized.

Finally, the program should have a part optimization process to control obsolescence, slow moving or no turn items and excess inventory (over max levels). Spare parts are similar to PMs – they tend to multiply over time. Naturally OEMs want their spares in stock and sometimes make warranties contingent upon it. Another spare parts building block is failures. When a failure happens and the part is not in stock or not enough of them are in stock the parts or multiple parts are added to inventory “just to make sure it is available next time.” An occasional slow delivery from a parts supplier can lead to inventory additions. Spare parts optimization can be accomplished in different ways. For example, a Kaizen event could be scheduled to bring key stakeholders together for a week to optimize a part or the entire inventory. Another approach could be to organize a team of key stakeholders led by a Reliability Engineer to optimize a percentage of the parts each quarter until complete. Still another approach is to use outside experienced REs to work with site resources to very quickly optimize the parts program. Each approach has advantages and disadvantages. Results from a spare parts optimization effort can be impressive. If one has never been done it is not unusual to remove 10 – 15% of the parts value in inventory.

Spare parts inventory is an insurance policy. It has a cost and that cost management is an important part of an effective EAM program. Some key metrics in use are as follows:

- Annual cost of spare parts expedited freight – any amount greater than zero should be examined and justified by the Planner & Reliability Engineer
- Stores Service Level – Target: 98 – 99% Note: this service level should include a supplier program such as consignment inventory and nearby offsite inventory, etc. (this means less that 2% stock outs of all requests)
- Inventory Turns – Target is 3 - 4 turns / year (Note: it is not unusual to find turns of .5 or less if optimization has not been done.)
- Inventory Value – Leading-edge practice is 0.5 to 0.75% of the Asset Replacement Value
As the old adage goes “a person without a plan is planning to fail.” A Maintenance & Reliability Strategy as has been discussed in this paper is another essential element to a leading-edge EAM program. It will include the components outlined here and will be published, communicated and updated as required. Key metrics for each of the elements must be identified, data gathered to populate the scorecard and results tracked and trended. The EAM program metrics will then become a part of the management program of the organization.

Implementing an EAM program requires time and organizations pass through several stages of maturity on the road to excellence. These stages are well documented and are represented in Figure 5. In order to track progress a periodic assessment of the EAM program should be completed to determine the degree of EAM implementation and to focus on gaps between the current state and leading-edge practices. An example “Mini Assessment” is included in Figure 6. A good assessment process will require a few days to complete and will be followed by a full report that details gaps between the current state and leading-edge practices and recommendations and suggested action plans to close the gaps.

Implementing or improving an EAM program will require some behavior changes. Therefore a Change Management process is an important element of an EAM program. The key components of a change management program are listed below and included in the graphic in Figure 7.

- Vision & Strategy
- Action Plan
- Resources
- KSA – Knowledge, Skills & Ability
- Incentives

If all of these components are present, successful change will occur. If the vision and strategy are not clear and communicated, confusion will result. If actions plans are not in place and followed up there will be false starts. When insufficient resources are applied, the new tasks just become more to do and frustration will result. When stakeholders affected by and involved in the change do not have the necessary knowledge, skills and ability personal anxiety will result. If proper and meaningful incentives are not included in the process the changes will not occur at the speed needed. Organizational leadership and the EAM champion are responsible to build the change management process and to manage it. It may be necessary to secure some internal or external change management resources to help move the process forward.

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Figure 1 – Enterprise Asset Management – Integrity View

- **Technical Integrity**
  - Construct and Maintain Hardware Barriers
    - Safety Management
    - Risk management
    - Integrity management

- **Design Integrity**
  - Design so Risks are as Low as Reasonably Practicable
    - FMEA for potential failures
    - Plant Maintenance on design team
    - Handoff to asset Owner

- **Operating Integrity**
  - Safely Operate Facilities Using The Most Current and Effective Reliability Practices While Managing Potential Risks From Hazards

Figure 2 – EAM Business Drivers*

- Knowledge Transfer: 57%
- Sharing Best Practices: 62%
- Corporate Social Responsibility: 62%
- Reduce Energy Costs: 65%
- Calibration for Quality or Yield: 74%
- Safety & Risk Management: 86%
- Extend Asset Longevity: 91%
- Cost Control for labor & Parts: 92%
- Improve uptime: 95%

65 Organizations Participated/1,300(+) Plants/463,000(+) Employees

*Source: ARC Advisory Group 2010 EAM (labor in chart above should be capitalized)

Figure 3 – EAM Operating Integrity Elements
Figure 4 – Ranking Index for Maintenance Expenditures

Figure 5 – EAM Maturity Continuum
<table>
<thead>
<tr>
<th>Component</th>
<th>Component Description</th>
<th>Enterprise-level Criteria</th>
<th>Current Status Score (1-5*)</th>
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</thead>
<tbody>
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<td>CM-03</td>
<td>Asset Field Tagging</td>
<td>All assets are tagged in the field in accordance with the CMMS numbering system.</td>
<td></td>
</tr>
<tr>
<td>CM-05</td>
<td>Master Asset List</td>
<td>A Master Asset List has been developed and registered in the CMMS including a standardized naming and numbering convention which is consistent and appropriate. All asset critical fields are populated with accurate information. Functional layout diagrams exist for visual reference.</td>
<td></td>
</tr>
<tr>
<td>CM-06</td>
<td>CMMS Failure Codes</td>
<td>A manageable list of failure codes are in place (by equipment type), are being documented after failure is understood, and are used to develop action plans to reduce failures.</td>
<td></td>
</tr>
<tr>
<td>CM-07</td>
<td>CMMS Labor, Material, and Service Cost Tracking</td>
<td>Labor, material, and service costs are tracked effectively on all work orders. Actual labor documented on the correct work orders is greater than 80%.</td>
<td></td>
</tr>
<tr>
<td>CM-10</td>
<td>CMMS Reporting</td>
<td>All necessary CMMS reports are accurate, accessible, and function properly.</td>
<td></td>
</tr>
<tr>
<td>CM-11</td>
<td>Work Order Critical Fields</td>
<td>Work order critical fields are populated accurately and consistently throughout work order history including Asset, WO Priority, Target Start Date, and Work Type.</td>
<td></td>
</tr>
<tr>
<td>MP-01</td>
<td>Key Performance Indicator Development and Alignment</td>
<td>Robust KPIs exist at all levels of the organization in order to establish goals and monitor continuous improvement efforts. The various levels of metrics are specific to the level in which they impact and aligned to common business outcomes</td>
<td></td>
</tr>
<tr>
<td>MP-02</td>
<td>Key Performance Indicator Tracking and Reporting</td>
<td>KPIs are tracked and reviewed routinely with auto generation capabilities. There is clear communication of performance metrics and expectations. There is complete understanding of the intent of the KPIs and metrics are consistently used to improve performance</td>
<td></td>
</tr>
<tr>
<td>MP-03</td>
<td>Communication Dashboard</td>
<td>There is a substantial visual communication of operational performance and updated communications is in place.</td>
<td></td>
</tr>
<tr>
<td>MP-04</td>
<td>Asset Performance Data Collection</td>
<td>All necessary performance tracking data from any manufacturing or process function is being collected in a database and communicated effectively, including losses due to availability, performance, and quality. Critical asset downtime and failures are tracked, reported, and actions to improve are identified and implemented.</td>
<td></td>
</tr>
<tr>
<td>MP-05</td>
<td>Promotion of Personnel Initiative and Voicing of Opinions</td>
<td>Personnel are encouraged to exercise initiative, identify areas for business improvement, are listened to, acted upon, and communication is provided up and down the lines of reporting</td>
<td></td>
</tr>
<tr>
<td>Component</td>
<td>Component Description</td>
<td>Enterprise-level Criteria</td>
<td>Current Status Score (1-5*)</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------</td>
<td>--------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>CM-03</td>
<td>Asset Field Tagging</td>
<td>All assets are tagged in the field in accordance with the CMMS numbering system.</td>
<td></td>
</tr>
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<td></td>
</tr>
<tr>
<td>MP-02</td>
<td>Key Performance Indicator Tracking and Reporting</td>
<td>KPIs are tracked and reviewed routinely with auto generation capabilities. There is complete understanding of the intent of the KPIs and metrics are consistently used to improve performance.</td>
<td></td>
</tr>
<tr>
<td>MP-03</td>
<td>Communication Dashboard</td>
<td>There is a substantial visual communication of operational performance and updated communications in place.</td>
<td></td>
</tr>
<tr>
<td>MP-04</td>
<td>Asset Performance Data Collection</td>
<td>All necessary performance tracking data from any manufacturing or process function is being collected in a database and communicated effectively, including losses due to availability, performance, and quality. Critical asset downtime and failures are tracked, reported, and actions to improve are identified and implemented.</td>
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</tr>
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<td>MP-06</td>
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<td>Personnel are encouraged to exercise initiative, identify areas for business improvement, are listened to, acted upon, and communication is provided up and down the lines of reporting.</td>
<td></td>
</tr>
<tr>
<td>MS-01</td>
<td>Asset Criticality Ranking</td>
<td>Criticality ranking has been performed using subject matter expert teams; ranking includes all necessary categories and uses a minimum of five graduations including safety, quality, and environmental/regulatory compliance.</td>
<td></td>
</tr>
<tr>
<td>MS-02</td>
<td>Predictive Maintenance</td>
<td>Condition-based maintenance (including predictive technologies) is used on a large number of assets, starting with the most critical, and associated PM tasks have been removed from the program. The CMMS is linked to a data control system with automatic work order generation based on real time performance criteria.</td>
<td></td>
</tr>
<tr>
<td>MS-04</td>
<td>Critical Spare Parts</td>
<td>Critical spares exist for all assets, starting with the most critical, and a process exists for classifying a spare part as critical based on failure impact (safety, quality, process throughput, costs, etc.).</td>
<td></td>
</tr>
<tr>
<td>MS-05</td>
<td>Asset Lifecycle Cost Tracking</td>
<td>Lifecycle costs are tracked for critical assets, reports are automatically generated from the CMMS, and bad actors are flagged on reports based on predefined criteria.</td>
<td></td>
</tr>
<tr>
<td>MS-07</td>
<td>Preventive Maintenance Optimization</td>
<td>Reliability-based analysis has defined the maintenance strategies for the most critical assets. PM optimization has been performed to minimize low-value work. PM tasks exist on 90% of PMS and are of high quality with all parts and tools identified on the job plan.</td>
<td></td>
</tr>
<tr>
<td>MS-09</td>
<td>Proactive Reliability Analysis (RCM, FMEA, and RFCA)</td>
<td>Reliability analysis and/or Root Cause Failure Analysis concepts are used extensively for critical assets, on major events, proactively to prevent major events, and is done formally with good documentation.</td>
<td></td>
</tr>
<tr>
<td>MS-11</td>
<td>Proactive vs. Reactive Maintenance</td>
<td>The percentage of proactive maintenance is 80% or higher (including PM and CBM work).</td>
<td></td>
</tr>
<tr>
<td>OR-01</td>
<td>Key Reliability Staffing Roles and Responsibilities</td>
<td>All reliability staffing roles exist within the organization including supervisors, planner, schedulers, and reliability engineers, with staffing levels consistent with bench marks for the industry. Job descriptions exist with defined roles and responsibilities in place without overlapping boundaries, including education, training, and experience requirements. There is a formal process for reviewing and approving job descriptions.</td>
<td></td>
</tr>
<tr>
<td>OR-02</td>
<td>Asset Management Mission, Vision, and Values</td>
<td>The mission, vision, and values for asset management are established and understood by the organization and business units.</td>
<td></td>
</tr>
<tr>
<td>OR-04</td>
<td>Management of Change</td>
<td>A management of change process is in place to effectively track and seek the necessary approval on improvements to the current maintenance program (asset information, reliability strategies, etc.).</td>
<td></td>
</tr>
<tr>
<td>-------</td>
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<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>OR-08</td>
<td>Collaborative Environment</td>
<td>A strong relationship between support functions and business units is evident and the entire organization is engaged with improving the organizational level of performance and is committed to achieving challenging objectives. Management has implemented training and tools to encourage cross-functional communication and synergy for improving overall performance for the organization.</td>
<td></td>
</tr>
<tr>
<td>OR-10</td>
<td>Asset Management Master Plan</td>
<td>The organization has a well-documented Maintenance Master Plan which spans the people, process, systems, technology, and governance of their maintenance programs.</td>
<td></td>
</tr>
<tr>
<td>PS-01</td>
<td>Job Plan Library</td>
<td>There is a formal process in place for how to write a job plan including consistent naming and numbering conventions. Job Plans for routine and non-PM activities are being captured including all necessary tasks, labor, and materials.</td>
<td></td>
</tr>
<tr>
<td>PS-02</td>
<td>Planned Materials Purchasing, Reservations, and Availability</td>
<td>There is consistent material planning integrated with the maintenance planning.</td>
<td></td>
</tr>
<tr>
<td>PS-03</td>
<td>Scheduled Outages</td>
<td>Outages are scheduled with strict adherence to schedule and are managed effectively where breaking schedule requires manager or champion approval. Planning and scheduling includes a full annual calendar with operations schedule (outages, etc.), as well as a detailed monthly calendar with priorities.</td>
<td></td>
</tr>
<tr>
<td>PS-04</td>
<td>Proactive Planning and Scheduling</td>
<td>The majority of work is planned and scheduled at least two weeks in advance.</td>
<td></td>
</tr>
<tr>
<td>PS-05</td>
<td>Schedule Disruptions</td>
<td>The daily schedule rarely changes due to reactive work arising.</td>
<td></td>
</tr>
<tr>
<td>PS-10</td>
<td>Work Order Prioritization</td>
<td>Work order priority is calculated by the CMMS and reviewed for prioritization when planning and scheduling.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Assessment Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 = Not Known</td>
</tr>
<tr>
<td>2 = Piloted</td>
</tr>
<tr>
<td>3 = In Place, still being established</td>
</tr>
<tr>
<td>4 = Fully implemented</td>
</tr>
<tr>
<td>5 = Best there is</td>
</tr>
</tbody>
</table>

Interpreting the score – Compare the total score to the following ranges to determine the likely state of the current maintenance program

<table>
<thead>
<tr>
<th>Total Score</th>
<th>EAM Program Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;29</td>
<td>Reactive</td>
</tr>
<tr>
<td>30 – 58</td>
<td>Planned</td>
</tr>
<tr>
<td>59 – 87</td>
<td>Predictive</td>
</tr>
<tr>
<td>88 – 116</td>
<td>Reliability</td>
</tr>
<tr>
<td>&gt;116</td>
<td>Enterprise</td>
</tr>
</tbody>
</table>

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Figure 7 – Change Management Key Components

KSA = Knowledge, Skills, & Abilities