Configuration Management for the 21st Century

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Executive Summary

"Statistically, American Industry spends over $425 billion annually, directly attributed to deficiencies in enforced Configuration Management (CM)." [PSM] Systems, products and projects are becoming more complex and as budgets dwindle and costs rise, making it increasingly difficult to make strategic decisions without a single source of accurate and valid data. In the Federal Government as computers, software, servers, and IT (Information Technology) mesh with the operational systems; Enterprise CM must be able to leverage this data to effectively manage and control it. We must prepare for changes (CM Strategic Change Points) that are right around the corner for every new and old system to ensure our success.

"*Enterprise CM is primarily a controlling activity and thus, enforcement of strategic business objectives must be supported by an Enterprise CM*" [European Space Agency]. The key Enterprise CM features are to document dependencies (relationships previously not captured) between Configuration Items, control requirements and manage baseline changes. Simply stated, we control, manage and make better decisions by knowing what we have (baseline) with the effective date of change (effectivity) in a closed loop process (when it was implemented and it was verified) and its relationship to everything else in an organization. The principal benefits derived from Enterprise CM are savings in resources and costs, with an added bonus of planning accuracy. One primary example (commonly practiced in government) is to perform redundant site surveys (an industry in and of itself) costing millions and millions of dollars annually, simply because it is not known what exists or where it is or its relationship (resource interdependences) to anything else.

Many Fortune 500 firms practice CM as a necessary discipline to ensure quality and effectiveness to deliver consistent deliverable products. However, CM is a key component of every business process improvement practice including; Capability Maturity Model Integrated (CMMI), Systems Engineering (SE), International Organization for Standardization (ISO) 10007, IT Infrastructure Library (ITIL), and most acquisition systems. With a tightly controlled Enterprise CM in place, millions of dollars a year could be saved through proper and correct planning.

With these proper controls in place, it will no longer be acceptable to allow the philosophies of "it easier to be forgiven than to obtain permission" and "pouring money into programs or product lines to make them well". It is crucial to make the financial, organizational and resource investments into managing what we know we have (Enterprise CM) to control costs, to lower overhead and maintain stable budgets. Without Enterprise CM, we fall into an endless cycle of runaway costs and treating the symptoms (intervention or rework) of poor control, that we never have sufficient funds available to put in proper controls (configuration management). Common sense dictates that more control and documentation (CM) is needed not less. We live in the safest and most modern nation in the world, but to maintain this status quo, we must set the bar higher through superior management and business practices with Enterprise CM. We must

embrace Enterprise CM and adopt it early if we are to keep pace with today's environment, present credibility to the public, the stakeholders and the governments of the world.

Introduction

There is a clear need to make plain, the changes, needs and the costs versus the benefits of Configuration Management (CM) for the future. The rapid pace of technological advances poses new challenges in business practices and CM has to evolve, to meet the ever-increasing requirements. The core purpose of configuration management is to allow for better decision making, on products, projects and programs in order to control changes through creation and maintenance of documentation and products with the ability to reference this data at any time. [PSM] "American industry spends more than a trillion dollars annually maintaining its plants and facilities with approximately 50 percent of this, $500 billion expense, as a direct result of breakdowns, partial loss of function, frequent rebuilds and other reliability-related problems. Statistically speaking, at least 85 percent ($425 Billion) of reliability problems, asset use and escalating life cycle costs are directly attributable to deficiencies in, or total lack of, enforced configuration management."

At one time, Configuration Management was only about establishing proven configurations for delivered products and controlling the changes to them, now it has to accommodate changes and manage the outcome in the best possible way. It is about maintaining accurate and valid data to retain corporate knowledge and history (i.e. lessons learned) so we don't have to keep paying for it over and over. Lessons learned usually resides in the mind of an engineer, program manager or project manager and gone forever, once they walk out the door. How do we capture that knowledge? What do we do with it? How do we accommodate change and yet manage it at the same time? These are all part of Configuration Management and this paper provides a brief look into the future of the Configuration Management world.

The lack of modern Enterprise CM processes in large organizations is rapidly becoming a major barrier to the deployment of reliable, secure, and correct products and systems. Those of who know CM, know that it is everywhere. If you understand it, you see it daily, and even hourly. Just listen to the news or read the newspaper, and observe how many issues are faced by organizations that lead to extreme costs, poor performance and undelivered products. These are nothing more than a failure to apply the fundamental principles of Configuration Management. Many in business or the government are unaware of CM or may not see any reason for CM at all. Are they correct? Or are they limiting the practice of CM, ignoring the obvious, or even damaging it -- or their careers and ours? We can either embrace it as control function, "a series of "checks and balances" throughout the life cycle of a system or systems or we can ignore it at a costly price (i.e. invalid data, uncontrollable or excessive costs, failed programs and inferior products).

What is Configuration Management

Configuration Management (CM) is a common phrase yet usually misunderstood; yet it is the most important and often neglected business process of any organization. It allows managers to

better identify potential problems, manage changes, track progress and performance of any product during its lifecycle, while complying with laws through recordkeeping, performance metrics, and recovery needs (knowing what you have, why it is, what changes have been applied and why…..baseline). So, what is CM anyway? In layman's terms, it is the plan (or blueprint) for a product, a process or a document before, during its lifecycle and beyond. It seems obvious, yet most have no idea what Configuration Management is, how it is performed or even how to begin doing it. Some are overwhelmed by it, believing CM to be too difficult or too costly. Then, they tend to discount it or just assume someone else is performing it as part of some support function. Many organizations continue to apply conventional configuration management methods, then blame this core discipline for failures, or abandon CM altogether out of frustration. Practitioners of CM often face constraining resources in their organizations with widespread unawareness of CM and lack the expertise in organizational dynamics (politics) to sell or enforce their CM concepts – outside of their own group. In the past, budgets were often trimmed of CM-related costs even before the program or project is funded in a misguided attempt to save money or to even use it as a sort of financial cushion for contingencies. In today's environment, this practice is totally unacceptable. CM has a major role to play in the planning for, procurement and lifecycle of any system or product as another related function, Project Management.

Project Management (PM) is a more widely recognized process. It is readily accepted, practiced and supported by management and even required for formulating budgets (OMB Exhibit 300). We budget for Project Management in every program but not configuration management, how then are we to control what we have or to even know what we have at any given time? Yet, each and every project / program manager knows that configuration management must take place by first establishing a functional / allocated baseline before even beginning to manage a project. The baseline must be controlled and maintained throughout the project and in its lifecycle and after completion (product baseline). [Hass] "Configuration Management allows management, project managers and program managers to take full advantage of available resources at hand. You really have to know, what you have to start with, before you can begin to control and manage it. Configuration Management activities all relate to the simple idea of controlled documentation by creating and maintaining a database of information regarding Configuration Items (CIs), and then inserting the usage of this database into the decision making process." Configuration Management as described by ISO 10007 is "a management activity that applies technical and administrative direction over the life cycle of a product, its configuration items, and related product configuration information". AND "CM documents the product's configuration. It provides identification and traceability, the status of achievement of its functional and physical requirements and access to accurate information in all phases of the life cycle." CM is much more than just a support function, it is the plan. In reality, we can still reach the finished product, but did we get it in the most efficient way and utilizing scarce resources efficiently? Then, how do we manage that "live" product, changes to the product and eventual replacement of the product without tightly controlled CM (e.g. knowing exactly what we have, where it is, what it is related to, who operates it, who maintains it (human resource management) and the requirements management for the product).

You have to have a plan . . . how many times throughout our lifetime and career, have we heard this? You wouldn't build a major factory without plans, nor would you expect an automobile

manufacturer to build your car without them and every organization knows you have to have a business plan to be successful. However, planning is just not enough, you have to be able to control the plan because change is not only going to happen, it is a certainty and an uncontrolled plan is not only ineffective but, tremendously expensive. More importantly, before planning, you need to understand and manage the requirements; what is needed, why it is needed, where it is needed, how it will be built, where it will be created, how it will be paid for and when it is needed. This is where Configuration Management shines; by identifying the plan and allowing the control of requirements, changes to the plan, risks and documenting everything associated with the plan or the "baseline" as it is more commonly known.

Even in the simplest of projects, every Project Manager knows that a change, no matter how small, in the baseline of a project, is a risk to its schedule, costs, scope and ultimately the final outcome. This is why every project / program manager must also practice CM, to control the changes to their product and be able to communicate effectively the ramifications of the change (e.g. risks, costs, and schedule). Two great philosophers *Confucius* and *Socrates* stated respectively that "Only the wisest and stupidest of men never change" and ″Only the extremely ignorant or the extremely intelligent can resist change″.

[Hass] "*While CM is not an easy discipline, it need not be a difficult one*", She also goes on to state "*CM is absolutely important to all projects*".

Another declaration from the Australian, Technical Regulation Army Material Manual (TRAMM) states:

"CM is the most important discipline for the establishment and maintenance of technical integrity of material" AND "With the increasing sophistication, complexity and cost of modern systems, Defense is demanding the more effective use of Technical Data to improve operational capability and readiness at a lower life cycle cost." In the past fifty (50) years technology has evolved from resisters and switches to vacuum tubes to transistors to integrated circuits, etc, etc. and the requirements for effective design and management have increased a thousand fold demanding the need for more sophisticated management of the assets and documentation.

Configuration management is often looked to help answer most continuing management questions:

- What is the requirement?
- How is it designed?
- Why is it designed in the way that it is?
- Does it interface with anything?
- Were there design changes?
- Why were the changes made?
- Where is everything?
- What state is it in?
- What is it doing?
- Is it deployed correctly?
- Who is paying for it?

- What does it have to do with my problems?
- What if we change it?
- Do we need more/less of it?
- Can we get rid of it?
- What is effected, by changing or removing it?

This is certainly not a complete list, but these questions illustrate the complexity of configuration management, beyond the theoretical understanding of it and the day-to-day management of it. Getting and maintaining a complete and accurate understanding of the "bits and pieces " that makes up the Enterprise almost overshadows the reasons for having configuration management in the first place. So, if there are gaps between design, architecture, and implementation, it stands to reason that other mechanisms are probably necessary to ensure the effective and efficient delivery of whatever the "bits and pieces " were meant to provide. Configuration management is one of the disciplines used to address these gaps. Managing the "bits and pieces" of an Enterprise can also be understood as establishing and controlling the logical environment. There are aspects worth reviewing like requirements were created, products were implemented, and money was spent all to meet the strategic goals set forth in every organization. But, it is the *relationships* between all these "bits and pieces" that really matters and then, the infamous big question, "does it do what it is supposed to do?"

Like it or not, configuration management is here to stay AND must be embraced and supported to succeed. In the 1960s, conventional CM was the only way to ensure products could be re-produced with the same characteristics, the same parts and with the same maintenance requirements. It was to ensure successful products in US defense systems could be produced, controlled, and changed with full documentation as a systems engineering function.

Conventional Configuration Management

Growing from its infancy in the early 1960s, today Configuration Management is widely recognized and practiced worldwide, in industry, manufacturing, and governments. A loose interpretation that Hass uses for CM is; configuration means; [Hass] "*to form from a relative arrangement of parts*." But in its simplest terms, it means "*looking after what you've got so far*." Hass further defines configuration management as the "*unique identification, controlled storage, change control, and status reporting of selected intermediate work products, product components, and products during the life of a system*." The CM guidance and requests are there for good reason. Let's take a look at some basic CM so a better understanding of what Conventional Configuration Management is before moving on to what Enterprise CM is.

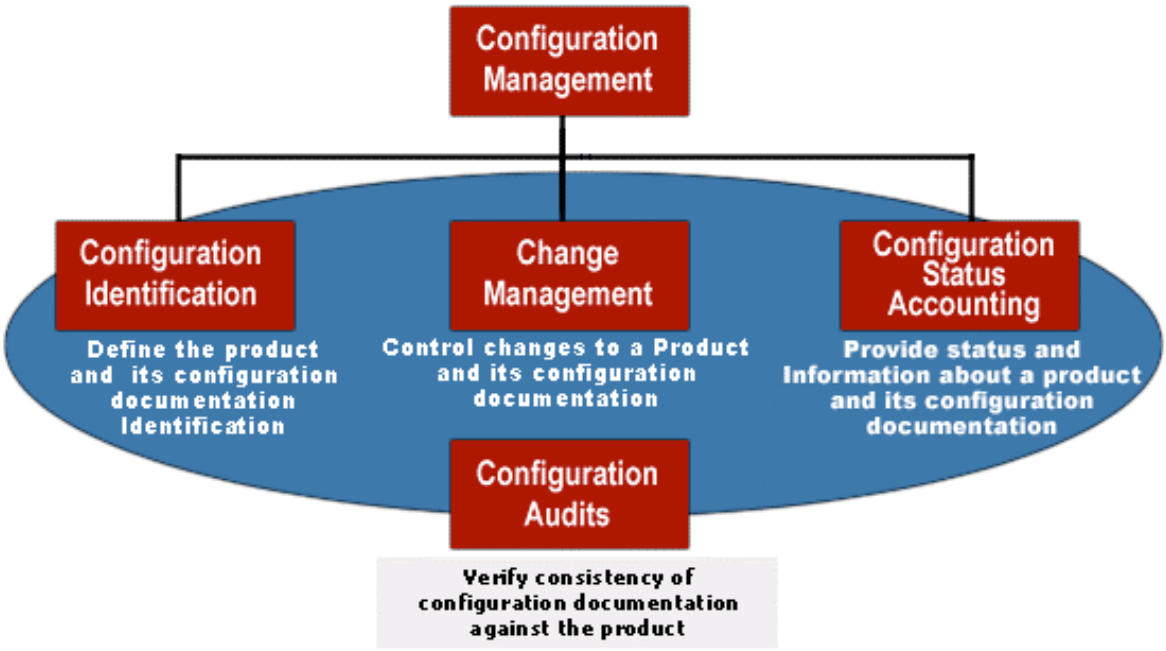


Figure 1. Configuration Management Process
(From DOT Guide to Configuration Management for Intelligent Transportation Systems April 2002)

Conventionally, there are five basic functions or tenets of CM, which apply to any product (Configuration Item (CI)) and they are;

Planning and management

Planning and management is basically what it says. It is the normal planning to define and establish organizational responsibilities, in this case, the CM Team's responsibilities as well as the CM-related responsibilities of others. It includes the resources necessary and the facilities that are needed. It ensures appropriate CM tools, processes, and activities are available and applied. Continuous improvement is another sub-function under planning and management and essential for reaching level two of CMMi. A slight change of wording and the responsibilities could apply to the planning and management function of any organization or the organization as a whole. The one area that is different or unique is the responsibility to ensure data preservation and interoperability (current data). Data preservation and interoperability means that all of the configuration items and documentation are stored, correct, and available when needed. In other words, a CM library is maintained with all the appropriate documents, and those documents are up-to-date (baselined) and accurate including requirements, drawings, as builds, effective dates (when a change is supposed to be in place and an excellent performance indicator), approved changes, change notices and release dates.

Configuration Identification

This process involves identification of documents comprising the configuration baselines for the system and lower-level items (including logistics support elements) and identification of those items and documents. When an item is identified, it is known as a configuration item (CI). Configuration Identification determines the makeup of any and all products along with their associated documentation. It defines performance, interface, and other attributes for configuration items; provides unique identity (i.e. drawing, document or ID numbers) to products, components, and documentation; specifies identification markings (if required); modifies product and document identifiers to reflect major changes; maintains release control and baseline definition; provides reference for changes and corrective actions; and correlates document revision level to product configuration, which enables users to distinguish between product versions, allows people to correlate a product to the appropriate instructions, and correlates items to service life. What it boils down to is that configuration identification determines how document control numbers and version numbering are applied and used so that everything is labeled correctly and understandably as prescribed by the Configuration Item (CI) manager of that product.

Controlling Change

Change Control Management during the lifecycle of a product is a shared function of both the CI manager and the Change Control Board (CCB) made up of stake holders, customers and executives. Change decisions are based on the knowledge of the change impact to the product, costs and the customer. This helps limit changes to those that are necessary or offer significant benefit to the product, the customer or hopefully both. The CCB should evaluate costs (investment analysis), savings, and trade-offs, ensuring that everyone's interests are considered before approving. CM maintains consistency between the products and all relevant documentation (i.e. as built, as planned and as released with effectivity dates). The CM process documents and limits all variances in a product and provides for continued supportability of the product after a change is implemented.

Status accounting

Configuration Status Accounting is just a fancy name for having information on products and processes, the key being having the valid and current information available for retrieval including any change decisions and change impacts. It provides access to complete configuration information on products and processes to answer any inquiries concerning design change planning, design problems, maintenance, and operating-life expectancy. It is a source for configuration history and accurate identification of each product delivered. Just having that information reduces risk, improves the project's or the customer's capability to identify, produce, inspect, deliver, operate, maintain, repair, and refurbish products all of which are necessary. Without CM, this information might

or might not be available, and its accuracy would certainly be in question. It can mean the difference between the success or failure of a system or product and provide management with answers as well as capturing corporate knowledge that departs weekly as baby-boomers retire.

Verification and audit

Verification and audit of physical and functional requirements is often the final project management activity for new and modified systems and / or products being implemented. Without a formal Quality Assurance (QA) process in an organization, this may be the only way to capture failures, compliance and implementation issues (not installed as specified in the plan (CM)). Normally, CM and QA together ensure the product design provides the agreed-to performance capabilities but in some organizations these activities may fall solely under CM, such as validating the integrity of the configuration documentation and the consistency between a product and its documentation (requirements, drawings, ECPs (engineering change proposals) etc). According to the acquisition process, AMS, iCMM, and SEI, CM is responsible for establishing the initial product baseline based on requirements, customer needs and organizational goals. It also ensures that the product has been designed in accordance with the initial requirements as modified along the way and as agreed to before being modified. It ensures that the first article built is how subsequent systems are built as designed and tested. This accurate configuration is the basis for operation and maintenance, instructions, training, spares, and repair parts for the product life-cycle.

Changes in Configuration Management

[Lyon] "Configuration Management (CM) today is a struggle, both for those who are trying to impose some degree of control over the design, production and support phases of programs and for those who are trying to resist CM in a misguided attempt to save time and money." Everything else evolves and so does Configuration Management. CM performed early in the process is analogous to value engineering when you can get the most "bang for the buck" if implemented then. At one point in time (the 1960s), CM was the only means to control costs, schedules, and variance of products or systems being developed or produced for DOD. It ensured that products turned over to the government, were standardized, supportable down to the lowest supportable sub-assemblies and that these sub-assemblies were the same or compatible in another like product delivered to the government. It ensured manufacturers would be able to produce more than one system that worked to specifications (requirements) and it helped the government save money in not re-inventing the wheel each time a product was produced and delivered. It made contracting and procurements more tenable and cost effective for multiple product deliveries and it made manufacturers more credible in producing multiple working products. But back in the 1960s, there was not the Information Technology (IT) explosion of today or the complexities of today's systems with hardware being the main thrust of CM. Looking back, Configuration Management could be recognized as the one the original information technology drivers (huge data bases). But in present day, IT is driving everything including CM. Most CM companies have moved away from conventional CM and moved on to

IT CM for software development or IT hardware (network technology, servers, and storage). Take for example, the Software Engineering Institute (SEI), their whole thrust of CM is primarily in IT. Although it speaks to the five (5) tenets of CM, it is directed primarily toward IT and software development because the IT world has basically run amuk with new and better ways of doing things (automation, applications, faster, WEB based, thin net, thick net, servers, SANs etc) spending massive portions of every organization's budget. This uncontrollable growth led to the need for CM in this environment and in the process has necessitated the need for changes in the CM process.

The ideal CM process will handle all IT and non-IT processes since it is becoming obvious that in today's complex environments, computers, software and hardware are all being meshed together. As the CM industry matures, Enterprise Configuration Management is emerging to become the dominant CM methodology working with the Enterprise Architecture (EA) process, which was originally established to provide modeling of the IT requirements for present and future needs. EA is the current method to control IT growth and costs but EA has evolved to capture the enterprise as a whole for both IT and non-IT. Interestingly enough, one of the major requirements of EA is that it must be under strict configuration management to be effective, there seems to be a pattern here.

Business Process Improvement

Enterprise Architecture is just one the business improvement processes widely recognized, others include CMMi, Systems Engineering (SE), ITIL and even Six Sigma yet, all require CM as a fundamental building block to improve business processes. <u>If you don't have the data elements to compare and measure you can't very well improve on them (again knowing what you have).</u> CMMi requires configuration management organization wide, just to attain level two status (the usual goal is for level 5 or 6). Most will never truly reach level two in any of the processes until CM is widely practiced throughout their organizations at an enterprise level with an automated system as a single source of valid data. Industry also recognizes this and has begun to promote and practice Enterprise Configuration Management with a CM database (CMDB). Many of the universities (University of Tennessee, Arizona State University, University of Ohio, University of Minnesota and the University of Houston just to name a few) are all recognizing and promoting the value of CM and re-introducing it back into their curriculums for their management, computer science and engineering programs.

<u>Enterprise Configuration Management</u>

[Guess CMII]"<u>Enterprise Configuration Management</u> includes any information that could impact safety, quality, schedule, cost, profit or the environment." It also provides a way to manage and accommodate changing technology, while capturing corporate knowledge from the significant numbers baby boomers exiting the workforce. It documents dependencies (relationships previously not captured) between Configuration Items while controlling requirements and changes through baseline effective date (when it happened). To put it simply, you can control and manage a Configuration Item (CI) by knowing what you have (the baseline

with updated documentation (drawings, manuals, requirements, lessons learned, etc.)) with the effective date of change in a closed loop process (knowing or receiving confirmation of its implementation as CM is supposed to be performed).

Enterprise CM has all the conventional functions of CM (planning, identification, change control, status accounting and audit) but also closes the loop and establishes baseline effectivity while accommodating change and keeping requirements clear, concise and valid. Enterprise Configuration Management transitions conventional document management systems to an enterprise information management environment that captures, stores, manages, and retrieves data but also identifies and retains the context of data and its relationship to projects, products, assets, processes, equipment, organizations, and users throughout the complete life cycles of any product within the organization. A centralized CM automated system (often referred to as PDM (product data management) or PLM (product life cycle management) systems) or CM database (CMDB)) provides the overall enterprise with complete visibility to all participating organizations and users. It ensures data integrity through closed-loop change management and controls changes in a logical sequence—from inception to change-effects analysis to notification to implementation and, finally, reporting by effectivity (dated baselines). This is an excellent performance metrics reporting method, a perfect disaster recovery method and a means to capture corporate knowledge before it leaves. While conventional CM was initially for Systems engineering and repeatable products, Enterprise CM shifts the emphasis of CM to:

- Supports a flexible life-cycle change process
- Identifying and standardizing best CM practices
- Assuring information integrity and information accessibility
- Assuring real-time valid information flow
- Conformance to requirements (process and products)

Enterprise CM promotes continuous improvement across all organizations supporting CMMi (level two for continuous improvement) and ISO 10007. Early involvement in CM supports requirements and reduces risk. It is essential that every organization enters into Enterprise CM, as early as possible, to encourage and participate in solutions and innovations.

Enterprise CM independence

Configuration Management in every organization is a management tool to control changes to products or processes with validated requirements management. Without it, little or no control would be realized. However, if the Enterprise Configuration Management process is ever to be fully successful, it requires that it be fully independent of divisional and organizational self-interests that may influence the outcome of a product. An example of this might be an engineering team or organization influencing the process or budget to circumvent CM activities in the mistaken belief that they are saving time and money. The Canadian Air Traffic System, NAVCanada has a tightly controlled Enterprise CM process which they say was critical to implementing their Safety Management System (SMS) for their own Air Traffic System. CM should not be influenced by organizations subject to Enterprise Configuration Management nor should it compete for adequate funding and / or support resources to perform.

This independence is what allows management to control products and processes by not allowing items under configuration management to be changed without going through the formal Configuration Control Board (CCB) made up of stakeholders, users, executives etc. The Enterprise Configuration Management process must be standardized and consistent across the enterprise just as the Enterprise Architecture process is. To maintain a world-class organization, it is essential to implement products or processes of the highest order and not be more concerned about schedules than properly implementing the programs, projects or products. If not, self interest groups may attempt to turn a product to their own interest for their own hidden agendas resulting in long-term costs and safety issues.

Strategic plans are developed around the configuration of products. In any large organization or government agency, this strategy must encompass products found in every line of business within their organizations to achieve the overall objective of that organization. Could you imagine the extreme costs and engineering nightmares of the Department of Transportation (DOT) and their sub-agencies like the Federal Aviation Administration (FAA) or the Department of Highways would be subjected to without a tightly controlled Enterprise CM process. Which is why Enterprise CM must be independent from divisional influences or everyone will be solving everything in an unmanageable way and the purpose of Enterprise CM is to fully control change requests for a product and of all implemented changes.

Enterprise Configuration Management and Enterprise Architecture

CM is usually thought of only for engineering projects but on an Enterprise level (Enterprise CM) it exists for products everywhere, such as software application(s) development, documentation control, business processes, change and requirements management, and baselines for projects, processes and investment analysis. To gain insight on how Enterprise CM best supports and sustains Enterprise Architecture (EA) principles it is necessary to condense some of those common principles.

An EA is basically an Organization-wide roadmap to achieve its mission through optimal performance of its core business processes within an efficient information technology (IT) environment. Or more simply stated, it is the "map" for systematically and completely defining an organization's current (baseline) or desired (target) environment. EA is essential for evolving systems, processes, developing new systems, and inserting emerging technologies to achieve mission goals. The enterprise is, and under-goes an iterative process of changing over time by new business processes, new technology, new capabilities, as well as the maintenance and disposition of existing elements.

CM of EA products are performed much the same way that configuration management is imposed on a product baseline. CM assures that all changes are identified, tracked, monitored, and appropriately documented. Enterprise CM helps to manage the EA and supports the principles in one way or another. In many cases one could argue that they are so central to the success of EA principles that without Enterprise CM, an Enterprise Architecture could not be complete. In the following table, Enterprise CM up to supporting the condensed high level Enterprise Architectural principles in an Enterprise context.

Enterprise Architecture Organization Wide			Does Enterprise CM support this?
Benefit the Enterprise	Management decisions are made to provide maximum benefit to the Enterprise as a whole.	**Yes**	Enterprise CM directly assists in the management of information and its business processes.
Business Continuity	Enterprise operations are maintained during disaster recovery.	**Yes**	Enterprise CM is crucial to supporting data and documentation of baselines, changes, requirements and processes.
Compliance with Law	Enterprise information management processes comply with all relevant laws, policies, and regulations.	**Yes Assists**	Enterprise CM assists in mapping policies and regulations to business processes.
Primacy of Principles	These principles of information management apply to ALL organizations within the enterprise.	**Yes**	Enterprise CM focuses on all products (hardware, software, processes, application and documentation) accomplished throughout the Enterprise.
Data is an Asset	Data is an asset that has value to the Enterprise and is managed accordingly.	**Yes**	Enterprise CM is crucial to managing data assets.
Data Security	Data is protected from unauthorized use and disclosure including, but not limited to, management pre-decisions, sensitive, operational, procurement and government proprietary information.	**Yes**	Enterprise CM is crucial to manage data access, changes, disaster recovery and trace ability.
Requirements-Based Change	Only in response to business needs and management approved, are changes to Enterprise products, business processes, applications, orders, technology, operations and facilities made.	**Yes**	Enterprise CM is crucial in managing requirements based changes.
Common Vocabulary and Data Definitions	Data is defined consistently throughout the Enterprise, and the definitions are understandable and available to all users.	**Yes Assists**	ENTERPRISE CM indirectly assists in managing this aspect by configuration management.

Enterprise CM Automation

Each and every organization has multiple sources of "must have" data somewhere for reporting and there is always one person that where it is and how to access it. But the lack of a centralized configuration management of this data means the data may not be up to date (valid) or might not be available for good decision-making. Just look around your own organization, there are repositories of data everywhere and most you don't even recognize. Someone may have

manuals or software, others may have it on an Excel spreadsheet, a WORD document or an Access database. Then, there are the diagrams in Visio or even PowerPoint not to mention the engineering CAD drawings or redlines spread about. This is all part of that corporate knowledge for those who have been here for years, compiling their own useful data for their particular jobs. It is unknown how many tracking systems there are now, just to track progress, status, incidents, budgets, performance, particular events or projects because of a lack of a single source of valid data. Automation is primarily to locate sources of valid data and formalize their maintenance and control providing access to this data to those who need it. The purpose of CM automation is to provide a single source of valid data.

Unfortunately, automation, in the minds of most, is some magical web based system that finds any data anywhere, self populates itself and does everything automatically but this is simply just not the case. The true purpose of automation is actually to lower costs, reduce errors due to human interface (manual data entries or extraction) and provide a single source for valid data for reporting, decision making, and risk management. Once this understanding is gained of what CM automation is then, it will be easier to uncover valid CM data. CM automation will gather and broker the Configuration Items (CIs) relevant for vital services, life-cycle management and reporting. It would also leverage that valid data with other lines of business (i.e. finance, management, budget) for reporting, performance metrics, costs and capturing corporate knowledge through an agreed upon common data format such as some Metadata format. As organizations become increasingly more complex with more and more IT components meshed into products, it is essential that IT CM data can also be represented with non-IT CM data to show relationships, locations and components. Present-day technology is a long ways from being able to translate high-level specifications automatically; current best practice involves a combination of manual procedures and automatic tools that provide a smooth translation of the requirements into controllable configuration details. Many factors, including the capabilities of the specific tool, will affect the level of detail at which the configuration needs to be manually specified.

Challenges for Enterprise Configuration Management (CM)

Technology
As technology grows, change is always the constant; new tools, new technologies, virtualized configurations may be required at a moment's notice making Enterprise CM truly a challenge

Business performance needs
Process improvement, Performance metrics, Risk management, Disaster Recovery (DR)

Laws and regulations
Recordkeeping, performance metrics, security, financial, budgetary, risk and recovery needs just name a few.

Enterprise CM prioritization
Formulate policy
Formalize through policy

Provide guidance and training
Perform needs analysis and baseline
Coordinate configuration changes that affect the enterprise
Challenges conventional CM paradigm

CM Awareness of value
Its value is not an easy sell; impact of poor CM is largely unseen by management.

Configurations are not strategically managed
Long-term management plans and strategies are often murky at best in many organizations, i.e. were the delays and cost overruns inherent the result of poor CM? Hard to say, since most are not documented properly in CM including lessons learned for future endeavors of the same type and magnitude (part of the ongoing problem).

CM discipline is absolute in the face of changes
Often, little thought goes into the purpose and need for changes (hence the need for control).

Automated CM toolsets help only if the processes behind them are clear and usable
However they are not the "silver bullet" they are perceived to be. Policy, CM discipline, and management support are essential.

As CM changes, the methodologies, disciplines and practitioners have to adapt
Yet, many CM practitioners apply conventional heavyweight methods and blame management or engineering for failures.

Resource-constrained organizations are looking for CM practitioners to do more than Configuration Management
CM professionals need a senior management champion to deal with the organizational politics to gain recognition, support and funding

Marketing the value of CM
Originators and CM practitioners need to sell the concepts everyday, everywhere and to everyone outside of their group (the choir)

Again, why Enterprise Configuration Management? It seems self-explanatory from the preceding paragraphs but, unless management is behind it, the benefits of it will whither away, wasted resources for re-work will take over and costs will become uncontrollable. Benefits seem to be the only way to get through to congress, managers and organizational goals so perhaps we should go a little into them. The major credibility issues are with Congress and the public. With a tightly controlled Enterprise CM in place with CM automation we could properly document any proposed or demanded changes with the documented requirements and show the ramifications of each change how it affects budget, schedule and safety. With CM it is an informed decision referencing a single valid source of data with documented requirements, schedules, materials, baseline effectivity (by date), risks and resource requirements. With this available, we could go to Congress, show them and let them decide what remains to be funded

and the ramifications of not being funded. Informed decisions would make us to be more credible in every sense.

Benefits of CM

The benefits of a good Enterprise CM process are many, with the biggest one being resource savings or cost avoidance. Savings can come from many areas, such as large purchases (100 identical products are cheaper than 100 unique products); ease of maintenance (maintenance information, training, and spares for that one product are much cheaper than for the many different products and vendors); updates and changes are less time consuming requiring less manpower (testing only a few components or builds is much faster than testing for many different components and configurations); and finally improvements are much faster and cheaper without all the rework and errors generated when CM is poor. If you can't trust in your own data to know exactly what you have then rework (intervention or corrective action) is most certainly a common practice, wasting valuable resources. In many cases, a change is often predicated on a previous change being in place already. Implementing that change without a previous one in place, may cause serious damage or even become a serious safety or technical issue to the public at large hence, the need for a closed loop CM system. In federal agencies, conventional CM is widely practiced at the Configuration Item (CI) level however, it is somewhat fractured with no central source for valid data or documentation. This created an industry in and of itself for site surveys within them, for every change or development. Currently, for each and every change or new product to be implemented in most federal agencies, a site survey is automatically performed, because of unreliable and valid CM data (not sure exactly what is where at any given time), a practice and cost so common, that it is now automatically put into every budget. If tightly controlled CM were in place, Status accounting would be practiced more often and more rigidly.

Site Survey costs for significant cost savings?

> How do we save approximately millions of dollars using CM? Most facilities have been around for many years yet site surveys are always performed for changes and / or installations because a single source of valid data is not available and reliance on engineering site drawings (as-builds, red-lines, etc.), RDFs (Reference Data Files) and CM documentation is too risky to be sure what is actually in place. In essence a lack of an Enterprise CM process, that it is not known what is in place or where it is. This is true with both the non-IT and IT assets and resources. A culture has developed, that once any project is completed, drawings and documentation updates are not usually a high priority, because engineers, programmers and project managers are already moving on to the next project. This is widely known and accepted in the federal government which is why engineers and program managers have long accepted the costs of lengthy or additional site surveys, to be included in the scope, cost and time for each and every new project. Just looking at existing site survey data alone, the potential for a real cost savings benefit in the government could be realized, if a single source for valid and current CM data were available.

Because of the unavailability of controlled, up to date drawings and documents, in a centralized CM database, the common practice for site surveys is conducted on each and every change to a system or the design of a new system whether in an existing facility or not. Most of the projects are in existing facilities, but to implement the projects, make engineering changes or add to those facilities; site surveys are always performed. This was (and still is) a major cost for federal agencies within the scope of engineering because they can't rely on their own documentation for what they actually have in place at any given time (again knowing what you have so we can manage it).

Since no lessons learned are recorded in the CM database or forwarded to program offices it never comes to light. This is just one potential benefit that could be realized with controlled Enterprise configuration management with full and accurate documentation. A few other benefits could include lessons learned (for every project, installation notes, problem areas etc), up to date drawings, records of Engineering change proposals being installed, standardization, meeting goals, performance measurements, customer satisfaction, freeing up resources, good business decisions, cost savings, identified skill sets, capture of corporate knowledge, increased and valid safety management, and valid requirements management just to name a few more but the list goes on. The bottom line is that most agencies would likely have save millions of dollars each and every year if, a tightly controlled automated Enterprise CM database were in place with single source of valid data. Site surveys are just one cost savings that an automated CM database could provide.

Capitalization and Enterprise CM working together

Applying asset management or capitalization in every organization always involves a finance group that purchases assets; users that consume those assets; and a technical group that maintains the operation of those assets. However, most organizations don't effectively bridge asset purchases with asset assignments, or initial costs with ongoing maintenance costs, which is why they struggle to capitalize costs with annual budgets. This is one of the great disconnects between the business process and the product life cycle costs of any organization. For every asset, the organization needs to know who owns the asset, who is accountable for it (who maintains and uses it), what is the effective cost of ownership and maintenance (what the replacement costs are), and to whom the asset is assigned (what organization owns it). Managing and using configuration management data properly for asset lifecycle management could enables both management and the finance departments to use the same set of data to perform their very different tasks. If management knows who is responsible for an asset, it can determine how fast (and thus how expensive) maintenance for that asset should be, to meet performance goals – which enables the organization as a whole to make decisions on assets, budget priorities, and staffing with spending based on real data. If finance knows how much it costs to maintain an asset, it can work with management to standardize on lower-cost hardware or software. If finance knows to order new hardware as a function of technology refresh or new priority requirements, it can work with those organizations to pull and replace those products in an orderly, controlled fashion that has minimal impact on all stakeholders. When those assets happen to be critical, this knowledge can make all the difference in the world.

The federal government recently mandated that every agency be fully capitalized. This often involved bringing in consultants (corporate knowledge that left the federal government) and teaming with subject matter experts to work with management in determining what is required in the agency, if it is in place and where it is. This could be accomplished with relative ease if an Enterprise CM system were in place (a single source of valid data with relationships shown) by knowing what we have so we can manage it. This is where configuration management and business goals can meet, and where real value will become evident. This is where organizations can expose the high costs of maintenance for products or programs to drive more intelligent business decisions and resource allocations. It is amazing, this power of configuration management. It glues all the pieces together to create consistency across the organization. It builds organizational process-controlled bridges between configuration management and assets so that we can manage what we know we have.

Records, templates, and knowledge

It would be much simpler to generate the documentation using templates and leveraging previously developed work for all documentation rather than have people build up specific expertise for a particular product. For example, an engineering team might concentrate on one version of equipment and its specifics rather than all of the nuances associated with different platforms and other systems because there are just too many variations. The problem extends further to the users and maintenance folks as well, a technician in one area of the country may not be able to work on the same system in another because of variations. With the recent re-organization from regions to service centers, this may become all too important. By the reuse of components, modules, software, or product configurations, good CM speeds up development as well as keeping costs down. The use of templates, for document preparation, can provide timesavings too. Finally, the corporate history and knowledge of products and systems with all of the versions of the product(s) and the documentation that goes along with each could be captured rather than exiting the federal government as the baby boomers retire. Proper documentation in CM includes, valid requirements, justifications, engineering designs and changes, personnel involved, lessons learned, as builds and approved changes with effectivity dates, ID or drawing numbers and released dates can be a life saver (or a career saver) and meets the criteria out lined in ISO9000 or ISO 10007 (document what you do and do what you document) as well as meet the requirements in CMMi and SEI. CM is there to help, not stop or hinder progress or change. The goal being to support the organization and reduce wasted efforts and resources, as it was initially intended when conventional CM was first instituted.

Security

On December 17, 2002 the Electronic government Act (Sarbanes-Oxley Act of 2002) was signed into law as OMB (circular A-130) policy to add to what the Clinger-Cohen Act did not. The Federal Information Security Management Act (FISMA) lays out a strict guidance to secure information and systems, identify risks and resolve current weaknesses. FISMA (section 3544(b)(2)(D)(iii)) requires that each Federal agency

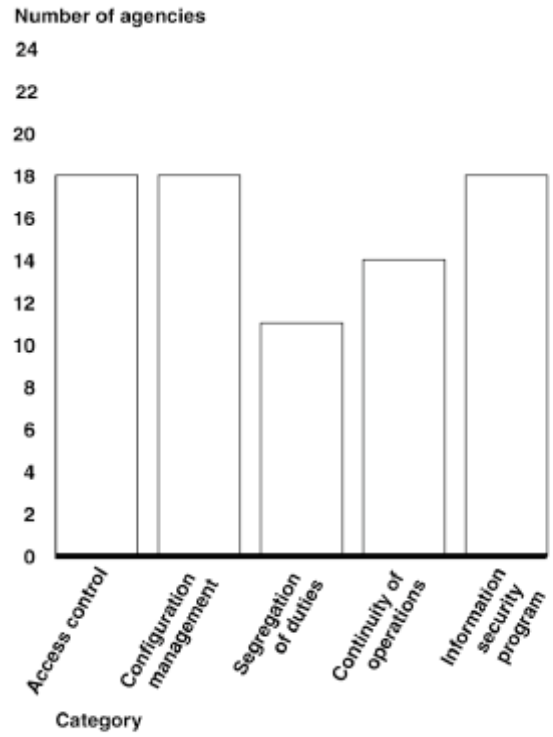
develop specific system configuration requirements that meet their own needs and ensure compliance with them. This provision encompasses conventional system configuration management, employing clearly defined system security settings, and maintaining up-to-date patches. Simply establishing such configuration requirements is not enough. It must be accompanied by adequate ongoing monitoring and maintenance to meet the requirements Accreditation and Certification under NIST (National Institute of Standards and Technology). Initially, agencies had three years to comply (2005) under the Security Certification Accreditation Process (SCAP) and Configuration Management was a requirement under this. Each SCAP identified risks and mitigations to those risks based on when the agencies would meet the requirements. CM was found to be a mitigated risk in almost every case and systems were certified and accredited for three years with a plan to put CM into place prior to a new SCAP being performed (every 3 years). It is now 2008 and the mitigations of the past three years now have to be dealt with including all the previously mitigated CM issues (or lack thereof). In 2006, GAO reported their findings for major systems.

What the GAO Found

In their fiscal year 2006 financial statement audit reports, 21 of 24 agencies indicated that they had significant weaknesses in information security controls. As shown by reports by GAO and agency inspectors general (IG), the weaknesses persist in major categories of controls—including, for example, access controls, which ensure that only authorized individuals can read, alter, or delete data, and configuration management controls, which provide assurance that only authorized software programs are implemented. An underlying cause for these weaknesses is that agencies have not yet fully implemented agency wide information security programs, which provide the framework for ensuring that risks are understood and that effective controls are selected and properly implemented. Until agencies effectively and fully implement agency wide information security programs, federal data and systems will not be adequately safeguarded to prevent unauthorized use, disclosure, and modification.

These persistent weaknesses appear in the five major categories of information system controls: (1) access controls, which ensure that only authorized individuals can read, alter, or delete data; (2) configuration management controls, which provide assurance that only authorized software programs are implemented; (3) segregation of duties, which reduces the risk that one individual can independently perform inappropriate actions without detection; (4) continuity of operations planning, which provides for the prevention of significant disruptions of computer-dependent operations; and (5) an agency wide information security program, which provides the framework for ensuring that risks are understood and that effective controls are selected and properly implemented. The following figure shows how many of the agencies had weaknesses in these five areas.

Figure 2: Information Security Weaknesses at the 24 Major Agencies for Fiscal Year 2006



Source: GAO analysis.

Without Configuration Management solidly in place, most organizations will not have reasonable assurance that controls are implemented correctly, operating as intended, or producing the desired outcome with respect to meeting the security requirements. Furthermore, they may not be fully aware of the security control weaknesses in their systems, thereby leaving their information and systems vulnerable to attack or compromise. Until an organization effectively and fully implement organization wide information security programs, data and systems will not be adequately safeguarded to prevent unauthorized use, disclosure, and modification.

In the federal government, Office of Management and Budget (OMB) requires that every agency officially formalizes authorize their information systems to process information and accept the risk associated with their operation. This management authorization (accreditation) is to be supported by a formal technical evaluation (certification) of the management, operational, and technical controls established in an information system's security plan, which includes Configuration Management in place, as required by law. Federal systems previously certified and accredited could now be at risk for failing unless they have Configuration Management in place and not just a mitigated plan to get it, that only worked for three years. Every system is unique in the SCAP (Security Certification and Accreditation Process) and the risk mitigation table will identify the risk associated for not having CM in place. Depending on the risk, a

currently certified system may or may not be re-accredited without putting CM in place and if it is a critical system, a lot of time, money and resources might be poured into it to comply.

CM Scenarios, where processes are not used properly

Scenarios 1 to 4 are possible scenarios, last one is noteworthy and an actual case study.

Scenario One

An engineer flies across country to install new equipment. The equipment is there and the room is ready, but he has the wrong version of drawings and is unaware. After working to get everything installed, it doesn't work. Finally after many days of trouble-shooting, he discovers the drawings he is using, just do not work. He returns to his office to research and finds the correct version of the drawings needed. Returning to worksite and using the correct drawings, everything works fine—but it has taken extra time and effort and putting him behind on other projects he is also scheduled for. This could have been prevented with the right version first time around with proper configuration management.

Scenario Two

A programmer takes what he believes is the most current version of software to a system and begins to install it. When he installs it, into the system, it fails. Why? It was not due to poor work or a program error but because he was not using the most recent and tested release and his change was no longer compatible with the system and incompatible with other changes already made. CM could have prevented this by tightly controlling versions and changes. This could just as easily have been a major power outage to a power system in a major airport.

Scenario Three

Another example could be major modifications made to a system in the field but different than other sites with the same equipment. CM would prevent this and maintain standardization making maintenance and safety much easier to maintain across like systems.

Scenario Four

Large efforts in capitalization would require lots of resources and corporate knowledge of assets to properly document assets. However, if everything is under proper Configuration Management; assets and associated components can be identified easier, quicker through baseline dated effectivity.

Actual Case Study

This last example (public record) is an actual FAA instance taken from the article "Flying In Place: The FAA's Air-Control Fiasco," by Mark Lewyn, Business Week, April 26, 1993 and is required reading at MIT and many other universities with computer science, engineering, configuration management, and management curriculums as a case study for a worst case study of what can go wrong and what not to do.

In January 1982, the Federal Aviation Administration proposed a $3.2 billion overhaul of the air traffic control system (AAS (Advanced Automation System). But by April, 1993, the new system was still at least nine years from completion and already $1.5 billion over its original budget and climbing. The FAA and IBM's Federal Systems Division, the prime contractor, at that time, said the system wouldn't be in place until well after 2000. In March 1989, IBM and the FAA finally, got to work. IBM's initial raw material was a four-foot-high stack of specifications. They spent more than a year refining the specs. It became obvious after a few months, that controllers should have more say in the design. They bombarded the FAA and IBM with proposed changes. The real software writing didn't begin until several months later and was slowed by a steady stream of change orders. As IBM finished one block of software, programmers would have to rewrite an earlier block. IBM didn't protest, partly because it would only add to the delays. IBMers were beginning to take shortcuts such as skipping software reviews to keep the project on its already-delayed schedule. In April 1993, the FAA froze the specs.

The AAS event and budget timeline, based on open literature sources (Krebs and Snyder, 1988; Scott, 1988, Levin, et al., 1992; Del Balzo, 1993; Ebker, 1993; Lewyn, 1993; Barlas, 1996; Beitel, et al., 1998), is briefly summarized below:

- 1982: The FAA sets the initial requirements for AAS and seeks contractors.
- 1984: IBM and Hughes named the finalists to build the prototype. At this point $500 million has been spent developing the bid.
- 1988: The FAA awards the prime contract to IBM worth $3.6 Billion. Hughes protests the award causing an initial project delay.
- 1989: IBM begins work on the AAS. The software component of the project is estimated to be 2 million lines of code.
- 1990 Requirements are still unclear for ISSS as indicated by the 500-700 requirements change requests for the year. To help finalize requirements, IBM builds a prototype center in Gaithersburg, Maryland so that controllers can try out the software under development. Despite the fact that requirements were not clear, approximately 1 million lines of code have already been written. Estimates indicate that 150,000 lines of code will need to be rewritten due to the requirements changes and the resulting bugs. To date the cost overrun is $242 million.
- 1992: The FAA announces a 14-month delay to the project completion. FAA and IBM shake up their management.
- 1993 April: IBM and the FAA freeze the requirements for ISSS.

• 1993: IBM announces that the project will not be ready until after year 2000. IBM starts working on more methodical, communication-oriented project management philosophy with new managers.
• 1994: The AAS program ceases to exist as originally conceived, leaving its various elements terminated, restructured, or as parts of smaller programs.

The overall FAA Advanced Automation System from 1982 to 1994 at a cost of $3+ billion was ultimately "restructured and downsized" due to deficiencies in the managing requirements and configuration / change management processes. Many of the components are still used today however, the problems that the FAA experienced in trying to improve the air traffic control system were extensive and very expensive.

In several studies of the AAS problems, there was a commonality in AAS and they were;

- "Inadequate requirements baseline control"
- "Extremely high availability requirements that led to high complexity in the implementation"
- "Changing mission needs"

The configuration management lessons to be learned from this are still valid today. With change comes great vulnerability, reflecting our greatest weakness unless we can control them. Controlling change and requirements affects every organization but by enforcing good CM processes, we can eliminate most of the excessive costs caused by remedial efforts to correct them over and over.

By being able to control change, an organization can succeed however, not controlling changes will result in a large amount of rework to correct problems or compensate for lack of controls. Correcting problems is usually the result of poor requirement controls, not knowing what we have and not controlling business processes. Enterprise CM at a strategic level within an organization maintains control of processes, controls requirements, manages resources more effectively and reduces re-work on products, projects or processes by managing what we know we have from a single valid source.

The Project Management Institute (PMI®)

The Project Management Institute (PMI®) embraces the need for Configuration Management as a critical component of Project Management. CM is also a component of the Project Management Professional (PMP®) certification process. Every project is presented with challenges relating to time, cost and scope. Only through careful management of these project elements will any project be successfully completed. Configuration management is implemented to actively guide the direction of the project and support communication that will facilitate successful completion. Due to the increasing complexity of projects, the knowledge of configuration management techniques is becoming more important than ever. PMI® defines Configuration Management as "Management process to establish and maintain consistency of a

product's, functional and physical attributes with its requirements, design, and operational information throughout its life [EIA-649]."©Project Management Institute

Those with conventional CM experience or knowledge may be surprised to learn how much the CM process has expanded over time to include other process such as Data Management, Property Management, Asset and Supply Chain Management, and documenting Technology Infrastructure. It is important for everyone to understand that more changes are occurring today than at any other time in history. So it is critical that we stay current with what is going on in CM and prepare for changes (CM Strategic Change Points) that are right around the corner. After all, change is unavoidable and CM has to change and evolve to accommodate and manage change. Without the enhancement of Enterprise CM and a centralized automated system, the amount of documentation generated by the configuration, reconfiguration and maintenance of products, systems, and assets will likely get in the way of good business practices. Further, critical errors can be made if documents are improperly updated or, worse, cannot be located in a time of need. Employee effectiveness increases with improvement in data integrity. Data may include all released information used to run the organization, contained in released documents, forms and records.

Conclusion

Enterprise Configuration Management is essential in every organization to manage our own existing assets, processes and tools. This will ensure success in moving forward to the 21st century with ever changing requirements. The costs to properly implement Enterprise CM and an automated CM system will need to be incurred within the Enterprise CM processes but the long term benefits derived will be felt organization wide for the foreseeable future. The cost savings resulting from Enterprise CM will more than justify the costs to implement it and those costs are only a fraction of the costs already being spent on rework by not being able to make good management decisions on what we have (not knowing what we have). It is fiscally responsible and it is only a matter of time before Congress and OMB mandates Enterprise CM for every federal agency to know what they have, so they can manage it properly. Other organizations (i.e. CMIS in DOD) and private industry (CMPIC, CMII™, Auto-Trol™) have already realized this and are elevating Enterprise CM processes to work in conjunction with the Enterprise Architecture process, security and efficiency.

It is the only way we can confidently measure and reduce intervention (rework) resource costs, implementation progress, while improving benefits. We can no longer allow the philosophy of "it easier to be forgiven than to obtain permission". This disrupts other programs, who did ask and managed their programs well, only to be penalized by having part or most of their budgets taken to pay for another program's mismanagement practices. Enterprise Configuration Management can no longer be driven from the bottom up, trying to gain upper management's interest and support. The Federal Government has become extremely complex and unless management in every federal agency knows what they have, it will be difficult if not impossible to make good decisions for the future. This is why upper management must drive Enterprise configuration management from the top down to bring costs down, control projects and add value to the organization as a whole by managing what we know we have.

At one time, the federal government mandated CM for defense systems now they must mandate Enterprise CM in every agency or pay the consequences in rising budgets, failed systems, missed goals and poor planning.

Configuration management is a key, core process essential for every business improvement process (CMMi, ITIL, SIX Sigma and ISO). We are bringing organizations into the 21st century and we must bring Enterprise CM into it as well, if we are going to set the bar higher. We can no longer just keep pouring money into a program (organization or agency) to meet schedule, requirements or making it well. For every system or product, we have to manage what we have, by knowing what we have, through Enterprise Configuration Management. Otherwise we will fall into the same old trap, where we want controls (Enterprise CM automation - managing what we know we have – or as I call it, capturing reality) but get frightened off by the costs of these controls. This leads to more reduction of control costs to an affordable level, which in turn, leads to problems created and cost overruns caused by the lack of control, which then costs more money. Then, we cut overhead costs to reduce overall costs and this, in turn reduces control even further. We repeat this loop repeatedly until so much money is being spent on treating the symptoms (intervention or rework) of poor control that we never have sufficient funds available to it to put the proper controls (configuration management) in place. This is the safest and most modern country in the world, let's keep it that way by setting the bar higher through superior management and business practices with Enterprise Configuration Management.

REFERENCES

[PSM] Plant Services Magazine article, R. Keith Mobley, contributing editor 2004-2008 plantservices.com articles
[**Barlas]** Barlas, S., 1996, "Anatomy of a Runaway: What Grounded the AAS." *IEEE Software* 13(1): 105.
[Del Balzo] Del Balzo, 1993, Statement Before the House Committee on Appropriations, Submittee on Transportation, Concerning the Advanced Automation System, April 19.
[Erbker] Erbker, G. W., 1993, Statement of Gerald W. Ebker, IBM Vice President Chairman and CEO of IBM's Federal Systems Company Before the Subcommittee on transportation and Related Agencies, House Appropriations Committee.
[Guess] Vincent C. Guess, CMII for Business Process Infrastructure, April 2002
[Hass**]**Ann Mette Jonassen Hass *Configuration Management Principles and Practices,* December 30, 2002
[Krebs & Snyder] Krebs, M. and J. Snyder, 1988, "Hughes Quits Fight with IBM for Air-Traffic-Control Pact." Automotive News: 8.
[Levin] Levin, R. E., R. D. Wurster, et al., 1992, GAO/RCED-92-264 Air Traffic Control: Advanced Automation System Still Vulnerable to Cost and Schedule Problems, GAO**:** 5.
[Lewyn] Lewyn, M., 1993, "Flying In Place: The FAA's Air-Control Fiasco." Business Week: 90.
[Lyon] Practical CM III, Best Configuration Management Practices for the 21st Century,
David Douglas Lyon, Raven Publishing, June 2004
[PMI®] Practice Standard for Project Configuration Management, Project Management Institute (PMI®), 2007
[Scott] Scott, W. B., 1988, "Protest Prompts Suspension of $3.6-Billion FAA Contract to IBM." Aviation Week and Space Technology 129(7): 27.
[SEI] Software Engineering Institute, http://www.sei.cmu.edu/productlines, 2006.

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