Metrics Working Group

A Metrics Model For NATO Use

A report to the Conference of National Armament Directors.

October 2000 **Version 1**

EXECUTIVE SUMMARY - Metrics Working Group Report

Background:

The NCMB was tasked at the Spring '99 CNAD to deliver a report and recommendations on Final State Metrics, which is to say the measures and targets by which NATO could assure compliance with its strategic objectives. The report was to focus on the contribution of CALS tools and techniques to the achievement of these aims.

Conduct of Tasking:

The NCMB subsequently tasked a Metrics Working Group (MWG), led by the US, to deliver a report to the October 2000 CNAD on its findings. The MWG, comprising members of the NCMB, the NCO and Industry, met on 3 occasions, reporting its progress to CNAD through the NCMB. In the course of its work, the MWG worked closely with other working groups, particularly the Life Cycle Working Group (LCWG), in order to co-ordinate it's findings. This summary details the major findings and recommendations contained in the detailed report.

Subject to CNAD acceptance of the report, the tasking of the MWG is considered completed. The recommendations of the report detail how the findings of the group should be taken forward in this very significant area of activity.

Report Findings:

The MWG determined that the principal role of metrics is to establish targets and indicators of performance by which the satisfactory conduct of acquisition and support processes can be measured and improved. Such measures will fall in the three principal areas, or domains, in which CALS tools and techniques act:

- Environmental domain: the managerial, structural and cultural ability and competence of an organization to absorb, apply and review technology and processes in order to achieve strategic goals.
- Technology and Infrastructure domain: the communications, technology, security and application capabilities on which an organizations process are built.
- Process domain: the working methods, procedures and systems by which an organization's required outputs are delivered and strategic outcomes achieved. This is the domain in which most direct business benefit is delivered.

The MWG determined that these domains are interdependent, and that metrics play a vital part in ensuring that investment is focused and prioritized between these domains in order to deliver the maximum business benefit.

The MWG determined that metrics must be scalable (that is, capable of being applied at a number of organizational viewpoints), and that they must be appropriate to the viewpoint selected (that is, capable of delivering effective management information and control of the Environment, Technology or Process to which they are applied).

The LCWG have recommended a process-focused approach to Life Cycle Management, based on the standard ISO 15288. The MWG ensured that its recommendations are complementary to this standard, by developing a metrics model that maps time- or phase-based metrics to the processes outlined in the standard. The body of this report describes in detail the methods by which this is achieved, and provide illustrative metrics.

The MWG determined that metrics play a key role in assessing organizational effectiveness. Whilst metrics are key within a single organizational boundary, for any form of partnership activity, at project, national or international level, it is essential that all partners have an understanding of shared capability and maturity. Where processes, and the information upon which they act, cross organizational boundaries, the efficiency and speed of those processes are dictated by the partner with the lowest technological capability.

In order to determine where such bottlenecks exist requires primarily that an organization, or a partnership, has a sophisticated understanding of its current capabilities and performance in each of the CALS domains. The Metrics Model developed by the MWG recommends a number of complementary techniques to undertake this analysis. Metrics may then play a key role in establishing a business improvement program to address deficiencies uncovered, by helping to shape the goal (the changed characteristics of the To-Be position from current state), and by determining the measures of performance/achievement in the transition.

The MWG recognized from the outset of the task that it would be impractical to suggest definitive metrics for NATO at this time. To do so would require that NATO nations share a common definition of their processes and expected outcomes. Much work is currently underway in precisely this area, through the Life Cycle Working Group, the Life Cycle Costing Group, the NATO Standardization Agency, etc. and it is assumed that if nations can harmonize on a common Work Breakdown Structure for acquisition, for example, they could also agree definitive performance and target metrics. Until this time, the metrics suggested by the MWG in the White Paper are necessarily generic.

In spite of this caveat, the MWG has provided indicative and/or predictive metrics for each CALS domain against the developed framework, and has made recommendations on the likely resources that will be required to complete the model. The MWG concludes that the fully developed model will be of significant assistance in prioritizing investment to improve the performance of organizations at a number of levels, and in assessing the capabilities of candidate partners.

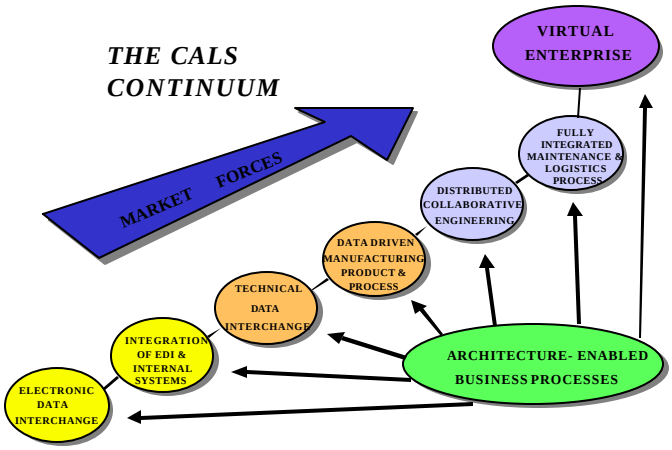
In this spirit, the aim of the MWG was to specifically answer the CNAD question: "what are the CALS final state metrics?" The MWG addressed this question by providing a definition of final state metrics as follows"

Target Final State Metric for CALS within NATO may be expressed as:

"Improved operational availability of NATO assets within an acceptable cost and time frame by delivering a fully integrated secure digital data environment shared across the equipment acquisition and support chain over the Lifecycle of the DS which is:

- ***Based on International Standards, and***
- ***Takes full advantage of the available commercial environment"***

Although "*operational Availability*" is a tangible metric, It did not satisfy the MWG as the "*solution*". Therefore, the MWG continued to analyze the issue of metrics ultimately developing the ***"CALS Maturity Model***".



The CALS Continuum

This model graphically demonstrates the relationship between technology and the improved processes which it enables.

Through the development of this model, the TWG realised that metrics, to be successful, must be applied in three areas: environment, technology, and process. The TWG concluded its work by detailing the application of this model across these three areas and by providing example metrics for measuring the benefits realised by applying CALS concepts.

1. METRICS WORKING GROUP REPORT

1.1. Introduction:

The adoption of CALS technologies and techniques is assumed to enable the delivery of benefits which make the strategic military/industrial aims of NATO significantly more likely to be achieved. Moreover, the CALS community has consistently championed the concept of the crucial value of information throughout the life of weapons systems in achieving these goals, a concept around which NATO is now re-aligning it's acquisition and logistics focus. However, there has always been a difficulty in establishing a direct causal link between the adoption of CALS tools and techniques and delivered benefits and outcomes – answering the question 'how do I know when I've implemented CALS?"

In 1999 the CNAD commissioned a report from the NATO CALS Management Board (NCMB) to suggest appropriate metrics which would indicate the extent to which CALS has become embedded within core NATO processes.

1.2. Objective:

The Objective of this paper is to establish a Metrics framework for the adoption of CALS tools and techniques within the NATO acquisition and logistics context; to make recommendations on how this framework should be implemented; to identify the likely resource requirements needed to sustain the activity; and to provide an illustrative example.

1.3. Working Method and Participants:

Following CNAD direction, the NCMB commissioned a Metrics Working Group (MWG), operating on a Project basis with an agreed project plan. The MWG was open to all members of the NCMB, the NATO CALS Office, and Industry members from the NIAG. The NCO acted as a Project Support Office throughout the activity. The MWG met on 3 occasions, in advance of NCMB meetings, in order that progress against the project plan could be reported through the NCMB to CNAD. Throughout its activities, the MWG has maintained close liaison with other interested authorities and Cadre Working Groups (such as Life Cycle Costing and Life Cycle Management) to ensure that the results are, as far as feasible, compatible with the emerging findings of these groups). The MWG also called on national sources from both industry and government to assist with data collection.

1.4. Approach:

The Metrics WG (MWG) recognized the high degree of convergence between this activity and that of others such as the Life Cycle Working Group (LCWG), and that therefore Metrics should be developed within a common conceptual framework and approach to the rapidly emerging NATO concepts of Defense

System Life Cycle Management. The LCWG have adopted and recommended to CNAD a standards-based approach to describing Life Cycle Management, based on recognized standards such as ISO 15288 and AAP-20 (PAPS). This approach attempts to reconcile the potentially conflicting viewpoints and roles of process and phase in the delivery, support and sustainment of Defense Systems, and has provided the MWG with a framework on which to map indicative performance goals and measurements.

1.5. Caveat:

The MWG recognised from the outset of the task that it would not be possible to provide definitive metrics to CNAD. Whilst the Group could determine that Depot Turn-Around time, for example, would be a sensible indicator of performance, it would be impractical to suggest a definitive target for NATO at this time. To do so would require that NATO nations share a common definition of their processes and expected outcomes. Much work is currently underway in precisely this area, through the Life Cycle Working Group, the Life Cycle Costing Group, the NATO Standardisation Agency, etc. and it is not unrealistic to assume that if nations could harmonise on a common Work Breakdown Structure for acquisition, for example, they could also agree definitive performance and target metrics. Until this time, the metrics (at Annex A) suggested by the MWG are necessarily generic.

2. Discussion:

2.1. The Industrial Environment

International corporations are changing their focus from cost control to value-based customer relationships, and are constantly seeking more innovation, better quality, greater responsiveness and agility, all at a lower cost. In pursuit of this goal, the means of conducting business has changed. For example, Honda US, with over 13,000 employees, only makes about 20 percent of the cost of their cars. Put another way, Honda buys 80 percent of the cost of every car it makes "to the tune of $6 Billion worth of goods purchased from North American suppliers every year". In this environment Honda, and other companies like them, come to the market only as fast as the slowest member of their supply chain and quality is only as good as the weakest member of the supply chain.

To remain competitive in this environment, Honda and other large corporations have been forced to reengineer their processes. Design, development, production and support of new products is conducted by teams representing a number of functional areas which are geographically dispersed (such as product planning, design engineering, reliability engineering, purchasing, manufacturing engineering, quality, finance and field support), and in which carefully selected suppliers and customers are all involved.
Shared technology and processes, with clearly articulated and understood measures of progress and targets, are the keys to making this work.

Anecdotal evidence indicates that the development of new products by such cross functional teams and the use of concurrent engineering practices can significantly improve three key business issues: time, quality, and cost. For example, extensive redesign, rework, and retrofit operations are common when operating in the traditional functional mode. Cost overruns and forgone cost saving frequently result when the designers fail to consider the supply base's design, manufacturing, quality and cost and support capabilities. Ultimately, the absence of teamwork results in products that will continue to burden long-term competitiveness.

The parallels between the business aims of industry and those of NATO and Nations are self-evident. This paper will seek to establish the role of metrics in relation to the business environment, technology and process.

2.2. The CALS Environment:

There is no one-size-fits-all total CALS solution which can be universally applied at any stage of a Defense System lifecycle and which can be guaranteed to deliver wholly predictable benefit to all stakeholders. This is unsurprising, given that the delivery of benefits is achieved by finding an acceptable and affordable balance between investment in technical infrastructure, applications and business process improvement, which balance must be assessed against the nature of the project and it's stage in the life-cycle. Benefit achievement also requires the vital

but often less tangible attributes of leadership, organizational flexibility and culture. Nonetheless, the Metrics Working Group determined that sufficient evidence is available to provide strong indicative metrics of the value of technology insertion and the application of CALS tools and techniques to Defense systems. These metrics should provide valuable assistance at project, program, national and NATO levels in guiding investment and assessing delivered benefit.

2.3. What are Metrics?

The MWG found no satisfactory dictionary definition of the term 'Metrics', and no synonyms offered in any Thesaurus examined. The term has been used variously to describe the act of measurement, and to imply performance indication.

The MWG therefore had to arrive at a working definition of the term to ensure a common focus. The group determined that a Metric may be defined as "**the *characteristic* of an object, organization or process which may be *assessed* by measurement or *indication* for the degree to which it fulfills its purpose**."

Thus, for example, the *characteristic* of a house may be that it is an enclosed construction designed to provide shelter; it's effectiveness in meeting that purpose may be *assessed* by measurement of floor area, volume, thermal efficiency, etc. or *indicated* by its market value, length of occupation, etc. Expanding the analogy: from a strategic viewpoint of energy conservation, thermal efficiency might well be a far more significant factor than market value in determining the fitness for purpose of the house. Equally, the thermal efficiency of a house may well be adjudged to be more important in Nebraska or Norway than in Florida or Southern Italy. However, and taking another viewpoint, market value is clearly an indicator of immense significance to the stakeholders of seller, purchaser and financier, and may well outweigh the impact of low thermal efficiency.

The key message is that the most appropriate Metric, or characteristic, for any scope of activity is crucially dependent upon the viewpoint of the stakeholder, and will change as the viewpoint moves.

In order to provide a satisfactory response to the CNAD tasking, the MWG had to reconcile these viewpoints as far as possible to distil meaningful metrics.

2.4. Where does CALS Operate?

CALS disciplines, tools and techniques operate on the management of information in 3 distinct but inter-related domains, as shown in Figure 1:

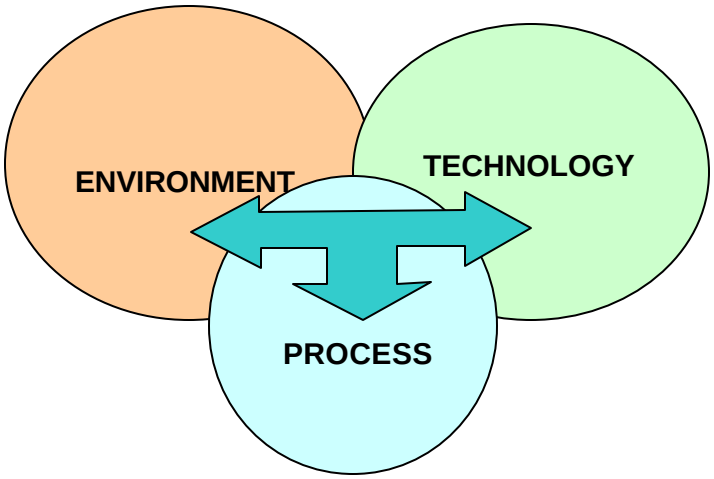


Figure 1: The CALS Domains

- Environmental domain: the managerial, structural and cultural ability and competence of an organization to absorb, apply and review technology and processes in order to achieve strategic goals.
- Technology and Infrastructure domain: the communications, technology, security and application capabilities on which an organizations processes are built.
- Process domain: the working methods, procedures and systems by which an organization's required outputs are delivered and strategic outcomes achieved. This is the domain in which most direct business benefit is delivered.

Each of these domains has different approaches to the establishment of metrics that set goals and measures achievement. However, the MWG determined that a common theme of metrics within these domains is that of Maturity – that is, the comparative and/or relative degree of absorption of CALS tools and techniques against a defined standard of best practice.

2.5. Granularity of Metrics:

The domains illustrated at Figure 1 represent an organizational, or enterprise, boundary. This boundary is scalable, in that it may be viewed at a number of levels in both process and phase. At the lowest level, an individual process within a particular phase within a single project, at the highest to a collection of shared processes in a multi-national enterprise – such as Operational Logistics within NATO, for example.

Whatever viewpoint, or level of aggregation, selected, the MWG have determined that the same principles of Maturity apply. However, as the viewpoint widens, the availability and granularity of empirical data to validate goals and performance diminishes, and the resource required to collect the data increases. Thus the nature of applicable metrics necessarily moves from *predictive* to *indicative*.

To illustrate the point: it is comparatively straightforward to analyze the relative maturity of environment, technology and process within a single project, to establish an action/change plan for environmental and technology investment needed to meet clearly identified process-improvement goals, and to predict the outcome of that investment in a sound business case. There is, generally, much empirical data and examples of best practice available to inform and implement such decisions, together with a rich set of widely available technology. Thus the causal link between the application of CALS tools and techniques, and subsequent outcomes, is relatively easy to establish, and goal and performance metrics simple to derive.

As the focus of the observer moves out to a wider organizational viewpoint, the maturity analysis becomes more complex, with the availability of hard, empirical data (and the resources required to collect them) becoming markedly more difficult. There will invariably be more stakeholders' interests and sensitivities to consider, and whilst it may still be possible to find examples of best-practice, and there may be commercially available technology to underpin identified process-improvement needs, these will tend to be more generic. Thus investment plans will normally be of a substantially greater order than those at project level, and carry a proportionately higher risk to a much wider community.

The MWG determined that this appreciation should not obscure or invalidate the linkage between the application of CALS tools and techniques, and outcomes; rather, the need for a maturity analysis, focused by *indicative* metrics becomes significantly greater in this more complex environment.

To support this concept we refer to "Purchasing and supply Management" by Dobler and Burt, which provides the following guidelines for developing metrics:

1. Performance measurement systems are a tool for good management – not a substitute for it. The effectiveness of the system will not exceed the perceptiveness and the sensitivities of the managers operating it.
2. A measurement system should be designed to support the individual or teams in doing a better job. Correspondingly***, these individuals should participate in designing the system and in establishing the standards that affect them and their work.***
3. The degree of sophistication of the system should be based on the specific needs of the organisation. As long as the system provides the major information required for control – the simpler the better.
4. The cost of a measurement and control system should be balanced against the management value of its output. When the cost of an incremental unit of output exceeds its usefulness, the system should be redesigned and cut back to the point of equilibrium.
5. The measurements of efficiency and effectiveness must be separated. Efficiency measures reflect the resource utilisation of the department and tend

to be quantitative in nature. Effectiveness measures focus on ho well people do their jobs and often involve subjective assessment to some extent. While efficiency is important, effectiveness offers far more opportunity for improved organisational performance.

6. A small number of precise measures typically are more useful than a large number of less precise approximations. Validity and accuracy are essential for effective use of the results.
7. Systems that measure past performance are of value primarily in providing information and experience that can be used for improvement in the future. Thus, the most effective systems are found in an environment that provides a positive stimulus for people to use the output of the system constructively.

2.6. Final State Metric:

The target Final State Metric for CALS within NATO may be expressed as:

> "Improved operational availability of NATO assets within an acceptable cost and time frame by delivering a fully integrated secure digital data environment shared across the equipment acquisition and support chain over the Lifecycle of the DS which is:
>
> - Based on International Standards, and
> - Takes full advantage of the available commercial environment"

This definition underpins the strategic objectives, derived from the Armaments Review and DCI (and contained with the NATO CALS Strategic Plan) which may be summarized as:

- Reducing life-cycle costs
- Reducing time-to-market
- Reducing the logistics footprint
- Improving reliability and maintainability
- Improving supportability

The task of the MWG was therefore to establish metrics that would provide satisfactory indicators of the extent to which CALS, as a key enabler of these goals, has been embraced by NATO nations.

3. The Maturity Model:

Figure 2 (below) illustrates the 'CALS Continuum', that is the progressive, incremental maturity of CALS within an organization (in this case a manufacturing enterprise) which lead to the state here described as the Virtual Enterprise, which in the NATO context represents the Final State Metric defined above.

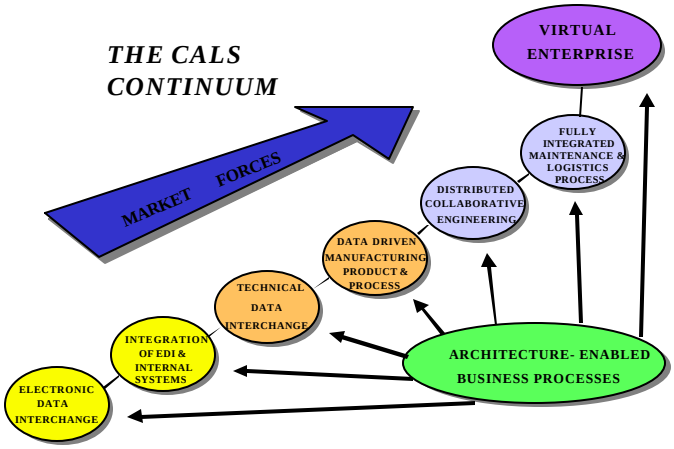


Figure 2: The CALS Continuum

This model graphically demonstrates the relationship between technology and the improved processes that it enables, and the statement that it is market forces which will drive forward along the maturity path. For NATO, it is the strategic objectives emerging from the Armaments Review which provide an equally compelling drive to decrease the cost and increase the efficiency and effectiveness of its processes.

Establishing the road map of how these objectives might be achieved requires primarily that an organization has a sophisticated understanding of its current capabilities and performance in each of the CALS domains in order that it can determine where it sits in the Maturity model. The Metrics Model employs a number of complementary techniques to undertake this analysis.

4. The Metrics Model:

The figure below illustrates the framework that the MWG established for its activity.

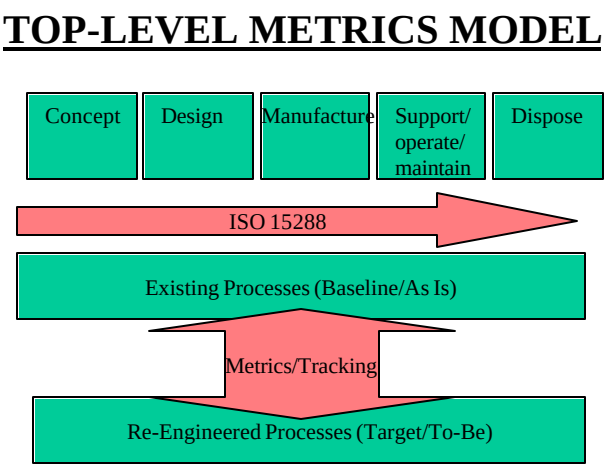


Figure 3: Top-Level Metrics Model

This model illustrates that whilst ISO 15288 focuses on the concurrent processes operated by stakeholders throughout a Defense System Lifecycle, it is essential also to consider the time dimension within which these processes are operated. CALS tools and techniques focus on the delivery of benefits by process improvement, but ***this clearly implies that the organization to which the Metrics model is applied, at whatever level, is moving from a current (As-Is) position, to a target (To-Be) by improving it's investment in environment, technology or process.*** Thus the role of Metrics is both to shape the goal (the changed characteristics of the To-Be position from current state), and to determine the measures of performance/achievement in the transition. Moreover, given that the Maturity model is predicated on an incremental approach to achieving the Final State Metric, a Metrics model based on phases helps significantly in focusing attention on specific areas of investment which can be predicted to deliver most benefit.

5. Applying the Model - overview:

Within each domain within which CALS operates, the MWG assessed the range of currently available methods and tools that can provide an objective assessment of the penetration of CALS. The purpose of this approach was to establish an objective mechanism for 'scoring' an organization against metrics within the Maturity model, and thus provide an indication of where improvement should be focused. Information about tools in use was primarily sought from nations, but industry views and products were also sought and researched.

5.1. Applying the Model – the Environment domain:

Although, on the surface, the most intangible of the 3 domains explored, organizational theory has been exhaustively studied for many decades, and has been a primary focus of business change programs. This focus has resulted in a rich toolkit to assist in business analysis. Many of the tools are industry-specific (e.g. directed at specific manufacturing or service–industry sectors, such as automobile manufacture or banking), and thus too narrowly focused for the purposes of this exercise. The MWG determined that the common feature of the tools examined which enable a more generic business analysis is a view on the organizational and cultural characteristics of successful enterprises, whether private or public sector, as measured by their performance outcomes (share price, policy implementation, etc.). In effect, they attempt to establish 'Best Practice'. Whilst each tool takes a different approach to assessment, there appears to be general consensus that the most significant areas of competence are:

- Strategic goal setting and Business Planning
- Leadership and Communication
- Staff competence and their alignment to strategic and business goals
- Resource management
- Review and action mechanisms

These factors are described as the enablers of business results.

Assessment may be by external review, by self-assessment, or a combination of the two, but each model examined applies both a methodology to assessment (thus ensuring a measure of consistency), and a scoring mechanism which serves to highlight areas of significant strength or weakness in each of the competence clusters.

Such models are not prescriptive about organizational structures – they may be flattened, hierarchical, or matrix – or about team organizations, which may be traditionally structured around a single function, or multi-disciplinary, integrated teams which are focused on a project. Neither do they suggest any model of leadership, resource management or strategic planning and review; rather, the scoring mechanisms are predicated on evidence of strength or weakness in each of these areas, and their impact on results and outcomes. Most of these tools have some form of weighting system, based on empirical evidence, for each of the areas examined, and most also have some form of overall scoring regime.

Whilst this may appear somewhat arbitrary, it does give a broad and useful metric, and a framework in which a more detailed analysis and comparison of results can be formed.

The MWG determined that the most significant benefit of this approach is that it allows both direct comparison between organizations with quite dissimilar functions (and between public and private organizations), and can also act as the springboard for business improvement within an organization.
The model of which many members of the MWG had direct experience was the European Foundation for Quality Management (EFQM) Business Excellence Model (BEM), which embraces the principles outlined above.

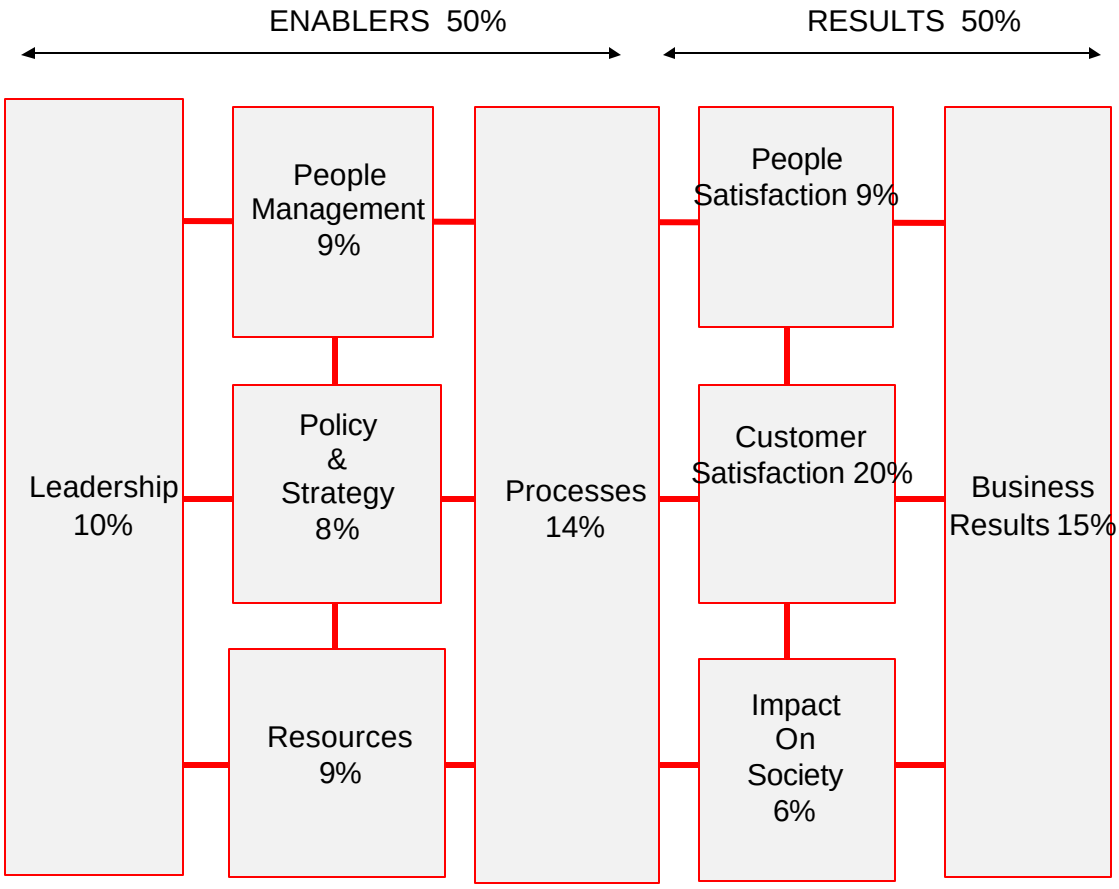


Figure 4: The EFQM Business Excellence Model (BEM)

This model is based upon a business evaluation model from the United States, the Baldridge Model, named after a US Commerce Secretary, and contains the illustrative weightings attached to each of the enablers in the model, and the consequent business results. The inclusion of this model is for illustrative purposes only, indicating an approach that is common to most models examined. A notable feature of all such models is that they can be applied at virtually any level of viewpoint, or organization boundary, and are well supported by a wide range of complementary business analysis techniques. Within the UK Defence Procurement Agency, for example, the model works in harmony with the Investors In People (IIP) standard and the Electronic Business Assessment

(eBAT) tools, each of which focuses on business improvement in specific areas of the BEM Enablers.

The MWG does not at this time make a firm recommendation on any particular model or methodology for business assessment in the Environment domain. Nonetheless, the value of the approach is self-evident, and is capable of providing indicative metrics of the environmental maturity of spheres of activity in both the government and industrial sectors at any level deemed appropriate. It may be used for comparative analysis, if so desired, though its major benefit perhaps lies in its ability to provide a platform for performance improvement. The value of the approach to NATO would, of course, be considerably enhanced if a common tool and methodology were employed, thus enabling fair comparison.

5.1.1. Resources:

Embarking on a Business Analysis should be viewed as a Change Program in its own right. Assuming that no such regime already exists within an organization, the resources required to adopt, implement and act upon the results of a common business assessment methodology are considerable. Many models are in the public domain, and therefore do not attract licensing or other ancillary costs. However, the staff and managerial resources and commitment involved may be substantial, and the assessment process itself is expensive, whether conducted as a self-assessment or externally assessed. Evidence provided to the MWG suggests that the initial costs of communicating the purpose and method of assessment alone may equal perhaps a half working day for each member of the organization to be assessed. Establishing the mechanisms to collect and collate evidence for the assessment are a further overhead and the assessment itself may well be accompanied by an extensive interview program. The costs of acting upon weaknesses exposed during the assessment will, of course, relate to the nature and severity of those weaknesses, but will invariably require some form of dedicated project-based activity. Finally, the entire exercise will require substantial and visible commitment of senior staff effort.

However, evidence provided to the MWG also suggests that the costs are very much at the front-end – that is, after the set-up costs, and once the practice of review becomes embedded in the culture of an organization, the ongoing costs for second and subsequent assessments are substantially reduced, and should, in theory, become negligible, as the evidence required to perform an assessment becomes a natural by-product of an organizations business practices.

5.1.2. Benefits:

It is impossible to specify direct business benefits which arise from employing a Business assessment tool, as these will be derived from the improvement program(s) that arise from the assessment itself. Nonetheless, the evidence provided to the MWG suggests that there are very considerable collateral benefits to be gained from simply adopting such a managerial approach, in terms of improved communication throughout organizations, and a renewed focus on the significance of relating and aligning the outputs and skills of an organizations

workforce to its strategic goals and policies. This is unsurprising, given all such models are based on the characteristics of demonstrably successful organizations. It should also be pointed out that even if an assessment were to reveal that an organization is a world-class performer, with strengths in every field examined, this would in itself be of value in pinpointing models of Best Practice.

5.1.3. The CALS Viewpoint:

Whilst the CALS community lays no claims to ownership of the management and organizational theory and practice on which these models are based, the importance of this domain to successful implementation of CALS tools and techniques is that of an organizations ability and competence to transform the data within an organization into information, and to competently manage the information itself in pursuit of its strategic goals. Until an organization achieves this level of competence, it will be unable to fully realize any investment it makes in either technology or process improvement.

5.1.4. Conclusions:

- You can not guess what your environment is, YOU HAVE to KNOW
- There are a number of well tested methods available to help
- However, you must use them to determine what is to be improved and to measure improvement
- The tool will also help identify best practices
- Use of these tools will help determine investment opportunities

5.1.5. Recommendations:

- CNAD accept that these tools are useful and will add value
- Selection of one tool would be most practical
  - Reduces learning curve
  - Standardizes measurement within NATO
  - Most easily identifies best practices
- CNAD to champion their use
- NATO should have a body of expertise for
  - Understanding and use of these tools
  - Maintaining a linkage to appropriate standards where applicable
  - Establishing appropriate bench marks
  - Serving as a repository of best practices

5.2. Applying the Model – the Technology & Infrastructure Domain:

The Technology & Infrastructure domain has the most direct relationship with the Maturity Model shown at Figure 2. It is also the most fundamental of the CALS domains. **Without some method of capturing, storing, disseminating and re-using information in a timely manner, the processes that act upon that information are inherently inefficient, no matter how well structured the organization that employs them.** It is unarguable that the basis of information capture, storage, dissemination and re-use must be digital.

There is a vast catalogue of technologies and applications available, some (particularly in the communications area) based on neutral International standards, many proprietary. Moreover, this is an almost uniquely dynamic industry, with extremely short technology cycle times, which are not aligned to customer investment cycles and decision points. These factors conspire to make the investment profile for technology and infrastructure projects extremely complex.

The MWG determined that Metrics, in this domain, can only be assessed by capability and maturity with respect to the model. Such metrics are key within a single organizational boundary, but for any form of partnership activity, at project, national or international level, it is **essential** that all partners have an understanding of shared capability and maturity. Put crudely, **where processes, and the information upon which they act, cross organizational boundaries, the efficiency and speed of those processes are dictated by the partner with the lowest technological capability.** This is the bottleneck that must be addressed.

Following the principles established for each of the domains, the MWG looked for the principle characteristics of maturity and capability. A concept that has often been used, and which complements the Maturity Model at Figure 2, is a step model of capability. This is illustrated at Figure 5.

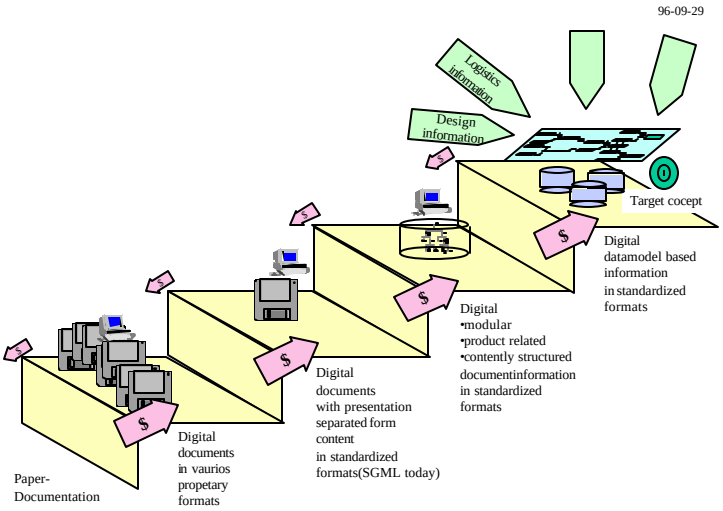


Figure 5: The Technology Development Steps

The model illustrates that there are recognizable characteristics of the progression toward the Virtual Enterprise that is the goal of the Maturity model. These may be summarized as:

- Paper based information
- Information is digital
- Digital information is exchanged
- Digital information has structure
- Standards are used
- Fully integrated secure shared digital environment – the Virtual Enterprise

The MWG determined that this progression summary, whilst crude, provides simple and powerful 'Acid-Test' metrics for this domain. There are clearly degrees of sophistication underpinning these questions – the exchange of information may be as simple as a transfer by diskette, or a dedicated, secure high-bandwidth telecommunications channel. Nonetheless, the principles are sound.

As in the other domains, the narrower the focus, the easier the task of assessment and the clearer the options available to improve any shortfalls discovered. As the focus moves out, the same Metrics apply, but will have to take account of pockets of excellence and areas of weak performance within the target viewed to form an overall view.

A particular issue to be considered will be the impact of Legacy systems on the overall result. These systems may be at a stage where it is not considered practical or cost-effective to invest in further development to improve the score on

the maturity model. If these systems are self-standing, then they may be safely excluded from the scope of assessment, or noted as a limitation on the result. However, where legacy systems form a key component of shared processes between partners then very careful consideration will need to be given to the overall impact of a decision not to invest further in the system. The investment issues behind such decisions between partners are extremely complex; it is generally difficult to justify capital investment in one business area, where the business benefit of the investment may well appear in another. Such issues are therefore likely to be a key indicator of the concept of 'partnership'. Care must be taken at this juncture to avoid sub-optimisation.

5.2.1. Security:

Whilst Security is a constraint in each of the CALS domains it most evident in the Technology domain, where the management of system security is a key design element of systems, and may result in significant escalation of costs and severe limitations in use of such systems.

The Final State Metric, which is a shared goal between governments and Industry, is predicated on the assumption that these security issues can be overcome. However, it must be recognized that the nature of the business of NATO, national Defense Ministries and Departments, and the Defense Industry itself pose extreme difficulties. It is hard to conceive of any other sphere of activity where the requirements of national security and commercial confidentiality coincide to such an extent.

Security per-se is not within the CALS domain although it must be considered in all aspects of information creation, storage and use. CALS can assist projects by pointing to products that satisfy national security requirements, and the national authorities that assess and accredit system design and implementation. However, the ownership of technical security policy in most cases lies outside of defense ministries. Moreover, the basis of security policy is, in many instances, enshrined in national constitutions and supporting legislation. A CALS viewpoint can certainly help to focus the debate and the need for change and harmonization throughout the NATO alliance in support of strategic goals.

One specific instance is the stated aim of 'reducing the logistics footprint'. One of the key enablers which has already been identified in meeting this goal is the increased integration of civilian components into the operational logistics environment, principally by adopting the 'factory to foxhole' concept. This would mean, in effect, that industry would subsume many of the consumer logistics functions in a stabilized theatre of operations at the earliest possible stage, thus reducing the military burden. However, this implies reliable and secure communications across which information flows could pass into industrial processes within nations. This would mean that either secure military communications would have to be extended to civilian components for the duration of an operation (requiring a substantial spare bandwidth capacity and a set of dual processes within Industry), or that industry builds its processes and information management mechanisms on a secure and deployable

communications network. Either of these options suggests a significant cost and technical overhead.

There are several bodies within NATO and within nations working these issues and the CALS community would wish to assist in the debate at any and all appropriate levels.

5.2.2. Resources:

The assessment of technological and infrastructure maturity is a key factor in deciding the ability of an organization to operate efficient processes. At an individual project level, the NATO CALS community offers products and assistance to help focus the relationship between project information management needs and the technology and infrastructure required to support those needs. This assistance includes selecting appropriate technologies, creating business cases to support investment, and employing/contracting against appropriate technical standards.

As the focus moves out to a wider level, the same CALS principles apply: however, the complexity and scale of analysis, the investment required, and the number of stakeholders involved, expand dramatically

5.2.3. Conclusions:

- The Technology and Infrastructure domain represents the basic building block of military/industrial capability for through-life information management
- This domain is a key enabler of partnership activity.
- There is increasing pressure to extend this domain into the operational environment
- There is no central focus for this within NATO, although there are numerous activities looking at pieces of this issue.
- Without a central focus, there is a danger of building isolated islands of incompatible architectures
- Maturity and capability are the key metrics that should be established
- The CALS community offers significant practical assistance and tools to develop capability at the project and program level
- There is a significant change in effort and resources required when applied at the national and international level.
- National Security and commercial confidentiality are major constraints on this domain, and need further analysis. This is beyond the scope of this project.

5.2.4. Recommendations:

- Support the maturity analysis process
  - Initially at the project/program level
  - Champion at the national and international level
- Establish a central group for Technology and Infrastructure with a focus on augment existing work efforts

5.3. Applying the Model – The Process Domain:

The Process domain represents the 'cutting edge' of capability, as it is the area where capability manifests itself in tangible business and strategic outputs and outcomes. There has been considerable investment in modelling processes to enable a shared understanding of their input, output and efficiency. One such model, which is highly relevant to NATO, is ISO 15288, which has been recommended by the Life-Cycle Working Group (LCWG). This model recognises the importance of process to life cycle information management. The MWG determined that this approach is wholly consistent with its approach to the other CALS domains, and that the same principles of maturity and capability apply.

The ISO model is predicated on the principle that there are key processes running concurrently throughout the life cycle of all Defense systems, and that the activities and outcomes of these processes can be described from the key stakeholder viewpoint of these processes. Whilst the MWG recognized the importance of this approach, it needed to develop the model (shown at Figure 3) to reconcile the process approach with a more traditional time or phase-based approach for describing the life cycle. This clarified both the importance and role metrics plays in planning and measuring transition from a current position to a desired outcome. The MWG also determined that, from a CALS perspective, the greatest end-user benefit was to be gained by assisting in focusing investment through time. In a resource-limited world, investment (particularly in technology) is invariably incremental, in that capability is added as it becomes essential to the efficient management or use of the defense system to which it is applied. The MWG sought a method to reconcile potentially conflicting stakeholder viewpoints and investment demands by ***focusing on agreed goals (or outcomes) through time.*** This focus will determine the combination(s) of technology and process that are most likely to achieve a successful achievement of a shared goal.

The MWG placed the concurrent processes within ISO 15288 against a generic phase model (AAP-20 – PAPS) to determine the key metric for that phase. For example, the key metric during the Concept phase is the time needed to finalize a decision to proceed against an operational or design concept. ISO 15288 argues convincingly that some element or degree of each of the core processes that it identifies will operate in this phase, but clearly some processes will be more dominant than others, and some stakeholders will 'own' more of these processes than others through time. A combination of stakeholder analysis (a ranking of interest) and objective setting (time to decision point) will determine the tools and technologies which are most likely to deliver the objective.

Figure 6 demonstrates this concept, using a simple Traffic Light system for the relative importance of process within a phase (Red being most important, Green least). This analysis indicates those technologies and tools that provide the greatest level of support to these key processes. This does not suggest that this is an exhaustive list of the tools and technologies available that are relevant to this phase, to the identified processes, or to the stakeholders. Nor does it argue that there is no business benefit to be gained from wider investment. The aim of the analysis is to prioritise investment where contention for resources exists.

Process	CALS Functionality	Metric
Requirements Definition Architectural Design Operate Maintain/Repair/Upgrade Supply Dispose Deployment & Evaluation I V & V Procurement Plans Integraton Life Cycle Cost Management Risk Management Configuration Management Information Management	Requirement Management Tool ?? Reduce time to Decision ?? Recuce Cost to Decision ?? Improved Impact Analysis ?? Improved Use, Maint, support Document Management Web Enabling Tools	Time to achieve Design Choice

Figure 6: Process/Stakeholder Analysis – Concept Stage

As a project or program moves through phases, the relative importance of process will change, and the richness of technology (and thus investment choices) available to support those processes will expand. The range of indicative metrics, or characteristics, which might be selected as shared goals, will also expand. **Figure 7** illustrates how these choices are likely to change as a weapon system enters into service.

Process	CALS Functionality	Metric
Requirements Definition Architectural Design Operate Maintain/Repair/Upgrade Supply Dispose Deployment & Evaluation I V & V Procurement Plans Integraton Life Cycle Cost Management Risk Management Configuration Management Information Management	Requirement Management Tool ?? Reduce time to Decision ?? Recuce Cost to Decision ?? Improved Impact Analysis ?? Improved Use, Maint, support Docum ent Management Web Enabling Tools Configuration Management Enterprise Resource Mgmt Procuct Data Management IETM/IETP	Reduce Log Sustainement Reduced Scrap and Rework Costs Reduced Maintenance Actions Improved Support Actions Improved Availability Reduced Lead Time ??ALT (Administration) ??PALT (Production) ??PALT (Procurement)

Figure 7: Process/Stakeholder Analysis – Sustainment Phase

Using data supplied by current projects, the MWG was able to establish a direct causal relationship between the deployment of technology and specific performance metrics. Figure 8 shows contractual Performance and Sustainment

Metrics from the F-117 program, which monitor data held in shared government and industry systems.

Total System Performance Requirements

Fiscal Year	NMCS	MICAP Delivery	RSP Kits	Depot Delivery	Depot Quality	Late DRs	WST	Total
Total Pts Available	250	150	150	150	150	100	50	1,000
93*	0	150	150	150	135	100	50	735
94*	175	150	150	150	135	100	50	910
95*	150	150	150	120	175	100	50	855
96*	250	150	150	120	135	100	50	955
97	250	150	150	90	135	100	50	925
98	250	150	150	90	120	100	50	910
99 (Oct-Jul)	250	150	150	150	150	100	50	1000

Performance Metrics

FY98	STD	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Sep-98
MC Rate (%)	80	Y	Y	Y	Y	Y	Y	G	G	G	Y	Y	G	82.9
NMCS Rate (%)	5	G	G	Y	G	Y	Y	G	G	G	G	G	G	5.4
MICAP Delivery (Hrs)	72	G	G	Y	G	G	G	G	G	Y	G	G	G	43.5
RSP Fill Rate (%)	96	G	G	G	G	G	G	G	G	G	G	G	G	98.0
Depot Delivery (Days)	1	R											G	0
Depot Quality (Disc)	4:10	G											G	3:8
DR Response (#)	1	G	G	G	G	G	G	G	G	G	G	G	G	0
WST Availability (%)	99	G	G	G	G	G	G	G	G	G	G	G	G	99.6
Spare Engines (#)	9	G	G	G	G	G	G	G	G	G	G	G	G	12

Sustainment Metrics

FY99	STD	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Jul-99
MC Rate (%)	80	G	G	G	G	G	G	Y	Y	G	G			86.0
NMCS Rate (%)	5	G	G	G	G	G	G	G	G	G	G			2.2
MICAP Delivery (Hrs)	72	G	G	G	G	G	G	G	G	G	G			33.9
RSP Fill Rate (%)	96	G	G	G	G	G	G	G	G	G	G			98.7
Depot Delivery (Days)	1	G	G	G	G	G	G	G	G	G	G			0
Depot Quality (Disc)	4:10	G	G	G	G	G	G	G	G	G	G			3:0
DR Response (#)	1	G	G	G	G	G	G	G	G	G	G			0
WST Availability (%)	99	G	G	G	G	G	G	G	G	G	G			99.8
Spare Engines (#)	9	G	G	G	G	G	G	G	G	G	G			10

Figure 8: F-117 program – Performance & Sustainment Metrics

5.3.1. Scalability:

This approach is most easily applied and proven at an individual project level, where performance metrics are specific and predictive. The principles of this approach can be applied at higher levels of viewpoint although the granularity of these metrics are likely to be lower and indicative rather than predictive. However, absent other means, this is potentially a very powerful approach to providing an investment framework.

5.3.2. The CALS Viewpoint:

The LCWG is currently developing and staffing the concepts of ISO 15288 to the requirements of the NATO emphasis on Through Life management of Defense system information. The MWG has developed an outline concept and model that provides metrics that are aligned to these emerging concepts. However, because of the importance of stakeholder analysis in the developing model, there has not been sufficient time to staff the approach through other interested NATO bodies. Nor has the MWG gathered a broad enough range of supporting empirical evidence from projects and industry to prove that the model is sufficiently robust in its current state of development. Nonetheless, there has

been considerable interest from other NATO groups (e.g. SILCEP) in assis ting development of the model and validating it with empirical evidence.

5.3.3. Resources:

It is essential that hard data be gathered from existing projects to validate the model. During the course of its activity, the MWG issued requests on nations and industry to provide information, but the result was disappointing. The responses received revealed that further work would be necessary to develop questionnaires that would minimize the information demands on industry and projects, and that some effort would be required to provide an effective analysis of the responses. This will require some specific professional assistance, particularly in the areas of questionnaire design and statistical analysis.

There is considerable data available in the public domain that supports further development of the model, but again will require some professional assistance to analyze effectively. If properly designed, any future information calls on both nations and industry should be readily answered from existing data.

5.3.4. Using The Model:

An illustrative example, with metrics, is at ***Annex A.***

5.3.5. Conclusions:

- The most direct business benefit is found in the process domain.
- The most direct link between investment and outcome is in this domain.
- The CNAD sponsored LCWG has taken the ISO 15288 as the model for defense system life cycle processes.
- The MWG have developed a complementary model that reconciles process against time providing indicative metrics and focused investment.
- The MWG attempted to validate the model using data from existing projects. This needs further work and consultation.
- Professional assistance is needed (e.g. statisticians) to make best use of publicly available information, and to minimize the impact of any further call for information on projects and from industry.

5.3.6. Recommendations:

- Support the process domain model
- Agree it should be further developed within NATO
- Support the need for professional assistance in data analysis
- Champion at the national and international level
- Assign responsib ility to a central group

6. SUMMARY:

As directed by the CNAD the Metrics Working Group (MWG), has defined end state metrics for CALS. The MWG also identified performance metrics that can provide an objective evaluation of the impact and value of CALS tools and techniques within NATO defense activities. The MWG, comprising NCMB, NCO and industry members, has established that there are 3 domains in which CALS operates and where these metrics apply:

- Environment
- Technology & Infrastructure
- Process

The strength and value of CALS lies in defense system life cycle information management and its impact on these domains.

The term 'metric' measures the impact of applying CALS tools and techniques in each of these domains. Different techniques apply to each domain, yet each has a common approach of determining the maturity and capability of the subject by using indicative or predictive levels of performance.

The MWG also wished to ensure that the application of metrics would be scalable, so that a common approach could be used at project, program, national and international levels. The granularity of these metrics should be appropriate to the viewpoint and needs of the stakeholder.

The MWG took the emerging recommendations of the CNAD-sponsored Life Cycle Working Group and other groups as a constraint on its activities, to ensure that the findings of the MWG are consistent and complementary to those of the other groups.

The key source standard is ISO 15288, a process-centered view of the management of defense systems. The MWG has developed a model, which reconciles this emerging process viewpoint with more traditional time and phase-based views of the equipment life cycle.

For each domain, the MWG has provided indicative and/or predictive metrics against the developed framework, and has made recommendations on the likely resources that will be required to complete the model.

The MWG concludes that the fully developed model will be of significant assistance in prioritizing investment to improve the performance of organizations at a number of levels, and in assessing the capabilities of candidate partners.

7. RECOMMENDATIONS:

- CNAD accept this report and close out the task
- CNAD recognize and sponsor the remaining work identified in this report.
- CNAD assign responsibility for this work to a central group.

A. ILLUSTRATIVE METRICS - APPLYING THE MODEL

The purpose of establishing and tracking metrics is to provide a means of evaluating how well a particular activity or process is performing against a set criterion. This necessarily implies that the desired output or outcome is clearly defined, is measurable, and has an unambiguous stated value to be achieved.

A process or activity is based upon a set of inputs and a change mechanism leading to one or more desired outputs. The process or activity of interest must be fully understood before practical and useful metrics can be established. All processes or activities have a limit as to what can be achieved when operating optimally. In quality terms this is referred to as "The process being in control" and this can usually be measured. Once the process owner has determined what his/her process or activity is capable of delivering, then he/she must decide if this is acceptable. If it is acceptable then the task is to monitor via metrics to make sure it stays in control. If this is unacceptable then the process or activity necessarily must be reengineered to improve performance. This is usually when technology is introduced.

It is up to each individual, business entity, organisation or nation to determine what they are trying to achieve and then design a set of measures to validate their objective.

Thus far the concept of how metrics can validate the achievement of NATO's strategic objectives for improved defence system availability while saving time, reducing costs and improving quality has been examined. This will be further developed by an example.

The example below assumes that, based on a sound business case, NATO has decided to digitise its core business processes for Defence system life cycle acquisition and support.

To accomplish this, the format described in this paper will be used to develop 3 sets of metrics: 1) Environment; 2) Technology; 3) Process. This example will only develop a high level subset of metrics in order to demonstrate the process. As previously stated each nation does business their way and will have to develop their particular set of metrics to the degree necessary to meets their individual needs. Likewise, joint projects and programs will have to agree to a set of metrics that meets the specific need.

A.1. Scenario:

Based upon an analysis of current activity NATO has determined that it needs a program of Business Process Improvement. In order to meet its strategic objectives of improving efficiency and effectiveness while at the same time reducing time, cost and improving quality, NATO has decided to issue a policy to digitise the entire Defence System Life Cycle process by the end of 2005. The following steps will be taken:

- ?? issue Policy
- ?? develop Strategy
- ?? produce Implementation plan
- ?? define Milestones
- ?? establish metrics

A.2. Project Plan:

Objective	Procedure	Metric
Digitise DS LC functions	Policy	Yes/No
?? Digitise all DS Acquisition functions by 2005	Strategy	Yes/No
?? Digitise contracting function	Plan	Yes/No
?? Payment and accounting	Plan	Yes/No
?? EC/EDI	Milestones	Yes/No
?? EFT	Milestones	Yes/No
?? Etc.	Milestones	Yes/No
?? Contractor Selection	Plan	Yes/No
?? Contract Writing	Plan	Yes/No
?? Contractor Administration	Plan	Yes/No
?? Auditing	Plan/	Yes/No
?? Contract Reconciliation	Plan	Yes/No
?? Close out	Plan/	Yes/No
?? Digitise Material handling function by 2005	Strategy	Yes/No
	Plan/	Yes/No
Decompose		
?? Digitise Maintenance and Repair function by 2005	Strategy	Yes/No
	Plan	Yes/No
Decompose		

The above matrix is designed to demonstrate a structured approach to introducing business process change. While this change is being implemented, a set of metrics needs to be established which measures the degree of improvement resulting from moving from the AS-IS to a TO-BE environment.

A.3. Macro Level Metrics

Metrics must address all areas of the business environment in order to assess the overall business impact when change is introduced. To avoid sup-optimisation, a business needs managerial targets and control metrics, which provide a functional view as well as a process view. To fully assess the impact of change, it must be measured from the top to the bottom of the organisation. Very large organisations (Service, National, and International) may require several level of metrics to support effective management. The next matrix is designed to illustrate some top-level managerial metrics.

NATO/Nation/Service	Environments	Technology	Process	Metric
Resources	**Available Skills** ?? Needs assessment **Training** ?? Computer skills ?? Web Tools ?? Office Tools ?? Process Analysis ?? Teaming ?? Job Competency Compensation ?? Salary ?? Benefits ?? Work Environment ?? Career Structure			?? Recruitment ?? Retention ?? Training Targets ?? Applicability ?? Timelines ?? Number people trained ?? Bench Marking ?? Relevant range assessment ?? Competitiveness

NATO/Nation/Service	Environments	Technology	Process	Metric
Infrastructure		**Infrastructure** ?? Computer Systems ?? Networks ?? Intra/inter net ?? Web enabled ?? Products ?? Office ?? Web Browsers ?? Data Base ?? Document Mgmt ?? Work Flow		?? Benchmark ?? Technology cycle ?? Investment cycle ?? Deployed capital cost ?? Deployed running cost

NATO/Nation/Service	Environments	Technology	Process	Metric
Business Functional Area			?? End Item Acquisition ?? Contracting ?? RFPs ?? SOWs ?? Inquiries **Procurement** ?? Proc Lead Time ?? Order Automated ?? Direct Vendor Delivery ?? Prime Vendors ?? Customer Satisfaction **Support** ?? TAV/Asset Availability ?? Avg. RCT ?? Inventory level ?? JIT Delivery ?? Automated Warehousing ?? Bar coding selection, shipping, handling, reordering ?? Automated ECPs ?? Items meeting predicted ?? performance ?? Customer Satisfaction ?? Etc	?? Benchmark ?? Degree of automation ?? Government ?? Industry ?? Benchmark ?? Degree of automation ?? Time ?? Cost ?? Scrap and rework ?? Benchmark ?? Degree of automation ?? Time ?? Cost ?? Scrap and Rework

A.4. Program/Project Level Metrics

The next level of metrics focuses on how well an activity is performing against its designed objectives of consistently providing top quality products in the shortest possible time and at the most economical cost to the customer. It is self-evident that these metrics should be appropriate to the activity examined, whilst supporting the overall managerial targets and metrics outlined above.

Phase	Environments	Technology	Process	Metric
Requirements Definition				**Total Time**
	Integrated Project Team ?? Focused expertise ?? Shared goals ?? Improved Communication ?? Stake holder interest ?? Security environment ?? Policy compliance ?? Performance measurement			?? Time ?? Scrap and rework ?? Resources
		Digital environment ?? WEB Enabled ?? Document Management ?? Requirement Mgmt Sys ?? Security Management		?? Time ?? Scrap and rework ?? Resources
			Develop Requirement ?? Configuration Control ?? Concurrent review ?? Approval	?? Time ?? Scrap and rework ?? Resources

Phase	Environments	Technology	Process	Metric
Design & Develop				**Time, cost, quality**
	Integrated Product teams ?? Focused expertise ?? Shared goals ?? Improved Communication ?? Stake holder interest ?? Security environment ?? Policy compliance ?? Performance measurement			?? Time ?? Cost ?? Scrap and rework ?? Policy compliance
		Digital environment ?? WEB Enabled ?? Document Management ?? Requirement Mgmt Sys ?? Finance ?? CAx ?? Simulation/Synthetic Environment ?? Configuration ?? PDM ?? ERP ?? Agreed Stds ?? Security management ?? CITIS		?? Policy compliance ?? Availability ?? Degree of Use

Phase	Environments	Technology	Process	Metric
			System Design ?? Requirement Compliance ?? Performance ?? Support ?? Maintenance ?? Contract compliance and Audit ?? Financial mgt ?? Configuration Control ?? Change Management ?? Concurrent review and Approval	Time ?? Design ?? Develop Cost ?? Resources ?? People ?? Space ?? Equipment ?? Physical prototypes Quality ?? Ease of Build ?? Scrap and rework ?? Maintainability and Supportability (Predicted) ?? IETMS ?? MTTR ?? MTBF ?? Availability ?? IETMS ?? MTTR ?? MTBF

Phase	Environments	Technology	Process	Metric
Build				**Time, cost, quality**
	Integrated Project Team ?? Focused expertise ?? Shared goals ?? Improved Communication ?? Stake holder interest ?? Security environment ?? Policy compliance ?? Performance measurement ?? Benchmarking ?? CPI			?? Time ?? Cost ?? Resources ?? Effectiveness ?? Efficiency
		Digital environment ?? WEB Enabled ?? Document Management ?? Requirement Mgmt Sys ?? Cax ?? IETMs/BIT/BITE ?? Configuration Ctrl ?? PDM ?? ERP ?? MRP/MRP II ?? Production Control ?? Finance ?? Agreed Stds ?? Security management ?? CITIS		?? Time ?? Cost ?? Scrap and rework ?? Resources

Phase	Environments	Technology	Process	Metric
			System Manufacture ?? Contract compliance and Audit ?? Performance ?? Schedule ?? Cost ?? Financial Mgt ?? Configuration Control ?? Change Management ?? Production control ?? Concurrent review and Approval ?? Verification/validation	Time ?? Manufacture Cost ?? Resources ?? People ?? Space ?? Equipment ?? Delivery Quality ?? Acceptance ?? Scrap and rework ?? Maintainability and Supportability (Tested) ?? IETMS ?? MTTR ?? MTBF ?? Availability (Tested) ?? IETMS ?? MTTR ?? MTBF (Tested)

Phase	Environments	Technology	Process	Metric
Operate/Maintain/ Support				Time, cost, quality, availability, logistics footprint
	Integrated Project Team ?? Focused expertise ?? Shared goals ?? Improved Communication ?? Stakeholder interest ?? Security environment ?? Policy compliance ?? Performance measurement ?? Benchmarking ?? CPI			?? Time ?? Resources ?? Effectiveness ?? Efficiency

Phase	Environments	Technology	Process	Metric
		Digital environment ?? WEB Enabled ?? Document Management ?? Requirement Mgmt Sys ?? CAx ?? Configuration ?? PDM ?? ERP ?? Production Control ?? Finance ?? Agreed Stds ?? Security management ?? CITIS ?? Maintenance Support ?? MRP ?? Asset Tracking ?? Inventory Ctrl ?? Base level turn ?? Intermediate level turn ?? Depot level turn ?? Inventory control		?? Time ?? Scrap and rework ?? Resources

Phase	Environments	Technology	Process	Metric
			Operations, Maintenance, & Support ?? Tech Info Mgmt ?? Base, Intermediate, Depot Repair ?? Material Management ?? Procurement ?? Contract compliance and Audit ?? Performance ?? Schedule ?? Cost ?? Shipping and handling ?? System Support Engineering ?? Configuration Control ?? Change Management ?? Concurrent review and Approval ?? Verification/validation ?? Financial Mgt	?? Time ?? Availability ?? MTBF ?? MTBR ?? MTTR ?? MTBMA ?? MTBD ?? Maintainability ?? TRCT ?? Materiel Management ?? Inventory Mgmt ?? % JIT ?? Procurement lead time ?? TAV ?? Order, ship, handling ?? Resources ?? People ?? Space ?? Inventory levels ?? Delivery ?? Quality ?? Acceptance(Contracted) ?? Scrap and rework ?? Maintainability & Supportability