A BUSINESS GOAL-BASED APPROACH TO ACHIEVING SYSTEMS ENGINEERING CAPABILITY MATURITY

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Using organization strategic objectives, business goals, and current significant problems to structure and prioritize process improvement programs enlists support from the people most affected by the improvements, as opposed to resistance to "just another initiative." This is because they see work being done to solve their immediate problems. This approach is implemented using five key questions:

- **MOTIVE** - Why change? What are the critical business issues driving process improvement?
- **MODEL** – Which reference model best maps to the organization practices?
- **METHOD** – How you can quickly and effectively identify improvement opportunities?
- **MANAGING CHANGE** – What factors impact the effectiveness of introduced changes?
- **MEASURES** – What are critical factors in setting up a measurement program?

The General Change Model

Change drivers are the catalyst for change. They push us out of our comfort zone and reveal an opportunity, need, discomfort, or pain that must be addressed. They may be problems with the way things are. Or they may be opportunities that, for the sake of the organization's future survival, cannot be ignored. They must be defined, understood, and provide a compelling business case for the organization. They must enable organization members to believe that what they want is more important than what they already have, and that upsetting the status quo is preferable to no action.

The change drivers help an organization understand and define an organizational response to the critical question of "Why change?" Typical change drivers might be declining market share, reduced profits, increasing personnel turnover, or new technologies which threaten existing products. Or an organization may just have a feeling that things need to improve in order for them to remain competitive. The change model involves an understanding of the present state, a vision of the desired state, and a process for transitioning from the present to the future.

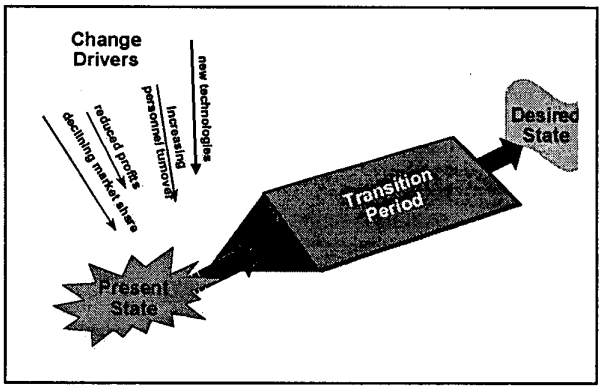

Figure 1. The General Change Model

MOTIVE - What Are The Critical Business Issues Driving Process Improvement?

Top Down – Setting Direction Based on Strategic Objectives

Strategic objectives are the critical "market drivers," those factors which ultimately determine organizational success or failure. Business leaders determine critical business drivers and associated strategic objectives to answer the question, "What do we want to achieve as an organization?" Typical strategic objectives are market share/time to market, revenue growth/profit growth, and company image as a reliable, cost-effective, value-adding supplier.

Business purposes focus on activities that the organization performs to achieve the strategic objectives. Purposes supporting the strategic objectives can be derived by addressing operational issues such as predictability (cost, schedule, capability, quality), amount of rework, customer

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satisfaction, cycle time, and employee satisfaction/reduced turnover. Department leaders identify business purposes and goals which support the strategic objectives. Key questions to ask at this point are "What do you want the process improvement program to accomplish? How will you determine if it has been successful?"

Process goals supporting the business purposes can then be derived which address more precisely defined issues. Example goals are understanding and controlling customer requirements, developing realistic plans, accurately tracking progress in order to take corrective action when there are deviations from plans, collecting historical data, and minimizing defects in deliverables. Technical and process leaders document process goals that support the business purposes. These are reviewed and approved by the appropriate business and department leaders.

Key indicators to help determine whether the process goals are being accomplished can then be derived. Typical measures include planned vs. actual (xxx), defect rate, amount of rework (quantity or cost), and productivity measurements. Technical and process leaders determine key indicators that measure progress against the goals. These are reviewed and approved by the appropriate business and department leaders.

Table 1 provides some examples of how process goals and key indicators can be related to business purposes and strategic objectives.

Table 1. Relating Process Goals and Key Indicators to Strategic Objectives

Strategic Objectives	Business Purposes	Process Goals	Key Indicators
Profit growth	Reduce cost Increase predictability (cost, schedule, capability, quality)	Develop realistic plans Track progress, take corrective action Collect historical data	Productivity Expenditure rates Planned vs. actual cost, effort, schedule
Market share, time to market	Reduce cycle time	Reduce rework Minimize defects	Amount of rework Elapsed time Defect rate

Bottom Up – Setting Direction Based on Organization "Pains"

Alternatively, or in concert with the top-down approach, an organization should determine its most significant problems – where its greatest "pains" are. This can be done a number of different ways. Typically, technical leaders and process owners meet with users to identify significant problems which impact operations and/or business results. Leaders and users then brainstorm possible remedies to address the pains. Process owners identify related process changes based on the proposed remedies. These proposed changes then serve as the basis of action plans to address the identified pains. Pains can also be identified using one of the reduced-scope assessment methods, which will be discussed later.

Integrating the Two Approaches to Develop a Vision of the Desired State

By considering the change drivers in concert with the organization strategic objectives and "pains" one can develop a vision of the desired state, what the organization should look like and how it should behave after the desired changes are achieved.

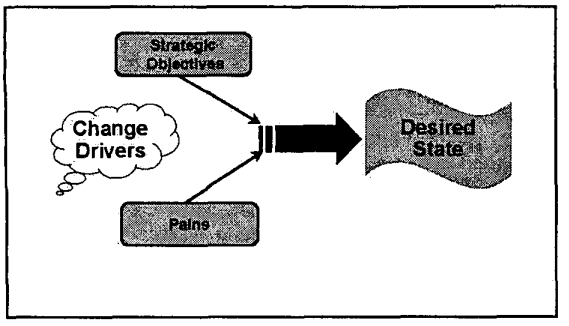

Figure 2. Envisioning the Desired State

For example, a small industry-leading company doing web-site development was experiencing rapid growth, and as a result had several problems:

- Schedules and budgets, not based on realistic estimates, were routinely exceeded.
- Schedule, cost, and design/code readiness could not be predicted.
- Resources were poorly utilized.
- Testing was inadequate.
- There was a high incidence of software defects.
- Product functionality and quality were sometimes compromised to meet schedule.
- There was no objective basis for judging product quality.

The company wanted to address these problems through a series of initiatives to improve:

- product/delivery standards,
- time-to-market,
- communications,
- internal training,
- resource utilization.

Combining a detailed list of "pains" with organization strategic initiatives enabled the organization to envision a desired state:

- Processes are documented, usable and consistent.
- Schedules and budgets are based on historical performance and are realistic.
- Expected results for cost, schedule, functionality and product quality are usually achieved.
- Disciplined processes are followed consistently because all participants understand their value.
- Broad-scale, active involvement across the organization in improvement activities.
- Roles and responsibilities are clear.

This process provided the organization with some clear direction to help it determine an appropriate model and assessment method to use, and some things to consider in developing a change methodology and appropriate measures to put in place.

MODEL - Which Reference Model Best Maps To The Organization Practices?

There are at least three reasons to use a reference model in structuring a process improvement program. A model provides:

- a language and constructs with which to communicate about process issues,
- a standard of comparison and benchmark to evaluate process "goodness,"
- process improvement investment guidance.

A model can also serve as a source of ideas for good practices. There are many improvement or process models available which are intended to address an organization's critical issues. Selection of the most appropriate model to support the organization's strategic objectives and business purpose is important. Two key issues in selecting a model are its **domain** and its **architecture**.

Model Domains

The **domain** of a model refers to the system whose order and effectiveness are to be improved. There are numerous models crafted to focus on the critical aspects of various domains, including software, system engineering, system acquisition, people issues, software integrity, etc. Example models are the:

- Software CMM®,
- Systems Engineering CMM®,
- Integrated CMM (CMMI[SM])
- People CMM®,
- System Acquisition CMM®

Model Architecture

The **architecture** of a model refers to its underlying structure and the relationship of maturity levels and process areas. A staged model (Figure 3) has specific Process Areas (PA's) that are associated with distinct maturity levels. For example, in the Software CMM, Requirements Management is a Maturity Level 2 PA, while the Peer Reviews PA is Level 3. These PA's are often referred to as Key Process Areas to emphasize the fact that the model is not comprehensive, but focuses on a few critical issues.

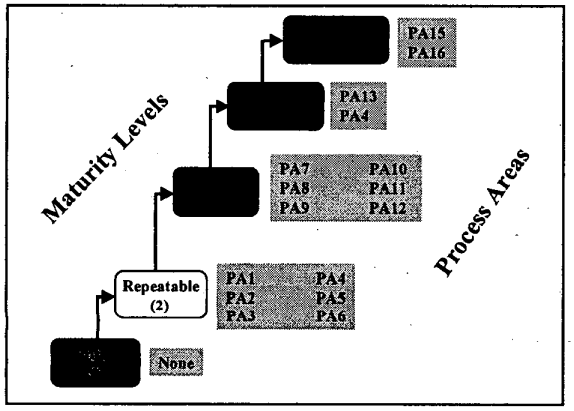

Figure 3. Staged Architecture

In contrast to the staged architecture, a continuous model (Figure 4) has Capability Levels within PA's. In the Systems Engineering CMM, for example, each of the Process Areas, such as Derive and Allocate Requirements or Integrate

the System, has within it the Capability Levels of:

- Not Performed (Level 0),
- Performed Informally (Level 1),
- Planned and Tracked (Level 2),
- Well Defined (Level 3),
- Quantitatively Controlled (Level 4), and
- Continuously Improving (Level 5).

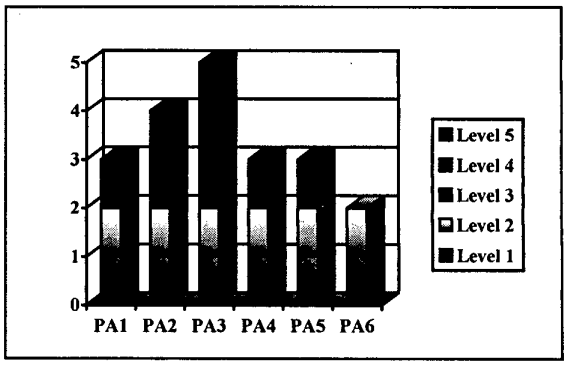

Figure 4. Continuous Architecture

The Integrated CMM (CMMI[SM]) is structured so that its content can be represented in either a staged or a continuous version.

The continuous architecture has the advantage of providing a fairly well defined improvement path for a specific PA. However, if you have a large number of process areas, it becomes more difficult to provide guidance to an organization which is attempting to rationally allocate limited improvement resources across the PA's. Do you focus on a few, or try to maintain uniformity of maturity levels across PA's, or use some hybrid approach? This question needs to be answered in the context of the organization's business goals and objectives.

The advantage of the staged architecture is that the organizational improvement path is well defined in terms of which PA's need attention first. (However, there may be valid business reasons to modify that recommended path.) The Maturity Level 2 PA's focus on getting documented processes in place at the project level. Maturity Level 3 provides a framework of standard processes for leveraging best practices across the organization. Maturity Levels 4 and 5 focus on detailed process and product metrics for control and improvement.

Choosing a Model

So how does all the above relate to selecting a reference model? First of all, you need to define the *domain*. What are the critical issues and areas you want to address? What are the Process Areas important to that domain? Don't try to be 100% correct in your model. If the model addresses 60-80% of the organization's critical issues you've done fairly well.

Next, which *model architecture* best fits your objectives? The architecture will probably be pretty well determined by which model you choose, unless you are developing a custom model or using the CMMI[SM] which allows you to choose the architecture. If you need a pretty well defined roadmap, try to use a model with the staged architecture. If you're more interested in seeing how your processes look across the board, or focusing on just a few processes, use a model with a continuous architecture.

But most importantly, don't get hung up with the Levels. Your main goal should be to improve processes, so select and use a model which maps well to your critical processes, and use it to help you determine where your organization may have some improvement opportunities.

METHOD - How You Can Quickly And Effectively Identify Improvement Opportunities?

After selecting a model it's necessary to decide how the organization will assess its conformance to the model parameters, in order to quickly and effectively identify improvement opportunities. There are various assessment methods available, ranging from less costly techniques such as a self-assessment, Interim Profile[SM] and mini-assessment to a full-blown CBA-IPI (CMM-Based Appraisal for Internal Process Improvement), SCE[SM] (Software Capability Evaluation), or SCAMPI[SM] (Standard CMMI Assessment Method for Process Improvement).

Key issues to consider in choosing an assessment method are assessment objectives and desired outputs, accuracy of the results, cost to prepare for and conduct the assessment, and extent of organization disruption.

Assessment Objectives and Outputs

Assessment Objectives

Any assessment has at least two objectives:

- Gather accurate data in an efficient, minimally disruptive way.
- Help to identify and prioritize improvement opportunities.

These objectives can be achieved in a number of different ways, with varying degrees of cost and accuracy. Sometimes a third objective is appropriate:

- Signal to the organization that a new way of life is beginning.

This third objective is particularly applicable when the organization wants to institute a change in its culture, its customary way of doing things. In this case disruption is good.

Assessment Outputs

Most assessments have two major categories of outputs: findings and recommendations.

Findings

- Provide an accurate picture of processes, using the Capability Maturity Model® (or other reference model) as a framework.

Recommendations

- Provide guidance on process improvement activities appropriate to the current state of the organization's process.
- Provide a framework and catalyst for action.
- Build ownership of results.
- Develop organizational commitment and energy.
- Sustain sponsorship and establish commitment.
- Facilitate continued process improvement.

Assessment Methods

A CMM self-assessment is used to educate the organization on the model and to begin to identify areas for improvement. The procedure can be administered in about one-half day and provides scores by Process Area Goal, based on the understanding of the participants involved. It is based on a detailed survey that is administered by the deploying organization. Accuracy tends to be low. As the organization becomes more familiar with the CMM® and undergoes more intensive assessments, accuracy generally increases. Cost and organization disruption are fairly low.

A Mentored Self-Assessment (MSA) requires a trained and experienced MSA Leader from outside the organization. He provides CMM

training and administers a CMM Self-Assessment in a group setting with selected organization members. The purpose of the mentored self-assessment is to ensure that an organization understands the meaning and intent of the CMM, and to provide an independent validation of the self-assessment results. Accuracy tends to be fair, with the cost and organization disruption being low.

Interim Profile[SM] is a Maturity Questionnaire (MQ) based technique [1]. After initial logistics and setup, the MQ is administered to a majority of project/organization members. The data are collected, analyzed, and summarized into a set of initial project profiles which are reviewed by project members. An organization profile is then created and distributed, and feedback on the process obtained. An Interim Profile is used to check the status of progress improvement efforts between assessments. It is not recommended as an initial assessment. Accuracy, cost and disruption are similar to an MSA.

A CMM mini-assessment is a reduced-scale modification of the CBA-IPI where two (or more) trained and experienced assessors from outside the organization review the documented processes and implementation evidence and conduct several group interviews. The purpose of the mini-assessment is to provide an independent verification of self-assessment results and to provide suggestions for improvements based on an independent review. Accuracy is fairly good for mini-assessments. Cost of assessment preparation and conduct and organization disruption are moderate.

A CMM Based Appraisal for Internal Process Improvement (CBA-IPI)[SM] is conducted according to an SEI-defined process [2]. Because of the considerable cost associated with formal assessments, they must be scheduled to provide maximum benefit to the organization. The normal output of a CBA-IPI is a findings briefing which includes KPA strengths and weaknesses, and Goal/KPA/Maturity Level satisfaction. Accuracy is generally good; preparation and conduct cost and organization disruption tend to be fairly high. The disruption can work to the organization's advantage by communicating that this is a significant event in the life of the organization, and the start of a new way of doing business.

A Software Capability Evaluation (SCE)[SM] is similar to a CBA-IPI, except that all the team members come from outside the organization being evaluated [3]. A SCE typically costs about the same as a CBA-IPI of similar scope. It is often used by government agencies or other entities desiring to assess the risk of using some organization to develop software.

SCAMPI[SM] (Standard CMMI[SM] Assessment Method for Process Improvement) is a part of the Integrated CMM Product Suite [4]. The method helps an organization gain insight into its process capability or organizational maturity by identifying strengths and weaknesses of its current processes relative to one or more of the CMMI models, including the Integrated Capability Maturity Model for Systems Engineering and Software Engineering (CMMI-SE/SW)

Assessment Considerations

There are at least three major factors to consider in choosing an assessment method:

- Accuracy of the assessment – How well will the assessment method identify improvement opportunities? Are there major opportunities it might miss?
- Cost – This includes both preparation costs, including team selection, training and preparation, if any, and organization preparation, and the costs of actually conducting the assessment.
- Organization disruption – How much will the assessment impact normal organization operations, and can this impact be used to communicate important issues to the organization?

Table 3 provides a summary comparison of the accuracy, cost and organization disruption of various assessment methods.

Table 3. Assessment Comparison*

Type	Accur'y	Cost	Disrupt'n
Self Assess't	Low	Low	Low
Mentored Self Assess't	Fair	Low	Low
Interim Profile	Fair	Low	Low
Mini-Assess't	Mod.**	Mod.	Mod.
CBA-IPI	High	High	High
SCE	High	High	High
SCAMPI	High	High	High

* Values are the author's estimates.

** Moderate

MANAGING CHANGE - What Factors Impact The Effectiveness Of Introduced Changes?

Success and Failure Factors

Watts Humphrey describes six basic principles which are critical to the success of process improvement [5]:

- Major changes to the software process must start at the top.
- Ultimately, everyone must be involved.
- Effective change requires a goal and knowledge of the current process.
- Change is continuous.
- Software process changes will not be retained without conscious effort and periodic reinforcement.
- Software process improvement requires investment.

The implementation of process changes using these principles can result in an environment in which developers can produce high quality code (or other product) effectively and efficiently.

Conversely, Hefner [6] identifies the top ten reasons process improvement programs fail:

Failures in strategy:

- Failing to define reasonable goals and plans.
- Failing to tie the improvement goals to business objectives.
- Having inadequate resources and unrealistic expectations.

Failures in planning:

- Starting improvement efforts without an assessment (and/or without CMM knowledge).
- Running improvement efforts like another Level 1 project, with no requirements, no plan, no tracking against plan, no configuration management, no quality assurance, etc.
- Over-focussing on a common solution – "Let's write a new standard development process."

Failures in execution:

- Ignoring middle management - Middle managers stand to lose the most, and are the most effective in resisting change.
- Confusing institutionalization with standardization - A strong culture does not imply everybody does it the same way.
- Defining process changes too early - Improvement is not simply about doing things differently; it requires a change in the culture to sustain the improvements.
- Trying a do-it-yourself approach - SEPG skills are different than software development and management skills.

Cultural Issues

The organization culture has a major (perhaps over-riding) impact on the success of a process improvement program. What is culture? It is a pattern of shared basic assumptions [7]:

- that a group learned as it solved problems,
- that has worked well enough to be considered valid, and
- is reinforced as the correct way to perceive, think, and feel in relation to resolving problems.

Humphrey suggests that many current software problems stem from the pervasive culture of software organizations [8]. This culture has developed over many years and has been largely responsible for the poor performance of these organizations. This "hacker" culture glorifies rapid coding, is schedule driven, and objects to planning. Commitments are generally missed, while quality is unmeasured and unmanaged.

Organization culture has three layers: communications (the visible aspects), expectations (the desired results), and assumptions (the subconscious aspects) [9]. Cultural change involves rethinking those basic assumptions, deciding some assumptions are no longer valid, and learning a new pattern of shared basic assumptions.

To achieve success, one must focus attention on the visible aspects of process improvement. But it is also necessary to pay attention to the invisible aspects of culture change. Start with understanding the assumptions, and improve by changing expectations and communication. Keep yourself and others motivated to change.

In order to achieve successful change, the existing culture must be recognized and dealt with. Existing culture tends to reinforce itself. For a change to stick, expectations must be:

- expressed - "Here's what we expect."
- demonstrated - "Here's what we do."
- reinforced - "Here's what we reward."
- believed - "Here's why this works for us."

Cultural change, enhanced by a transformed leadership and appropriate tools and enablers, will enhance the formal process change process. Absent that foundation, portrayed in Figure 5, the formal process change is likely to flounder.

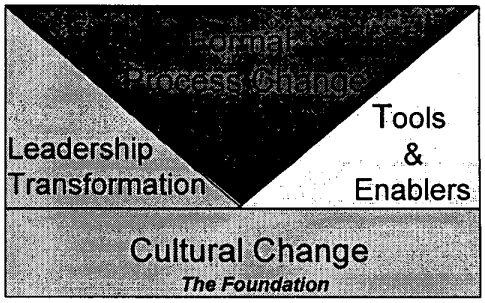

Figure 5. The Foundation for Process Improvement

Transition Strategies

Transition strategies are used to facilitate the introduction of process changes. They address eight key organizational issues and possible points of resistance to be dealt with throughout the entire change process [10].

- Team structure – Establish the team and its structure to plan, implement and sustain the change: sponsor, leadership team, change team, change coach, and transition team.
- Leadership – Establish the sponsorship development activity and learning organization environment for achieving and sustaining the desired change.
- Education and training – Establish the education and training to provide stakeholders the knowledge and skills of methods, tools and processes integral to the change initiative.
- Measures – Establish the business value, process, and readiness measures that should be tracked and monitored to enable learning and measure progress, as well as results. (See Measures section of Guidebook.)
- Business and technology integration – Determine the desired changes in business performance and integrate the technology-driven changes that will support it, such as systems life cycle, project management, or new tools.
- Performance management – Identify the desired behaviors and performance results

for the change; establish the reinforcement mechanisms for each behavior (positive and negative) to institutionalize the change.

- Relationship management – Determine how the change will impact your customer or supplier and establish a win-win business relationship for working together.
- Communications – Establish communications for the change within all levels of the organization.

Implementing Change Methodology (ICM)

The Implementing Change Methodology framework, developed by Implementation Management Associates, incorporates the eight transition strategies in three phases [11]:

- Develop a Shared Understanding - Describe the change, build the team structure, assess the organization's readiness, and complete project startup
- Develop Key Strategies - Determine scope, develop transition management structure and process, and prepare a phased implementation with the enabling strategies, processes, and associated training
- Align the Organization - Apply the transition plan, evaluate progress and results, align the organizational components, sustain continued improvement, and create added organizational capacity for future changes.

Critical Elements for Cultural Change and Process Improvement

Sponsorship, is, of course, one of the most critical elements in successful process improvement. Without serious top management involvement and support long term successful process improvement is doomed. Senior management understanding is the first critical element in a series of steps towards successful process improvement, including senior management commitment, organization assessment, process documentation, improvement implementation, and a focus on project management discipline [12].

Change agents are those individuals who serve as catalysts to bring about organization change. They should be respected opinion leaders who can influence others to implement change. Some basic principles for change agents include: get a sponsor with appropriate budget and spending authority; do "real work;" be a missionary; rather than tackle an entire process area, do one thing better, faster, cheaper than people did it before; advertise, advertise, advertise - make certain that every victory makes the evening news [13].

The Software Engineering Process Group, as the focal point for process improvement, provides guidance and leadership to the organization [14, 15]. Composed of line practitioners who have varied skills, the group is at the center of the collaborative effort of everyone in the organization who is involved with software engineering process improvement. Group size is usually equal to 1-3% of the development staff. Because the process group is generally small, it relies upon support of the support of a management steering committee and various technical working groups to address specific process issues.

Process Action Teams (PAT's) are a good choice for actually defining and implementing specific process improvements [16]. Getting PAT's up to speed quickly is easier with a defined process. One such process is documented in ETVX (Entry, Task, Verification, eXit) format, which is also used by the team to document the model of the process they are working on. In addition to assorted templates and guidelines for both project outputs and for project planning and status reporting, each step in the process has entry and exit criteria, roles, measures, standards and tools [17].

MEASURES - How Do You Set Up A Measurement Program?

Measurement Basics

The final step in process improvement (and the first step in the next cycle) is to determine the impact on the organization of the changes that have been implemented. This implies some set of measures which can be compared against a baseline in order to determine quantitatively how successful the process improvement program has been. To be

effective, software measurement should be integrated with an overall strategy for software process improvement.

There are three questions to consider in setting up a measurement program:

Are the measures relevant?

- How will you know if your critical parameters have improved?
- How do those measures relate to the Key Process Areas?
- Will moving up maturity levels achieve improved effectiveness?

Are the measures significant?

- Is the CMM maturity level consistent with measured improvements in business and quality?
- Does the organization prepare with rigor for an assessment but afterwards give less than that effort to sustain and improve? The appearance of process maturity is not a substitute for having process maturity - there's more to the CMM than an assessment!

Are the measures objective?

- "Think of the organizational measurement system as the dials and indicators in an airplane cockpit. For the complex task of navigating and flying an airplane, pilots need detailed information about many aspects of the flight: fuel, air speed, altitude, bearing, destination and other indicators that summarize the current and predicted environment."[18]
- "Now consider what this analogy would be like if it included a multitude of tiny gremlins controlling wing flaps, fuel flow, and so on of a plane being buffeted by winds and generally struggling against nature, but with the gremlins always controlling information flow back into the cockpit instruments, for fear that the pilot might find gremlin replacements."[19]

Answering these three questions can help organizations select the most appropriate measures and set up a measurement program to guide the implementation of the process improvement program. Capers Jones suggests that the best way to decide what to measure is to find out what industry leaders measure, and then measure the same things [20]. He recommends a large number of metrics in three categories: Quality Measures, Productivity and Schedule Measures, and Business and Corporate Measures.

On the other hand, lower maturity organizations should not try to do too much. A few metrics should be selected which will be useful for project management and applied them across the board. As experience and confidence are gained, more metrics can be added. Those which don't add significant value should be removed. For example, if the business goals are based on functionality, cost, time to market, and quality, project and process issues that relate to achieving those goals should be identified. Process performance can then be quantified by measuring attributes of products produced by the processes as well as by measuring process attributes directly [21].

The Goal-Question-Measures (GQM) Approach

The Goal-Question-Measures approach is very useful in determining what measures to collect. In goal-driven measurement, the primary question is not "What metrics should I use?" but "What do I want to know or learn?" Because the answers depend on the organization's goals, no fixed set of measures is universally appropriate. The goal-driven measurement process is based on three precepts:

- Measurement goals are derived from business goals. The goal-driven process begins with identifying business goals and breaking them down into manageable sub-goals.
- The primary mechanisms for translating goals into issues, questions, and measures are the mental models that you have for the processes you use. These mental models gain substance and evolve as you begin to make them explicit. They are the engines that generate the insights that guide you to useful measures and actions.
- GQM translates informal goals into executable measurement structures. The

process ends with a plan for implementing well-defined measures and indicators that support the goals. Along the way, it maintains traceability back to the goals, so that those who collect and process measurement data do not lose sight of the objectives.

More detail can be found in "Goal-Driven Software Measurement - A Guidebook" [22]

Setting Up A Metrics Program

A metrics program (a metric is defined as a combination of two or more measurements) should be set up in three phases [23]. The approach and the metrics should be customized to meet the needs of your organization.

PLANNING:

- Define information needs.
- Define metrics and analysis methods.
- Define selected measures.
- Define the process of collecting measurement data.

MEASUREMENT IMPLEMENTATION:

- Collect the measurement data.
- Analyze the measurement data to derive metrics.
- Manage the measurement data and metrics.
- Report the metrics.

MEASUREMENT PROGRAM EVALUATION:

- Review the usability of the selected metrics.

Measurement Dangers

There are two main uses of measurements: information and motivation [19]. Each use has a set of problems associated with it. Further, mixing the two uses can have negative effects. Additionally, informational measures can be intentionally or inadvertently subverted into motivational measures.

Informational measures are used to provide process/product insight and a basis for decision-making. They should not affect behavior.

Informational measures have two kinds of problems [19]:

- Unclear meaning. Numbers may not be clearly understood, due to not realizing the implicit model between the numbers and the reality [24]; e.g., what is the meaning in the real world of the Technical Complexity Factor in the Function Point Method? How does this impact project effort?
- Inappropriate operations. Not all numbers can be meaningfully averaged or otherwise combined or manipulated; e.g., a 2000 LOC program probably will take something other than twice as along as a 1000 LOC program to complete.

Motivational measures are used to promote greater effort in pursuit of organizational goals. They should affect behavior. The main problem with motivational measures is that they can become dysfunctional; i.e., they can motivate undesired behaviors. "Dysfunction occurs when the validity of information ... is compromised by the unintended reactions of those being measured." "The major problem for most incentive systems is ... bias intentionally introduced by those being measured." [19]

Some examples of dysfunctional measures are:

- Standardized tests (coaching and preparation skews results)
- Production targets ("storming" ignores quality and equipment maintenance)
- Sales commissions (overselling, not providing value to the customer)
- Stock value (quick cuts, short-term changes)
- "Kills" (Vietnam deaths ncouraged/inflated)
- Piecemeal pay (can lead to quality problems)
- Planned vs. actual (re-baselined cost, schedule)
- Defects (over/understated, misdiagnosed)
- Maturity levels (do processes add business value?)

- ISO 9000 certification (more than just documented standards?)

Possible dysfunction in the measurement program should be considered and dealt with up front, in the planning stage. Some ways to prevent dysfunction include [25]:

- Don't have the measures take the place of the underlying goals.
- Workers should be internally motivated; measurement should provide them with self-assessment information.
- Reinforce, don't enforce, human behavior.
- Watch out for opportunistic behaviors.
- Set solid objectives and plans.
- Make measurement part of the process.
- Understand benefits and limitations.
- Focus on cultural issues.
- Create a safe environment for collecting and reporting data.
- Be ready to change.
- Have a complementary suite of measures.

Conclusion

Any process improvement program should be driven by and related to some set of business or over-arching organizational needs. By considering change drivers in concert with the organization strategic objectives and "pains" one can develop a vision of the desired state, what the organization should look like and how it should behave after the desired changes are achieved. An appropriate reference model is then chosen and used in an assessment to identify improvement opportunities. Based on the assessment findings an action plan is developed and implemented which addresses both specific process changes and organization cultural issues. Finally, an appropriate set of measures is defined and implemented to help measure the effects of the various changes.

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References

[1] Whitney, Rosalyn, et. al, March 1994, "Interim Profile: Development and Trial of a Method to Rapidly Measure Software Engineering Maturity Status," CMU/SEI-TR-94-4, Pittsburgh, Carnegie Mellon University

[2] Dunaway, Donna and Steve Masters, April 1996, "CMM[SM]-Based Appraisal for Internal Process Improvement (CBA IPI): Method Description,"CMU/SEI-96-TR-007, Pittsburgh, Carnegie Mellon University

[3] Dedolph, F. Michael, et.al., June 1994, "Software Capability Evaluation Version 2.0 Method Description,"CMU/SEI-TR-94-6, Pittsburgh, Carnegie Mellon University

[4] CMMI Product Development Team, October 2000, "SCAMPI[SM] , V1.0 Standard CMMI[SM] Assessment Method for Process Improvement: Method Description," Version 1.0, CMU/SEI-2000-TR-009, Pittsburgh, Carnegie Mellon University

[5] Humphrey, Watts, 1989, **Managing The Software Process**, Addison-Wesley, p. 19ff.

[6] Hefner, Rick, March 1999, "The Top Ten Reasons Improvement Efforts Fail," SEI SEPG Conference*

[7] Caputo, Kim, March 1997, "Level 3 Culture is More Than Just the Artifacts," SEI SEPG Conference

[8] Humphrey, Watts, March 1999, "Changing the Software Culture," SEI SEPG Conference

[9] Caputo, Kim, March 1999, "Facilitating CMM Culture Change," SEI SEPG Conference

[10] Waina, Richard and William Phifer, March 2000, "Purpose-Driven Process Improvement," SEI SEPG Conference

[11] Implementation Management Associates, 1996, "Accelerating Change" training course, www.imaworldwide.com

[12] Davis, Darryl, March 2000, "On the Cart and the Horse: Putting Process Improvement Activities in the Right Order," SEI SEPG Conference

[13] Ferguson, Robert, March 1998, "The Guerrilla Warfare Approach to Process Improvement," SEI SEPG Conference

[14] Wigle, Gary B., March 1999, "The SEPG From Level 1 to Level 5," SEI SEPG Conference

[15] Rifkin, Stan and Priscilla Fowler, September 1990, "Software Engineering Process Group Guide," CMU/SEI-90-TR-24, Pittsburgh, Carnegie Mellon University

[16] Eagen, Bob, 1999 March 1999, "Where the Rubber Meets the Road: Getting it Done with Process Action Teams" SEI SEPG Conference

[17] Waina, Richard, May 2001, "A Process Action Team Process That Works," Air Force Software Technology Conference, Salt Lake City

[18] Kaplan, Robert and David Norton, Jan-Feb 1992, "The Balanced Scorecard – Measures That Drive Performance," **Harvard Business Review**

[19] Austin, Robert, 1996, **Measuring and Managing Performance in Organizations**, New York, Dorset House Publishing

[20] Jones, Capers, Feb 2001, "Software Measurement Programs and Industry Leadership," **Crosstalk**, pp. 4-7

[21] Florac, William, et. al, April 1997, "Practical Software Measurement: Measuring for Process Management and Improvement," CMU/SEI-97-HB-003, Pittsburgh, Carnegie Mellon University

[22] Park, Robert et. al., August 1996, "Goal-Driven Software Measurement–A Guidebook," CMU/SEI-96-HB-002, Pittsburgh, Carnegie Mellon University

[23] Timothy K. Perkins, February 2001, "The Nine-Step Metrics Program," **Crosstalk**, pp. 16-18

[24] Zuse, Hort, 1998, **A Framework of Software Measurement**, New York, Walter de Gruyter, p. 42

[25] Dekkers, Carol, April 1999, "Secrets of Highly Successful Measurement Programs," **Cutter IT Journal**, pp. 29-35

- * SEI Software Engineering Process Group Conference (annual) Proceedings, Pittsburgh, Carnegie Mellon University.
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