

# Developing Systems Engineering Capabilities within Businesses and Enterprises

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The pursuit of continuous improvement is a constant for many organizations. The description of Toyota (Morgan and Liker 2006), the Lean principle of “pursue perfection” (Oppenheim et al. 2010), and the principle of “don’t let up” (Kotter 1995), all drive a need for continuous improvement.

The ability to manage teams through their lifecycle - mobilize teams rapidly, establish and tailor an appropriate set of processes, metrics and systems engineering plans, support them to maintain a high level of performance, capitalize acquired knowledge and redeploy team members expeditiously as the team winds down - is a key organizational competence that has substantial leverage on project and organizational efficiency and effectiveness.

The enterprise provides teams with the necessary resources, background information, facilities, cash, support services, tooling, etc. It also provides a physical, cultural and governance environment in which the teams can be effective. The key functions of the enterprise include generating and maintaining relevant resources, allocating them to teams, providing support and governance functions, maintaining expertise and knowledge (on process, application domain and solution technologies), securing the work that teams perform,

organizing finance, and maintaining the viability of the enterprise.

For improvements to persist, they must reside in the enterprise rather than just the individuals, so the improvements can endure as personnel leave. This is reflected in the Capability Maturity Model Integrated (CMMI) (SEI 2010) progression from a "hero culture" to a "quantitatively managed and optimizing process".

This topic outlines the issues to be considered in capability development and organizational learning.



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## **Overview**

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Figure 1 shows an "analyze - organize - perform - assess

- develop" cycle, which is essentially a reformulation of the Deming (1994) PDCA (Plan Do Check Act) cycle. The analysis step should cover both current and future needs, as far as these can be determined or predicted. Goals and performance assessment, as discussed in Assessing Systems Engineering Performance of Business and Enterprises, can be based on a number of evaluation frameworks, such as direct measures of business performance and effectiveness and the CMMI capability maturity models. There is evidence that many organizations find a positive correlation between business performance and CMMI levels (SEI 2010). This is discussed further in the Economic Value of Systems Engineering.

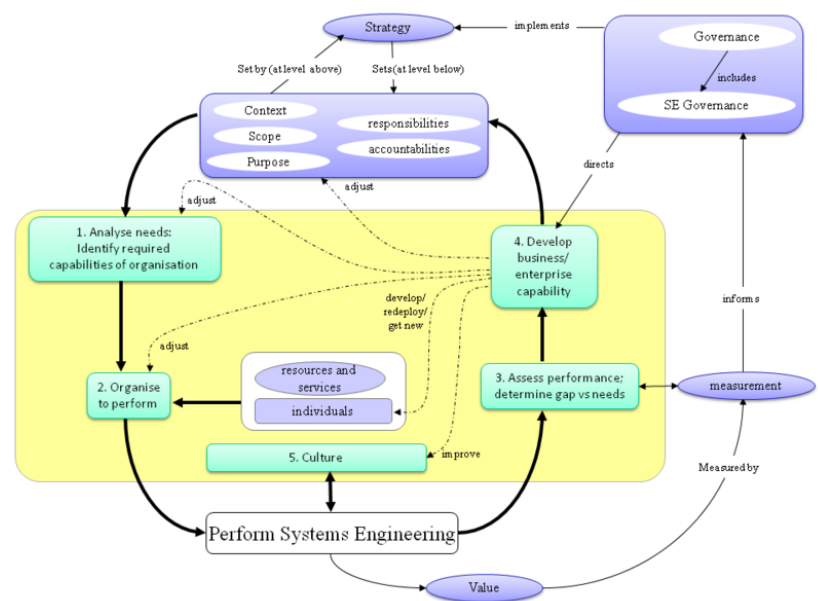


Figure 1. Concept Map for Businesses and Enterprises Topics. (SEBoK Original)

## Change Levers

SE managers have a number of possible change levers they can use to develop SE capabilities. The amount of time delay between moving a lever and seeing the effect varies with the type of level, size of the enterprise, culture of the enterprise, and other factors.

### Adjust Context, Scope, Purpose, Responsibility, Accountability Business Enterprise

If the other change levers cannot achieve the desired effect, the business or enterprise may have to renegotiate its contribution to the higher-level strategy

and mission.

## **Review and Adjust Required Capabilities**

In the initial analysis the needed capability may have been over- or under-estimated. The need should be re-evaluated after each rotation of the cycle to make sure the planning assumptions are still valid.

## **Adjust Organization within Business Enterprise**

Adjusting organization and responsibilities so that "*the right people are doing the right things*", and ensuring that the organization is making full use of their knowledge and skills, is often the easiest change to make (and the one that may have the quickest effect).

A potential risk is that too much organizational churn disrupts relationships and can destabilize the organization and damage performance. Process improvement can be set back by an ill-considered re-organization and can jeopardize any certifications the organization has earned which demonstrate its process capability or performance.

## **Develop/Train/Redeploy/Get New Resources, Services and Individuals**

Resources, services and individuals may include any of the components of organizational SE capability listed in Organizing Business and Enterprises to Perform Systems Engineering.

Levers include subcontracting elements of the work, improving information flows, upgrading facilities, and launching short-term training and/or long-term staff development programs. Many organizations consider how they approach these improvements to be proprietary, but organizations such as NASA offer insight on their APPEL website (NASA 2012).

Development of individuals is discussed in Enabling Individuals.

## **Improve Culture**

Culture change is very important and powerful but needs

to be handled as a long-term game and given long term commitment.

## **Adjust and Improve Alignment of Measures and Metrics**

Measurement drives behavior. Improving alignment of goals and incentives of different parts of the business/enterprise so that everyone works to a common purpose can be a very effective and powerful way of improving business/enterprise performance. This alignment does require some top-down guidance, perhaps a top-down holistic approach, considering the business/enterprise as a system with a clear understanding of how the elements of enterprise capability interact to produce synergistic value (See Assessing Systems Engineering Performance of Business and Enterprises). It is commonly reported that as an organization improves its processes with respect to the CMMI, its approach to metrics and measurement has to evolve.

## **Change Methods**

### **Doing Everyday Things Better**

There is a wealth of sources and techniques, including Kaizen, Deming PDCA (Deming 1994), Lean (Womack and Jones 2003, Oppenheim et al. 2010), Six-Sigma (Harry 1997), and CMMI.

Value stream mapping is a powerful Lean technique to find ways to improve flow and handovers at interfaces.

### **Managing Technology Readiness**

In high-technology industries many problems are caused by attempting to transition new technologies into products and systems before the technology is mature; to make insufficient allowance for the effort required to make the step from technology demonstration to reproducible and dependable performance in a product; or to overestimate the re-usability of an existing product. NASA's TRL (Technology Readiness Level) construct, first proposed by John Mankins in 1995 (Mankins 1995), is widely and successfully used to understand and mitigate technology transition risk. Several organizations beyond NASA, such as the U.S.

Department of Defense, even have automation to aid engineers in evaluating technology readiness.

Variations on TRL have emerged, such as System Readiness Levels (SRL) (Sauser et al. 2006), which recognize that the ability to successfully deliver systems depends on much more than the maturity of the technology base used to create those systems; e.g., there could be surprising risks associated with using two technologies that are relatively mature in isolation, but have never been integrated together before.

## **Planned Change: Standing Up or Formalizing SE in an Organization**

Planned change may include:

- introducing SE to a business (Farncombe and Woodcock 2009);
- improvement/transformation;
- formalizing the way a business or project does SE;
- dealing with a merger/demerger/major re-organization;
- developing a new generation or disruptive product, system, service or product line (Christensen 1997);
- entering a new market; and
- managing project lifecycle transitions: start-up, changing to the next phase of development, transition to manufacture/operation/support, wind down and decommissioning.

CMMI is widely used to provide a framework for planned change in a systems engineering context. Planned change needs to take a holistic approach considering people (knowledge, skills, culture, ability and motivation), process, measurement and tools as a coherent whole. It is now widely believed that tools and process are not a substitute for skills and experience. Instead, they merely provide a framework in which skilled and motivated people can be more effective. Therefore, change should start with people rather than with tools.

Before a change is started, it is advisable to baseline the current business performance and SE capability and establish metrics that will show early on whether the change is achieving the desired effect.

## **Responding to Unforeseen Disruption**

Unforeseen disruptions may be internally or externally imposed. Externally imposed disruptions may be caused by:

- the customer – win/lose contract, mandated teaming or redirection;
- competitors – current offering becomes more/less competitive, a disruptive innovation may be launched in market; or
- governance and regulatory changes – new processes, certification, safety or environmental standards.

Internal or self-induced disruptions may include:

- a capability drop-out due to loss of people, facilities, financing;
- product or service failure in operation or disposal; or
- strategy change (e.g. new CEO, response to market dynamics, or a priority override).

## **Embedding Change**

In an SE context, sustained effort is required to maintain improvements such as higher CMMI levels, Lean and Safety cultures, etc., once they are achieved. There are several useful change models, including Kotter's 8 phases of change (Kotter 1995):

1. Establish a sense of urgency;
2. Create a coalition;
3. Develop a clear vision;
4. Share the vision;
5. Empower people to clear obstacles;
6. Secure short-term wins;
7. Consolidate and keep moving; and
8. Anchor the change.

The first six steps are the easy ones. The Chaos Model (Zuijderhoudt 1990; 2002) draws on complexity theory to show that regression is likely if the short-term wins are not consolidated, institutionalized and anchored. This explains the oft-seen phenomenon of organizations indulging in numerous change initiatives, none of which stick because attention moves on to the next before the

previous one is anchored.

## Change Management Literature

SE leaders (directors, functional managers, team leaders and specialists) have responsibilities, and control levers to implement them, that vary depending on their organization's business model and structure. A great deal of their time and energy is spent managing change in pursuit of short-, medium- and long-term organizational goals: "doing everyday things better"; making change happen; embedding change and delivering the benefit; and coping with the effects of disruptions. Mergers, acquisitions and project start-ups, phase changes, transitions from "discovery" to "delivery" phase, transition to operation, sudden change in level of funding, can all impose abrupt changes on organizations that can destabilize teams, processes, culture and performance. Table 1 below provides both the general management literature and specific systems engineering knowledge.

**Table 1. Change Management - Business and SE References.** (SEBoK Original)

<b>Area</b>	<b>Business references</b>	<b>SE references</b>
Doing Every-day Things Better	<ul style="list-style-type: none"> <li>• Kaizen; Lean (Womack and Jones 2003); 6-Sigma (Harry 1997)</li> <li>• Four Competencies of Learning Organisation - Absorb, Diffuse, Generate, Exploit (Sprenger and Ten Have 1996)</li> <li>• The Seven Habits of Very Effective People (Covey 1989)</li> </ul>	<ul style="list-style-type: none"> <li>• CMMI</li> <li>• Visualizing Project Management (Forsberg and Mooz 2005)</li> <li>• INCOSE IEWG "Conops for a Systems Engineering Educational Community" (Ring and Wymore 2004)</li> <li>• INCOSE Lean Enablers for SE (Oppenheim et al. 2010)</li> </ul>
Dealing with Unplanned Disruption	<ul style="list-style-type: none"> <li>• Managing Crises Before They Happen (Mitroff and Anagnos 2005);</li> <li>• Scenarios: Uncharted Waters Ahead (Wack 1985)</li> <li>• Scenario Planning: Managing for the Future (Ringland 1988)</li> </ul>	<ul style="list-style-type: none"> <li>• Architecting Resilient Systems (Jackson 2010)</li> <li>• Design Principles for Ultra-Large-Scale Systems (Sillitto 2010)</li> </ul>



Driving Disruptive Innovation	<ul style="list-style-type: none"> <li>• The Innovator's Dilemma (Christensen 1997)</li> <li>• Rise and Fall of Strategic Planning, (Mintzberg 2000)</li> <li>• BS7000, Standard for Innovation Management (BSI 2008)</li> </ul>	<ul style="list-style-type: none"> <li>• Architecting for Flexibility and Resilience (Jackson 2010)</li> <li>• Open System Architectures; Lean SE; (Oppenheim et al. 2010)</li> <li>• Agile Methodologies</li> </ul>
Exploiting Unexpected Opportunities	<ul style="list-style-type: none"> <li>• Rise and Fall of Strategic Planning (Mintzberg 2000)</li> <li>• Mission Command (military), Auftragstechnik (Bungay 2002, 32)</li> </ul>	<ul style="list-style-type: none"> <li>• Doing it differently - Systems for Rethinking Construction (Blockley and Godfrey 2000)</li> <li>• INCOSE UK Chapter Z-guides: <ul style="list-style-type: none"> <li>◦ Z-2, Introducing SE to an Organisation (Farncombe and Woodcock 2009);</li> <li>◦ Z-7, Systems Thinking (Godfrey and Woodcock 2010)</li> </ul> </li> </ul>
Implementing and Embedding Planned Change	<ul style="list-style-type: none"> <li>• Kotter's Eight Phases of Change (Kotter 1995),</li> <li>• Berenschot's Seven Forces (ten Have et al. 2003)</li> <li>• Levers of Control (Simons 1995) - Tension between Control, Creativity, Initiative and Risk Taking</li> <li>• Chaos Model from "Complexity Theory Applied to Change Processes in Organisations"; (Zuiderhoudt and Ten Have 1999)</li> <li>• Business Process Re-engineering (Hammer and Champy 1993)</li> <li>• The 5th Discipline (Senge 2006)</li> <li>• Change Quadrants (Amsterdam 1999)</li> </ul>	<ul style="list-style-type: none"> <li>• Doing it differently - Systems for Rethinking Construction (Blockley and Godfrey 2000)</li> <li>• INCOSE UK Chapter Z-guides: <ul style="list-style-type: none"> <li>◦ Z-2, Introducing SE to an Organisation (Farncombe and Woodcock 2009);</li> <li>◦ Z-7, Systems Thinking (Godfrey and Woodcock 2010)</li> </ul> </li> </ul>

Understanding People's Motivation, Behaviour	<ul style="list-style-type: none"> <li>• Maslow's Hierarchy of Needs</li> <li>• Myers-Briggs Type Indicator;</li> <li>• NLP (Neuro-Linguistic Programming) (See for example: Knight 2009)</li> <li>• Performance by Design: Sociotechnical Systems in North America (Taylor and Felten 1993)</li> <li>• Core Quadrants, (Offman 2001)</li> </ul>	<ul style="list-style-type: none"> <li>• INCOSE Intelligent Enterprise Working Group – "Enthusiasm", Stretch Goals (Ring and Wymore 2004)</li> <li>• Sociotechnical Systems Engineering, Responsibility Mapping, from "Deriving Information Requirements from Responsibility Models" (Sommerville et al. 2009)</li> </ul>
Understanding Culture	<ul style="list-style-type: none"> <li>• Cultural Dimensions, from "Culture's Consequences" (Hofstede 1994)</li> <li>• Compliance Typology, from "A Comparative Analysis of Complex Organizations" (Etzione 1961)</li> </ul>	
Helping Individuals Cope with Change	<ul style="list-style-type: none"> <li>• 5 C's of Individual Change, and Rational/Emotional Axes, Kets De Vries, quoted in "Key Management Models" (Ten Have et al. 2003)</li> </ul>	<ul style="list-style-type: none"> <li>• Rational/Emotional, NLP and Other Methods, from "Relationships Made Easy" (Fraser 2010)</li> </ul>

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None.

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