

Systems Engineering Confronts Enterprise Change:
Frameworks and Lessons from MITRE Projects

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Enterprises are large-scale entities composed of multiple organizations often without a central authority to plan and control. Interdependencies are set by market practices and negotiated among the component units. Performance is highly dependent on context, including the relative power of the component units, their historical relationships, key individuals who shape communication patterns, and technologies that enable work and information flow.

Our understanding of enterprises is developing gradually along with recognition that traditional organizational forms are subsets and only partial explanations of larger entities in an era of markets, networks, and enterprises. Not surprisingly, the same considerations for organizations apply to understanding how enterprises develop and change. Our conception of change are likewise based on models of organizational change. We have neither an accepted theory of enterprise, nor an accepted theory of enterprise change.

In a collaborative research project with with MITRE Corporation, the MIT Lean Aerospace Initiative is examining case studies of MITRE clients, typically government units, undergoing large-scale change. Because MITRE operates in the sphere of government, these change efforts often involve relationships among different government units. Because MITRE's expertise is systems engineering, there is a heavy technology and engineering aspect to these change efforts. An example would be the Department of Defense Intelligence Information System (DODIIS) which involves efforts to securely share intelligence information across multiple DOD units with varied legacy systems and varied data requirements. MITRE Corporation leaders have recognized that its expertise in systems engineering, which typically refers to technical systems at a component level (such as an information system), must be expanded to

include the social, political, organizational, and financial context around such systems. In short, systems engineers must enlarge their skill set to become “Enterprise Systems Engineers.” The project selects cases where MITRE personnel have encountered this new situation in their engagements and assumes that considerable wisdom, or at least stories of more or less success, reside in the MITRE staff.

Our collaborative MIT/MITRE team has structured the research as a series of case studies. Although we incorporate elements of grounded theory, there are several frameworks that we are actively using in the analysis of our case data (primarily interview-based). In this paper, we will present these frameworks and propose them as a nascent theory of enterprise change.

Overall, we take the change aspect of enterprises as a starting point, and therefore in Fig. 1 outline the current state and the future state. Of course, the future state as a plan is only one input into change and the outcome of a change process is never fully predictable. We also divide the technical from the social-organizational aspects of enterprises to reflect the formal technical capabilities that are contracted when government agencies hire MITRE. The capabilities that enable change are also separated in terms of the classical systems engineering tools that MITRE systems engineers use to create system requirements and manage the project that implements their design, in contrast to everything else that has to be done to integrate that design into organizations and change the organizations and their relationships to one another in the process.

The first set of tools is the classic Systems Engineering tools that are employed by MITRE personnel in their engagements. In this context, where they occasion technical change, they are necessary, but rarely sufficient, to accomplish enterprise change. In our cases, we see multitudes of tools in use, with statements about how the tools had to be modified, amplified, or used in different ways to address enterprise issues. For example, [look up something in the cases].

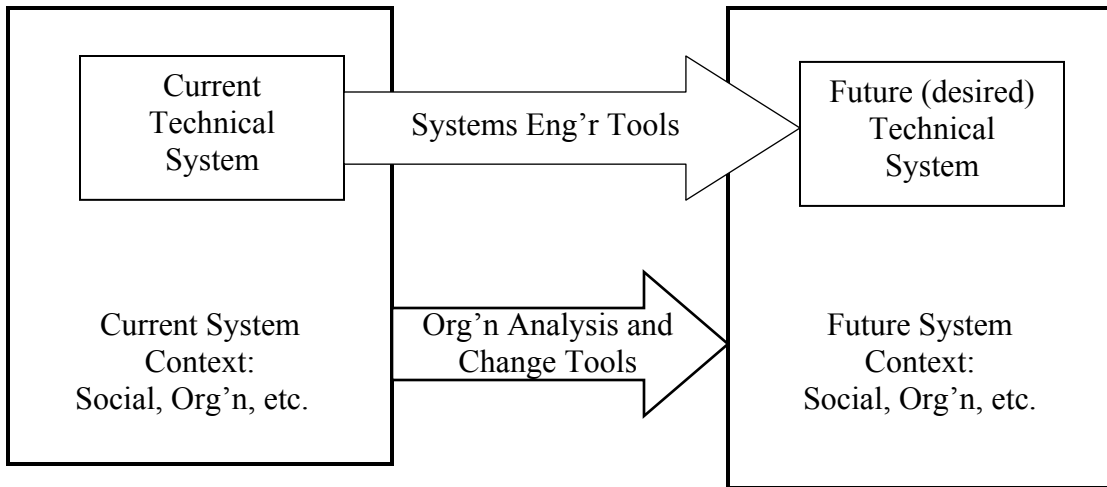
The second set of tools is an organizational analysis approach called the Three Lenses, developed at the MIT Sloan School of Management (Ancona et al., 2006;

Carroll, 2006). The Strategic Design lens considers organizations to be rationally designed to achieve organizational goals, whereas the Political lens views organizations as multiple stakeholders with possibly distinct interests and sources of power. The Cultural lens examines meaning making in organizations, including symbols, artifacts, values, and underlying assumptions shared in subcultures or the organization as a whole. For example, consider the case where two different system designers with two different approaches (one that was highly formalized and comprehensive from a large company, the other quick-and-dirty from a small, new company) were forced to combine into a single project run by the smaller, newer organization [TBONE/TBMCS case]. The Strategic Design lens would focus on issues around reorganizing tasks and information flows, and aligning incentives. The Political lens would see these groups as contesting for status and power (such as when the smaller company hired away key people from the larger), and the Cultural lens would examine how various parties understood the meaning of this merged project and how differences in language, values, and worldviews could make a shared, collaborative effort that much more difficult. Together, the lenses provide more insight into organizational dynamics.

The third set of tools is an analysis of project complexity developed by Renee Stevens at MITRE, called the Enterprise Systems Engineering Profiler. The Profiler looks at the nature of the design effort involved in a project and the enterprise context around that change. It contrasts a “traditional” and well-understood system development context of extending existing capabilities in a single, known technological system, with a stable mission/goal in a single organization, stable relationships, and agreement among stakeholders, with the increasing complexity of many of MITRE’s engagements that are building fundamentally new capabilities in an evolving and not fully predictable technological system linked to many other systems, with a fluid or even ad hoc mission in an extended enterprise with no single hierarchical authority, and many constituencies who distrust each other and resist change. MITRE is facing more and more projects with elements of the latter sort, and working to address them with a thin experience base of tacit knowledge of what has seemed to work.

The fourth set of tools is an analysis of enterprise change capabilities (Roth, 2006) developed from the experiences of the Lean Aerospace Initiative in implementing lean practices and from analyzing the literature on organizational change. Five capabilities are proposed for enterprise change: (1) rethinking organizational boundaries – attending to and managing the entire value chain, not simply what is within functions or inside the corporation; (2) installing innovation sets – managing change as total system change, including internal restructuring, boundary management, and process improvement; (3) pushing and pulling change – utilizing both top-down goal-driven change and bottom-up commitment-based continuous improvement; (4) seeking growth opportunities – a focus on growth at individual, organizational, and business enlargement levels; and (5) distributing leadership practices – building and enacting a system of distributed leadership across all levels of the enterprise.

By using these frameworks together in analyzing the cases developing from MITRE, we hope to develop a more comprehensive and integrated understanding of enterprise change. This is a daunting task: although there is an extensive literature on organizational change, there is no accepted simple theory of change, and even less is known of change at the enterprise level that involves collective action and alignment of a complex array of stakeholders and their organizations. In our opinion, it is unlikely that any single theory can encompass this terrain, but creating a useful map with focus on key principles and measurable variables will be a valuable contribution. As the MITRE cases are still under development and being cleared for internal distribution within MITRE (via conversations with the interviewees and other stakeholders at the time of this writing), we will be presenting our latest thinking, looking across the cases for illustrations that can be shared publicly at the Symposium.



**Meeting the Practical Challenge of Government Enterprise Change:
Lessons from Large-Scale Systems Implementations**

Proposal for 2007 Academy of Management Symposium

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JoAnn Brooks (MITRE)
John S. Carroll (MIT/Sloan) and George Roth (MIT/Sloan)
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Discussant:

Michael D. Cohen (University of Michigan) *[invited – response pending]*

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Divisions:

Organizational Communication and Information Systems (OCIS)
Organizational Development and Change (ODC)
Technology and Innovation Management (TIM)

Meeting the Practical Challenge of Government Enterprise Change: Lessons from Large-Scale Systems Implementations

This symposium focuses on practical improvement efforts in situations of enterprise change. By enterprise, we mean a large-scale set of interdependent organizations with a common purpose, such as a supply chain organized around a systems integrator. Efforts to shape and change such enterprises involve multiple dimensions of complexity: 1) complexity of inter-organizational relations, politics and leadership at the focal enterprise level; 2) complexity of design and innovation concerns at the level of technological systems integration; and 3) *evaluative complexity*¹ – a term which connotes the concerns involved in identifying what counts as “doing good” in complex situations – often with regard to interactions between the former two dimensions, and across stakeholders with competing interests.

The symposium features early results from a series of case-based investigations into government enterprise change efforts, that are facing the practicalities of these interacting complexities. Four of the efforts are US-based, the fifth is international; most are organized around military concerns. As government enterprises, all the cases ostensibly aim to support the common benefit, yet in each case interactions among dimensions of complexity present fundamental challenges to understanding what “doing good” actually means in practice.

Government Enterprise Change

Organizational change has been recognized as a worthwhile topic for some time, characterized by a wide variety of theoretical approaches. Beer & Nohria initiated efforts to integrate change theories of economic value and of organizational capabilities; their published anthology (*Breaking the Code of Change*, HBS 2000) indicates that this work is barely begun, and calls for longitudinal studies and sharing information across researchers to develop understanding. In considering closely-related issues of leadership, Heifetz (1998) argues that adaptive problems (distinguished from routine technical

¹ Thanks to Joe Sussman at MIT’s Engineering Systems Division, for this term.

problems), require deeper consideration of values and stakeholder responsibility. A recent special issue of *Organization Science* on the topic of organization design (edited by Dunbar and Starbuck, 2006), highlights the importance of practical improvement efforts by well-educated employees and consultants even while theorists are still trying to sort out conceptualizations of organizational change.

Government enterprise change efforts share many of these aspects with traditional organizational change, and also exhibit further complications unique to government enterprises. Because government agencies are not subject to the same bottom-line pressures as market-driven organizations, constituent organizations within a government enterprise often rely on inertia as a key strategy for opposing externally-originated change. Lacking a clear and effective organizational hierarchy, in the enterprises under study, governance is often agreed to only after a long period of ad hoc efforts and leadership changes frequently with shifts in political administrations. The resulting context for government employees and contractors trying to carry out intended enterprise change is like being adrift in a turbulent sea – budgets are cut, programs cancelled, and leadership shifts at a rate precluding substantial progress in any single direction.

Systems Engineering / Systems Integration

Many of the enterprise change efforts are actually motivated directly or indirectly by the enabling and constraining aspects of technology: Efforts to consolidate multiple organizations into an enterprise arise out of pressures to achieve cost savings and efficiencies through reducing duplication via networked technologies, as in the US Department of Homeland Security. And/or enterprise change may be motivated by government mandates to “share information” across multiple and diverse organizations and organizational functions as within the “community” of intelligence agencies. At the same time, inter-organizational coordination may be required because of the interdependencies inherent in systems integration work of getting multiple complex technologies to interoperate for a single customer such as a globally distributed military service. The recursive influence of technology and social action, pervasive but emergent rather than deterministic (Barley 1986; Orlikowski 1992), makes planning such technical systems extremely difficult because it is impossible to predict the future. Also, because

each government enterprise is unique, developing systems for it requires custom systems engineering and systems integration work.

Yet, as many technologists note, “*technology is the easy part*” in such governmental enterprise change. It is not known beforehand exactly what is needed to accomplish desired changes (organizationally or technologically) on such a large scale, nor is it clear who is in charge of which aspects of a complex integration effort. Political conflicts involving information systems are common (Feldman & March 1981) and the inherent relational tensions of coordinating technological design across organizations (O’Sullivan 2006) are accentuated at the enterprise scale.

As a result, boundedly rational managers and technologists struggle with the overwhelming complexity of the change effort. Individuals drastically lower their expectations; many become frustrated and depressed. Under such circumstances, although few people are really ill-intentioned, few are willing to sacrifice their own interests to advance changes which are not clearly defined, which vacillate with shifts in national politics, and which may be easily perceived as threatening in any event. The notion of “doing good” in such a setting is more a puzzle than a guideline. At the enterprise level, the outcome is frequently an unfortunate grid-lock of institutionalized fiefdoms and power struggles.

Research Study

Our research is grounded in the practical efforts of technologists working to support such change efforts in government enterprises. The symposium presents results from a collaborative research effort of the MITRE Corporation and MIT’s Engineering Systems Division (MIT/ESD). Our joint project on *Social Contexts of Enterprise Systems Engineering* (SCESE) is one of four collaborative research efforts regarding enterprise systems engineering (ESE) endeavors involving government agencies,² and highlights perspectives of technological practitioners. The strategic importance of such engineering projects and their perspectives on government enterprise change should not be

² Two other projects are concerned with real options (engineering design and financial), and the fourth with modeling and simulating dynamics of enterprises.

underestimated, as systems integration in particular is growing and a key vehicle for organizing networks of production within and across the broader society (Hobday, Davies and Prencipe 2005).

The ESE programs under study include an information system for sharing intelligence data across multiple Department of Defense agencies; a coordinating office for designing and developing a next generation national transportation system; and systems supporting communication and/or command and control across multiple military services (Air Force, Army, Marines, Navy; also international). The intent of these cases is to collect the experience and wisdom of technologists who have been on the front lines of enterprise change, and to analyze it within the context of the organizations literature and drawing on approaches and insights from MIT/ESD's Lean Aerospace Initiative (Murman et al 2002).

Symposium Presentations

The presentations in this symposium are as follows:

Jon W. Beard (MITRE) draws from the work of Rittel & Webber (1973, 1984) and Unidata (2000) respectively, in arguing that characterizing enterprise change as a *wicked problem* is an apt way to capture the inherent richness and variability encountered in enterprise change, and that stating the problem that needs to be solved IS the problem. He proposes that enterprise change be viewed as an on-going process in which the journey (i.e., the process) is considered more important than specific design, for there is no destination or end point that can be clearly defined in advance as the final goal or target.

Renee Stevens (MITRE): will describe a diagnostic tool for analyzing complexity and uncertainty in government enterprise technological change (called the *Enterprise Systems Profiler*), and discuss how it was applied in a particular government enterprise change effort, highlighting some the differences in how it was used across respondents at different positions in the enterprise.

JoAnn Brooks (MITRE) will discuss NATO's approach to explicating enterprise capability. As a large-scale government enterprise comprised of 26 sovereign nations

committed to common defense, NATO is a pre-eminent example of government enterprise undergoing change. NATO's governance process explicitly manages *capability packages*, formalized bundles of financial, technological and organizational descriptions, through a consensual decision-making process.

John S. Carroll (MIT) and **George Roth** (MIT) will present frameworks and lessons from MITRE projects as a nascent theory of enterprise change. The frameworks include classic Systems Engineering tools, an organizational analysis approach called the Three Lenses, developed at the MIT Sloan School of Management, and Renee Stevens' ESE Profiler. Additionally, they include an analysis of five enterprise change capabilities developed by Roth (2006) out of the experiences of the Lean Aerospace Initiative in implementing lean practices and from analyzing the literature on organizational change. Although there is no accepted simple theory of change, and even less is known of change at the enterprise level, they propose that creating a useful map with focus on key principles and measurable variables is a valuable contribution.

Conclusion

Assuming that pressures toward efficiency and control will continue to mandate change in government enterprises, the key question our presentations address is: *How is it possible to reach commonality of purpose across large-scale government enterprise change efforts?* We provide insights into mechanisms used by practitioners for identifying/establishing common language, values, logics (mental models); developing strategic capabilities and routines, as well as constructing effective technological infrastructure across an enterprise without stable leadership, all within contexts of unprecedented complexity.

Interest to AoM / Divisions

The study of enterprises, and government enterprises in particular, is a relatively new field; the symposium contributes both empirical data and theoretical insights into this growing area. Our work also reflects and contributes to growing efforts in the Academy of Management to bridge the gap between organizational and technological perspectives as evidenced in the growing interest in virtual teams, virtual organizations, e-government, etc. The symposium extends that trend to the enterprise level of government. The juxtaposition is consistent with the growing convergence of organization theory and technology studies, illustrated by Anne Miner speaking to the TIM division at AoM '05 and the forthcoming special issue of *Organization Science* on technology and organizations.

Explanations by division:

OCIS: The government enterprise change cases described in this symposium involve technological systems engineering and systems integration on a vast scale. As in all IT/IS development, political issues and communicating across disparate subcultures are intrinsic aspects of the process. The symposium offers an opportunity for OCIS Division members to enter into the larger dialog with other divisions around such issues – considering technology and its structuring properties as an integral aspect of the larger challenge – neither dominant at center stage, nor side-stepped altogether.

ODC: Enterprise change efforts leverage much of what is already known about organizational development and change. Yet government enterprises differ from traditional organizations in several ways (e.g. government vs. corporate; enterprise vs. organizational); the symposium will therefore contribute to developing theories of enterprise change. The combination is particularly important because in government enterprises with unique mission(s), learning needs to occur from samples of one or fewer (March, Sproull and Tamuz 1991).

TIM: This symposium discusses cases which stretch traditional boundaries of scale for technology and innovation management. While “herding cats” may be a common metaphor for managing technological innovation in organizational settings; a more

appropriate metaphor for the enterprise context might be “aligning tectonic plates.” Early results of our research suggest that existing theories of technology and innovation management may not extend to this scale. Unintended consequences of the increasingly rapid pace of innovation require different approaches to systems integration as Hobday et al (2006) note, and may even challenge the ability of government enterprises to carry out their mission.

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Systems Engineering Confronts Enterprise Change: Frameworks and Lessons from MITRE Projects

**John S. Carroll, MIT Sloan School of Management and
Engineering Systems Division**

George Roth, MIT Lean Aerospace Initiative

**Meeting the Practical Challenge of Government
Enterprise Change: Lessons from Systems Engineering
Academy of Management, Philadelphia, May, 2007**

Why Did MITRE and LAI Partner?

■ MITRE

- MITRE has been providing system engineering and development (especially IT) to government clients
- “Unintentionally” acting as organizational architects and change agents with lots of uncodified field experience
- MITRE Officer Objective 2: *“strengthen our systems engineering practice and advance the development of large, complex systems engineering at the enterprise level”*

■ LAI

- LAI has been catalyzing the transformation of the aerospace industry using “lean” (Toyota) principles
- The Air Force, our principal client, has lagged behind the prime contractors (and behind Army and Navy!)
- Attempts to study “leading edge” Air Force practices frustrated: lack of examples
- “Aerospace” and “Air Force” are huge enterprises of multiple organizations; no one in charge

Enterprise Systems Engineering Case Histories

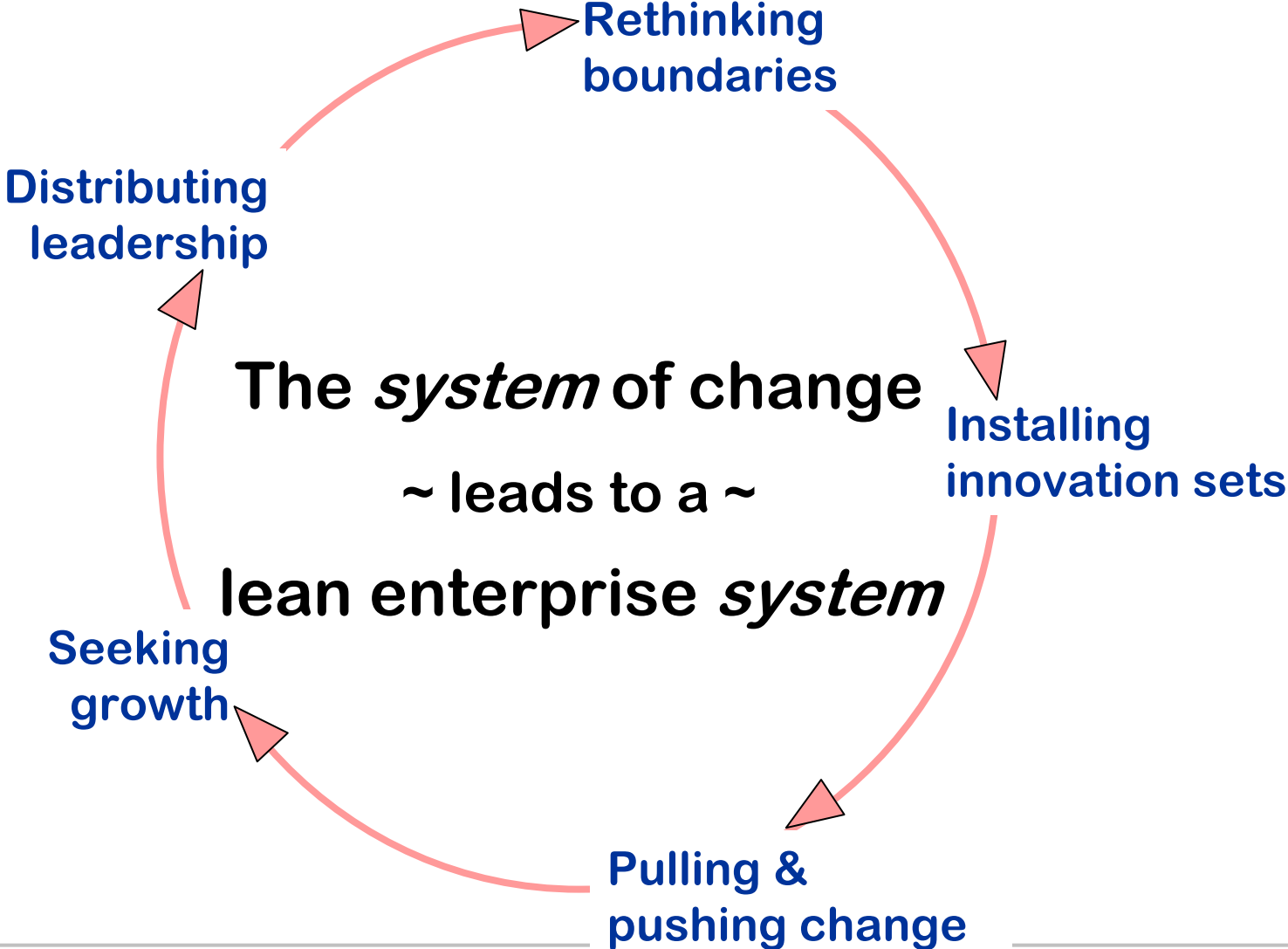
1. **Software modernization for joint battle planning**
2. **An information system for sharing intelligence data across multiple defense agencies**
3. **A coordinating office for designing and developing a next generation national transportation system**
4. **An improved communication system for warfighters**
5. **An integration of legacy systems for command, control, and consultation (diplomatic policy)**

Goal for our talk: Examine the case studies through our developing frameworks of enterprise change

Five Capabilities for Lean Enterprise Change

- Rethinking organizational boundaries
 - View organization along with suppliers and customers as a value stream
 - *extend improvement domain to include stakeholder environment*
- Installing sets of innovations
 - Complementarities of change
 - *extend scope to consistent and coherent programs in a system of change*
- Pushing and pulling change
 - Set structure and process that enables virtuous learning and change
 - *extend the tools to sequence and integrate divergent change approaches*
- Seeking growth opportunities
 - Project positive vision for continual renewal
 - *extend the strategy to base it on fundamental growth and development*
- Distributing leadership practices
 - Recognize interdependent roles in a system of leadership
 - *extend the leadership to all levels of the enterprise*

Successful Lean Enterprise Change

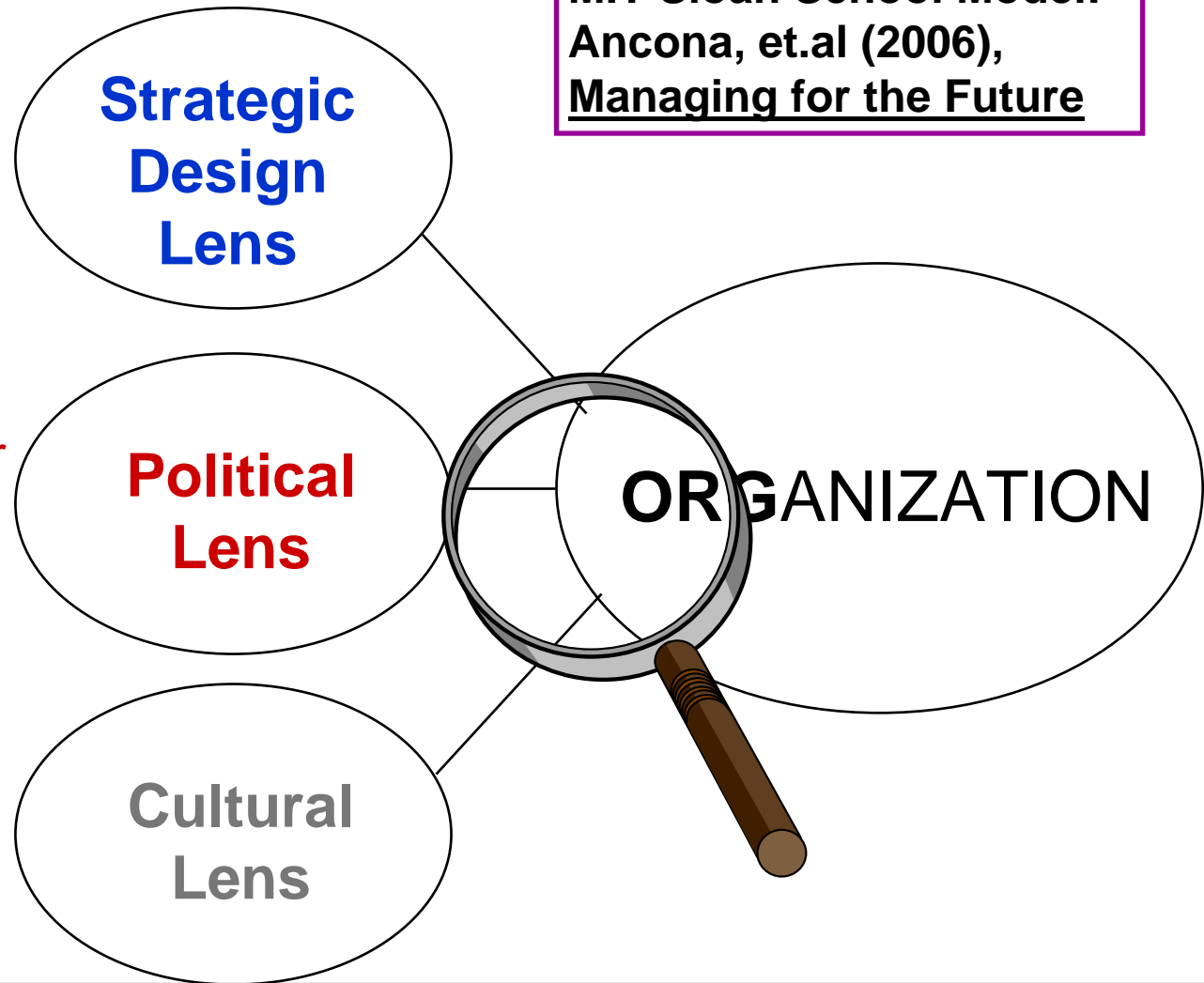


The Three Lenses

organizations are machines with roles, info flows, & incentives to achieve goals

organizations are contests for power and autonomy among interested stakeholders

organizations are ~shared mental maps, routines, symbols, values, & assumptions



**MIT Sloan School Model:
Ancona, et.al (2006),
Managing for the Future**

1. Software modernization for battle planning

- Improve coordination of combat planning and execution by integrating and upgrading legacy software systems
 - After early small-scale success with an agile, iterative process, small contractor given responsibility for system
-
- **Boundaries**: expanded rapidly but never “rethought”
 - **Innovation sets**: an innovative, fast approach scaled up without understanding weaknesses and complementarities
 - **Change**: pushed from generals and pulled from the warfighter community, but resisted by acquisitions and systems engineering communities (robustness vs. flexibility goals, etc.); MITRE can exercise influence, but little power
 - **Growth**: a goal for the contractor but not the system
 - **Leadership**: ambivalent between top-down and bottom-up

Note: *color coding refers to the 3 Lenses*

2. An intelligence information system

- Provide intelligence to the military command through IT infrastructure, technology, systems, and services
- From 1978 distributed development shift in 2005 to “Enterprise”
- **Boundaries**: one Directory acquired control over separate IT budgets and resources
- **Innovation sets**: reorganize, re-architect, codify standards, new capabilities, formal requirements process (“break your process”), ongoing training and education, ongoing set of meetings & conferences, regular personal communication by Chief Eng’r, less effort to “MITREize” new people
- **Change**: push change from the top; bottom with growing concern about usefulness of current system
- **Growth**: capabilities and flexibility for future system
- **Leadership**: centralized IT leads, local groups follow with decentralized development and execution

Enterprise Transformation

Cases	Rethinking boundaries	Installing innovation sets	Pushing & pulling change	Seeking growth opp'ties	Distributing leadership
1					
2					
3					
4					
5					

Conclusions

- Systems Engineering is about more than design of new technologies; it is about enterprise transformation
- We have a lot to learn about enterprise transformation that stretches theories of change to the breaking point: even getting the pieces right may not result in system change!
- Especially challenging in government organizations and enterprises that mix of government and for-profit companies
- Organizational processes are out of sync; change efforts keep colliding as each organization responds
- People are looking for tools and methods without considering how context and culture affect implementation
- Engineers are in a key position to facilitate change, but they need an expanded skill set: the “soft stuff” is hard!

Extra Slides

MITRE's World

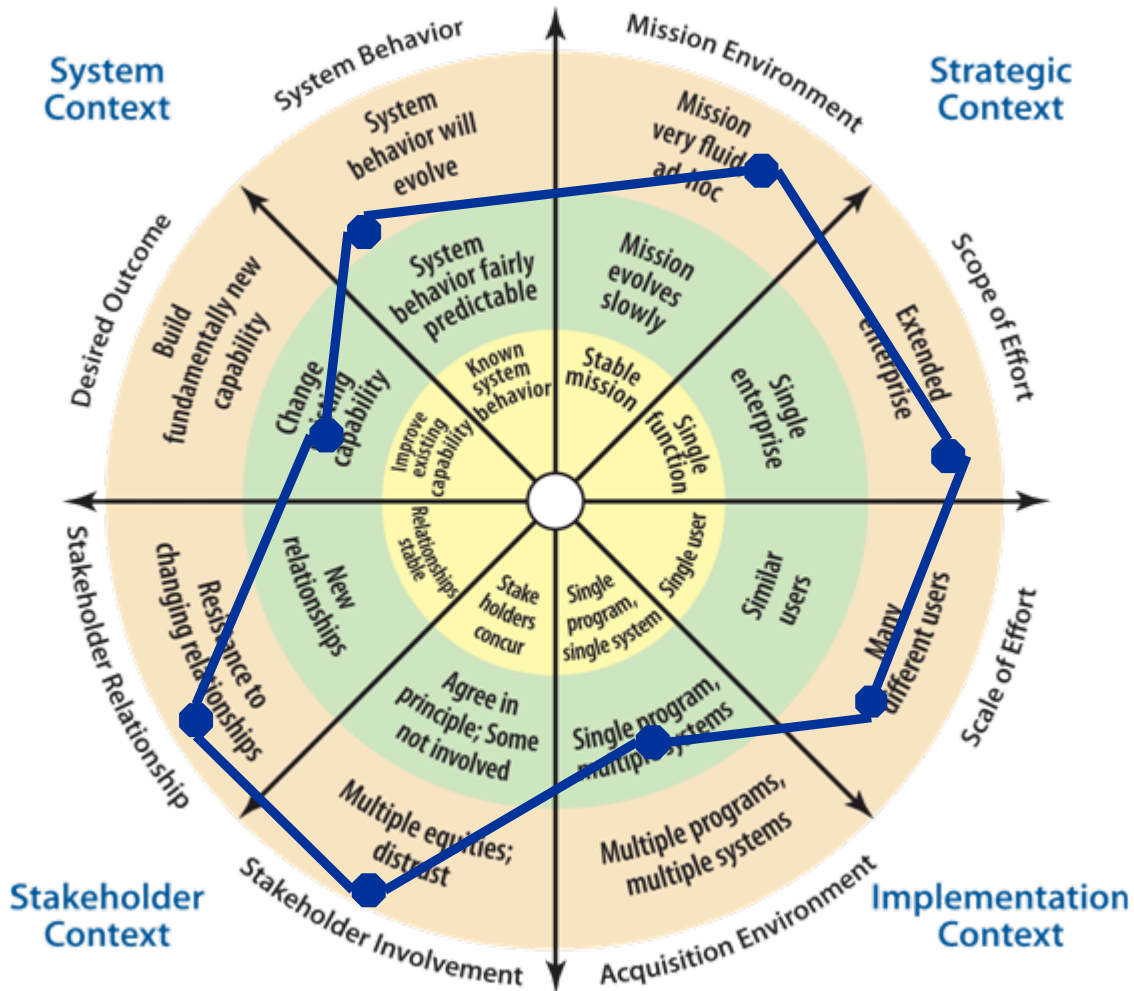
- **MITRE is embedded in shifting institutional “forces” of technological innovation and stakeholder politics**
 - Standalone stovepipe systems to networks
 - Custom-built to commercial off-the-shelf
 - Weapons systems to IT
 - Fragmented to consolidated sponsor fiefdoms
 - Large system contractors to multiplicity of vendors

- **MITRE has always managed the technological intricacies/contingencies of Systems for government agencies**

- **As the technology and the world change**
 - MITRE's business is changing
 - The pace of change is accelerating



Enterprise Systems Engineering Profiler



Original by R. Stevens (E300)

LAI's Mental Model of How LAI Works

