Interfacing Three Complementary Technologies: Strategic Planning, Process Modeling, and System Dynamics

W. L. McCoy
Systems Research and Technology Department
Naval Surface Warfare Center Dahlgren Division
Dahlgren, VA 22448-5100

ABSTRACT

This concept paper explores the utility and feasibility of interfacing three complementary technologies: (1) strategic planning, (2) process modeling, and (3) system dynamics to assist with the engineering of complex computer-based systems. Interfacing these technologies appears especially appropriate and timely. The Government Performance and Results Act of 1993 strives to make federal agencies operate more like businesses by requiring strategic plans and conducting performance audits. Process modeling technology aimed at providing assistance for the Integrated Product and Process Development (IPPD) approach for system development is being developed. In today's environment of perpetual change, a means of effectively predicting the impact of such changes on system development would be valuable. System dynamics modeling provides promise in this area. Since the product of strategic planning can be viewed as improved business and operational processes that will likely undergo major changes in response to events occurring in today's environment, there appears to be a natural synergy between application of these three technologies. This paper addresses exploitation of this natural synergy and hypothesizes that such exploitation would facilitate the development and operation of complex systems over the entire life cycle.

INTRODUCTION

To improve the acquisition and development of complex systems prevalent in the Department of Defense (DoD), the Integrated Product and Process Development approach [1] has been mandated. Reference 1 defines IPPD as "A management process that integrates all activities from product concept through production/field support, using multifunctional teams, to simultaneously optimize the product and its manufacturing and sustainment processes to meet cost and performance objectives." Key tenets of IPPD include Customer Focus, Concurrent Development of Product and Processes, Early and Continuous Life Cycle Planning, Multidiscliplinary teams, and Seamless Management Tools. The technologies of strategic planning, process modeling, and system dynamics, when interfaced appropriately, would appear to offer tremendous advantages. Interfacing these technologies is especially appropriate and timely for a number of reasons as will be discussed later. The Government Performance and Results Act of 1993 [2] encourages federal agencies to operate more like businesses by requiring strategic plans and conducting performance audits. A current research effort [3] in support of technology to assist with complex systems development is developing advanced process modeling technologies with the goal of effectively operationalizing the mandated Integrated Product and Process Development (IPPD) approach. In today's environment of perpetual change, a means of effectively predicting the impact of changes on system development in order that appropriate revised actions can be crafted and pursued would be very valuable. System dynamics modeling provides promise in this area. The product of strategic planning exercises, when done effectively, can be viewed as improved business processes. Such processes will likely undergo major changes in response to unplanned events occurring in today's environment. Thus there appears to be a natural synergy between these three technologies. Exploitation of this natural synergy should facilitate system development and operation over the entire life cycle.

STRATEGIC PLANNING

In the context of this paper, the term strategic planning is used in a broad sense to include initiatives to evolve the enterprise to make it more effective, as well as the life cycle planning associated with the development of complex computer-based systems. Strategic planning addresses deriving and evolving the mission of the enterprise, enumeration of goals and objectives, identification of strategic actions, and programmatics such as schedule, cost, and enterprise resources. Products that support strategic planning are typically billed as decision support tools. They typically offer software and techniques that guide users through exercises needed for making decisions. They typically

0-7803-4778-1/98 $10.00 © 1998 IEEE

support analyses concerning market attractiveness, competitive position, and strategic drivers in selected markets; strategic actions required to achieve organizational goals; and investment strategies to implement those strategic actions. Some products use advanced decision support techniques such as the Analytic Hierarchy Process (AHP) to assist with quantifying the various alternatives needed to make decisions [5].

In the acquisition and development of complex systems, the term "life cycle planning" is often used in lieu of strategic planning [1]. However, the goals of developing strategic actions and devising an investment strategy for achieving those actions are quite similar.

PROCESS MODELING

The acceptance by DoD of the tenets of IPPD validates the need to use process modeling technology for the acquisition and development of complex systems. Since the processes to be employed are major determiners of important systems attributes (including cost, quality, and schedule), technologies that allow the development and optimization of efficient and cost-effective processes should be in great demand. Process modeling is concerned with deriving an efficient set of activities (processes) required to accomplish an objective. It spans the areas of process definition and analysis, predictive process simulation, process execution, and design process management. In the future, process modeling will play an even greater role in the acquisition and development of complex systems and contribute directly to the success or failure of the effort.

The feasibility and utility of using process modeling to operationalize the IPPD approach is being explored. One such effort [3] has produced an architecture for a product with the following attributes: Web-enabled, form based templates for process definition; Innovative integrated product team (IPT) metrics (e.g. IPT Influence, IPT schedule vulnerability); Platform-independent, architecture-neutral Java/HTML implementation; Interface to selected simulation engines and desktop tools, and Visualization of intra-IPT and inter-IPT interactions.

SYSTEM DYNAMICS

System dynamics has been defined as a rigorous method for studying problems in system behavior using the principles of feedback, dynamics, and simulation. It examines systems as a whole as opposed to breaking them up into smaller pieces. It can be viewed as a means of quantitatively assessing the impact of changes on current development plans. The sources of such change may be external or internal and include resource constraints, schedule compression or extensions, new technology innovations, and the like.

System dynamics modeling has been described as having the following characteristics: (1) uses computer simulation models to understand and improve such systems; (2) builds qualitative knowledge and numerical information; (3) employs methods and insights from feedback control engineering and other scientific disciplines to assess and improve the quality of models; and (4) seeks improved ways to translate scientific results into implemented improvements. Though system dynamics has its roots in socioeconomic systems – having been applied broadly over the past three decades in such areas as environmental change, economic development, social unrest, urban decay, psychology and physiology, it appears that the engineering of complex systems may be another area which may benefit from this technology. Some explorations into applying system dynamics modeling to the acquisition and development of complex Navy systems have been performed and the results to date appear promising [4].

INTERFACING THE TECHNOLOGIES

In the natural order of things, strategic planning would be performed first to derive a set of strategic actions (and priorities) for meeting some goal. Process modeling would then be pursued to derive an optimized set of processes or activities to implement the strategic plan. When important factors change, system dynamics modeling should be performed to assess the impact of such changes. If significant impacts are observed, then strategic planning should be revisited, followed by process modeling, and so on. Since the world is very dynamic and the rate of change appears to be ever increasing, very seldom is a planned activity of any significance completed without having to revisit the planning process. From an initial look, it appears that the three technologies have little in common and interfacing (or integrating) them would perhaps not be worthwhile. Since all three technologies are either explicitly called out or inferred by the IPPD approach [1], a closer look is warranted.

One way to further explore interfacing these technologies is to examine in more detail the input required by and output produced by each technology, and attempt to automate the exchange of such information. When performing strategic planning, one is very much concerned with goals, available alternatives, judgments, and current enterprise performance. The major result is a set of prioritized strategic actions to be performed to accomplish the overall goals. For process modeling, the basic inputs are objectives, strategic actions, available

resources, and constraints. The result of process modeling is a set of optimized processes that when visually portrayed should facilitate communication, understanding and execution of the activities required to accomplish the goals. In system dynamics modeling, the input parameters describing changes that will affect the outcome of the system under development are expressed typically as input to a simulation model. The output would be the impact of changes expressed possibly as cost deltas, schedule extensions, resource changes, and system performance. Table 1 identifies the basic information that could be used by the various technologies. It is observed that there is significant commonality.

Technology	Input	Output
Strategic Planning	Goals Alternatives Judgments Performance feedback	Mission Needs Assessments Objectives Strategic Actions Outcome measures
Process Modeling	Mission Objectives Strategic Actions Resources	Optimized Processes (models) with - role, person, goal, resource Graphical Process depictions Process Metrics
System Dynamics	Models - Organization - Development Changes considered	Impacts (measures) -cost -schedule -performance, ..

Table 1: Interfacing Technologies Model

Upon closer scrutiny, one will observe that the results of strategic planning can be viewed as input useful for processing modeling. With this as the case, then strategic planning can result in graphical optimized processes with metrics and hence the resulting plan can be optimized and made more efficient and effective. In addition, planning in the acquisition and development world deals with cost, schedules and other resources needed using sophisticated estimation techniques. Hence it should be more closely aligned with the actual activities required to develop a system. Some of the system dynamics models, as appropriate, could be built from the actual processes to be employed in system development using metrics from actual development activity or derived from similar efforts (perhaps using case-based reasoning technology). The results of system dynamics modeling could assist with the identification of new goals, objectives, and alternatives needed to drive revised planning efforts.

The above observations inspired a return to the basic issues with respect to the scope and use of the respective technologies and generated the following questions:

1. What is the natural scope of strategic planning? Or more precisely, should strategic planning include sophisticated cost, schedule, and resources estimation techniques?
2. Where do metrics fit in? Should metrics be employed across the entire spectrum of the three technologies?
3. Should system dynamics modeling be a part of strategic planning for performing sensitivity analysis on parameters likely to change?
4. Is case-based reasoning a technology which could be employed as a part of the other three technologies?
5. How do these technologies fit into the overall systems engineering support environment?

To some developers, these technologies are seen as activities that contribute very little value to the overall effort but consume significant resources. They hypothesize that resources could be better utilized in the actual development of the products. After all, a document containing plans and process descriptions does not provide functionality. Perhaps, a reason for this view is the lack of sufficiently powerful and robust tools that

provide the help desired. Currently, these functions are done manually (perhaps using a word processor, spreadsheet, and presentation graphics tools) mainly because the payback to effort ratio for existing support tools is viewed as being too low. For the new crop of internet-based products currently under development along with a repository to capture and maintain enterprise information, it is envisioned that the drawbacks will soon disappear. The challenge to this technology is to provide the proper mix of capabilities, and at the same time make use easy and effective. Issues that affect these criteria include cost of ownership, learning curve, visualization capabilities, and accessibility of tools.

The realization and general acceptance that product attributes are a direct reflection of the processes used to develop them has inspired to the following initiatives: (1) more emphasis is now being placed on documenting, a priori, the planned acquisition and development processes, (2) strict adherence to those documented processes during actual development, and (3) configuration management of documented processes as needs arise during the actual development. In the end, the updated process description will provide an accurate portrayal of the activities and steps performed to build the product. In this context, one may also view strategic planning and system dynamics as processes. Thus activities that support strategic planning and system dynamics would be modeled as processes. Such process documentation could be used by independent verification and validation teams along with other testing techniques to make assessments of the quality of the end product.

A generic solution to interfacing these technologies is desirable. Care should be exercised to avoid implementation solutions that would apply only to specific incarnations of the technologies.

APPLICATIONS

Numerous applications in both the DoD and commercial world could exploit this synergy. Key IPPD tenets of customer focus, concurrent development of products and processes, early and continuous life cycle planning, multidisciplinary teamwork, and seamless management tools support this exploitation. Judicious application of the technologies should contribute to the effectiveness and efficiency with which systems are developed, acquired, operated, and maintained. These outcomes are possible because of the many potential benefits of these technologies including: (1) logically derived, complete and consistent strategic plans based on effective application of decision support technology, (2) common understanding of the processes to be employed since they were derived from systematic and consistent definition, communication and documentation of processes, and (3) effective assessment of the impact of changes on system development plans and processes. The ability to capture this information in a repository and to reuse it "as is" or modified as appropriate should contribute significantly to the effectiveness of these technologies. Successful application of the technologies should result in higher quality systems developed with fewer resources and shorter development cycles.

These technologies can be employed in many other contexts regardless of whether conformance to the IPPD approach is required. The following potential applications are identified: establishment and maintenance of plans and processes for software development and life cycle support; business process reengineering in various markets such as telecommunications, entertainment, manufacturing, insurance, and banking industries; improving organization-wide processes for contracting, procurement, waiver regulation, logistics, purchasing, and payment; analysis and redesign of health care processes with internet/intranet-enabled information systems; and even definition and analysis of procedures and policies for conducting research and development initiatives.

To enhance the effectiveness of these technologies, integration with other technologies would appear appropriate. For the engineering of complex systems, integration into the systems engineering environment (SEE) containing other tools for systems development would appear especially appropriate. Such integration would advance implementation of the IPPD approach by providing computerized support for increased automation of development and operational processes along the existing computer support for product development. If accomplished appropriately, such technology could be used to support process management, guide process execution, and support automation of major portions of the process. In this context, the concept of a process-centered systems engineering environment could be realized. Such an environment will allow process specifications to influence and potentially control the activities associated with the development of major portions of complex systems.

SUMMARY

In today's environment of constant change, it would be advantageous to be able to cooperatively, iteratively and synergistically (1) devise realistic and practical strategic plans, (2) develop optimized processes to carry out those plans, and (3) assess the impact of internal and external factors (budget, schedule, technology, etc.) that could affect those strategic plans and optimized processes. It appears that interfacing effective technologies for strategic planning, process modeling and system dynamics would provide a significant capability in this direction and would offer major advances and support for the IPPD approach.

This investigation hopefully provides motivation for the marriage of these important technologies. Such a marriage could potentially make it easier, faster, and better to perform the three functions since data from any one activity could flow to the others, thus contributing to the efficiency with which these activities are performed. Such could represent a significant contribution to the ability of the DoD and the commercial sector to more effectively acquire and implement complex systems and at the same time satisfy required planning and development mandates. This interfaced technology could be used by planners, managers, process engineers, and systems engineers in DoD and the commercial sector to more effectively perform their respective functions.

REFERENCES

[1] Office of the Under Secretary of Defense (Acquisition and Technology), "DoD Guide to Integrated Product and Process Development (Version 1.0)," February 5, 1996.

[2] Phillip Blackerby, "Strategic Planning, An Overview for complying with GPRA (P.L. 103-62)," http://www.perfstrat.com/articles/overview.htm, 1993.

[3] Azad M. Madni, W. L. McCoy, Carla M. Madni, "Process Support for IPPD-Enabled Systems Engineering," Proceedings 1998 IEEE Conference on Systems, Man, and Cybernetics, October 1998.

[4] CD-ROM, "IPT Learning Campus," Bellwether Learning Center, A Division of Dynamic Systems, Inc., http:/www.dynsys.com, 1998.

[5] Karl M. Kapp, "AliahTHINK! Multicriteria-based Decision Support Software," APICS - The Performance Advantage, Volume 8, Number 4, April 1998, http://lionhrtpub.com/apics/apics-4-98/swr.html.