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On the Applicability of Requirements Engineering to Strategic Project Management

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Abstract—**Although debate still prevails about specifics, (e.g., tools, level of granularity, elicitation techniques), there is common agreement on the importance of requirements engineering. Since good requirements are vital to completing projects on time, within budget, and to delivering products that meet their intended purpose, awareness is also increasing that requirements engineering plays a significant role in project management. But what role, if any, can requirements engineering play in strategic business management? Research has begun to suggest that an emerging discipline, strategic project management, enables organizations to deploy projects that are well aligned with enterprise business strategies and to achieve better strategic growth. This emerging field relies on the integration of 2 disciplines - sound project management and organizational strategic management. The aforementioned connection between requirements and project management then suggests that, if there are ties between strategic management and requirements engineering, the triad of these disciplines might enable further improvements for overall business success. This paper explores such connections, presents an initial conceptual framework, and examines how requirements linkages provide vital insights into the ability of the enterprise to meet defined performance objectives and to preserve technologies, capabilities, and competencies that may be impacted by potential funding decisions.**

Keywords- portfolio management; requirements; portfolio; systems engineering; strategic portfolio management

I. INTRODUCTION

For a firm in the business of delivering products to the consumer market place, the concepts of Return on Investment (ROI) and Risk are well understood in relation to financial impact. In such a business environment, the use of portfolio management tools and processes to manage efforts has been seen to be of considerable value. The authors in [3] suggest that companies use portfolio management to evaluate potential projects with regard to their expected ability to contribute to the overall success of the organization based on prioritization in relation to other potential projects. The authors further suggest that, by starting with the company's business strategy and goals, the portfolio evaluation process results in the selection of projects which are not only thought to contribute strongly to organizational profit, but also are well aligned with the goals of the business. In the review of recent research in [2], the author presents the notion that the selection of a project portfolio often includes the concepts of core competencies and capabilities of the organization. This integration of focus on organizational competencies and capabilities with alignment to the strategic business direction results in a "resource-based view of strategy" wherein organizational competitive advantage is tied to the character of its particular differentiating capabilities. The author further postulates that the addition of strong leadership and competency in project management serves to contribute to the overall successful implementation of those projects selected in the strategic portfolio, thereby enhancing organizational ability to achieve and sustain their competitive advantage.

When considering a business enterprise not within the private sector, the drivers for business decisions are seen to be transformed, since the concepts of ROI and risk take on different meaning for such an entity. In [1], the authors articulate that basic private vs. public sector differences necessitate a shift in the approach to strategic portfolio management. Adaptations are outlined in [1] that effectively expand traditional portfolio balancing approaches by broadening organizational goals to include concepts such as "scientific and technical human capital". Such conceptual expansion is proposed to enable a public-sector R&D enterprise to apply strategic portfolio balancing methods to achieve more relevant goals.

Sandia National Laboratories (SNL) is a non-private R&D enterprise, funded largely through the Department of Energy (DOE), and having a spectrum of responsibilities that span basic research and development (R&D) to the sustainment of national technical resources (e.g., testing and prototyping facilities, advanced computing capabilities, and intellectual competencies). SNL is not only subject to constraints as discussed in [1], including Congressional budget cycles and contracts, but is also obligated to carry out contractually negotiated responsibilities related to its defense mission. With this latter responsibility comes the need to focus on organizational competencies and capabilities – and indeed on the concept of "S&T human capital" as discussed in[1] – since SNL must assure that the right facilities, skills, and capabilities are ready to support the nation, when and if they are needed.

Therefore, the environment of an enterprise such as SNL might best be considered to be a sort of hybrid – not privately funded, but not fully "public" either because of security concerns. Although SNL must respond to the demands and fluctuations driven by political and economic changes, the organization has an overarching need to address longer term technology stewardship demands – bringing in

both a tactical and strategic focus to planning and portfolio management. In addition, negotiated deliverables apply to the work undertaken by the company during any period of time, as specified by contract or Federal mandate.

These "hybrid" characteristics bring into question the extent of the applicability of common strategic portfolio and project management models. A brief review of some typical issues that an organization such as SNL faces reveals the need to augment the traditional approaches with an additional dimension:

- Do the projects selected for funding provide the right opportunity to develop and retain the critical competencies that are likely to be needed to address future defense needs?
- If a particular effort is not funded now, what are the consequences to critical test facilities – can the facility even be kept operational until needed by the next project?
- If a funding cut results in a project cancellation, what contract obligations are placed in jeopardy and what other projects might be affected?
- If the funding to develop a computational algorithm is cut, how many other requirements and project interdependencies are affected?

These types of issues necessitate that additional information be made available to decision makers regarding the interdependencies between project deliverables, the level of demand and utilization of critical skills and capabilities, and the connections between any given project and the drivers, needs, or requirements for the work. This focus on interconnections and drivers leads us to explore the extent to which concepts from requirements engineering might be applied to typical portfolio management processes and what might be gained from doing so. This paper discusses the work undertaken to explore reasonable connections between requirements engineering and strategic portfolio management. The preliminary results of this work are presented along with associated observations and conclusions. In particular, the notion that requirements engineering can provide a third critical discipline which, when coupled effectively with strategic portfolio management and project management, can provide the organization with key insights to enhance overall business success.

II. Hierarchies and Terminology

A. Requirements Hierarchy

An initial step in applying requirements engineering principals to the problem of portfolio management was to develop a requirements hierarchy and identify the associated source documents available from which to mine requirements. Several attempts were made to establish a hierarchy of source documents. The principal difficulties associated with this task centered on whether to consider a particular document as a source of guidance or as more of a binding commitment to deliver something. Secondary issues were associated at what level in the strategic structure the source document would apply. The resulting simplified requirements structure appears in Figure 1.

1) External Programmatic Drivers

The highest level of source "requirements" in the structure has been identified as "external drivers." The customer or sponsor provides guidance on the nature of the work to be done. Although there is often a broad range of approaches in the selection of what will be undertaken [1], typically, guidance is prepared as a result of considerable dialog between the corporation doing the work and the sponsoring agency. Once the nature of the work is agreed upon, guidance can be prepared in some form to reflect the agreements. This category of strategic requirements includes information from the following kinds of sources:

- *Customer or Sponsor strategic Guidance:* examples include: government-issued strategic plans, reports, and directives; military planning documents; and high level program guidance documents identifying program goals and objectives.
- *Contractual work authorizations:* examples include: production quantities; delivery schedules; and program requirements.

2) Strategic Goals and Objectives

As the enterprise receives source documents containing external needs and drivers, internal strategic efforts transform this information into actionable strategic planning documents that define goals and objectives within the organization. For example, the existence of a nuclear test ban treaty could drive the creation of agency planning directives to develop algorithms to analyze and predict weapon system performance. This in turn could be used internally within the organization to establish strategic guidance on analytical algorithm development and on launch trajectory simulation. These goals might in turn be associated with particular program areas within the organization and further developed into specific objectives to be met. Examples of these types of source documents include: Internal Strategic Goals and Objectives: planning guidance; briefings; and scorecards.

3) Project level requirements

Once strategic planning is completed, internal strategic goals and objectives can be provided to project managers and teams for their use in assuring that project goals are in alignment. In practical application, however, project teams do not always directly have access to this information. Project teams work more routinely with technical and internal business process requirements, to develop initial project plans for the work that will be conducted. The types of "requirements" generated at the project planning level are derived in conjunction with the project plans and schedules created for the effort. These have been categorized into three main types in this effort.

- *Project-specific goals & objectives:* Project plans and schedules; project deliverables and milestones; goals; and technical performance characteristics
- *Inter-project needs:* sub-tasks and deliverables; inter-project deliverables

- *Resource demands:* funding needs, specific skills and competencies required for project success, facility usage demands

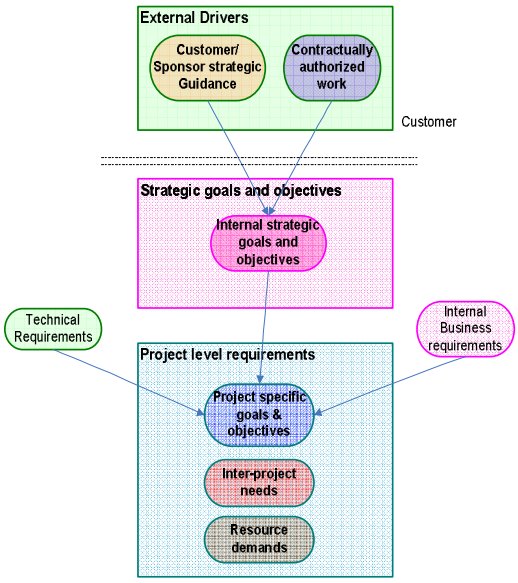

Figure 1. Requirements Structure.

B. *Terminology*

The categories of requirements just noted are laden with terms like "goal" and "objective" and "deliverable" – terms more traditionally thought of in the context of strategic planning. Since we are concerned with strategic project management, the presence of these terms is really expected. However, it is reasonable to consider in what context these terms can apply within the domain of requirements engineering. The terms *Goal* and *Objective* are defined in [4, definition 2] as being virtually the same. Both describe "what" is to be done or achieved. What then is the major difference between these terms? The difference seems to focus on scope and quantification. *Goals* dominantly refer to a broader scope or an intangible or immeasurable end, while *objectives* take on a more concrete, tangible, and measurable connotation as highlighted in [5].

A requirement can be defined as something that is needed for a purpose or a condition or capability necessary to meet a formally imposed contract obligation, as discussed in [6].

Thus, the terms goal, objective, and requirement all clearly refer to something that is to be met or achieved. Considering the term *deliverable*, we find it is often used to refer to a condition (*e.g.,* milestone) that must be "met." Since a deliverable can also refer to something that is provided to a system or user satisfy a need, for the purpose of this work, the terms goal, objective, need, and deliverable have been interpreted to be types of requirements.

C. *Planning and Management Hierarchies*

In addition to a requirements structure, strategic project/portfolio management processes are dependent on key organizational structures. These individual structures were observed within the organization by examination of the mechanisms of strategic business management, ownership or leadership for work implementation, and the management or ownership of the competencies and capabilities that would be critical to the success of the work.

1) *Strategic Structure*

The management structure responsible for developing and implementing strategy within the organization was identified from the collection of program manager interviews and internal website reviews. Several levels of responsibility were identified. The level structure varied across the organization, and appeared to be dependent on a number of factors such as breadth and scope of responsibility, size of budget, product type and complexity, current designs, and advanced concepts. Additionally, the program management structure was found to be heavily influenced by the corresponding management and reporting structures adopted by the government sponsor. The most significant levels identified included: Strategic Management Unit, Strategic Area, and Program Element. Often the Program Element level was further subdivided, for example into Program Sub-elements. Data gathering was not encouraged at such a level of granularity due to the size of the organization and potential for an overwhelming amount of data.

2) *Work Ownership Structure*

The organizations responsible for proposing and planning work at the project level were typically referred to within SNL as "Line" organizations. Line organizations were found to often own work efforts based on product type. Line organizations were observed to possess an inherent structure based on Centers, Groups, and Departments. Here again, level variation was observed based on a number of factors, including the volume of the business, particular product areas, numbers of staff, and numbers of customers. Actual project planning activities were most often conducted at the department level. However, to limit the amount of data and to encourage higher level dialog, structures below Group level were omitted and projects were assigned to the responsible Group level.

3) *Resource Ownership Structure*

The resource ownership structure was found to be identical to that for work ownership. Critical skills and competencies, capabilities, and facilities are owned and staffed at the lowest level of the organization, the department level. Again, however, the level for data gathering was limited to the Group level to reduce the data volume and to encourage discussion at a less granular level. Generic resource types were therefore assigned to the Group level.

III. GATHERING DATA

Data were gathered principally through one-on-one interactions with responsible individuals. It is important to note here that program managers had been gathering information such as this each year to support work

management and funding discussions. However, additional data were requested for this effort, including specific descriptive meta-data attributes, and information identifying the driving need for the work, and where that need was identified. These additions were designed to enable creation of linkages from project to project or from project to driving need.

IV. Mining for Gold

Strategic documents were individually reviewed for "nuggets of gold" that identified the requirement, need, goal, or objective that was intended to be met. The following is intended to provide insight into the challenges and complexity of this effort.

As an example, consider a fictitious guidance document that could be released by the sponsor discussing a study to identify options for an existing system to be launched from a different platform. The strategy document might discuss the reason behind wanting to use a different platform - perhaps there is evidence that after some years the existing platform will no longer be available. The document might highlight constraints on the focus areas of the study. There might also be discussion of how multiple research laboratories and defense contractors will work together to develop the options. There may also be discussion of how the study will be reviewed and presented. In addition, there could be options that the sponsor wants applied elsewhere as well. Thus, finding the statements that will serve as the driving need or requirement is likely to be time consuming. A scheduling document often accompanies guidance such documents. The schedule might define the timing of the study in relation to other activities.

Internal strategic documents are developed from an understanding of sponsor guidance – obtained from both discussions and documents. A similar requirement mining effort was applied to internal strategic guidance. Where interpretation of sponsor statements was needed, the internal guidance provided additional insights. Internal guidance also coupled together information from several sources to provide investment guidance, technology development insights, and strategies for enhancing or preserving skills and capabilities. Figure 2 illustrates a representative flow of the mined driving needs and requirements that were identified in this phase of the analysis. *(Note: exact data gathered on this effort cannot be presented due to security concerns.)*

V. Establishing Traceability

The elements shown in Figure 2, while not actual data, do illustrate the kind of requirements that were mined for the source documents, and the nature of the traceability interconnections that were identified. Notice that the project level requirement "Validate models using test data," is a product deliverable that is required by two other project deliverables, namely "Develop models for material interactions" and "Simulate untestable environments." The latter project level connection means that task of performing a simulation of environments that cannot be tested *requires* that we use models that correctly represent the environment, and that such models have been validated in some manner. The former connection means that as we develop models of material interactions, we must confirm the models using test data is some manner. Note that the "Validate models…" deliverable is also driven by two internal strategic goals that are tied to several external drivers

VI. Connection to Project Portfolio Managemnent

The traceability paths represented in Figure 2 offer a very powerful representation of the flow of external drivers to internal strategies to project level deliverables and their interdependencies. By a simple examination of the traceability links for any project level requirement entity, we can readily determine the rationale for doing the work the entity represents. When we create a portfolio – a collection of projects that are strategically related in some manner – we can easily identify any projects or project level deliverables that are weakly or not at all traceable to either internal or external drivers.

Figure 3 illustrates what begins to unfold as we add in the dimension of portfolio management by allocating or assigning projects and their deliverables to an element of the organizational strategic structure and assigning critical resources.

In Figure 3, each of the project level requirements have been assigned to one of the strategic program elements shown in pink. In this example, the program element "System Certification" has responsibility for the three certification project deliverables, the program element "Modeling and Simulation" has responsibility for the three modeling-related deliverables, and the program element "Materials Science" has responsibility for the remaining materials related deliverable.

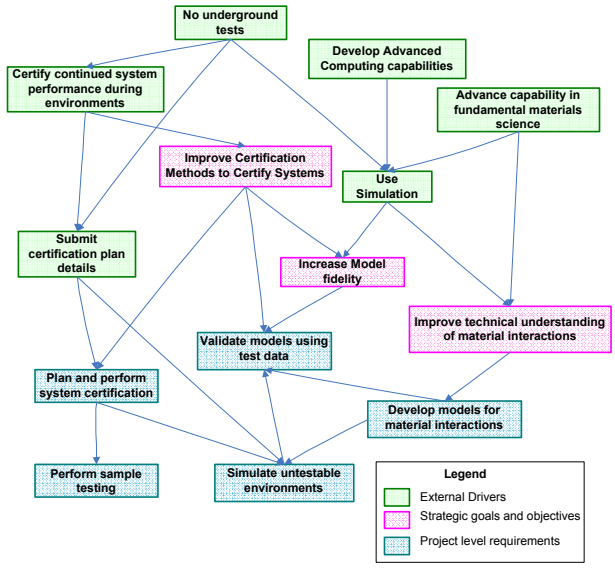

Figure 2. Representative Requirements Flow

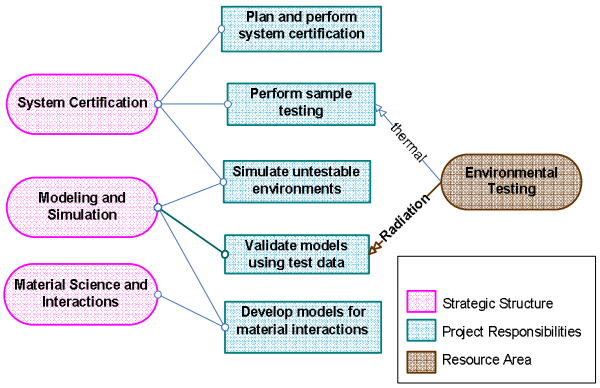

Figure 3. Portfolio Management Dimension

The resource dimension is brought into the analysis with the assignment of environmental testing facilities and skills as depicted by the connections in the diagram. For this discussion, the connection of the environmental testing resource owner would likely indicate that a particular environmental testing facility is required by the "Validate models using test data" and by the "Perform sample testing" deliverables, but these two project entities do not use the same testing facility.

VII. Strengthening Strategic Portfolio Decisions

Referring to Figure 3 once again, consider the implications of a determination that the radiation facility is obsolete and that there are too few users and insufficient funds to justify any renovations, so that the facility will be shut down. It would therefore follow that unless the Modeling and Simulation program element can find an alternative facility, or unless they have sufficient funding to cover the essential facility renovations, they would be unable to perform the model validation that is expected. A quick portfolio review at the program level might suggest that the risks and costs of continuing to implement the model validation project would be too large to justify its inclusion in the portfolio, even though based on the other criteria in Table I, the project was rated as a reasonable investment.

TABLE I. Possible Portfolio Evaluation for "Validate Models Using Test Data"

Strategic Mod-Sim Criteria	**Project Score**
Improves model fidelity and confidence	4
Enhances ability to Certify Systems	4
Provides Opportunity to enhance skills	3
Low Cost (low = 5)	1
Low Facility Risk (low = 5)	1

With the addition of the requirements dimension it becomes possible to "pull the thread" and determine that cancelation of the project impacts other projects and the deliverable traces to virtually every requirement shown in Figure 2. Having the requirements traceability information available provides for richer dialog between program managers to explore alternatives and solutions. This information also provides the organization the opportunity to discuss with the customer/sponsor the impacts of insufficient funding and impending funding cuts, as well as the foundation to establish the requirements basis for portfolio and project activities.

I. Status

This work has demonstrated the successful application of requirements engineering concepts and explored some initial benefits. Preliminary expectations were to include over seven source documents and four strategic internal documents for requirements mining. The sheer volume of material made this a prohibitive approach. Ultimately a single authoritative source document and a single internal strategy document were used. However, since the documents were not written in the style of a requirements document, identifying meaningful requirements proved to be a difficult task. The situation becomes further complicated by the facts that source documents are owned by the sponsor and are often not readily available in the desired electronic format. Consequently, configuration management of the mined requirements therefore becomes difficult if not impossible.

The second year evolution of this effort has placed more focus on the identification of interconnections between projects and deliverables, along with a description of the understood need or driver for the effort. This has resulted in a collection of over 2000 project level requirements and associated interdependencies. It is apparent that effective management and retrieval of specific interconnection data necessitates the use of a tool designed for that purpose. For small amounts of data, spreadsheets may provide a useful alternative. However due to the existence of many-to-many trace links, use of a suitable tool has become preferable.

II. Future Indications

Continued exploration of the ties between requirements engineering and strategic portfolio management are of further interest based on the preliminary findings of this work. Portfolio management, as explored in [2], provides the mechanisms for organizations to select the right projects that are strategically well aligned to goals and objectives. The addition of strong competency in project and program management allows the organization to do those projects right once they are selected for the portfolio. Adding the requirements dimension helps assure that investment and disinvestment decisions are made with the full knowledge of the impacts. Requirements traceability clearly enables decision makers to determine which requirements are placed in jeopardy by a project's cancelation. Having knowledge of the requirements in the context described in this paper also enables the organization to dialog with sponsors regarding the potential impact of funding shifts and budget cuts with respect to both short and long term needs. Further, by adding in consideration of key competencies and capabilities (including skills and facilities) the organization can develop

a closed loop model for resource utilization in the context of the driving needs and requirements, as depicted in Figure 4. This closed loop understanding is critical for any organization faced with the need to retain skills and competencies for a long term envisioned demand when short term demands are subject to considerable variation.

Although the efforts described herein are still at the early stages of implementation, much progress with regard to traceability and interdependencies has been made. Considerable opportunity for further research remains. There is still much to be learned regarding how traceability could be used in portfolio evaluation, including connectivity indices or demand indicators as quantitative measures. More understanding is also necessary to define constructs and possibly standards for identifying key capabilities and competencies. It is common today for portfolio management tools to handle resources at the level of named individuals. While this approach provides value from a tactical deployment and project management perspective, it is less clear of the value of such granularity when approaching strategic capability development decisions at the enterprise level. Further efforts are also needed to create effective guidelines for specification and management of strategy documents to facilitate their use in this context.

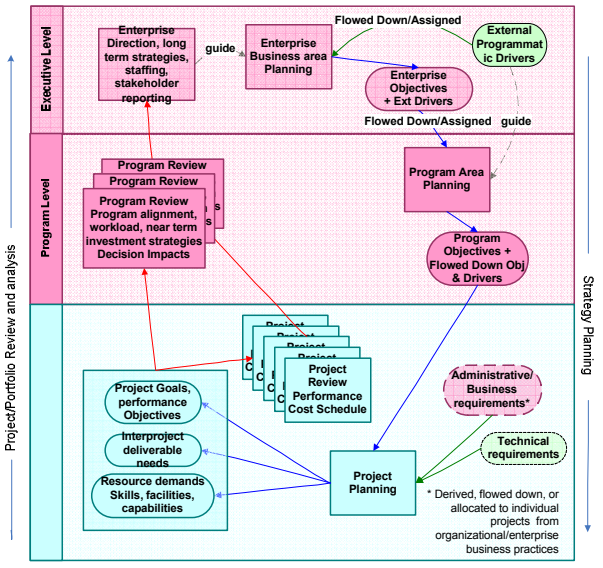

Figure 4. Portfolio and Requirements Management: A Closed Loop View for the Enterprise

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