Considerations for a Requirements Engineering Process Model for the Development of Systems of Systems

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***Abstract*—The complexities associated with managing requirements for building systems within systems, interconnected and networked systems, and systems communicating with each other across many distributed types of environments has long since been recognized. However, dealing with the process of requirements engineering for these types of systems is still a serious concern for most complex projects, given the various types of system development paradigms that are carried out today, and the rapid evolution of requirements at various phases of the project. In order to obtain optimal requirements that reflect the characteristics of and constraints imposed by systems of systems, there needs to be an appropriate requirements engineering process in place. In this paper, the authors present several considerations for an ideal, generic requirements engineering process model that would be helpful in guiding the requirements engineering process for the development of systems of systems.**

Keywords-Requirements Engineering Process; Process Model; Systems of Systems

I. INTRODUCTION

The process of carrying out Requirements Engineering today is an escalating challenge, due to several factors such as increasing complexity in the systems that are built, constantly changing customer needs, reduced time to market, and the plethora of development methodologies that are followed for different portions of systems development in both local as well as distributed set-ups. Carrying out RE for systems of systems (SoS) becomes a more complicated task, as the additional characteristics and constraints imposed by SoS have to be dealt with.

In order to obtain a stable and reliable means of eliciting, analyzing and managing optimal requirements for SoS, it is desirable to have a generic RE process model that, at an abstract level, incorporates the nuances exhibited by SoS, and can hence serve as a concrete framework for guiding SoS development more effectively and thoroughly.

II. THE RE PROCESS AND PROCESS MODELLING: A BRIEF OVERVIEW

The process of Requirements Engineering may be described as the set of activities directed towards discovering, obtaining, and continuously validating a set of several different types of requirements that a system under development must meet. RE is multi-disciplinary in nature [1][2] and is roughly comprised of the five phases of Requirements Elicitation, Requirements Modeling and Analysis, Requirements Communication and Agreement or Validation, Requirements Evolution, and overall Requirements Management [2][3].

Other views of the RE process have also been purported by several authors. For example, Rzepka [4] says that the RE process is comprised of the three central activities of eliciting, insuring, and validating requirements, while Yu [5] mentions that the process is largely composed of two phases – the uncertain early phase whose activities need to be integrated and aligned more thoroughly, and the more well-understood late phase. Several authors have worked on different realms of the RE process, such as mechanisms for improving existing RE processes [6], measuring the success of RE processes [7], overall management of the RE process [8], and the application of RE process models to specific domains [9].

We use the term 'process model' in this context to refer to a simplified representation of a conceptual, complex process [10]. According to Curtis *et al*., the various forms of information people would want to gauge from a process model include determining what tasks are going to be accomplished, who is responsible for accomplishing each task, why and how each task will be carried out, and dependencies between and among tasks and actors. A process modeling language should *permit evaluation of the adequacy of a proposed process, and the model itself should be analyzable for such properties as syntactic correctness, consistency, risks, and provide opportunities for improvement* [10].

Keeping in mind that the RE process is diverse, multi-disciplinary and increasingly complex, a trade-off between the various types of information that an RE process model is capable of providing and the level of granularity and generality at which the process model is expressed is inevitable. It is nevertheless desirable that a generic RE process model should provide as much contextual information as required, while incorporating suitable mechanisms by which it may be adapted to the type of development method and the environment in which it is applied.

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III. A GENERIC RE PROCESS MODEL FOR SYSTEMS OF SYSTEMS

The constituent parts of any complex system behave in a non-deterministic and dynamically non-linear fashion [11]. Leveson mentions that the underlying factor involved in assessing the *complexity* of any system is the intellectual manageability associated with it: *a simple system has a small number of unknowns in its interactions within the system and with its environment. A system becomes intellectually unmanageable when the level of interactions reaches the point where they cannot be thoroughly guarded against, anticipated, understood, or planned* [12]. Additionally, at every level of system development within a SoS, varying degrees of the stakeholders' domain knowledge may lead to solution biases entering the requirements generation process [13]. [14] purports the necessity of both top down, as well as bottom up approaches to engineering for SoS development.

In order to develop a suitable generic RE process model that would address these characteristics, one has to view the process holistically:

1) from the *external* view, which includes taking into account, as far as possible, the factors outside of the process (such as organizational and environmental factors) that affect its behaviour,

2) on the *surface* view, which implies the incorporation of immediate and direct factors that surround the process, such as stakeholder considerations and roles, resources for the RE process, input and output parameters, and criteria for effectively adapting the process to reflect changes in these surrounding factors as and when necessary, and

3) from the *internal* view – getting inside the process to understand its complexities, mapping its entities and internal causality, such as decisions within the RE process, and studying how these process entities, constructs and pathways linking them dynamically affect each other, as well as their overall effect on the process parameters and subsequent process outputs (please see Fig 1.)

Most RE process models in literature follow just one or the other of these plane views of the process, and, being largely uni-dimensional in nature, are not ideally suitable for SoS development. In addition, there are few process models that are represented by means of a formalized language. A simplified process model, such as a series of process steps or cyclic/iterative process descriptions would fail to capture the intricacies of SoS. Adapting a multi-plane view of the RE process itself – looking at the process from *around*, *on* and *within,* while keeping in mind the nature of the nuances exhibited by SoS development, would enable the creation of an RE process model that better suits the demands and constraints of SoS. Building and refining this sort of a generic process model might be a complex task; however, in order to cater to the numerous issues that arise while dealing with the complexities associated with SoS development, as well as factors associated with project execution in a distributed/global setting, the generic RE process model needs to incorporate complex constructs by which these characteristics may be addressed.

IV. CONCLUSION AND FUTURE WORK

We stress on the need for a generic RE process model that:

1) encompasses both the external, surface and internal views of the RE process

2) takes into consideration the characteristics exhibited by SoS development,

3) is grounded in a solid representational framework, so that appropriate constraints of the process can be easily captured using the representational rules of the language in which it is depicted

4) can be further modified according to the domain or context in which it is applied – and hence serve as a baseline for obtaining a clearer understanding of the real world RE process that it represents.

Some of the ways in which this process model may be realized include incorporating the principles of the Process Architecture Framework [15], or agent based modelling concepts [16]. Currently, we are developing a generic RE process model that tries to address these criteria. The work is at a very nascent stage, and we acknowledge that this sort of process model would encompass only a very high level view of the RE process. Several RE process parameters, including new constructs that pertain to the RE process for SoS, and the process modelling language used for representing the process, will be identified. Once a base model is in place, mechanisms will be derived to fine-tune the model so that RE process-related metrics may be optimally estimated to ascertain construct validity.

This generic RE process model will be useful for both the RE research community as well as RE practitioners. For RE research, the model can be further refined to explore issues relating to the semantics and rules of the modeling language in which it is represented, as well as tailored to suit context specific applications, in order to obtain a better understanding of the new age RE process for SoS. Additionally, the model can serve as a base framework to explore numerous other purposes that may also be the objective of the process, apart from steering the RE process. For example, since requirements vary with the scale of a system in an SoS, decision making criteria in the process may be incorporated by following the analytical hierarchy method [17] for determining common base requirements for classes of systems.

For the industry fraternity, the process model would serve as a reference for visualizing and estimating process parameters, and aid in effective management of the RE process.

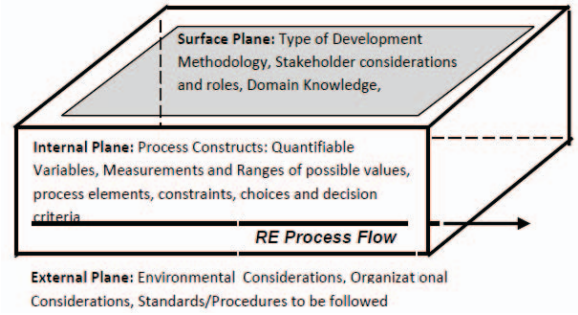

Figure 1: Multi-plane view of the Generic RE Process Model

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