



Project: COMPASS

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*Comprehensive Modelling for Advanced Systems of Systems*

C O M P A S S

**Guidelines for Systems of Systems  
Requirements**

COMPASS White Paper WP01

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**Abstract:**

We propose a model-based approach for Systems of Systems Requirements Engineering, which consists of three main areas: a framework for model-based requirements engineering (MBRE); extensions to this framework to give specific coverage for system of systems projects; and a set of processes. This white paper summarises the underlying SysML model of the extended requirements framework and requirements processes described within. The SysML model has been created using Atego’s Artisan Studio UML and SysML modelling tool. The framework and processes will be disseminated to COMPASS stakeholders by means of Atego Process Director (APD), a web-based tool supporting the capture and dissemination of processes.

## Introduction

This white paper<sup>1</sup> summarises an approach for systematically managing requirements for Systems of Systems (SoS) proposed by the COMPASS project. The approach considers three main areas: a *framework* for Model-Based Requirements Engineering (MBRE), extensions to this framework to give specific coverage for SoS projects and a set of processes. The underlying SysML model of the extended requirements framework has been created using Atego’s Artisan Studio UML and SysML modelling tool.

We begin with a high-level description of the framework for MBRE and the six main views which it contains, then outline the extensions to the framework for SoS modeling and the processes defined for SoS requirements engineering.

## A Framework for Requirements

The framework for MBRE given in this report is based on the Approach to Context-based Requirements Engineering (ACRE).

## High-level Description

The approach to context-based requirements engineering described in this document is a *view-based requirements framework*. It describes a number of *views*, each of which captures some necessary aspect of a system’s requirements. The framework relates the views together, ensuring *consistency* between the views and coverage of all the relevant requirements engineering *concepts*. These requirements engineering concepts are shown in Figure 1 below.

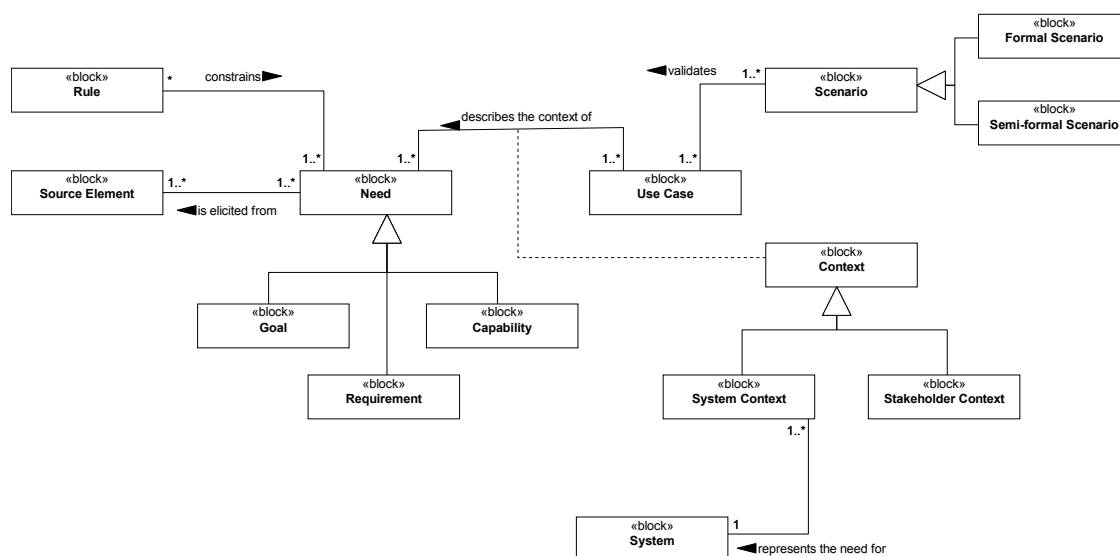


Figure 1 The model-based requirements engineering ontology

Figure 1 shows a model-based requirements engineering *ontology*, represented using a SysML block definition diagram. An ontology, in the context used here, is a model of all the key concepts, the terminology used to describe them and the

<sup>1</sup> This white paper provides a summary of the COMPASS Deliverable: Report on Guidelines for SoS Requirements, Document Number: D21.1.

inter-relationships between said concepts. This use of ontologies for defining frameworks is well-established and used extensively throughout industry.

### The Framework Views

The core framework intended for use in engineering the requirements of a single system comprises six core views and a supporting view. These views are shown in the diagram below.

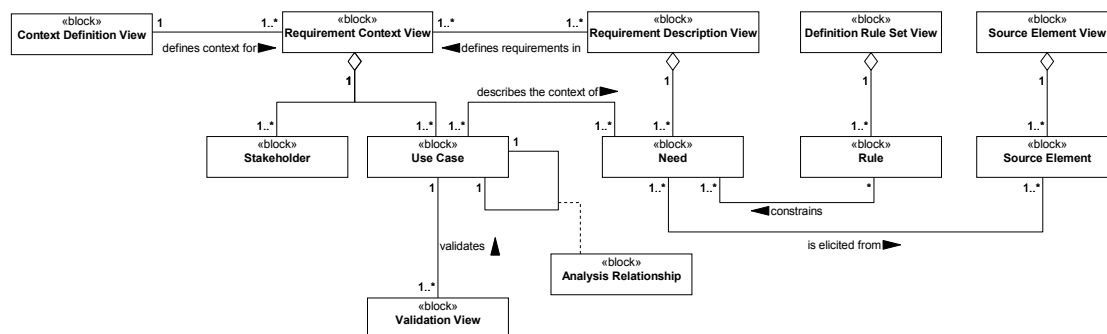


Figure 2 The ACRE framework views

The six main views shown in Figure 2, beginning with the right-hand side, are:

- *Source Element View*: contains all the source information that is required in order to get the requirements right.
- *Definition Rule Set View*: contains the rules that may have to be applied to each requirement definition. For example, these may be complexity rules in the form of equations or more general text-based rules.
- *Requirement Description View*: contains structured descriptions of each requirement. These requirements are considered individually and will have a number of attributes associated with each one.
- *Requirement Context View*: takes the requirements and gives them meaning by looking at them from a specific point of view - putting the requirements into context.
- *Context Definition View*: identifies the points of view (contexts) that are explored in the Requirement Context View. These contexts may take many forms including stakeholders and levels of hierarchy in a system.
- *Validation View*: provides the basis for demonstrating that the requirements can be met or complied with in some way. These views can be informal (such as scenarios at various levels of abstraction) or may be formal (such as mathematical-based representation).

Alongside these six core views there is an essential supporting view, the *Traceability View*, which allows traceability between different elements of the model to be explicitly shown.

### Extending the Framework for Systems of Systems Use

While all of the concepts and views hold for SoS requirements engineering there are some additional concepts and views that are needed to extend the approach to fully address requirements engineering for SoSs.

## Changes to the Ontology

The diagram below takes the original MBRE ontology and extends it to cover the additional concepts needed when dealing with SoS.

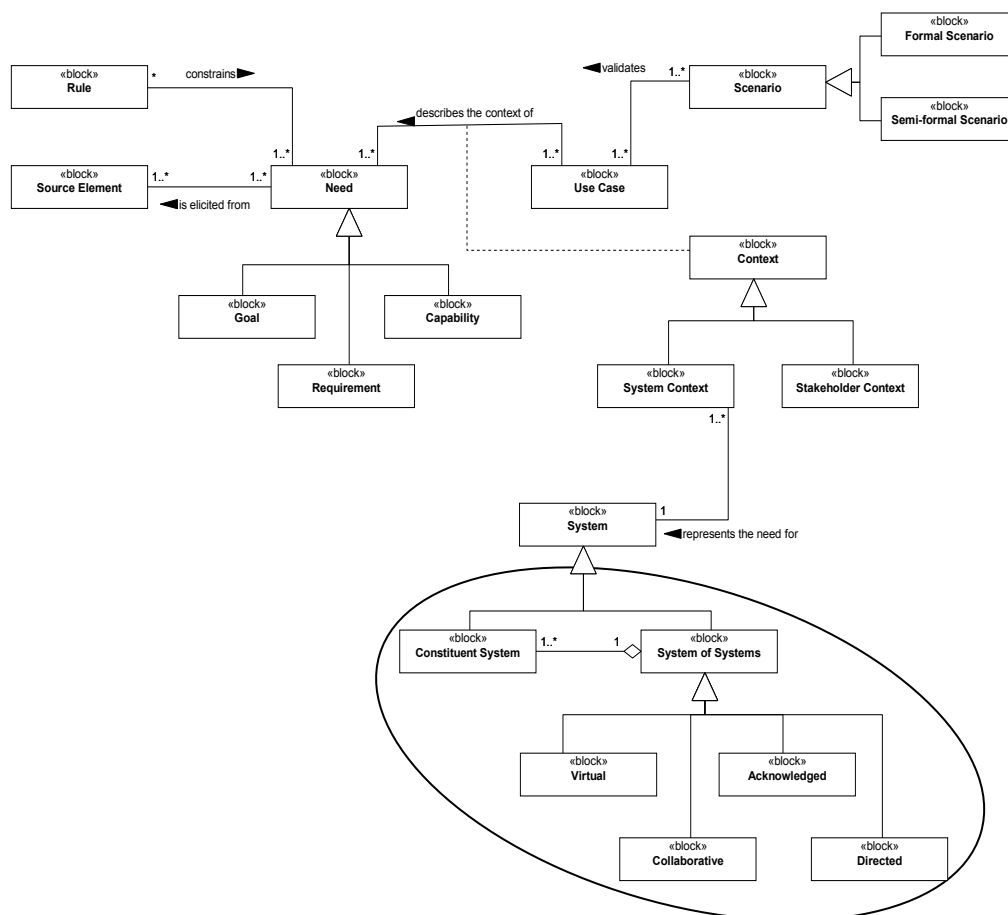


Figure 3 The model-base requirements engineering ontology extended for SoS

The key change is the differentiation between types of ‘System’. Two types of ‘System’ have been introduced, the ‘System of Systems’ that is made up of one or more ‘Constituent System’. For the ‘System of Systems’ there are four types: ‘Virtual’, ‘Collaborative’, ‘Acknowledged’ and ‘Directed’.<sup>2</sup>

Although two types of ‘System’ have been introduced this does not directly affect the creation of a ‘System Context’, which still represents the need for a ‘System’. The ‘System Context’ (realised in the framework as a Requirement Context View) can be produced either for the ‘System of Systems’ or each individual ‘Constituent System’.

<sup>2</sup> This list of SoS types is adopted from the US Department of Defense publication: Office of the Deputy Under Secretary of Defense for Acquisition and Technology, Systems and Software Engineering. Systems Engineering Guide for Systems of Systems, Version 1.0. Washington, DC: ODUSD(A&T)SSE, 2008.

## Changes to the Framework

The two additional views in the extended ACRE framework are the 'Context Interaction View' and the 'Validation Interaction View'. They are related to the other views as shown below.

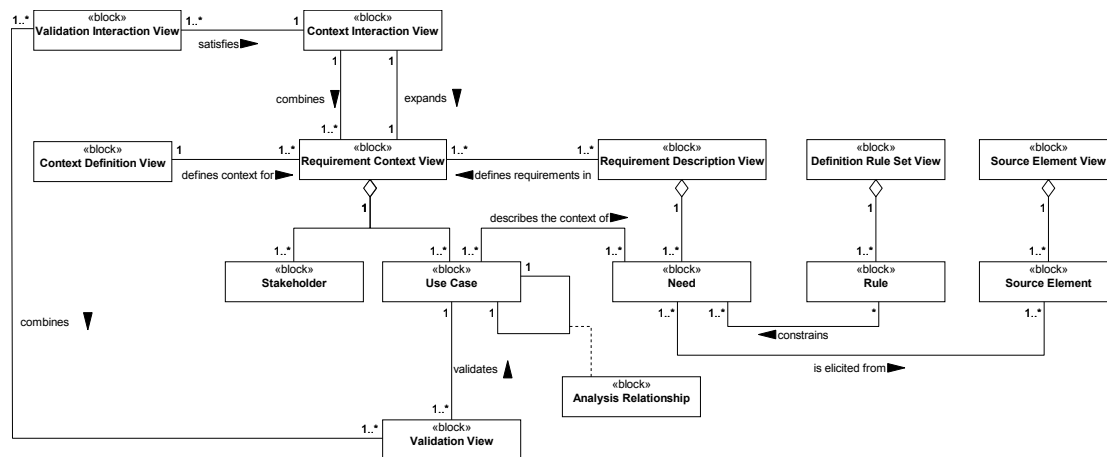


Figure 4 The Eight Extended Requirement Views and their Relationships

These two additional views are described in the following subsections.

- The Context Interaction View. The Context Interaction View is intended to provide an overview of the relationships between the contexts of the various constituent systems that make up a SoS.
- The Validation Interaction View. The Validation Interaction View is intended to provide a combined view of the scenarios for use cases that are involved in the SoS.

## Requirements Processes

This section introduces the processes that have been defined that relate to requirements engineering and requirements engineering for systems of systems. Two areas are covered – the approach and the process definitions themselves.

### The 'Seven Views' Approach to Process Modelling

The 'seven views' approach to process modelling has a framework that consists of the following views:

- The Requirements View. The requirements view specifies the overall aims of the process.
- The Process Structure View. The process structure view represents the ontology for the process model and is, therefore, essential for consistency of the language used throughout the project.
- The Process Content View. The process content view shows the actual content, in terms of activities and artefacts by representing each process as a single block. The process content view may be thought of as the library of processes that is available for use on the project.

- The Process Behaviour View. This view defines the order in which the activities are executed and the artefact flow between them. This view also shows which stakeholder are responsible for which activities.
- The Information View. The information view is concerned with identifying the key artefacts for the system and then identifying their inter-relationships.
- The Stakeholder View. The stakeholder view represents a simple classification of the different types of stakeholder roles that are involved with the process.
- The Process Instance View. The process instance view that relates the actual processes that are specified back to the source requirements and validates that each requirement has been met.

### The COMPASS Process Model

This section introduces the processes that have been defined for requirements for system of systems engineering.

### The Requirements View

The requirements view for the system of systems processes is based on a subset of the ACRE views. This has been done to ensure consistency and traceability between all the various elements of the process model.

### The Source Element View

The source elements that were used as basis for the work are shown in the SysML block diagram below.

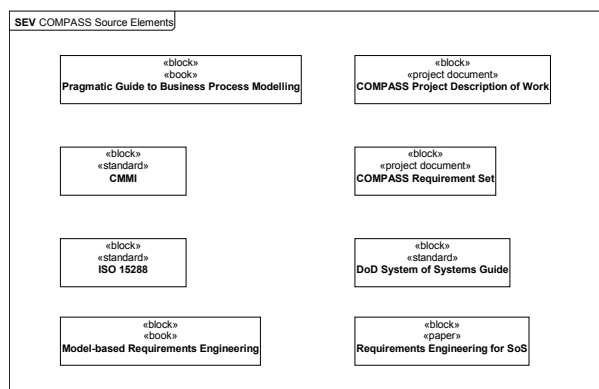


Figure 5 Source element view

These source elements were used as the primary information sources for the requirement description that were, in turn, used as the basis for the use cases that define this work.

### The Requirement Description View

The source elements contained a number of needs, in the form of requirements, which are relevant to the COMPASS project.

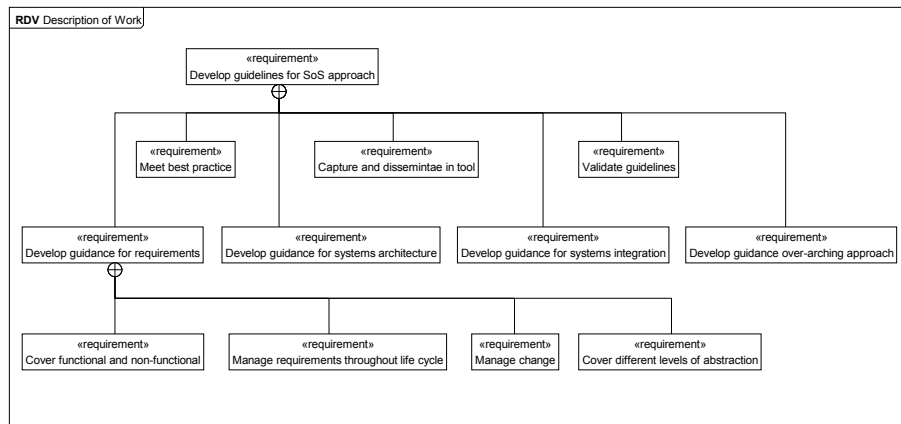


Figure 6 Example Requirement Description View for the 'Description of Work'

The requirements shown here were elicited from the source elements and represented as requirement descriptions.

### Traceability View - traceability from the needs to the source elements

The traceability between the needs and the source elements is represented explicitly in the model using a traceability view where the SysML «trace» relationship is used to establish traceability between two elements.

### Requirement Context View

The Requirement Context View shows the context of the requirements from the point of view, in this case, of a single stakeholder, an example of which is shown below.

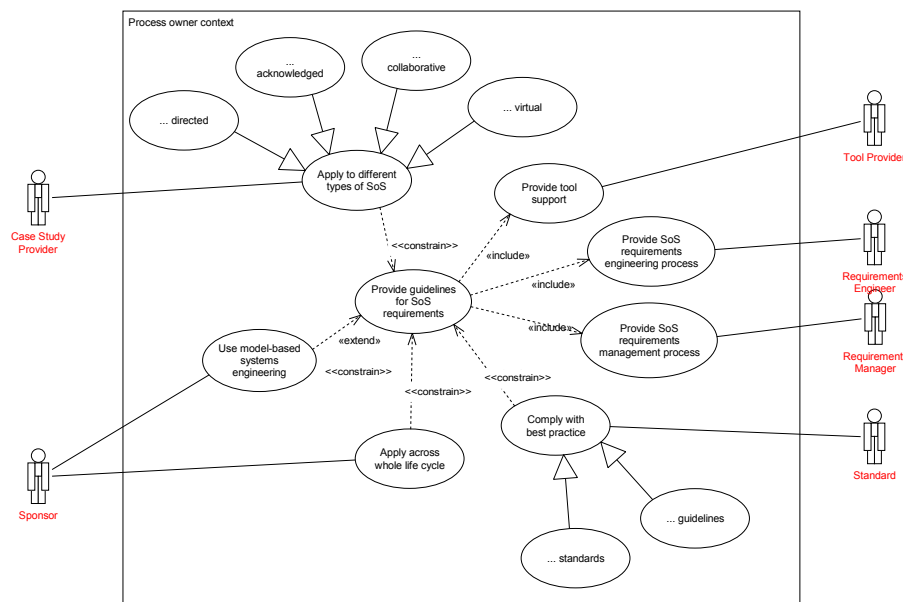


Figure 7 Requirement context view for the Process Owner

The diagram in Figure 7 shows the context from the point of view of the Process Owner.

The processes that are defined as part of the COMPASS project must be able to satisfy all of these use cases for the system of systems requirements engineering.



### Traceability View - traceability from the use cases to the needs

The traceability between the use cases and the needs is represented explicitly in the model using a traceability view, where the SysML «refine» relationship is used to establish traceability between two elements.

### The Process Structure View

The Process Structure View identifies and defines all the concepts and terminology associated with the processes or, in other words, it provides an ontology.

The following diagram expands the standard ontology to include these concepts and terms that relate the processes.

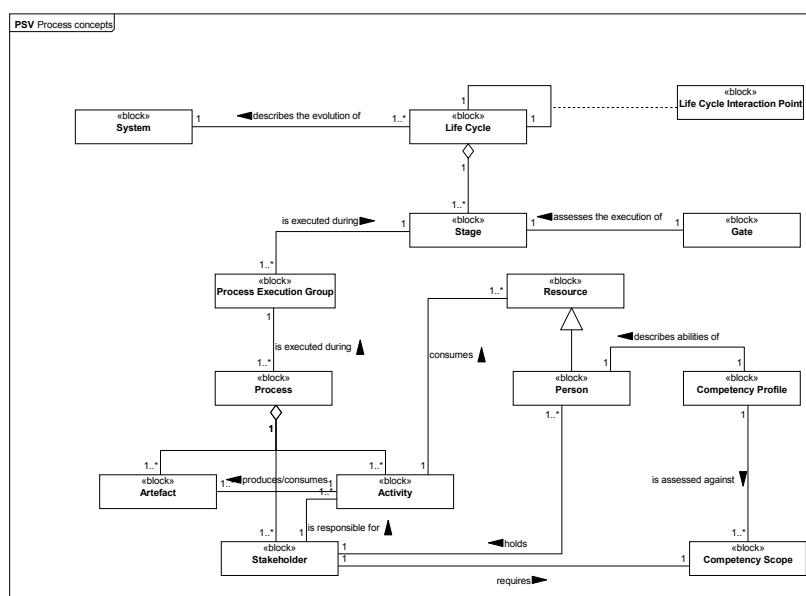


Figure 8 Expanded ontology showing process-related terms and concepts

The diagram in Figure 8 shows the expanded ontology, that may be described as follows.

### The Process Content View

The Process Content View presents the library of processes that are available to the stakeholders.

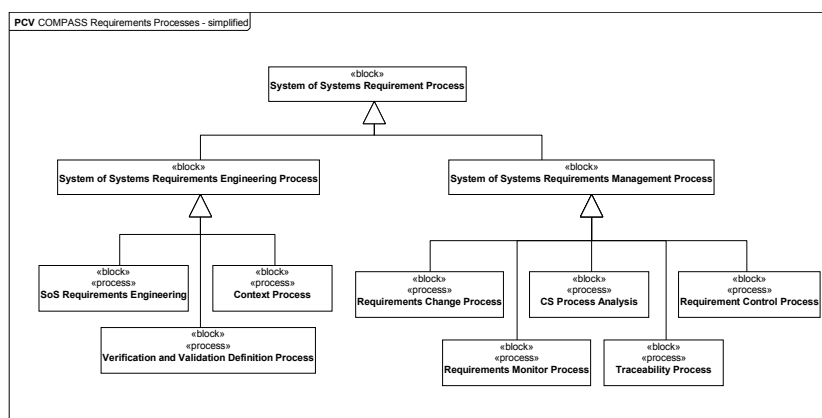


Figure 9 Simplified view of the Process Content View for the System of systems Requirement Process

The diagram in Figure 9 shows the processes that have been defined for the ‘System of Systems Requirement Process’. It can be seen that there are two classification of process, each of which has a number of processes defined: the ‘System of Systems Requirements Engineering Process’ and the ‘System of Systems Requirements Management Process’.

**The Stakeholder View**

The Stakeholder View shows a classification hierarchy of the stakeholder roles.

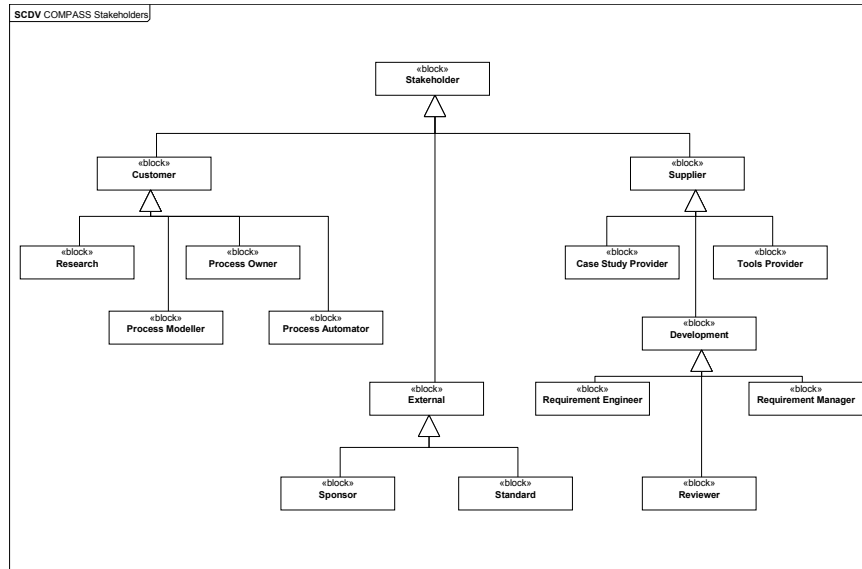


Figure 10 Stakeholder view showing classification of stakeholders

The diagram here shows the stakeholders for the COMPASS project processes.

**The Information View**

The Information View shows the main artefacts associated with the process and the relationship between them.

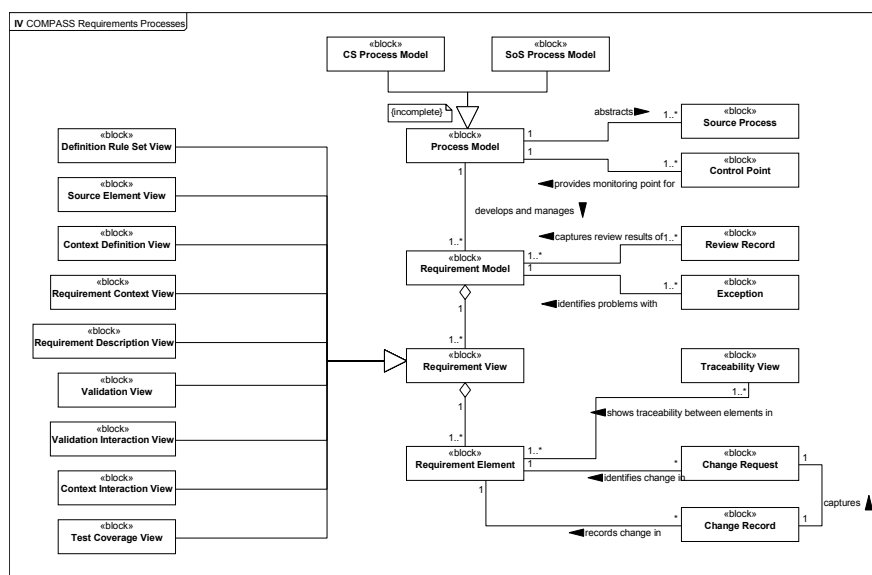


Figure 11 Information view for the system of systems requirement process

Figure 11 shows the information for the system of system requirements process where each artefact is represented as a SysML block.

### The Process Behaviour View

Each executable process that has had its structure defined in the process content view must have its behaviour defined in the form of a process behaviour view. The process behaviour view describes the flow of control and artefacts inside the process and also shows responsibility. The process behaviour view is realised using a SysML activity diagram.

The process behaviour view for the System of systems requirements engineering process - 'SoS Requirements Engineering' is shown below.

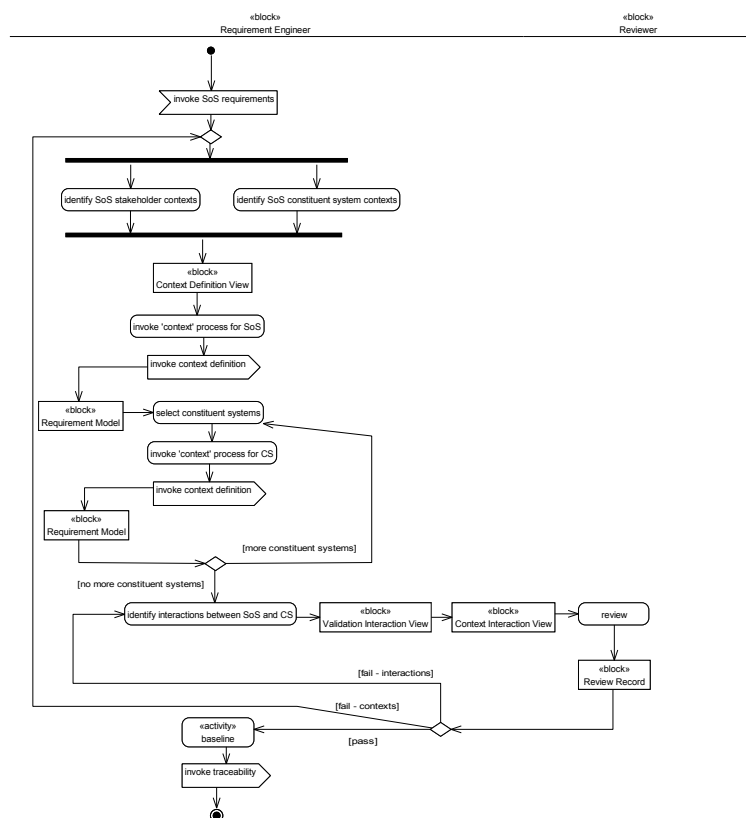


Figure 12 Process behaviour view for the 'SoS Requirements Engineering' process

The diagram in Figure 12 shows the process behaviour diagram for the 'SoS Requirement Engineering' process using a SysML activity diagram.

### Dissemination of the framework and Processes

In order to ensure the validity and applicability of the requirements framework and processes described in this document it is essential that they be made available to users so that they can be executed and user comments and feedback gathered to allow the processes to be improved as necessary based on such feedback.

The framework and processes will be disseminated to COMPASS stakeholders by means of Atego Process Director (APD), a web-based tool supporting the capture and dissemination of processes. As well as allowing for process dissemination, APD also supports process feedback enabling users to submit comments and feedback on the processes directly in APD.

**Summary**

This white paper has presented a set of processes for the development and management of requirements for systems of systems.

The report has used, at its core, the ACRE approach to model-based requirements engineering. The ACRE approach uses an ontology and framework to define a number of views that may be used for requirements engineering for systems engineering. This approach was then enhanced for use on systems of systems. This included extending the ontology and adding two new views the standards set of ACRE views.

Based on the enhanced ontology and framework, a set of processes was defined for requirements engineering and requirements management for systems of systems. A model-based approach to process modelling, known as the ‘seven views’ approach was used to specify these processes. The framework and processes will be disseminated to COMPASS stakeholders by means of Atego Process Director (APD), a web-based tool supporting the capture and dissemination of processes, in order to gather user comments and feedback.