

Method for Weapon System of Systems Requirement Acquisition Based on Problem Frame

Zhao Qingsong¹, Changlei Lei¹ and Jiangjiang¹

¹ Affiliation (Use “Affiliation” Style) College of Information Systems and Management & National University of Defense Technology of the Chinese People’s Liberation Army, Changsha hunan 410073 P.R China

Abstract. The requirement acquisition of weapon system of systems(WSoS) plays a very important role in the development of WSoS ,which is the basis of the design of WSoS and runs through the research of WSoSs. Based on the requirement engineering method of problem frame, the problem frame of WSoS requirement(WSoS SR) is built which is consisted of requirement domain, mission domain, operation domain and system of systems(SoS) domain. Based on the above model of problem frame, the method for WSoSR acquisition is proposed

Keywords: Weapon System of systems; Problem Frame; Requirement Acquisition

1. Introduction

With the development of the technology and the revolution of the operation theory, the characteristics of SoS in the modern warfare is becoming more and more obvious. WSoS is a typical complex system which shows many SoS encounter characteristics. Therefore, the requirement of WSoS needs to be acquired from the point of the war target, war system and joint operations of the entire nation instead of a single system[1]. With WSoS highlighted growing significance in the national defense, many countries, such as America, Britain and Canada, are interested and involved in the study of WSoSR acquisition[2].The June 2003 release of the radically-revised CJCSI 3170.01C and CJCSM 3170.01 promulgating the new Joint Capabilities Integration Development System(JCIDS) literally turned the legacy Requirements Generation System (RGS) upside down[3,4]. Problem frame is proposed by Michael Jackson and is a new method of the requirement engineering[5,6]. Problem frame is a means of understanding and describing the problem context and gives a framework of converting the problem into the solution

2. Problem frame model of WSoSR

WSoS is a high level complex system which is composed of the associated weapon system for a certain mission. WSoSR is the necessary condition and function provided by WSoS for the future operational demand.

The problem frame of WSoSR is formalized as a triplet $WSoS = \{D, P, C\}$ where D is the set of domain, P is the set of phenomena and C is the set of constraint. Fig.1 describes the problem frame.

1) The set of domain $D = \{R, M, O, S\}$

In the problem frame of WSOSR, the set of domain includes system of system domain, operation domain, mission domain and requirement domain. Each high-level domain is supported by the corresponding low-level domain. There exists the interface between the domains which defines the phenomena observed by the domain.

System of system domain: System of system domain represents WSoS. The target of a WSoS is achieving a strategic mission.

Operation domain: Operation domain describes the operational factors such as operational mission, operational task, operational target and operational mode in the joint operations.

Mission domain: Mission domain is the first abstract of the world that describes the entity, activity, task, interaction and environment in the joint operations. Mission domain is the basement and source of WSoSR.

Requirement domain: Requirement domain describes the requirement of WSoS that limits the target of WSoS.

Each domain $d \in D$ associates the phenomena $I(d)$ satisfied that $I(d) \subseteq P$.

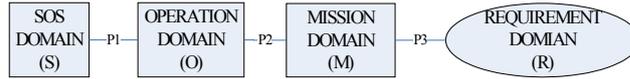


Fig.1 WSoSR Problem Frame

2) The set of phenomena $P = \{p_1, p_2, p_3\}$

p_1 denotes the phenomena that can be observed by system of system domain and operation domain. p_1 is the interface between system of system domain and operation domain. Operational domain constrains operation domain based on p_1 . p_2 denotes the phenomena that can be observed by mission domain and operation domain. p_2 is the interface between mission domain and operation domain. Mission domain constrains operation domain based on p_2 . p_3 is the phenomena that both mission domain and requirement domain can observe. A relation can be built between mission domain and requirement domain through p_3 . Based on p_3 , the requirement of WSoS is proposed.

A capability is the ability owned by WSoS and written as E . First, the capability limits the operational type and operational range. On the other hand, the capability is the target of weapon system of system building. Based on the capability, WSoS can arrive the operational target. In the description of WSoSR, the capability is the phenomena observed by both system of system domain and operation domain. The capability establishes the bridge between the commander and the system of system designer. Let $p_1 = E$. The system of system domain accomplishes the target by offering the corresponding capability.

The operational mission is accomplished by different cooperative weapon system of system, weapon system and operational unit together. For getting the WSoSR, the operational mission is divided into operational task written as T . First, the operational task refines the target that capability will realize. On the other hand, accomplishing the operational task means the accomplishment of the operational mission. Then the operational task is the phenomena observed by both operational domain and mission domain. Let $p_2 = T$.

Mission is the upper target associated with the intention that WSoS will arrive and is the ultimate target. Mission is the phenomena that both the requirement domain and mission domain can observe and written as M . Let $p_3 = M$.

The set of constraint $C = \{C_{SE}, C_{ET}, C_M, C_O\}$

$C_M \subseteq C$ is the set of condition that the mission analysis is ensured. $C_{MT} \subseteq C$ is the set of condition under which the mission decomposition is guaranteed. $C_{SE} \subseteq C$ is the set of condition under which the element in system of system domain can offer the requisite capability. $C_{ET} \subseteq C$ is the set of condition under which the capability can accomplish the set of tasks. $C_O \subseteq C$ is the set of condition that the operation domain analysis is ensured.

First, a constraint c references some set of phenomena $R(c) \subseteq P$ and touches a set of domain $T(c) \subseteq D$. The touches relation must obey a well-formedness property: For any constraint c and phenomena $p \in R(c)$, there must be some domain $d \in T(c)$ such that $p \in I(d)$. That is, if a constraint references a phenomena, it must reference some domain and the domain references the phenomena. If a constraint references a domain, it must reference some phenomena and the domain references the phenomena.

3. Transformation of WSoSR based on problem frame

The model of WSoSR is the transformation from requirement domain to system of system domain. Fig.2 describes the process.

Firstly, the mission of WSoS is analyzed for acquiring WSoSR. In this stage, the strategic mission is converted into the mission accomplished by WSoS in system of system domain through the mission p_3 . The constraint in this stage is C_M .

According to the layer structure of war system, the mission of WSoS is segmented into strategic layer, campaign layer, combat layer and activity layer. Through thinning the target, the upper-level mission is divided into low-level combat tasks and denoted by $M \rightarrow T$. The constraint in the stage is C_{MT} . Based on $M \rightarrow T$, the original mission is converted into the task that WSoS needs to complete. The accomplishment of the tasks means the accomplishment of the mission, thereby, the strategic target is accomplished.

The accomplishment of the task is under the specific scenario. The battle scenario stipulates the main campaign pattern for accomplishing the mission of WSoSR according to the strategic target, campaign task, campaign environment, defense stratagem and so on. Based on the campaign pattern, the relation between the capability and the task can be build. Through the relation, the requirement of accomplishing the task target is converted into the requirement of offering the specific capability. The constraint in the stage is C_{SE} , C_{ET} and C_O .

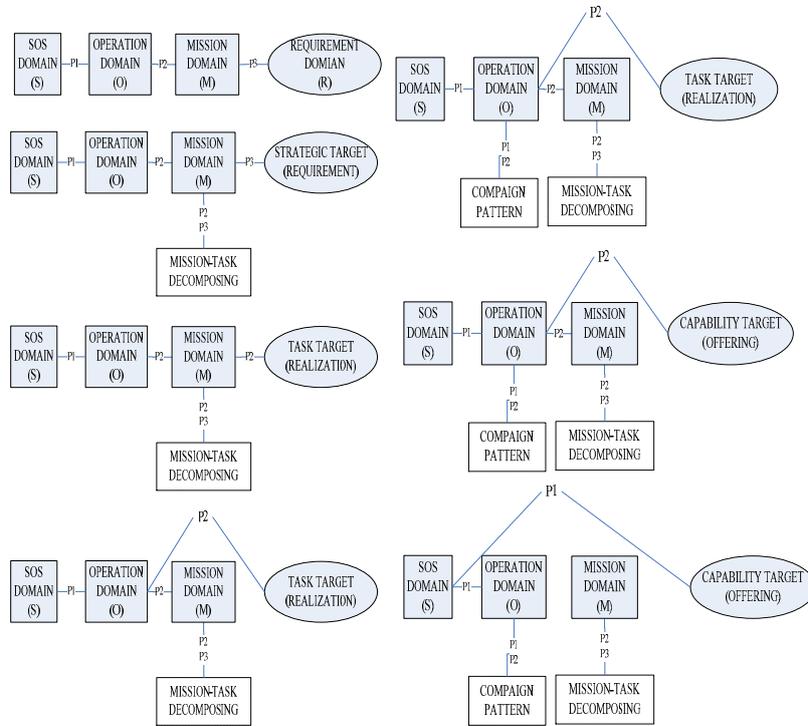


Fig.2 the transformation of WSoSR based on problem frame

In the above process, military strategic personnel gives the strategic target of WSoS in the view of the requirement domain. Military strategic personnel and the war fighter decide the mission of WSoS based on the phenomena p_3 that is observed and understood by both. The war fighter converts the mission into operational task p_2 based on the campaign pattern analysis. The capability requirement is obtained based on the phenomena p_1 that is observed and understood by the system of system designer and the war fighter. $H(p_3, p_2), H'(p_2, p_1)$ between p_1, p_2 and p_3 are the knowledge and experience about WSoSR that can be reused for the future.

In general, given a requirement R over the phenomena p_3 , the process of transformation is the process of search the rule. Based on $H(p_3, p_2)$ and $H'(p_2, p_1)$, the strategic target in the requirement domain can be converted into the capability requirement in system of system domain. The implication takes the form

$$R(p_3) \wedge H(p_3, p_2) \wedge H'(p_2, p_1) \Rightarrow S(p_1)$$

In the requirement model of weapon system of system, the requirement of military stakeholders is described in the requirement domain and mission domain instead of the system of system domain. Which decreases the mistake for the reason that the military stakeholders don't understand the system and knowledge in the system of system domain. That is, the risk of direct jumping the requirement of stakeholders to the requirement of system of system is decreased. Based on the constraint and rule, the original requirement that is away from the system of system domain is mapped gradually into the capability requirement that is close to the system of system domain(the requirement closing to the system of system domain is satisfied easily). In the requirement model of weapon system of system, the detail of requirement analysis is substituted by the choosing of the domain and the finding of the constraint and rule. In the meantime, the historical project and correlative experience and knowledge can be used again.

4. Mmaries Summaries

The engineering of WSoS plays a very important role in the development of weapon system of system .which is the basis of the demand modeling and combines together with the design of weapon system of system. Under the analysis of the theory and characteristic of WSoS, the problem framework of WSoS is given and the method of requirement acquirement is proposed .

5. Acknowledgements

This paper supported by National Natural Science Foundation of China: The Design and Optimization Approach to System-of-System Structure oriented to evolution(No. 71001104).

6. References

- [1] DoD Architecture Framework Working Group. DoD Architecture Framework Version 1.0 Volume I: Definitions and Guidelines[R]. U.S.: Department of Defense, 2003.
- [2] Boehm, Barry. Spiral Acquisition of Defense and Space System of Systems[R]. Ground System Architectures Workshop, 2004,1.
- [3] Joint Chiefs of Staff. CJCSI 3170.01F: Joint Capabilities Integration and Development System[R]. U.S, Department of Defense, 2007.
- [4] William K. McQuay Collaborative Environment for Capability-based Planning [C] Proceedings of SPIE Enabling Technologies for Simulation Science ,2005,318-327.
- [5] J.G.Hall,L.Rapanotti and M.Jackson.Problem frame semantics for software development.Journal of software and systems Modeling,4(2):189-198,2005.
- [6] Robert Seater,Daniel Jackson.Problem frame transformations:Deriving specifications from requirements.IWAAPF'06.