

## A Study on the Application Examples of the Systems Engineering to the Nuclear Sector

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### 1. Introduction

The systems engineering is an emerging discipline which helps coping with complexity.

Although there are some systems engineering process standards which are not difficult to learn, the practical application of systems engineering is not easy. So the examples of application are very important for those who want to apply systems engineering to their projects.

Therefore the applications of systems engineering in nuclear reactor design, nuclear safety regulation, radioactive waste management and tritium extraction facility are introduced and reviewed in this paper.

### 2. What is the Systems Engineering

Systems engineering is defined by INCOSE as an interdisciplinary approach and means to enable the realization of successful systems [1]. Although there many products made by systems engineering processes, the most important product of systems engineering is the system specification. The core process of systems engineering is represented in fig 1.

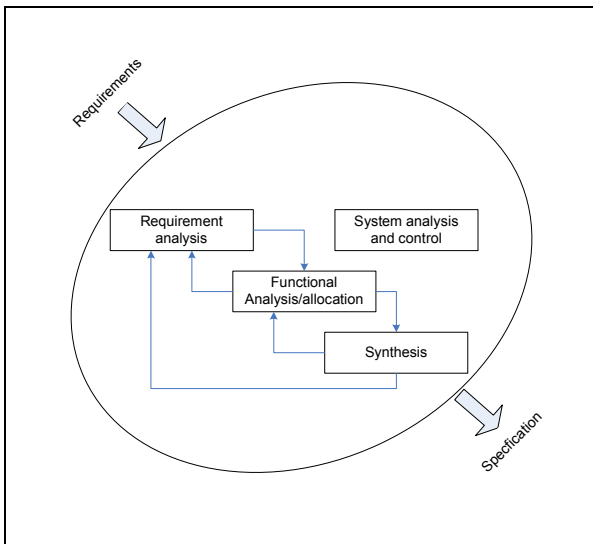


Fig 1 Core Process of Systems Engineering

The input to the process is the requirements which come from customer, user, contract, regulation and other stakeholders. The technical constraints and external interfaces also can be treated as inputs to the core process.

Requirement analysis defines the problem domain. It defines the function, performance, constraint, physical attribute of the system.

Function analysis/allocation defines the logical solution for the requirement. It decomposes the high level functions to low level functions and defines data interface and control logic. Allocation defines how well the functions should be performed.

Synthesis defines physical architecture of the solution which satisfies the functions defined in the functional analysis/allocation process and physical attribute defined in requirement analysis process.

The objective of the system control and analysis is to track progress and ensure the requirements traceability and evaluate alternatives and manage risks.

Although there are many systems engineering standards [2,3,4], the core process is almost the same.

### 3. Application of the systems engineering to the nuclear sector

Systems engineering can be applied to any systems. But the point is the effectiveness of application of systems engineering. Systems engineering is effective in development of a complex system.

This paper introduces 4 cases of application of systems engineering to the nuclear sector.

- Nuclear reactor development
- Nuclear safety regulation
- Radioactive waste management
- Tritium extraction facility development

#### 3.1 Nuclear Reactor Development [5]

##### Objective of the Project

Develop innovative nuclear reactor systems

##### Organization

GIF (Generation IV International Forum)

##### Why SE

To effectively manage multi-organizational and technological complexes.

##### SE Process

Comprehensive SE processes are being used starting from goal definition, concept definition, writing requirement, validation requirement and so forth.

##### Results

- Creation of seamless management
- Focus on advanced NGNP development
- Create problem-solving environments
- Encourage strategic alliances and collaboration

#### 3.2 Nuclear Safety regulation [6]

##### Objective of the project

Refine 10 CFR 60 for regulation of the HLW disposal program

#### Organization

CNWRA (Center for Nuclear Waste Regulatory Analyses).

#### Why SE

Because the 10 CFR 60 has never been applied.

#### SE Process

- Requirement Validation
- Functional Analysis of the disposal site

#### Results

- Identify uncertainties in 10 CFR 60
- Identify missing regulatory requirements in 10 CFR 60

### *3.3 Radioactive waste management [7]*

#### Objective of the Project

To cope with the complexity of the LLW management program

#### Organization

US DOE (Department of Energy)

#### Why SE

Define LLW program mission and identify the system requirements

#### SE Processes

Define mission  
Functional analysis,  
Requirement analysis

#### Results

- System Description Document developed
- Enhanced understanding of the program by all participants
- Clear accountability of each participant from clear system definitions
- Enhanced program control due to identification of system and program interfaces

### *3.4 Tritium extraction facility development [9]*

#### Objective of the Project

To define the functions and requirements necessary to design and operate tritium extraction facility

#### Organization

Westinghouse Savannah river Co.

#### Why SE

Because the TEF was the one of a kind system

#### SE Processes

- Functional and requirement(F&R) analysis,
- Risk Management,
- Interface Control

#### Results

- Help the TEF design meet the specified mission
- Up-front F&R analysis and risk management work to design a feasible facility
- Lower cost alternative solutions were evaluated and selected to meet the requirements

### 4. Conclusion

Systems engineering is an approach to cope with complexity and develop a balanced solution through the lifecycle of a system.

In nuclear sector, systems engineering have been applied for the systems that are too complex to be dealt with conventional problem solving approaches and the systems that have been never developed before, the one-of-a-kind systems.

Application of systems engineering helps to clearly define the problem, and determine a balanced and feasible solution.

## REFERENCES

- [1] <http://www.incose.org/practice/whatisystemseng.aspx>
- [2] ISO, ISO/IEC 15288, "System Lifecycle Process", 2002
- [3] Electronic Industries Alliance, EIA-632, "Process for Engineering a System", 1998.
- [4] IEEE, IEEE Std 1220, "IEEE Standard for Application and Management of the Systems Engineering Process", 1998.
- [5] Edward J. Gorski et. al., "A Systems Engineering Framework for Design, Construction and Operation of the Next Generation Nuclear Plant", INCOSE Proceedings, 2004.
- [6] Center for Nuclear Waste Regulatory Analyses, "Identification and Evaluation of Regulatory and Institutional Uncertainties in 10 CFR 60 volume-1 Evaluation", CNWRA 90-003, 1990.
- [7] US. DOE, "DOE Low-Level Waste Program Management Plan Rev.0", March, 1997.
- [8] US. DOE, "DOE Low -Level Waste System Description Document Vol. 1", September, 1996.
- [9] Philip Simpkins, "Application of the systems engineering Approach to the Tritium Extraction Facility Design", INCOSE Proceeding, 2003.