See text for detailed information. There are several stages involved in SE development, they are early practices from 1920s and 1930s; and government gave a push forces starting in 1940s; now the information age with increasing demand of the complex systems and development of technology, Systems Engineering has become a profession and play a major role in these systems design.

CHAPTER 2

1. What is a life cycle? Describe the general life cycle stages for a system.

   Life cycle, according to Webster Dictionary, refers to "*a series of stages through which something (as an individual, culture, or manufactured product) passes during its lifetime*." The life cycle of an engineering system is a sequence of stages/phases in the life of the systems. It is the life span or history of the systems, from the need to create the system to the point that the system is retired and removed from its service. There are two basic elements involved in the system life cycle, one, any system starts from a need, this need determine the systems concepts, from the concept, system functions are derived, decomposed and allocated to its components, hardware or software, all the way to its final configuration, developed, constructed and delivered. All the different stages of systems life cycle, different systems forms are driven by the initial needs; Secondly, from the first characteristics we just talked about, one can easily see that system evolves from general form to specific forms. This evolvement is a top down process, started with the big picture – the need for designing the system, with greater details added along the life cycle phases. In the following section, we will describe the major phases in system life cycle, these life cycle phases summarizes a common form for most of the systems,

despite the fact that different the system has the different variations for these forms, the fundamental phases should be similar. Generally speaking, system life cycle consists seven major phases, *operational need for the systems, system concept, system concept exploration and validation, engineering model development; systems production, deployment and distribution; systems operation and maintenance and finally system phase-out and retirement.*

2. Describe waterfall model, VEE model and spiral model and their unique characteristics.

Waterfall model is one of the most popular and oldest design process models for systems engineering, as the name indicates, waterfall model describes the system development in a linear manner, one stage to another, with the feedback loop back to one step earlier. Students can draw a waterfall model here as in the text book. Waterfall model provides a clear structure of the system design process and life cycle, however, due to the increasing level of complexity, hardly a system design is purely using waterfall model.

Vee model is an extension/variation model from waterfall model, after the detailed designed is accomplished, which are the system definition phases, the design process will shift focus on the verification and validation activities, leading to system integration. Vee model integrates the users and designers together by linking the system definition and integration together, by quacking address the interaction between the design and verification, so the changes can be addressed in an efficient manner.

Spiral model is originated from software development process, based on the concepts of fast prototyping, it combines the process from waterfall model but emphasized also on prototype development and evaluation, the top down design process and the bottom up evaluation process is carried out simultaneously to obtain a faster turnaround time for the design, rather than waiting for the previous step to complete. The idea of Spiral model is continuous system development based on prototyping and evaluation.

3. What is a system requirement? What is a function? Give an example of system function.

   Requirements are formal documents that define system intended purposes. A requirement is a single formal statement containing "***shall***" to define a need that a system must provide or perform A function is a specific action or activity that a system does or provides, it is a meaningful purpose for which the system is developed or designed for. Since it is an action, a function usually contains a verb. The common syntax for a function is verb + noun.

4. Describe the system user classes.

   System users/operators. Also called customers sometimes, system users can be further divided into two categories, direct end users and indict users. End users are easy to understand, these are the people that interact with system directly. Besides end users/operators, there are also people who don't direct interact with the system, however, their opinion will impact the end users so much that can't be neglected. For example, family members of end users, managers or supervisors of the operators. These indirect users play a significant role in influencing users/operators decisions and behaviors; their

needs constitute a major part of the system requirements.

System Maintainer/Supporters: another group of human involved in systems design and life cycle are those who maintain and support the system. Design requirements for system maintainers' need should be considered and specified in early design phase, as it also has a major impact in the system configuration in later stages;
System designers: system designers are the third class of human involved in system design, these include the systems engineering team members, and related system management personal and administration.

5. List the major system design processes and describe the purposes and major output for each of the process.
   Conceptual design: in conceptual design, system requirements are being defined and refined. Systems needs are captured, design rationale is being developed, feasibility analysis, major output is the functional model of the systems and functional baseline (Type A spec)

   Preliminary design: applying conceptual design to a more detailed level; Purpose: demonstrate the design concepts are indeed valid in the sense of that they can be implemented through systems components, including hardware and software. Design concepts are further explored, with information of components implementation for the design concepts, translating the "what" aspects of the system (systems functions) to the "HOWs" the system requirements are actually fulfilled (function allocations to

components). Major output for preliminary design phase is the functional model at the component and sub-system level and allocation baseline (Type B spec).

Detailed Design: The purpose of the detailed design is to integrate system components into its final form based on the results from functional baseline and allocation baseline. The main goal of detailed design is to develop design specification for all the lower level components and items; develop, procure and integrate the system components into final system configuration; and conduct critical system review, identify any possible problems with the system configuration, with regard to systems requirements, control and incorporate changes to system configuration. The main output from detailed design should be the production baseline (Type C spec), process baseline (Type D spec) and material baseline (Type E spec).

System installation, deployment, operation and maintenance: System is to be installed and/or delivered to customers and put in operation. The purpose of the this stage is to make sure system is operating in a satisfactory manner and systems designers and engineers are primarily concerned about the follow up evaluation and feedback from the users, to find out how well the system performs at the user's site and what difficulty users have for the systems. Incidents and accidents need to be documented and investigated, to find the cause of the incidents, in order to lead to the improvement for the next version of the system. Necessary maintenance and support activities are carried out, for example, recalling the faulty components, providing updates and patches, and supporting the system maintenance and warranty activities. These activities are carried out on a

continuous basis, possibly till the end of the system life cycle, in order to provide data for the system improvement, provide materials for training and more importantly, a more competitive system for the next version.

6. Describe the system functional model, operational model and physical model. What is the relationship among these models?

   A functional model of the system describes the system functions architecture. It illustrates the hierarchical relationships among systems functions. Operational model describes the systems in terms of the system operations, similar to system functional flow block diagram, it illustrates the system operations from a temporal perspective, describing the systems operations on a timeline relationships. physical model describes the physical components of the system, including system hardware, software and the geographical location information for the physical model distribution, as well as the environmental information for the components.

   These three models are instances of model based system engineering design outputs, they describe and define the systems from different perspective, and we can say that none of the models is 100% complete, they address the system from one particular dimension of system characteristics, in order to get a complete picture of the system, we need to integrate all these models together.

7. Define what is model-based systems engineering.

Model based systems engineering (MBSE) is a formalized application of models to design systems, defining system requirements, system elements, verification and validation and relevant design activities, in order to support structures and communications in the systems engineering efforts throughout the system life cycle. MBSE uses structured modeling languages and semantics to define systems elements and their relationships, such as System Modeling Language (SysML). SysML is inspired by Unified Modeling Language (UML), a common used objective oriented design language for software engineering.

System modeling language, or SysML was developed in 2003, as a dialect (or profile) of the popular unified modeling language (UML). It uses part of the UML construct, removed those constructs that are not needed in system and also provides an extension of UML modules for unique systems engineering application.