UNIVERSITY OF TEXAS ARLINGTON

IE 5351 – Introduction to Systems Engineering

Team 4

Final Project

Systems of Systems

Submitted to

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&

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Contents

System Engineering Body of Knowledge (SEBoK)

- **Introduction**
  - The Guide to the Systems Engineering Body of Knowledge (SEBoK) is a guide that discusses information about Systems Engineering.
  - SEBoK is a widely accepted system engineering book that updates its information every 6 months.
  - It does not contain all the information related to systems engineering.
  - It provides a starting point to access the information available in published sources.
  - Each section of SEBoK is divided into information groups with a related theme. These information groups are designated as KAs.(Knowledge areas)

(SEBoK, 2021)

System Engineering Body of Knowledge (SEBoK)

- **Description**
  - SEBoK is a broad summary of knowledge about systems engineering.
  - Provides information from external sources to update information.
  - It defines the general SE lifecycle and process information.
  - It explores the interaction between SE and other disciplines and explains the relationships between these disciplines.

(SEBoK, 2021)

System Engineering Body of Knowledge (SEBoK)

- **Purpose**
  - The book is intended to serve as an up-to-date guide for SE students and professionals.
  - SEBoK defines the boundaries, terminology, content and structure of systems engineering.
  - For this, SEBoK systematically and consistently supports six following broad objectives. (Mediawiki, 2021)
    - Inform Practice
    - Inform Research
    - Inform Interactors
    - Inform Curriculum Developers
    - Inform Certifiers
    - Inform SE Staffing

(SEBoK, 2021)

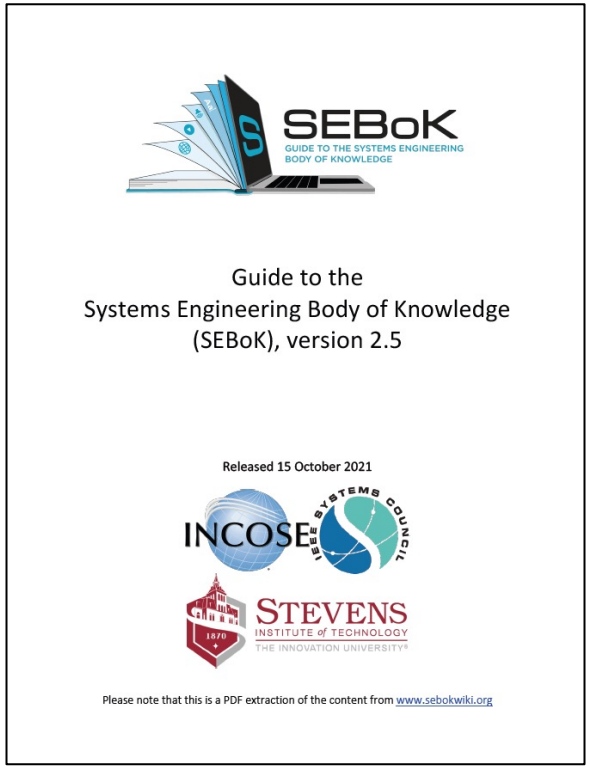
System Engineering Body of Knowledge (SEBoK)

- **History**
  - The project began in 2009.
  - BKCASE started under the sponsorship of U.S. Department of Defense (DoD) between 2009 and 2012.
  - Authors and professionals from many companies and different countries contributed greatly to the creation of the book.
  - The first comprehensive design was published in September 2012.

(SEBoK, 2021)

System Engineering Body of Knowledge (SEBoK)

- **Current Status**
  - There are 23 versions of SEBoK gathered in 15 main versions so far.
  - First version, Version 1.0, was released on 15 September 2012.
  - The most recent version, Version 2.5, was released on 15 October 2021.



(SEBoK, 2021)

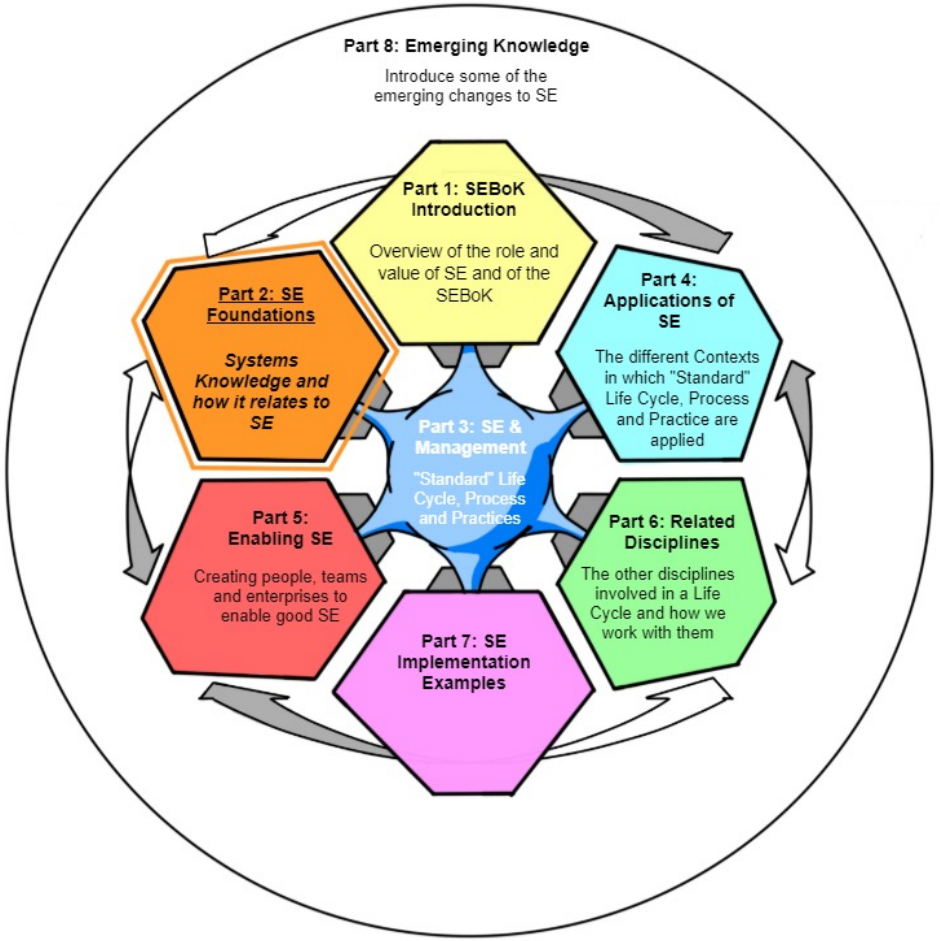
System Engineering Body of Knowledge (SEBoK)

- **Relationship to other system engineering reference sources**
  - A primary reference has been identified as a "key“ reference, which is critically important to understanding a given subject.
  - Each article has around 10 reference sets.
  - Each primary reference article contains complete bibliographic information and article listing for that reference.
  - Primary references generally clearly explain all the key concepts relevant to the topic. The user who reads these sections comprehends the general concepts related to the subject.
  - Example: Primary Reference>Balancing Agility and Discipline>System Life Cycle Process Models: Vee

(SEBoK, 2021)

System Engineering Body of Knowledge (SEBoK)

- **Overview**
  - Summary of the eight sections of the SEBoK.
  - Each section is divided into knowledge areas that group related information.



(SEBoK, 2021)

Systems of Systems – Description/Purpose

- Systems of Systems is a combination/collection of several individual systems which are connected together but gives unique capabilities to accomplish the task. (Systems of Systems - IEEE Reliability Society, 2014)
- Each systems has its own requirement, goals/targets, but in the end, it works to meet same goal while combining several systems

Systems of Systems – Description/Purpose

Systems of Systems are usually:

- Several levels of stakeholders with competing interests
- Multiple contradictory objectives and purpose
- Multiple different operation priorities with unclear process routes
- Elements are implemented asynchronously with multiple lifecycle stages
- Independent resourcing decisions made by multiple owners.

Systems of Systems – Description/Purpose

Characteristics of Systems of Systems: (Maier 1998, De Laurentis 2005)

- Operational and Managerial Independence
- Geographical Distribution
- Emergent Behavior
- Evolutionary Development
- Heterogeneity of Constituent Systems
- Purpose – Combines and relate resources, tools capabilities together for ease of understanding the complex systems while creating new systems

Types of SoS

- Virtual – The purpose changes and the management is not as expected.
- Acknowledged – Though SoS has a defined objectives, resources etc, but the component systems work independently with their objectives, development and approaches
- Directed – There are specific purposes of why SoS is built and managed. Considering the overall goal, the systems need to produce one goal, but they all work independently
- Collaborative - To fullfil the overall objectives, the components interact with each other.

SoS Applications

Some of the SoS applications are:

- Media – Radio, Television
- Business – Finance, Banking
- Energy – Grids, Houses
- Defense – Military Systems
- Railways – Network, Rail Station
- Healthcare - Facilities & Health Management
- Transportation – Traffic Control systems, Airport

SoS Methods

Elements: (Jackson & Keys, 1984)

- Understand Constituent Systems and Relationships
- Translate SoS objectives into requirements
- Assess SoS performance with objectives
- Develop, evolve, maintain SoS architecture
- Monitor and assess impacts of changes on SoS performance
- Address SoS requirements and solution options

SoS Methods

Process: (*Systems of Systems*, 2017)

- Requirements Development Logical Analysis
- Design Solution
- Implementation
- Integration
- Verification
- Validation
- Transition
- Decision Analysis
- Technical Planning
- Technical Assessment
- Requirements Management
- Risk Management
- Configuration Management
- Data Management
- Interface Management

History

- Systems of Systems defines the complex system
- Initiative by Boulding (1956), Jackson (1984), Muller Merbach (1994)
- Established in 1980s United States Strategic Defense Initiative
- 1989 - Systems of Systems term introduced
- Focus on joining independent systems together

Approach/Methods

- Systems of Systems promotes new way of thinking to solve difficult challenges while the interactions with policy, technology and economics.
- It is related to the study of complexity, designing, Systems Engineering
- It can operate independently but the interactions gives important emergent properties

Current Status

- The Systems of Systems is established but however there are current and future challenges for a global level.
- SoSE is required to consider socio-technical and socio-economic phenomena.
- There are Challenges/differences in
  - Technology of constituent systems
  - Testing of overall SoS functionality
  - Data issues
  - Stakeholder interest
  - System Documentation

Relationship of SoS to Systems Engineering

E-COMMERCE

- We can take an example of SoS being in the line of E-Commerce. People require a lot items and goods on a daily basis , this can be done by using services provided by the online shopping.
- E-Commerce not only involves pricing, sales, inventory but also handling a large number of suppliers, these E-Commerce companies have wide range of systems that are under their control. This is a virtual marketplace.
- Since it is a virtual marketplace, the systems needs to handle all the payment transactions, inventory management delivery and shipping too.

- As there are many systems which can be a third party or made by the people working in-house. Since, all the systems have a common goal, it would be efficient if we can integrate all the systems and get it completed.
- The E-Commerce would involve many large number of systems that are independently working together so, that they can reach the daily target of sales and the objectives.

Claus Ballegaard Nielsen, Peter Gorm Larsen, John Fitzgerald, Jim Woodcock and Jan Peleska, 2015. Sys tems of Systems Engineering: Basic Concepts, Model-based Techniques, and Research Directions. ACM Comput. Surv. V, N, Article XXXX (2015). DOI http://dx.doi.org/10.1145/2794381

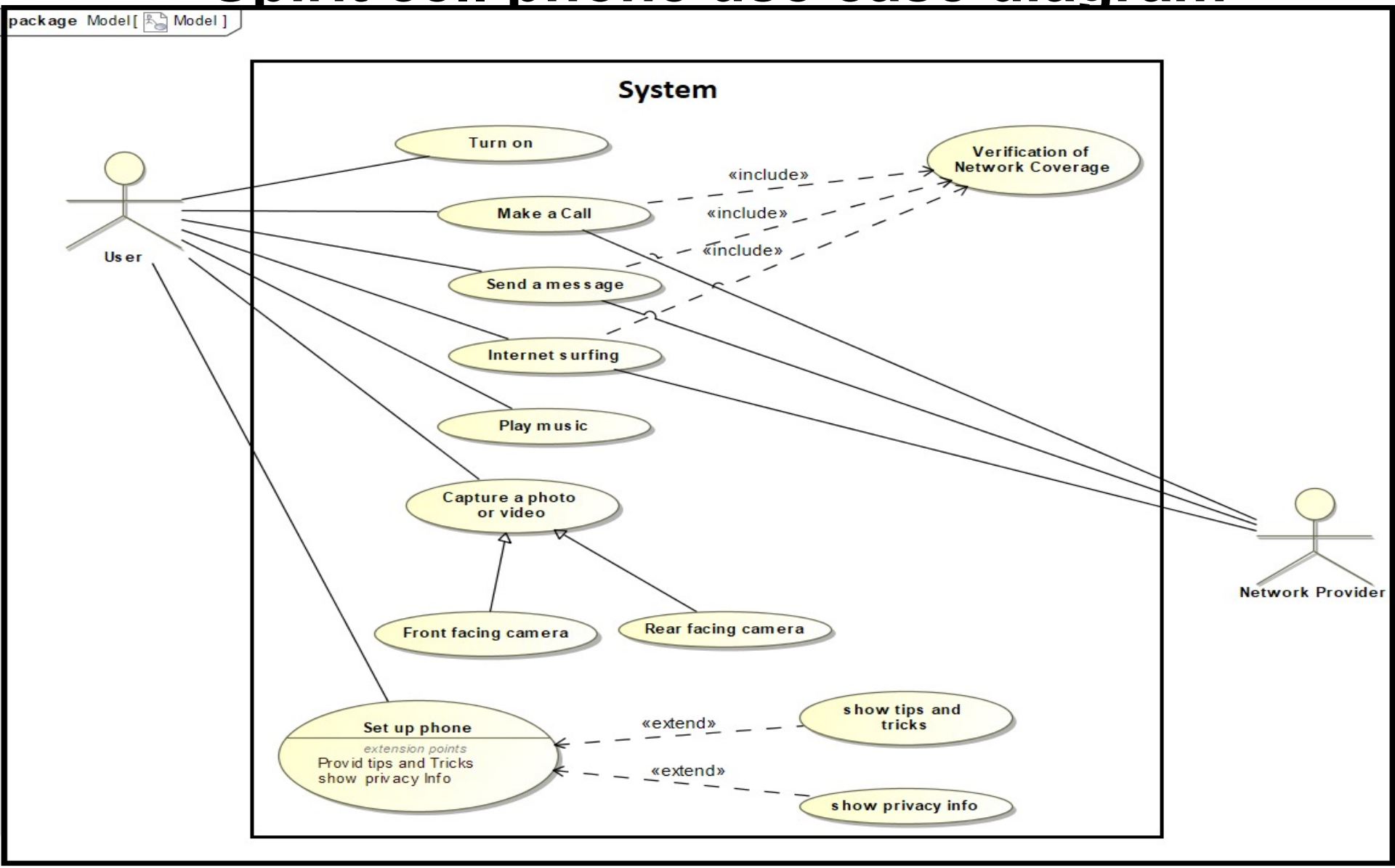
Identify how Millennium Systems or another organization can use the topic (or an understanding of the topic) to its benefit.

- The system being developed depends on various factors for the effectiveness of the system. These factors would include:-
  - Task Characteristics
  - Character of the system
  - Application environment
- When mobile systems are being designed, the designer of the mobile systems needs to consider certain patterns and protocols.
- A realistic system would be created for the problem solving and decision support with the constraints in resources.

- Advancement in the field of innovation has given the systems to connect similar or an individual dynamic units together in an association.
- These systems will have a great critical thinking and encourages the choice help.
- A mobile system with various decision support is a critical enhancement.

(Chung, 2012)

Spirit cell phone use case diagram



Use case diagram specification

Actors – In this use case there are two actors first is user and second is network provider.

Where "user" can directly interface with the system use cases and all the different use cases can be operated by the user.

Second is "network provider" which interface with some of the use cases and it provide the connectivity to the system for its operation.

Success scenario

Use case – Make a phone call
Level :- operational goal
Primary actor :- User
Precondition :- Sim card must be inserted into the phone
• User turn on the spirit cell phone and check the battery health.
• User check the network connectivity
• User must be dial the number or open the saved contacts
• User press the dialer key to contact the other end.
Postcondition :- Call is connected to the other end

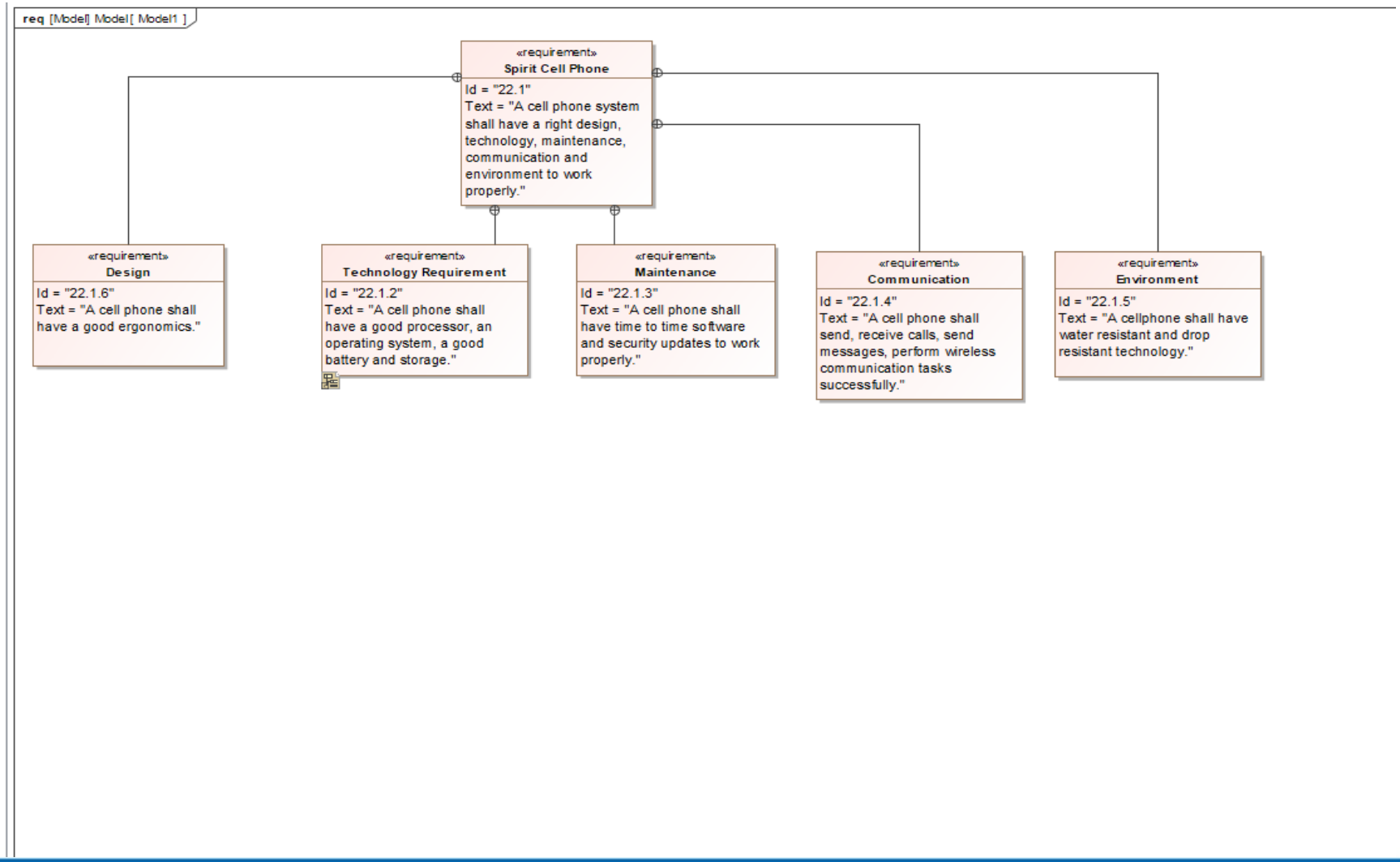
Success scenario

Use case :- Internet surfing
Level :- Network connection
Primary actor :- User
Precondition :- Cell phone must have the network coverage
• User check the connectivity with network on the cell phone
• Network provider give the connection access to the user
• User open the browser for internet surfing on cell phone
• User type the web address to reach it
Postcondition:- Use can connect to the dedicated website

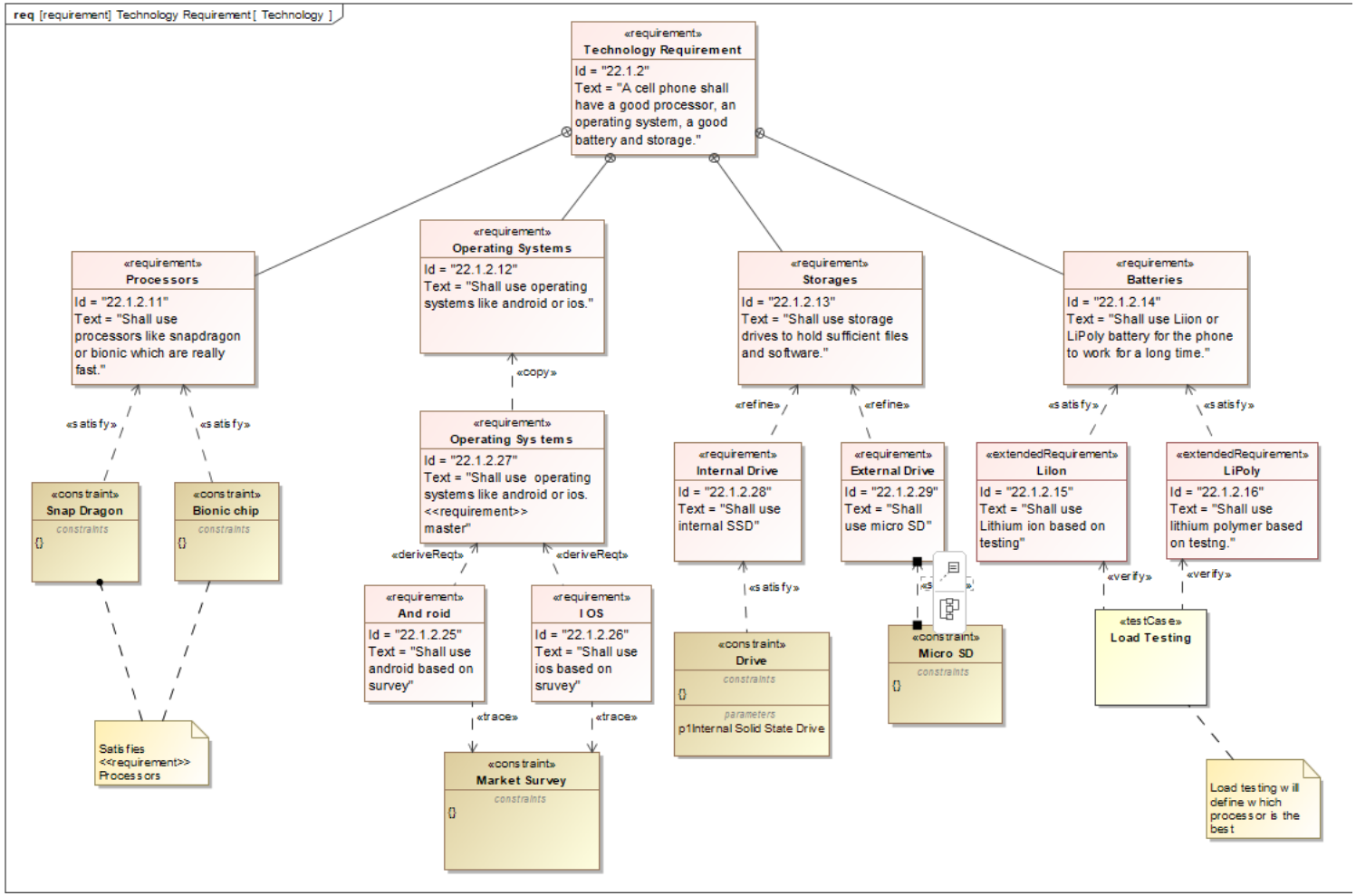
Use Case Justification

- User successfully turn on the cell phone and be able to operate cellphone functions.
- After turning on user set up the cell phone where it shows some tips and tricks about the spirit cell phone and provide privacy information.
- After setting up user insert the sim card and verify the network coverage for make a call or send message or doing some stuff on internet.
- Network provider successfully allow network connection to spirit cell phone user.
- Also, user can play music, take pictures and videos using the front as well as rear camera that doesn't need any network connection.
- This is how user and network provider successfully operate all the functions of spirit cell phone. system.Aregbesola, K., & Osunade, O. (2013)

Requirement Diagram Top Level



Requirement Technology



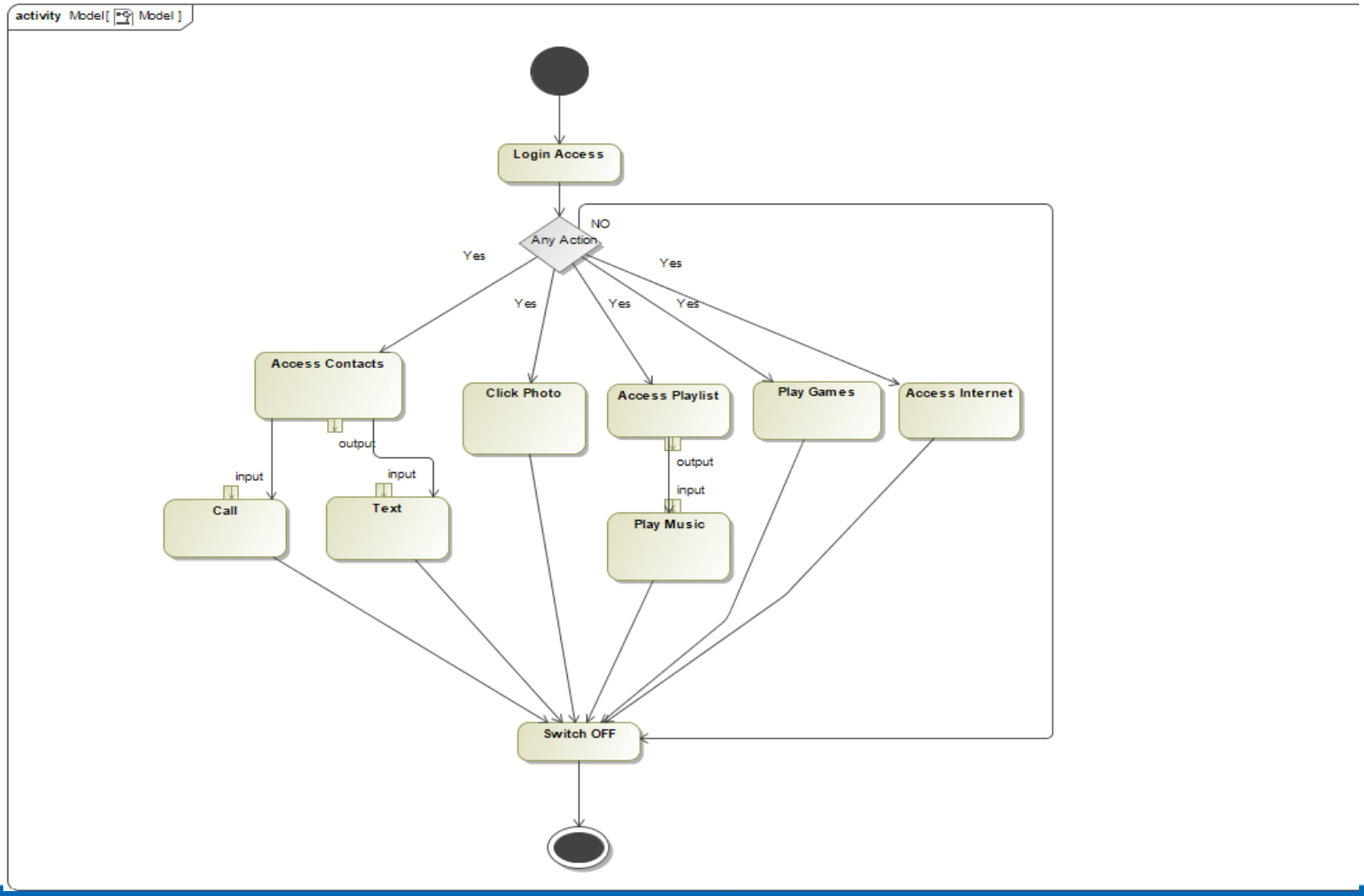
Requirements Justification

- The top level Requirements diagram consists of 5 main requirements for the Spirit Cell Phone System -
  A) Design
  B) Technology
  C) Maintenance
  D) Communication
  E) Environment
- We need these primary requirements so that the Spirit cell phone system qualifies the cell phone market in every aspect.
- The user should be able to have all the access while using this cell phone system.

Requirement Justification

- The base requirement diagram for technology has 4 sub requirements -
  A) Processors
  B) Operating Systems
  C) Storages
  D) Batteries
- The cell phone shall have processors like snapdragon or bionic chip to work efficiently.
- The cell phone shall have operating system like android or IOS depending upon the market survey.
- The cell phone shall have storage which is very important to store sufficient data. There are two types - Internal SSD and External hard drive.
- The cell phone shall have batteries like lithium ion or lithium polymer based on the load testing.
- Each requirement is connected using one of relationships callout, directly, compartment, containment, trace, copy, verify, refine, derive and satisfy.

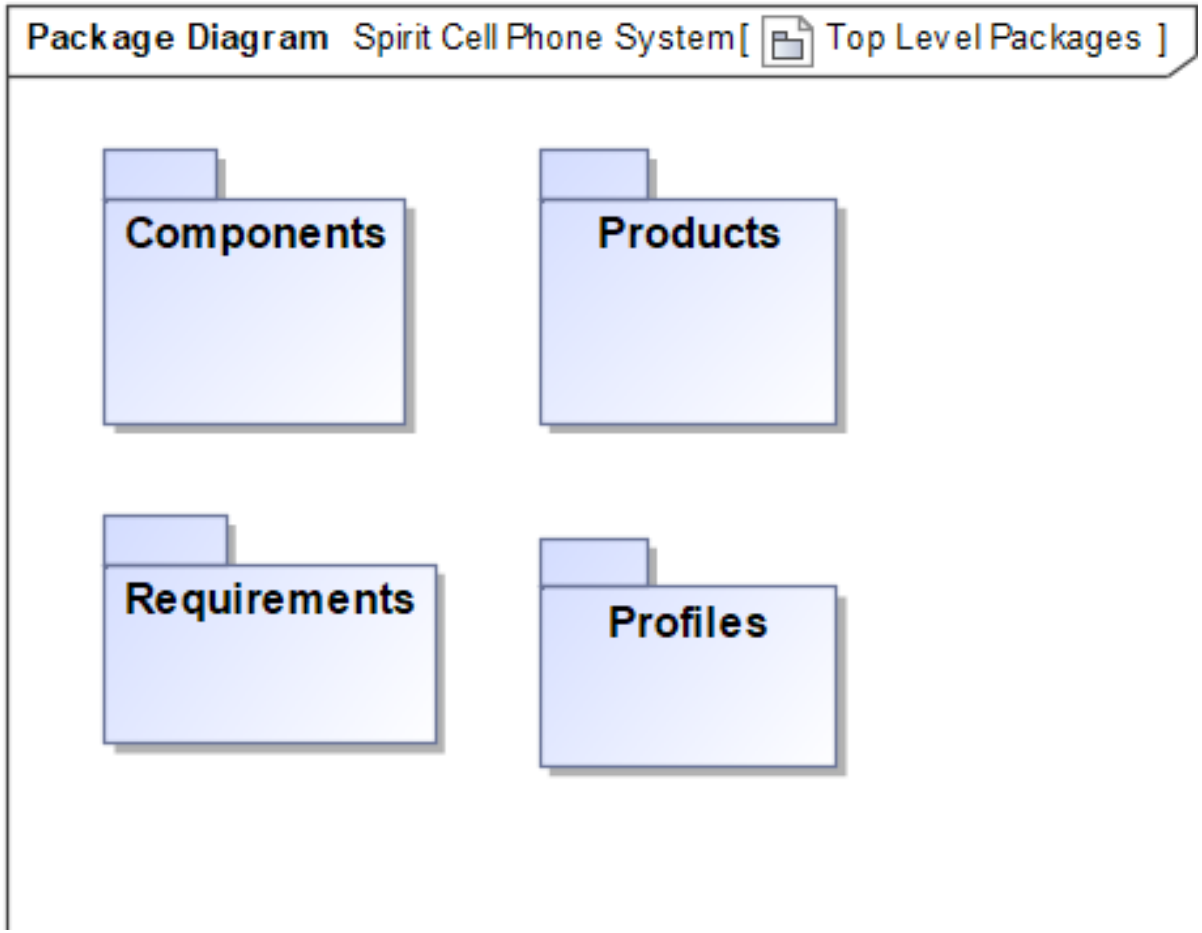
Activity Diagram



Activity Justification

- The cell phone activity starts with the login action.
- The user decides whether any action needs to be performed or not.
- If YES, then the user moves ahead for an action.
  If NO, then the user can switch off the cell phone and return later.
- The user can call, text, click photos, play music, play games, or surf on internet.
- To make a call or text message, the user needs to access the contact list. The selected contact list as an output is fed as an input to the call or text action.
- Similarly, the user performs actions like photos, music, games and internet.
- After the action is executed, the user can switch off the cell phone. This concludes the activity diagram.

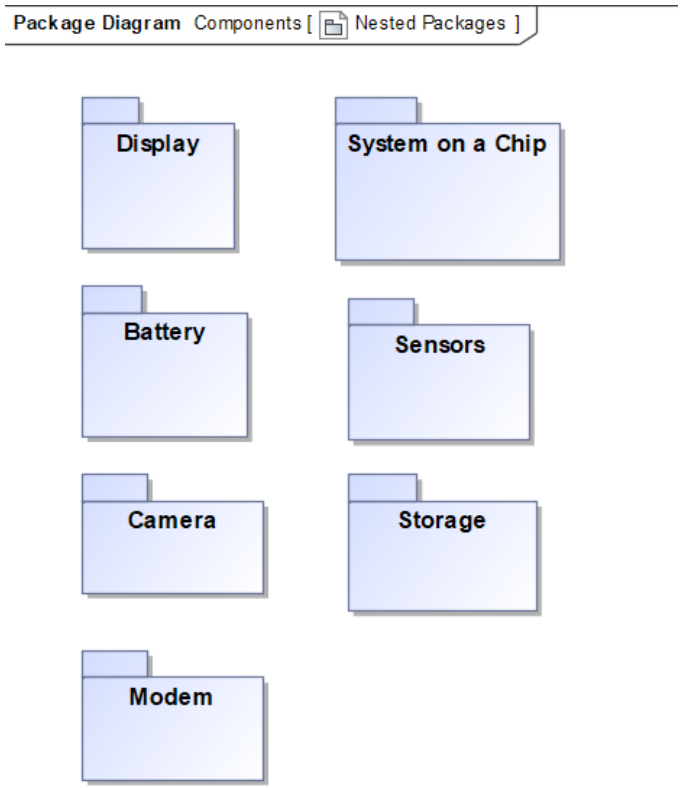
Package Diagram Top Level

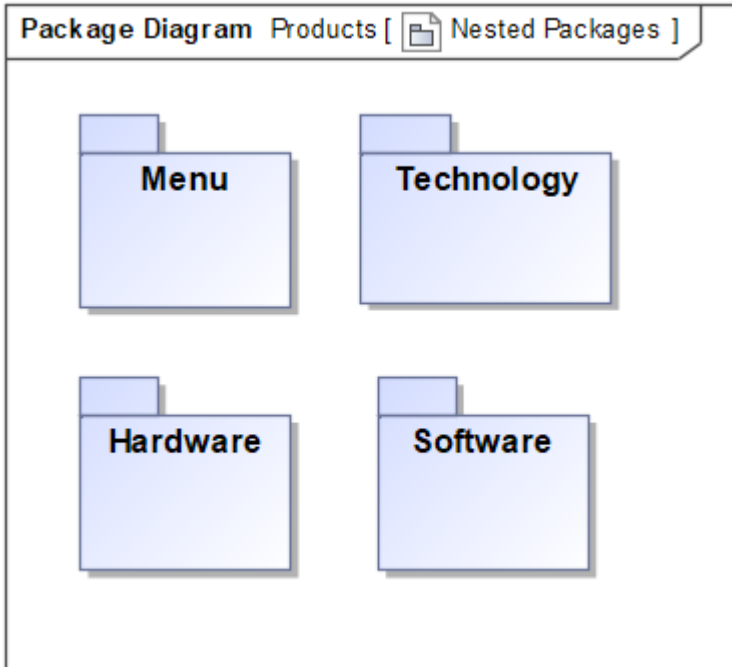


Package Justification

- Components – There are several components for Spirit Cell Phone System to work. Components include display, camera, modem, storage, sensor, battery, etc.
- Products - The products are divided into menu, technology, hardware, software, etc.
- Requirements – The requirements are divided into voice communication, short message service, personal digital assistant, etc.
- Profiles –The profiles are important in maintaining user information and provide security.

Package Lower Level





Lower Level Package Justification

Components :

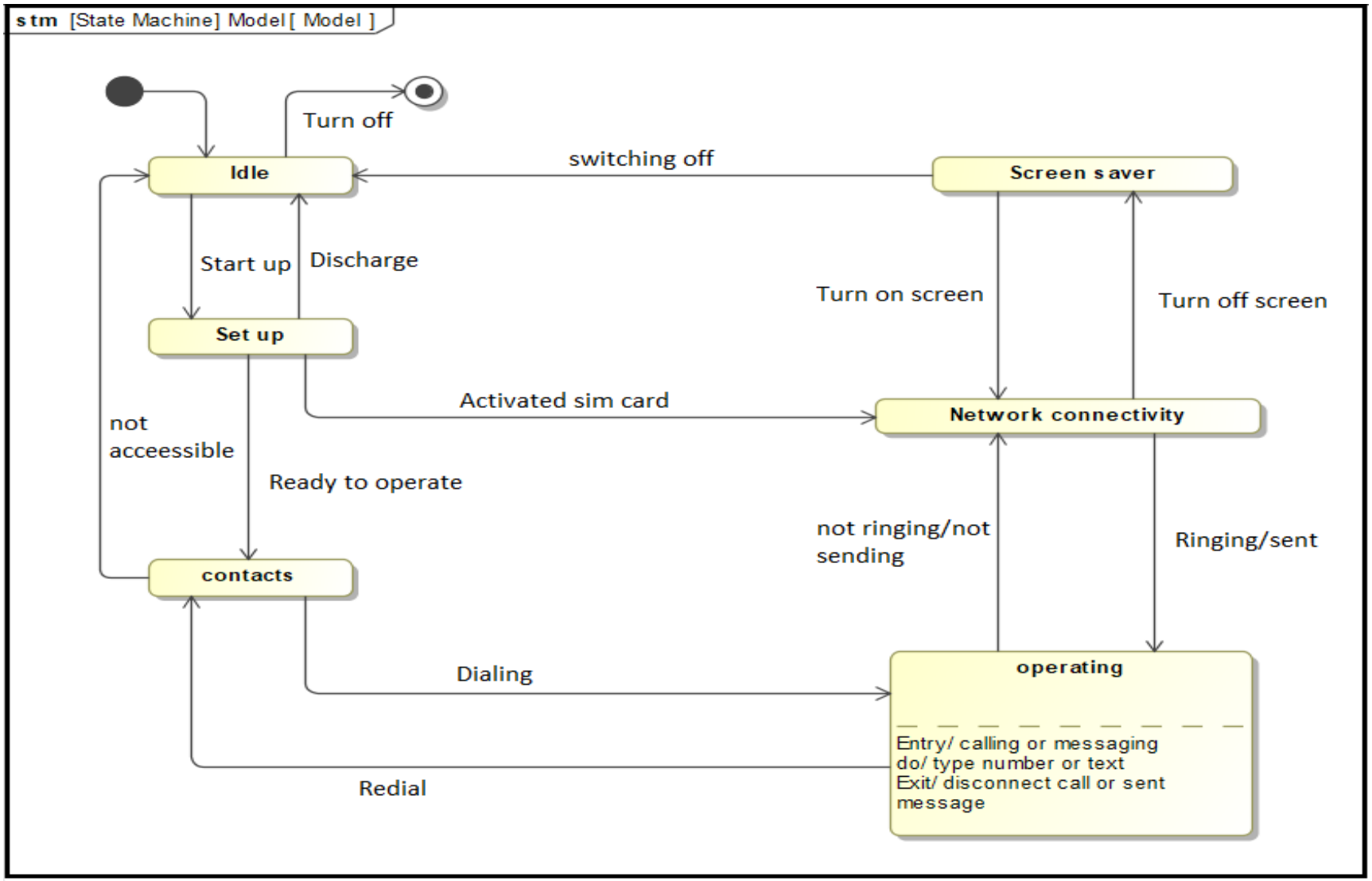
- Display - It provides visuals to the user.
- Camera – It is used to capture still images.
- Battery - It is used to provide power to the cell phone.
- Sensor - It is used to give cell phone functionality.
- System on chip - It consists of CPU, GPU, LTE, modem etc.
- Memory - It provides storage in the cell phone.
- Modem - It provides wireless connectivity to the cellular network. Tonella, P., & Potrich, A. (2005).

Lower Level Package Justification

Products :

- Menu – Menu considers the various options that the user can select from the cell phone.
- Technology - Major and significant area which helps the cell phone system work as it is supposed to. This will drive the overall working system of the cell phone.
- Hardware - Hardware comprises of all the physical things which help in building of the cell phone system.
- Software - Software works internally to provide interface, security, etc for the working of the cell phone system.

State Machine Diagram



State Machine Diagram Justification

- This diagram explain about the spirit cell phone operating system
- The spirit cell phone needs to be switched on and then it should be set up for operation. If battery is not sufficient charged, then it can be discharge and cell phone going to be turn off
- After setting up the cell phone it is ready to operate. Which can access the contacts for making calls and messages.
- There are mainly six parts of the cell phone to look after and do accordingly. IDLE,SET UP, CONTACTS, OPERATING,NETWORK CONNECTIVITY,SCREEN SAVER

State Machine Diagram Justification

- Once the contact is available that can be ready to dial and if it is not accessible then it went to its idle condition.
- Operation must be begun once contact has been dialed so it can be ready to ring if network connection available if not it can be disconnected.
- Once the call connection done it can be disconnected and back to the main screen of the cell phone and complete the entire operation successfully.
- After that screen saver has been turn on and if switching off the device it went back to its idle condition and turned off.Herrmannsdörfer, M., Konrad, S., & Berenbach, B. (2008)

References

Aregbesola, K., & Osunade, O. (2013). System Design for Mobile Phone Data Backup. System, 4(13).

Claus Ballegaard Nielsen, Peter Gorm Larsen, John Fitzgerald, Jim Woodcock and Jan Peleska, 2015. Sys tems of Systems Engineering: Basic Concepts, Model-based Techniques, and Research Directions. ACM Comput. Surv. V, N, Article XXXX (2015). DOI http://dx.doi.org/10.1145/2794381

De Laurentis, D. (2005), " Understanding Transportation as System-of-System Design Problem", 43d AIAA Aerospace Sciences meeting and exhibit.

H. M. Chung, "Toward implementing a mobile collaborative system," 2012 International Conference on Systems and Informatics (ICSAI2012), Yantai, 2012, pp. 1248-1252, doi: 10.1109/ICSAI.2012.6223262.

Herrmannsdörfer, M., Konrad, S., & Berenbach, B. (2008). Tabular notations for state machine-based specifications. Crosstalk, 21(3), 18-23.

Jackson, M. C., & Keys, P. (1984). Towards a System of Systems Methodologies. Journal of the Operational Research Society, 35(6), 473–486. https://doi.org/10.1057/jors.1984.101

References

Maier, M.W., (1998) “ Architecting principles for systems of systems”, Syst;E,g., Bol. 1, Nà 4, pp. 267-284, 1998

SEBoK Editorial Board. (2021). The Guide to the Systems Engineering Body of Knowledge (SEBoK), v.2.5, R.J. Cloutier (EIC), Hoboken, NJ: The Trustees of the Stevens Institute of Technology (2021, 10 November 2021). www.sebokwiki.org.

Siewiorek, D. P., Smailagic, A., Furukawa, J., Krause, A., Moraveji, N., Reiger, K., ... & Wong, F. L. (2003, October). SenSay: A Context-Aware Mobile Phone. In ISWC (Vol. 3, p. 248).

Systems of Systems. (2017, November 29). The MITRE Corporation. https://www.mitre.org/publications/systems-engineering-guide/enterprise-engineering/systems-of-systems

Systems of Systems - IEEE Reliability Society. (2014). IEEE Reliability Society. https://rs.ieee.org/technical-activities/technical-committees/systems-of-systems.html

Tonella, P., & Potrich, A. (2005). Package Diagram. Reverse Engineering of Object Oriented Code, 133-154

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