Individual Research Paper

ENGN2225 Systems Engineering Design

Australian National University

System Function Definition and its application to Doorway Redesign project

Minh Tri Nguyen

U5142082@anu.edu.au

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Abstract

In System Engineering Design, System Function Definition including Use Case, Functional Analysis and Concept Generation is the tool to identify the all possible users and their interactions with the system (Use Case). Furthermore, System Function also describes the desired operational step in a particular Use Case by using Function Flow Block Diagram (FFBD) – a tool of Functional Analysis. In addition, Concept Generation is a way of brainstorming all ideas that relate to customer requirements so a better idea can be identified. In this paper, System Function Definition including its key points and tools will be analysed. Particularly, background theories of System Function Definition will be briefed as well as examples in applying them. The most important part in this paper is to apply these theories to Doorway Redesign project for Canberra City Care Community; that is to provide potential solutions for a safe, accessible and reliable doorway system for people that might have difficulties in using the old push-pull door system.

Background

Use Case

1. Theory review:

   Use case (Cockburn, 2001) describes how the system should response to a request of stakeholders to achieve a specific goal. Cockburn (2001) also states that the use case collect all different scenarios which are different sequence of steps depending on the requests made under various conditions. Kettenis (2007) categorises two type of "actor" which are primary actor and supporting actor. The primary actor is

stakeholders of a system such as people or things that have an interest of achieving a goal while the supporting actor sometimes needs to provide a service to the system (Kettenis, 2007). Kettenis (2007) also states that an actor can be primary actor for one use case and the supporting actor for another. Moreover, discovering of "hidden" actors at the early stage such as service technicians, sales etc. is important since it may reveal missing requirements of the system. According to Cockburn (2001), use case is a tool to serve the communication from one person to another and it can be in text form, flow charts, sequence charts, Petri net or programming languages.

The benefit of Use Case is that it helps brainstorming of what could go wrong, establishing the cost and complexity of the system (Improving the User Experience, 2014).

2. Literature review:

   An example of use case of an ATM system as shown in Figure 1 (Appendix-Background) (Creately, 2013): use case of different actors which was identified as administrator, bank customer and the bank. The use case of administrator is to maintain the system including reporting and shutdown while a bank customer and the bank is to achieve a transaction either withdrawal, checking balance, deposit or print receipt. However, in bank customer's use case, a bad pin entry was shown as an extension use case.

Functional Analysis

1. Theory review:

   Functional Analysis is a tool of identifying, describing and relating functions that a system must perform to achieve its goal (NASA, 2007). This can be done by arranging functions in a logical sequence as top level function and then decompose into lower level sub functions (System Engineering Fundamentals, 2001). Functional Analysis (Viola, et al 2012) is particularly useful during conceptual design stage since it consists as many feasible options as possible without missing any ideas that may have significant advantages.

   Functional Analysis can be performed using various methods, one of which is Functional Flow Block Diagrams (FFBDs). FFBDs (NASA, 2007) is made of functional blocks and developed using series of level diagrams in which show the functional decomposition and display functions in their logical, sequential relationship

using consistent numbering scheme. This will provide traceability from lower level to top level (NASA, 2007).

2. Literature review:

   Figure 2 (Appendix - Background) shows an example of FFBDs of Shuttle-Base Radar Mapping Mission. Sequence of operations as top level was shown clearly and logically in FFBDs. It also shows the decomposition of top level function into second level sub function and furthermore into third level. By using FFBD, alternative function is also considered; for example, in Figure 2, from 3.0 Transfer to OPS Orbit to 6.0 Transfer to STS Orbit, there are two paths including 4.0 Perform Mission Operations and the alternative 5.0 Contingency Operations. These alternative paths are indicate by an "OR" gate. As shown in Figure 2, only top level function 4.0 was decomposed into second and third level sub functions; considering a full version of FFBD, traceability becomes crucial.

Concept Generation

1. Theory review:

   Concept Generation is a process starts with a set of Customer Requirements and results in a set of solutions from which will be used to make final selection (Ulrich & Eppinger, 1995). It is very important in design requirement and therefore must be considered in the early stage of designing process (NASA, 2007). NASA (2007) states that having good concept generation and use case with exploration of alternatives early in the process will reduce likelihood of overlooking of requirements and design functions. With full space of alternatives has been explored, it helps in finding a design concepts that will differentiate from competitors (Ulrich & Eppinger, 1995).

2. Literature review:

   Ulrich and Eppinger (1995) show an example of using Concept Generation in nailer design project. This example shows that the nailer designing team explore all possible concepts for energy source of the nailer which are chemical, pneumatic, hydraulic, electrical and nuclear. The nailer team then broke those concepts further and found that there are two promising branches: chemical with explosive system branch and electrical branch.

Application

The Doorway Redesign project for Canberra City Care Community is to design an accessible door which will provide a safe and secure travel path for all possible users including people that have business in the building, cleaners and trade people who do maintenance. However, this project focuses on people who have problem with the old push – pull door. In order to understand how different users interact with doorway system and identify most suitable solution, System Function Definition with three key points including Use Case, Functional Analysis and Concept Generation is used.

Use case

As per discussion session with client at early stage, primary actor of Doorway system was identified and categorised which are:

- Group 1: people with wheelchair, walker, heavy goods and pram unable to access the building.
- Group 2: Senior people and people with disability having difficulty in using push – pull door.
- Group 3: normal people and staffs that work in the building.
- Group 4: service technicians including maintenance, cleaning.

Note that group 3 and 4 might fall into group 1 or 2 under specific conditions.

Each of those actors listed above has different use case as well as different goal. In particular, this project focuses on “actors” in group 1 and 2 that have the goal of accessing the building either getting in or out. For normal people, their use case is simply as approaching door, looking for visual aids, electronic sensing and mechanical motor driving of Doorway system, walking through and achieving their goal. However, for those with disability and walking aids including wheelchair and parent with pram need extra supporting steps in their use case; particularly, they need either ramp or handrail or both. In addition, an after hour access is also consider as one of the use case for building staff; however, as discuss with client, it is not necessary.

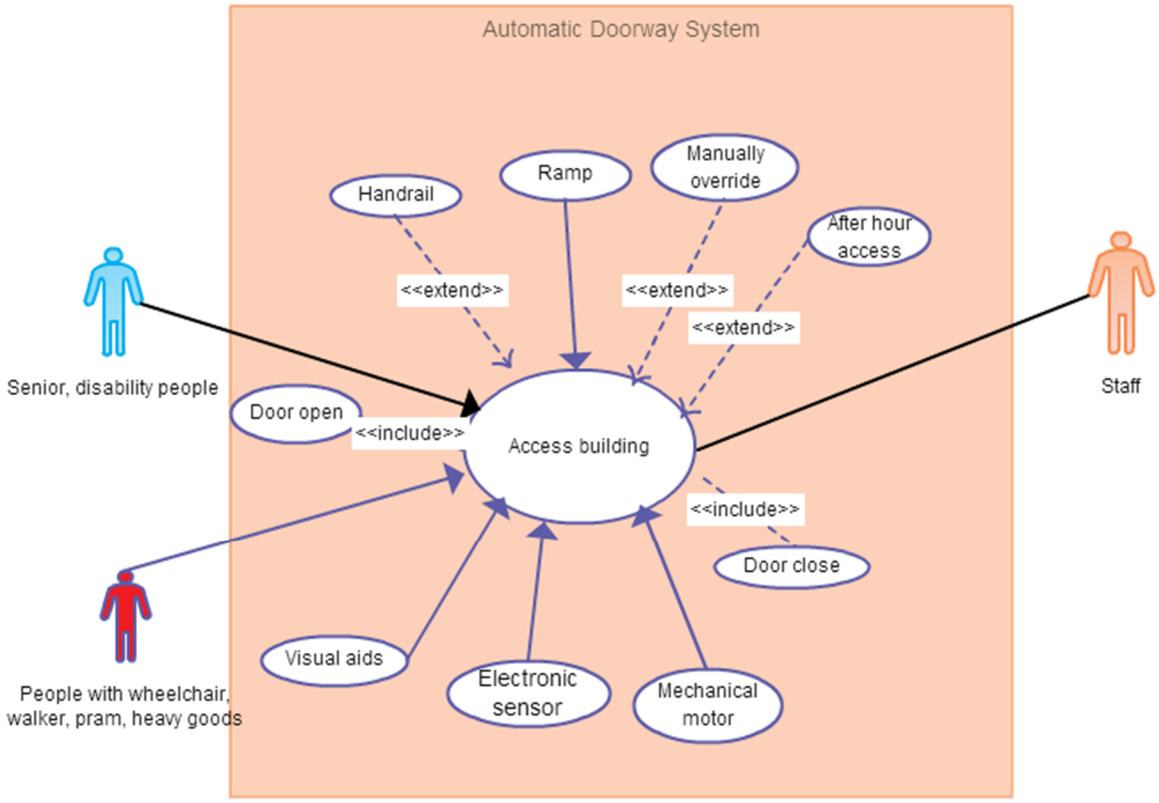

Figure 3: Use case of Doorway system

Figure 3 shows use cases of Automatic Doorway system in which unbroken arrows are used for common functions and broken arrows are for extra supporting steps that might be needed.

Functional Analysis and Concept Generation

According to Customer Requirement, the Doorway system has to be automated electronic control. This is a very clear requirement; therefore this project will only consider automatic doorway system. By identifying use case, it appears that group 1 and 2 have similar use case except for some extra supporting steps such as ramp and handrail. The Functional Flow Block Diagram (FFBD) for Automatic Doorway system as shown in Figure 4 below was built base on that use case.

FFBD shows general use case as in top level function with its sub functions in detail. Along with Concept Generation, investigation on FFBD was done by comparing different automatic doorway system to see its behaviours and its effects on different group of actors.

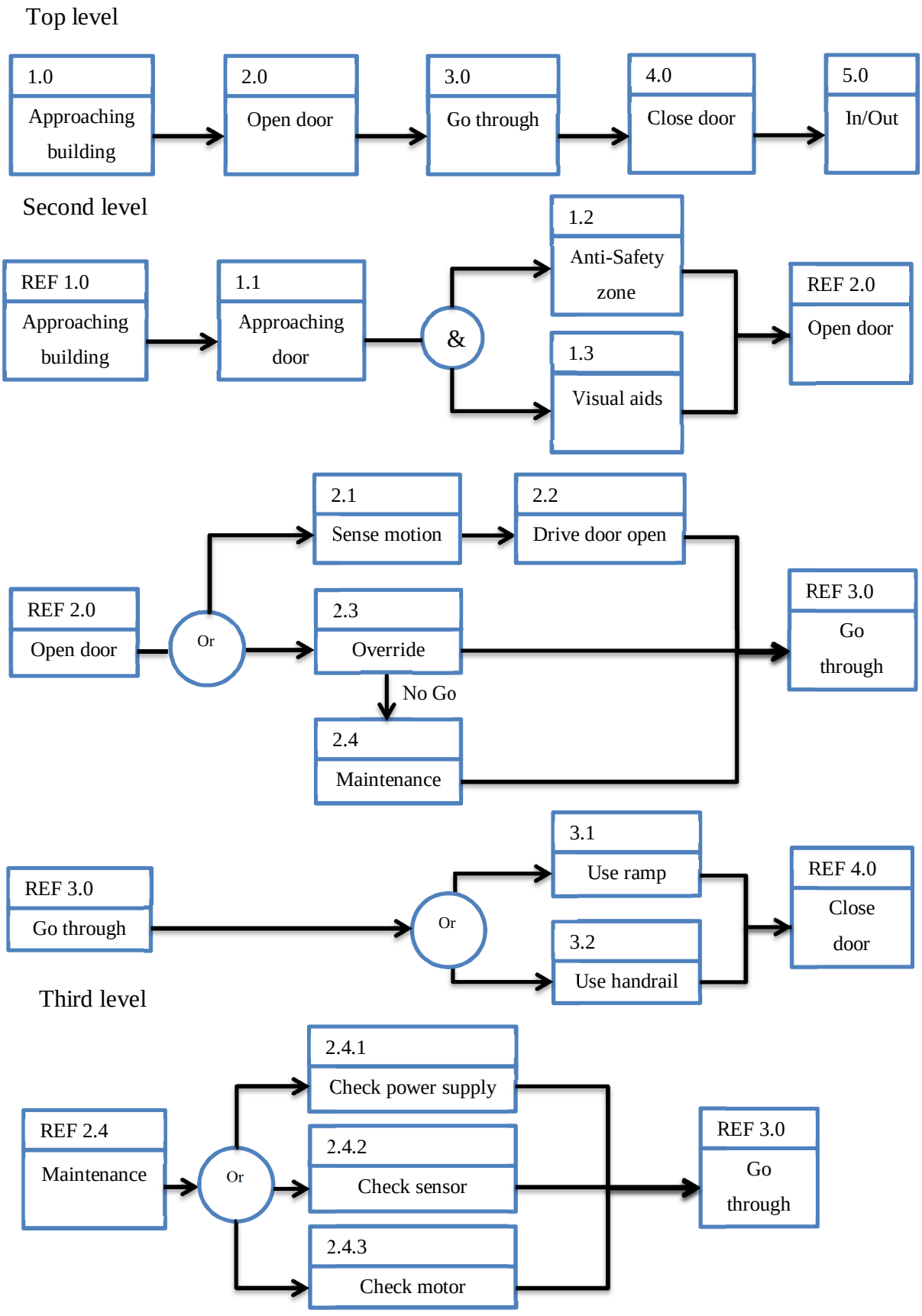

Figure 4: FFBD of Automatic Doorway system

As customer requires an automatic door, these options were considered as possible solution: swinging, sliding and bi-folding door. Observation on how each design affects the system as shown below:

- Swinging door: take more time to be fully opened (function 2.2)
    - Requires an anti-safety zone (function 1.2) for doors to swing inward or outward. This can be done by providing yellow box layout on floor.
    - Visual aids (function 1.3): sign for notification of slippery, uneven surface, after hour authorise personel and most important, beware of door open inward/outward.
    - Handrail (function 3.2): if door open outward, it will cover a part of handrail. One possible solution for this is to attach handrail on the door.
    - Override button (function 2.3): this is used in case of electronic malfunction. This button is normally placed close to door. However, this does not work well if doors swing toward a person who presses the button and even more difficult for people with wheel chair or walker. Placing the button at an appropriate position has to be considered carefully.
- Sliding door: open/close time possibly less than swinging door
    - Anti-safety zone: does not require
    - Visual aids: requires signs listed above as swinging door but does not require the sign beware of door open inward/outward.
    - Handrail: does not cover handrail.
    - Override button: can just place next to the door. However, it has to be within reaching range of all users.

From the above analysis including Functional Analysis and Concept Generation, the whole system was clearly shown in FFBD for general case. It provides traceability of sub functions; therefore it helps to keep track of which function from top to lower level will change or how it affects the others when considering different designs. Particularly, in second level REF 1.0 to REF 2.0, using sliding door does not require anti-safety zone and ‘beware of door open inward/outward’ signs while they are needed if using swinging door. Further investigation in sub function REF 2.0 to 3.0 and REF 3.0 to 4.0 show that there are 3 sub functions, which are 2.2, 2.3 and 3.3, will behave differently such as sliding door possibly having faster open/close

time, easier to place override button and handrail. In conclusion, sliding door would be a better option compare to swinging door.

Conclusions/Recommendations/Summary

This paper shows the background theories behind System Function Definition and how to apply in Doorway Redesign project. By using System Function Definition including three key points Use Case, Functional Analysis and Concept Generation, all possible actors was identified and categorised into groups. Also, FFBD was generated base on Use Case and used in supporting Concept Generation for brainstorming all possible solution along with how they affect the system. As the analysis above in application to Doorway Redesign project, sliding door would be a better solution. However, this paper has not considered bi-folding door and its affections. This paper also has not consider all Customer Requirement in Concept Generation such as durability, security, budget constrains etc. For further analysis and better possible solution, researching and brainstorming base on all customer requirements has to be done. Also expanding maintenance into more details is worth doing since this can help improve system life cycle.

Appendix

1. Background

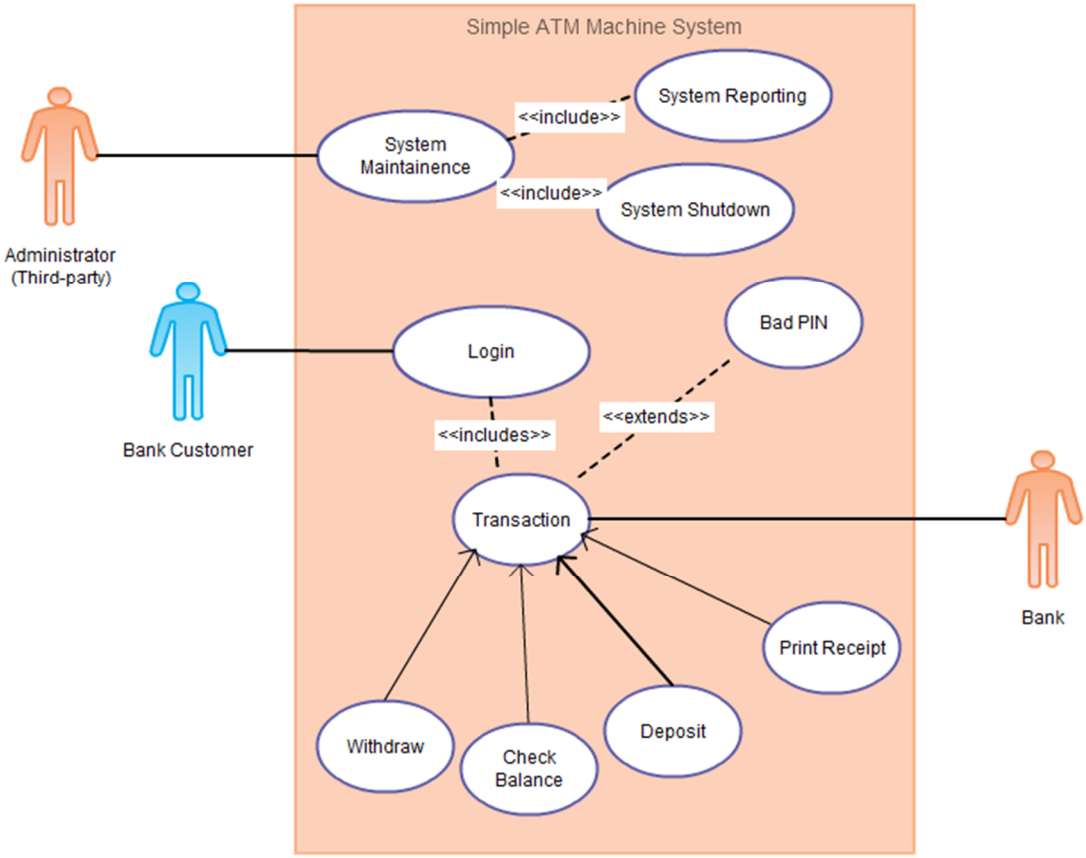

Figure 1: Use case of ATM system

Source: http://creately.com/diagram-type/template/g86xq8y6/usecase-diagram

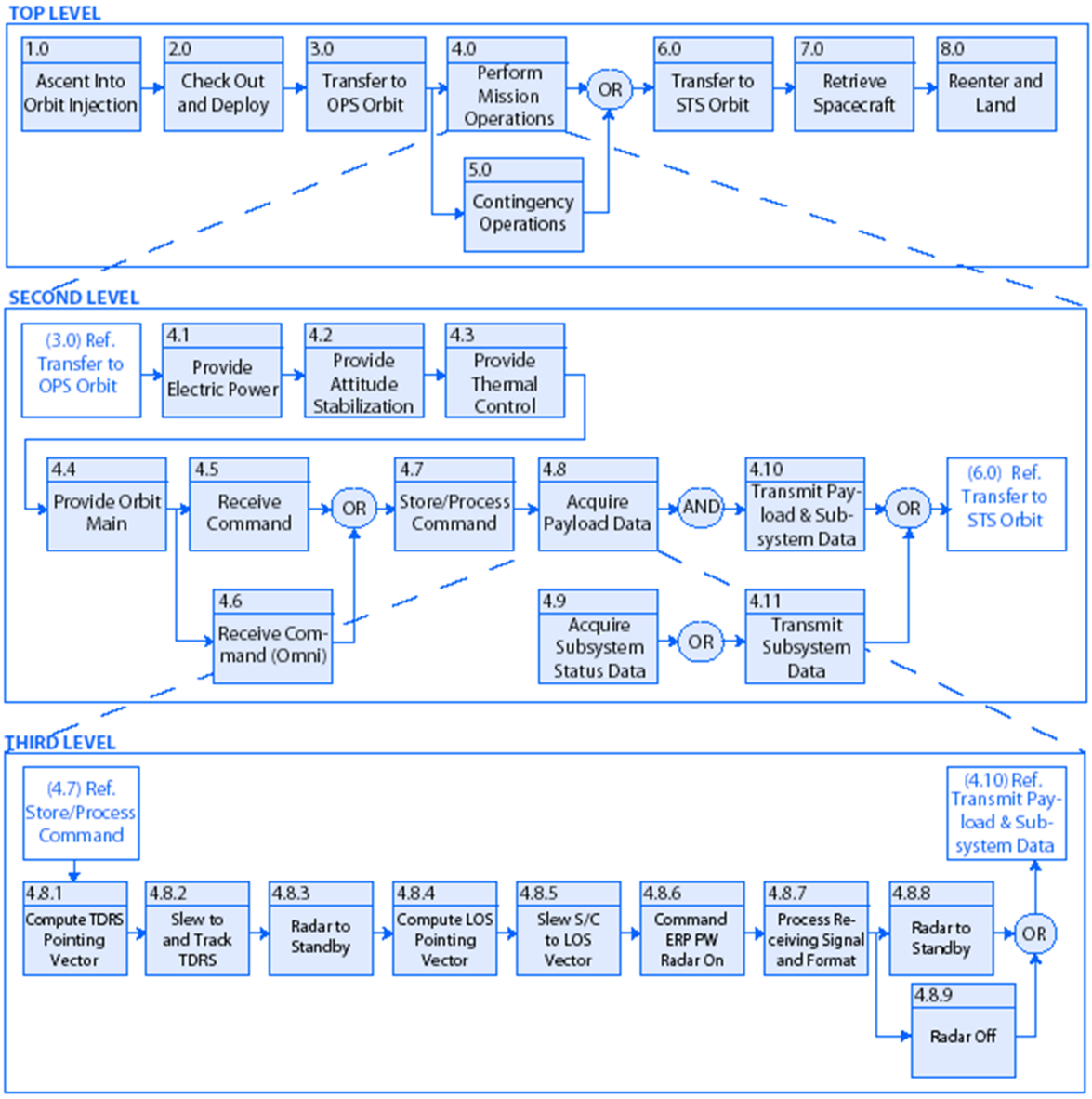

Figure 2: FFBD of Shuttle-Base Radar Mapping Mission

Source: http://spacese.spacegrant.org/uploads/Functional%20Analysis/12.%20Functional%20Analysis_Module_V1.0.ppt

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Peer Review Critique

Despite some non-relevant recommendations, feedbacks from peer review and especially from tutor help a lot in improving this research paper.

- As in draft paper, in the abstract, short descriptions and goal of the project (outcome of the paper) was not included and the application for Concept Generation was left blank intentionally. These were added to final paper as reviewer suggested.
- Tutor also helped to improve FFBD by pointing out non-relevant sub function as well as the wrong logic within the FFBD; hence it was updated.
- Recommendations on adding more discussion about the outcome of FFBD and explanation of why sliding door is better were noted. Hence in final paper they were expanded.

That was good to have peer review from both reviewer and tutor since it helps pointing out what was done well and what was not or what could be done better. This process helps me save a lot of time and focus on the right parts.