PROJECT MANAGEMENT DOCUMENTATION FOR MYSAT DEVELOPMENT PROCESS

by

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ENDORSEMENT

I, Noor Raweyah binti Othman hereby declare that all corrections and comments made by the supervisor and examiner have been taken consideration and rectified accordingly.

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DECLARATION

This thesis is the result of my own investigation, except where otherwise stated and has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any other degree.

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Date:

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ABSTRACT

The purpose of this thesis is to document the activities related to managing design, analysis, construction, testing, and integration of a qualification and possible flight of Cubesat from USM Space System Lab (USSL) named Malaysia Youth Satellite (MYSAT). This thesis will basically describe the process and result obtained from all the subsystem involve in MYSAT development, including the project cost analysis and scheduling as early as April 2017 for easy view by the project team. Since few subsystem involve including costing and scheduling, there are no system to sort out and organized the information accordingly. Therefore, project management tools have been suggested to help make all the information be in organize manner. As for MYSAT itself the mission is to measure electron density in the ionosphere E-Layer to prove the correlation between the correlation between seismic activity and ionosphere anomaly and the changes of the electron-density. Thus, system engineering and project management tools is used to support the conceptual design of MYSAT. MYSAT small satellite system engineering utilizes a spreadsheet-based approach to efficiently track information regarding the mass, power, and volume of the satellite and satellite subsystems. All information gathered so far will be stored in the Microsoft Excel for detailed view which derived using Work Breakdown Structure (WBS) method. For WBS the method used is by deriving the information into levels and subdivision based on their priorities and arrangement. For instance the information divided into project management part, mission overview part and subsystems part. Therefore, documentation using Microsoft Excel have been develop as for now.

DOKUMENTASI PENGURUSAN PROJEK UNTUK PROSES PEMBANGUNAN MYSAT

ABSTRAK

Tujuan tesis ini adalah untuk mendokumenkan aktiviti yang berkaitan dengan pengurusan reka bentuk, analisis, pembinaan, pengujian, dan penyepaduan kelayakan dan kemungkinan penerbangan Cubesat dari Makmal Sistem Angkasa yang dinamakan Malaysia Youth Satellite (MYSAT). Tesis ini pada dasarnya akan menghuraikan proses dan hasil yang diperoleh daripada semua subsistem yang melibatkan pembangunan MYSAT, termasuk analisis kos projek dan penjadualan seawal April 2017 untuk memudahkan pengurusan oleh pasukan projek. Memandangkan beberapa subsistem melibatkan termasuk kos dan penjadualan, tidak ada sistem untuk menyusun dan menganjurkan maklumat dengan sewajarnya. Oleh itu, alat pengurusan projek telah dicadangkan untuk membantu membuat semua maklumat dalam cara yang teratur. Adapun MYSAT sendiri misi adalah untuk mengukur ketumpatan elektron dalam E-Lapisan Ionosfera untuk membuktikan hubungan antara korelasi antara aktiviti seismik dan anomali ionosfera dan perubahan ketumpatan elektron. Jadi, kejuruteraan sistem dan alat pengurusan projek digunakan untuk menyokong reka bentuk konseptual MYSAT. Kejuruteraan sistem satelit kecil MYSAT menggunakan pendekatan berasaskan spreadsheet untuk memantau maklumat mengenai jisim, kuasa, dan jumlah subsistem satelit dan satelit secara cekap. Semua maklumat yang dikumpulkan setakat ini akan disimpan di Microsoft Excel untuk melihat terperinci yang diperolehi menggunakan kaedah Struktur Pecahan Kerja (WBS). Bagi WBS, kaedah yang digunakan adalah dengan menerbitkan maklumat ke peringkat dan sub-bahagian berdasarkan keutamaan dan susunan mereka. Contohnya maklumat yang dibahagikan kepada bahagian

pengurusan projek, bahagian keseluruhan misi dan sebahagian subsistem. Oleh itu, dokumentasi menggunakan Microsoft Excel telah dijalankan buat masa sekarang.

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LIST OF ABBREVIATIONS

MYSAT	Malaysia Youth Satellite
USSS	University Space Systems Symposium
MPA	Multiple Payload Adopter
OSSS	One Stop Satellite Solutions Inc.
RAX	Radio Aurora Explorer
COTS	Commercial-Off-the-Shelf
LEO	Low Earth Orbit
MBSE	Model Based Systems Engineering
PMI	Project Management Institute
ECSS	European Cooperation on Space Standardization
WBS	Work Breakdown Structure
OSS	Open Source Software
CVS	Concurrent Versions System
OMG	Object Modelling Group
INCOSE	International Council on Systems Engineering
CNES	Centre National d’Etudes Spatiales
ESA	European Space Agency
P-POD	Poly-Picosatellite Orbital Deployer
ADCS	Attitude Determination and Control System

RF	Radio Frequency
TeNeP	Electron Temperature and Density Probe

CHAPTER 1

INTRODUCTION

1.1 Background Study

The number of the small satellite projects recently dramatically increasing and there are great demands for effective project management methods for them. Therefore, the goal of this paper is to propose helpful and effective project management methods for Malaysia Youth Satellite (MYSAT). MYSAT is a scientific Cubesat-based project initiated by School of Aerospace Engineering Universiti Sains Malaysia in 2016. Cubesat is a cubic shaped satellite, whose size is 10 x 10 x 10 cm^3 and its weight is restricted within 1kg. Cubesat program was originally adopted in the University Space Systems Symposium (USSS) in Hawaii in November, 1999, and has been promoted mainly by Japanese and U.S universities community (Yuichi Tsuda et al., 2000).

This program has started primarily for an educational purpose to enhance students' skills of space engineering and project management. Applications of project management tools, including open source software which play crucial roles in cost effective for small satellite approaches and the system engineering process are also summarized and examples of them are illustrated. Small satellite ventures change from the typical non-specialized activities as it requires profoundly specialized and explicit state-of-the workmanship skill and information yet like every other task, they need the best possible undertaking the executives for the fruitful execution (Muhammad Fiaz et al., November 2012).

1.2 Problem Statement

There is no system to manage MYSAT project documentation which make it is difficult to review and referred at once. Furthermore, there is no easy way to monitor the budget and cost analysis of the whole process since there is no specified and organized platform to store and check all the important data. Other than that, all the information about MYSAT have no management system at one point so it is a problem and time wasted to search each information at once as mentioned above. As solutions, this study focuses on developing the medium and system to manage and document all the information gathered and achieve as of now.

1.3 Objective

Total of three objectives derived from the problem stated in section 1.2 are to be attained in this study as below:

- To design and develop a system for MYSAT project management and documentation.
- To develop financial management and risk analysis for MYSAT.
- Document all the information gathered.

CHAPTER 2

LITERATURE REVIEW

2.1 System Engineering

Systems engineering is concerned about the general execution of a system with for various goals like mass, cost and power. It is an interdisciplinary access and means to enable the realization of successful systems. System engineering integrates all the disciplines and major groups into a team effort forming a structured development process that proceeds from concept to production to operation. The systems engineering process is methodical approach to balancing the needs and capabilities of the varied subsystems in order to improve the performance of the system. The size, volume, and mass constraints often encountered in small satellite development programs, combined with increasing pressure from customer to pack more capability into a given size, making systems engineering methods particularly important for small satellites (Allan I. McInnes et al., 2001). Spacecraft systems engineering is an entrenched and well-understood disciplines. Nevertheless, many of the standard tools and techniques used to perform conceptual design of spacecraft contains implicit assumptions that are based on the characteristic of the huge satellites.

Considering that characteristic of small satellites can differ from those of traditional huge satellites in a number of ways as shown in Figure 2.2, therefore these differences mean that although the process used to design small and large satellites is identical, the tools required to support the process are distinct. Meanwhile (David Kaslow et al., 2014) agreed that Model Based Systems Engineering (MBSE) is a key practice to advance system engineering that can benefit Cubesat missions. MBSE create system model that helps integrate other discipline specific engineering models and simulations.

The system level method is initiated at the start of a project and evolves throughout development. It provides a cohesive and consistent source of system requirements, design, analysis, and verifications. MBSE is the formalized application of modelling to support system requirements and validation. It begins in the conceptual design phase, continuing throughout development and into later life cycle phases including operations.

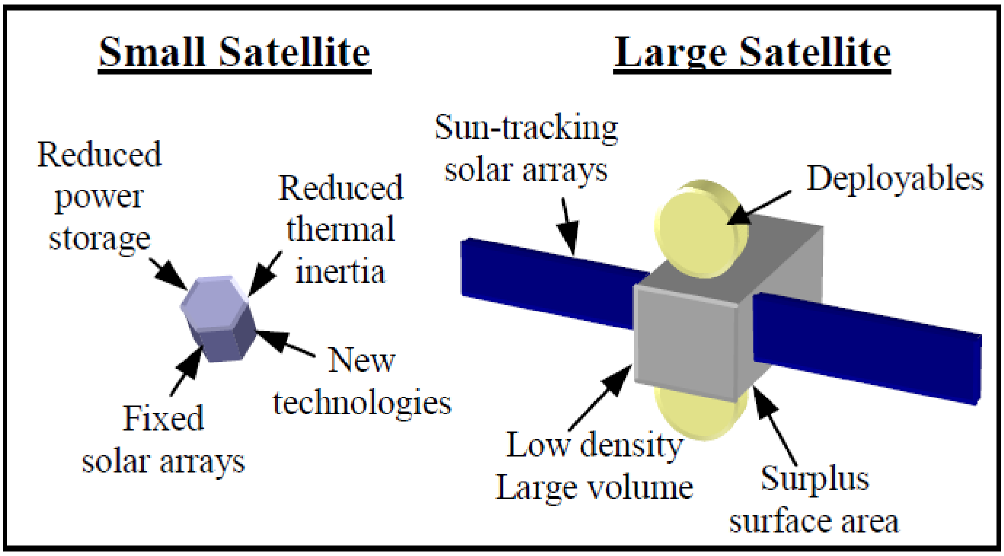


Figure 2.1: Small Satellite vs Large Satellite (Allan I. McInnes et al., 2001)

2.2 Project Management

Project management has existed, in theory, for centuries with its informal application by the Chinese and Egyptians in such feats as the Great Wall of China and the Pyramids (Alan Murphy and Ann Ledwith, 2007). However, (Fox G.M., 2004) stated that modern project management is a recent phenomenon gaining initial acceptance in the rapid development of the information technology industry. Over time modern project management has emerged as a discipline that has constantly remoulded itself to allow for expansion in its practise. (Crawford L. and Pollack J., 2005) suggest that as a discipline, project management is “dynamic facing new challenges, as tools, methods and approaches to management that comprise the discipline are applied to different areas, for different ends, and in different culture".

Application of knowledge, skills, tools, and techniques to project activities to meet the project requirements is called project management. Based on (Project Management Institute, 2000) it includes five processes as initiating, planning, executing, controlling, and closing which are executed to complete the life cycle of every project (Project Management Institute, 2004). Small satellite projects include many phases and sub-process which makes their execution more complex. The disparate phases have been discussed detail.

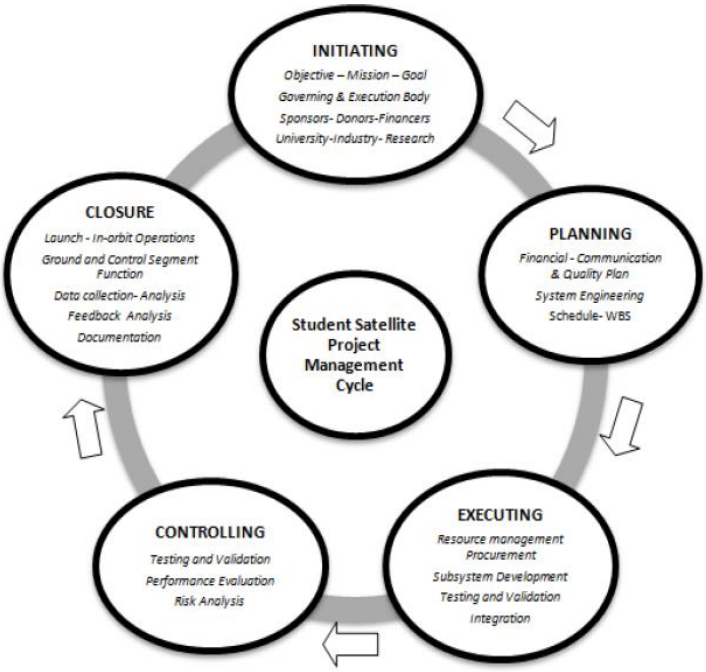


Figure 2.2: Student Satellite Project Management Cycle

Based on Figure 2.2 above starting from initiating phase of the small student satellite project involves defining of objective for developing the satellite that may involves the development of human resource for the satellite industry or to give handson experience to the undergraduate and graduate students of the university. It is also including the definition of mission that either the satellite will be the communication or the Earth observation based mission. This phase of project management involves the identification of sponsors, funding agency, industry, stake holder or other partner university that might join the project.

Second, the planning phase which comprises two major task which are technical and administrative planning. The technical task starts with the mission requirements according to the objective and goal defined in the initiating phase. It summarise the specific requirements of the mission in qualitative and quantitative terms. It motivates the technical mission design that involves the orbit and path definition. Besides, it also includes the selection of payload for the required mission and the life of overall mission with required accuracy and precision. This mission definition navigates the system engineering that involves the designing of different subsystems like structure, ADCS, power, communication and payload. It will definitely involve power and mass budget too. The second administrative task defines the financial plan and budgeting. It also involve the team building and tasks assignments with schedules and Work Breakdown Structure (WBS) and Gantt chart (Muhammad Fiaz et al., November 2012).

Third, execution phase is the most crucial one in any project and especially in student satellite projects it involves many intricacies and supervision issues. The main task of this phase is to practically develop the different subsystems of the satellite according to the mission requirements and the system engineering guidelines. It also includes procurement issues and the resource management using the facilities at the university premises and also at the collaborating universities, industry or public research organizations. After that, the second task is the testing and validation of each subsystem according to the defined quality instructions and finally integrating all subsystem (Muhammad Fiaz et al., November 2012).

Fourth, the controlling phase for student satellite projects involves testing and validation of the complete satellite that includes the thermal and vacuum tests. Performance evaluation is also performed at this stage with the applications of risk analysis. This phase also demands for the final negotiations with the government and international regulatory bodies and finalizing the contracts and timings with the launch providers and control stations. Last but not least, this is the last step which is to close the project management loop. At this stage decisions are made for a specific project to terminate or continue the process (Kotnour T.G., 1999). The final phase manages the satellite launch and initial in-orbit operations with the help of public research organizations or national space agency which includes ground segment functions like retrieving the data and monitoring the health status of the satellite. The final phase covers the documentation and feedback analysis and to validate the required technical and qualitative mission goals and achievements.

Few project management tools have been studied and propose by numerous project has been successfully and in the process of making to ease the information gathering and to keep track on each progress by all subsystems. Sidewise, project management theory offers a number of simple and advance methods which help with project management in project life cycle stages and lead to increased success of project implementation (Kostalova et al., 2015)A number of studies confirm that the project success rate increases if project management method are used (Patanakul P. et al., 2010). First of all, the Project Management Institute (2000) define a project as a temporary, definitive beginning and definitive end, endeavour undertaken to create a unique product or service. Projects based on (Alan Murphy and Ann Ledwith, 2007) can be considered as the achievement of a specific objective and involve the utilisation of resources on a series of activities or tasks. (Munns A.K and Bjeirmi B.F, 1996) in their studies on project success, differentiate between project success and project management success.

Their definition of a project suggests an orientation towards longer-term goals such as return on investment, profitability and competition, while project management focuses on short term goals and a more specific context for success. The following distinction between project success and project management (Cooke-Davies T., 2003) are project success is measured against the overall objectives of the project while project management success is measured against the widespread and traditional measures of time, cost and quality success. In reference to C.Annique Un et al (2009) project is unique endeavour with a definitive beginning and an end, having definite goals, cost, schedule and quality while Project Management Institute (Project Management Institute, 2000) share that project consumes limited resources to meet defined objectives. Application of knowledge, skills, tools and techniques to project activities to meet the project requirements is called project management (Muhammad Fiaz et al., November 2012).

It includes five processes as initiating, planning, executing, controlling and closing Project Management Institute (Project Management Institute, 2000) and are executed to complete the life cycle of every project, Project Management Institute (Project Management Institute, 2004). Small satellite projects include many phases and sub-process which makes their execution more complex (Dawson C.W et al., 2000). From Toshinori Kuwahara et al (April 2008) point of view, project management is a coordination of resources to achieve goal within a restricted time. For satellite development projects, project management plays a significant role strongly connected with all aspects of the projects, such as engineering activity, personnel affairs and financial management. Project preparation and utilization is usually divided into partial phases, which together form the project life cycle. After the beginning of the trend of Cubesat which is proposed by professor Twiggs of Stanford University, the number of small satellite projects is adequately increasing and, accordingly, a considerable amount of them are educational purpose.

According to these backgrounds, there are great demands for effective methods of project management for small satellites projects, enabling newly joining institute to start their projects smoothly, efficiently and supporting existing projects to be provided with further possibilities to stabilize and optimize their activities. Application of project management methods is easier by software applications which lead to a decrease in time demands of project management, simplification of the process of implementation of the respective method, and also an increase in the success rate of project implementation (Kostalova et al., 2015). One of them is utilization of the existing applications. For example office software, spreadsheet processor, text editors, or software applications supporting time management. Aside from project management support in individual project life cycles stages, the other crucial functions of most such applications include project documentation administration, sharing of this documentation across the project team, and any other involved parties (Meredith J.R. and Mantel S.J., 2006, Braglia M. and Frosolini M., 2014), and support in the multi-project environment (Ahlemann F., 2009, Kaiser M.G. and Ahlemann F., 2010, Reyck B.D. et al., 2005).

Meanwhile, the research Irja Hyvari (September 2005) addressing project management effectiveness in project-oriented business organizations includes the following themes: (1) organizational structures, (2) technical competency, for example project management tools and methods, (3) leadership ability, and (4) the characteristic of an effective project manager. The organizational structures mean a system that draft how certain activities are directed in order to achieve the goals of a successful organization which those activities can comprises of rules, roles and responsibilities. The organizational structures also determine how information flows between levels within the company or any project development. For instance, in a consolidate structure decisions flow from the top down, while in a dispersed structure, decision making is distributed among various levels of the organization.

There are four familiar and common kind of organizational structure which are administrative structure, functional structure, divisional structure and matrix structure. Administrative structure includes a specific level of regularization that are preferably relevant for larger scale or greater multifaceted organizations. Functional structure includes enterprise like supervision, direction, management, and allocation of responsibilities. This type of organizational structure selects how the processes and presentations of the organization can carry. Divisional structure which is also called as product structure is an adjustment and arrangement of a business or project that breakdown the organization into separation which is self-concerned with.

Next, technical competency which means the capability to use project management tools and methods to carry out projects. A survey of project management institute (PMI) members in the USA shows that most project management professionals rely a great deal on project management software (Pollack-Johnson B. and Liberatore MJ., 1998). Another survey confirms that there are actually dozens of project management tools on the market either it is open source software or need to be purchased beforehand. Nonetheless, the majority of project manager tend to use only a small subset of these tools, which is the widely use being are Microsoft products such as Microsoft Project and Microsoft Excel. Thus one needs a project management tool that is capable of dealing with time and capacity simultaneously. There are lots of open source software tools available and can be access online or available on one's computer. It must not be necessary to use only one software but it can be use more than one for one single project.

2.2.1 Project Breakdown Method

Applications of project breakdown structures originally provide a project with several benefits which are the (1) creation of common understandings by identifying items, associated tasks, and responsibilities, (2) identifications of interfaces, (3) management of configuration and recording of changes, and (4) enhancement of the effective project management. There are disparate space project management measure and methods, which provide practical information on project management. One good example of those measure and standards is the one specified by the European Cooperation on Space Standardization (ECSS), (Standardization, June 2003). This standard specifies the application of project breakdown structures as graphically summarized in Figure 2.3.

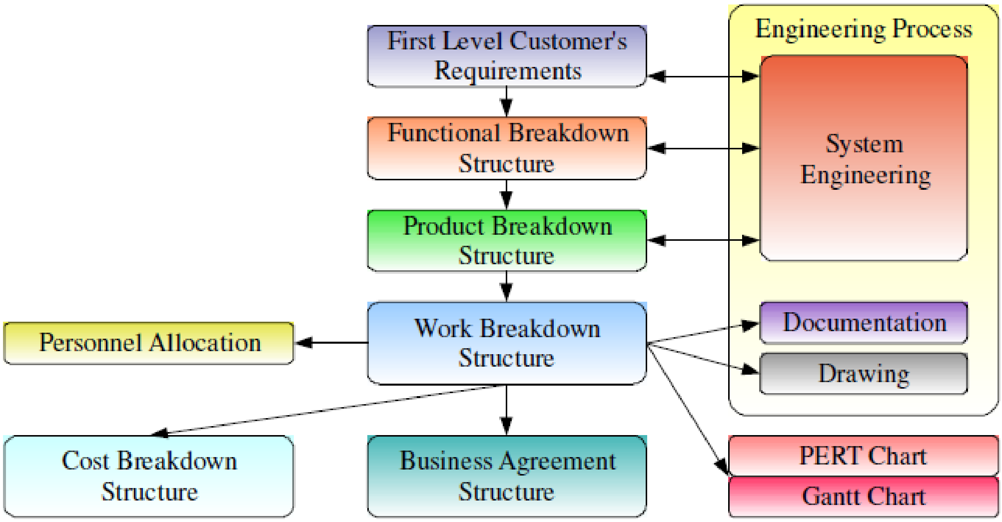


Figure 2.3: Graphical Representation of ECSS Standard of Project Breakdown Structure (Tohinori Kuwahara et al., April 2008)

These requirements are expressed into a functional breakdown structure and a work, at first, and then into a product breakdown structure and a work breakdown structure (WBS) in continuance supported by system engineering process. Through functional requirement derivation, the top level requirements and this disintegration builds up a hierarchical breakdown of the functional requirements. The functional breakdown structure can be represented as hierarchical matrices or integrated block diagrams (Wertz J.R. and Larson W.J., 1999). The functional breakdown of *Flying Laptop* is done using SysML modelling language. The WBS represents a summary of work packages, in which the depiction of identified specific works, human resources, and time durations are describing precisely. This WBS becomes the backbone for other breakdown structures such as the cost, as well as for the derivation of the other project management activities, such as schedule management, documentation management and so forth. The project breakdown process goes through WBS elaboration. For this occasion, it is still convenient to divide the satellite system into several subsystems and classify all hardware components used in the whole system.

In different circumstances, however, there are some drawback of using this kind of standards in conjunction with small satellite projects. It is predominantly because the WBS shall be almost perfectly established at the project's initial phase, which is quite strenuous and needs overwhelming efforts for small satellite projects in most cases. This is very apparent in student-driven projects because the responsible person for project management are students and their turnover rate is very high, which means that well-experienced students leave the project with a few year interval. It is often the case that there is nobody who can spend time for managing this WBS through the project lifetime. Other than that, WBS comes at most of the advantages which helps project a lot by smoothing and efficiently organize information. Therefore elucidating the impression that using WBS for project management and documentation is a wise and smart decision for small satellite project.

On two separate occasion, the other application that can also be used aside from WBS is product tree. A product tree is a meticulous definition of the system elements and represents the hardware oriented breakdown of the system into successive levels of product, based on the functions identified. In case of the *Flying Laptop* satellite (Tohinori Kuwahara et al., April 2008), it has only one on-board computing system and there is no need to divide this product tree into hardware tree and software tree, or their combination. Because the on-board computing system of the *Flying Laptop* does not have any software, but has hardware logic only, it is just denoted as “hardware tree” in the project in Figure 2.4. This hardware tree is the core of the project management and the methods mentioned here are based on this hardware tree. It is helpful that we utilize this hardware tree as the foundation of the project management, on the grounds that typically small satellite comprises of few segments which permits an unmistakably orchestrated hardware tree. Most of the satellite development activities can be associated directly to one of those components.

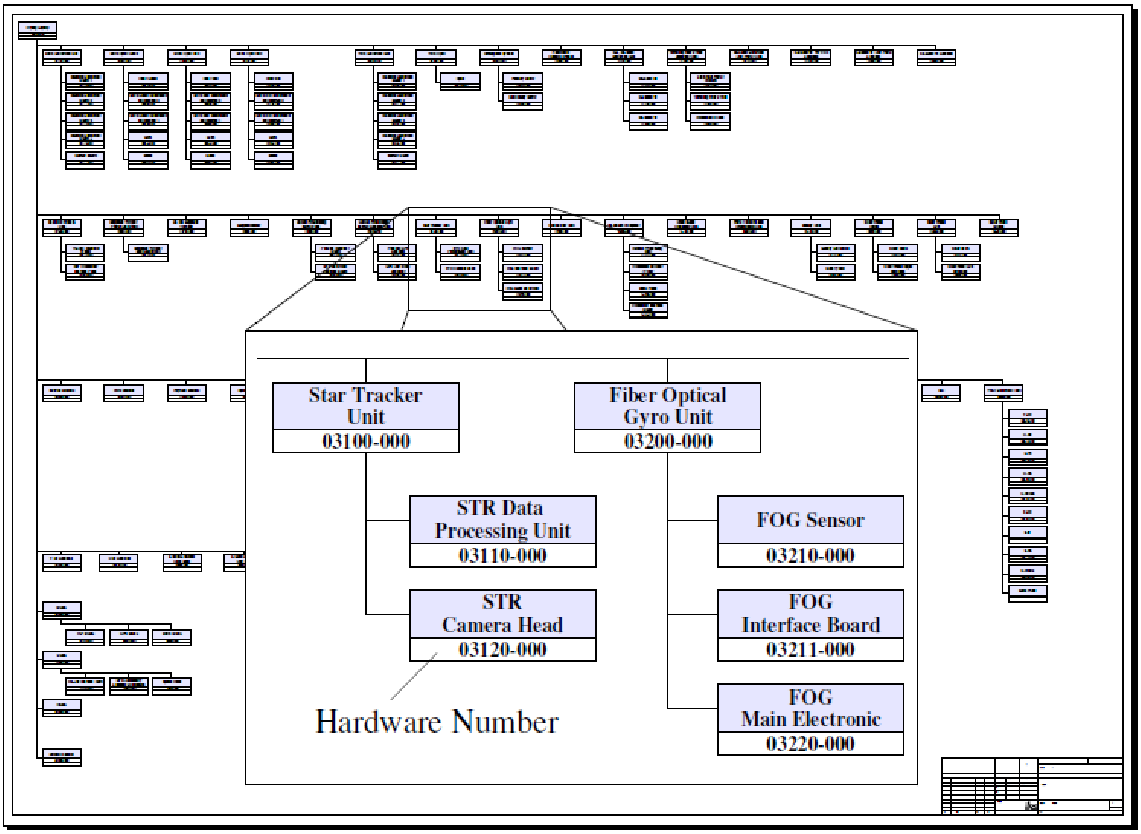


Figure 2.4: Hardware Tree of the *Flying Laptop* Project (Tohinori Kuwahara et al., April 2008)

Based on NASA (2008) Work Breakdown Structure (WBS) is a product-oriented family tree that identifies the hardware, software services and all other deliverables required to achieve an end project objective. The purpose of WBS is to subdivide the project's work content into manageable segments to facilitate planning and control cost, schedule and technical content. A WBS is developed by first identifying the system or project end item to be structured, and then successively subdividing it into increasingly detailed and manageable subsidiary work products or elements. Most of these elements are the direct result of work for example assemblies, subassemblies and components while others are simply the aggregation of selected products into logical sets for example buildings and utilities for management control purpose. The project WBS structure should encompass the entire project's approved scope of work. It usually consists of multiple levels of products along with associated work content definitions that are contained in a companion document called the WBS Dictionary.

All NASA projects have the capability of subdividing the work content to any level necessary for management and insight. However, the Agency's Core Financial System currently limits the ability to capture costs to a maximum of seven levels. These seven levels of the WBS are first Level 1 which is the entire project. Second, Level 2 which is the major operational products element along with key common and enabling products. Third, Level 3-7 which contains further definable subdivisions of the products contained in the Level 2 elements such as subsystems, components, documents and functionality. All the level are illustrated as shown in Figure 2.5 below.

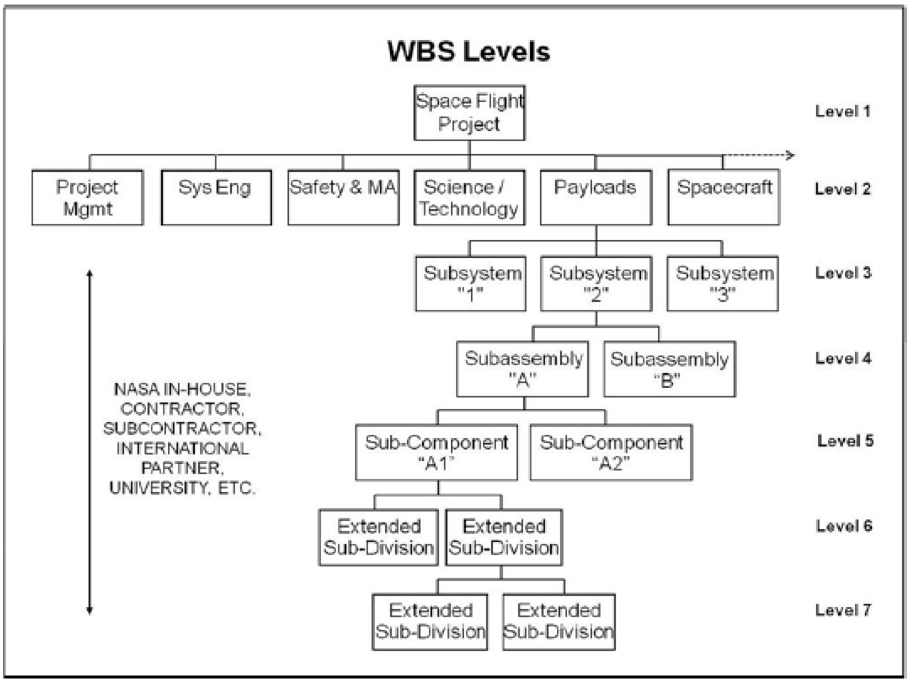
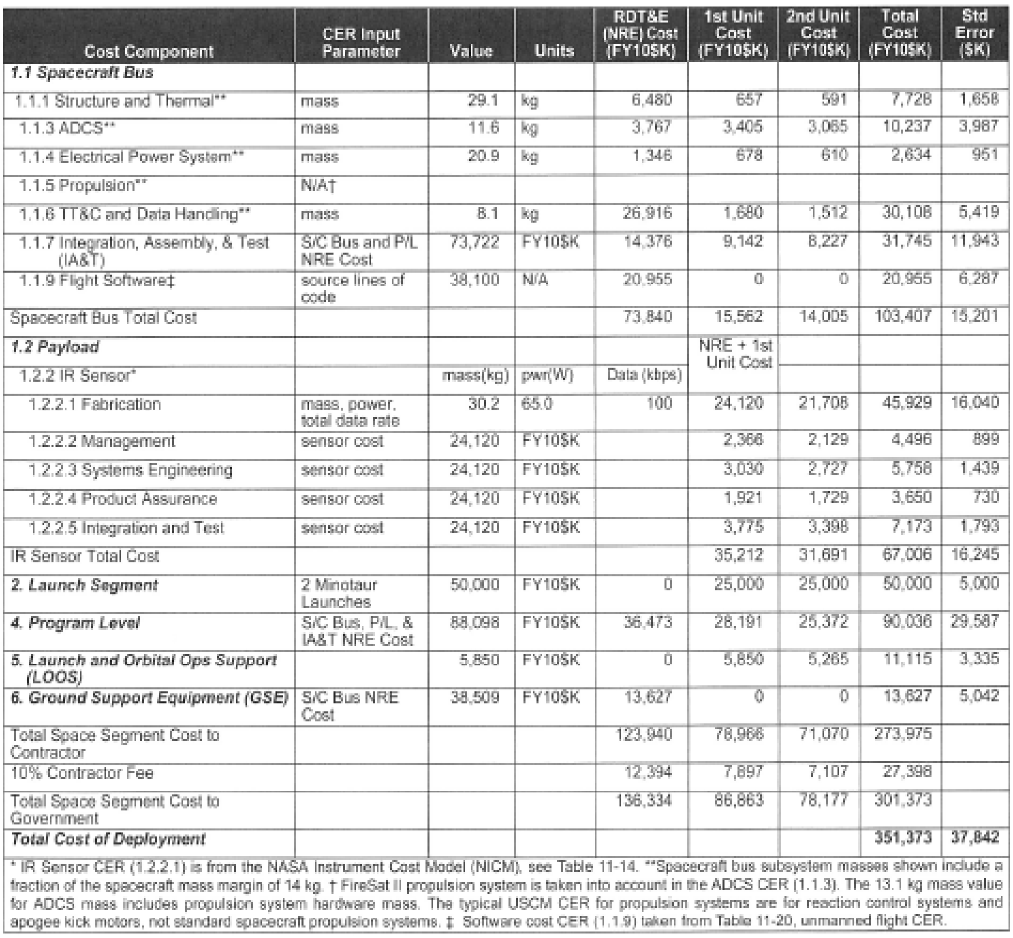


Figure 2.5: WBS Levels Illustration (NASA, 2018)

2.3 Costing

In the past decade, developers of space systems have turned toward small satellites as vehicles for science and technology demonstration mission. Small satellites, because of their practical and operational characteristics and comparatively low development and service costs, provide access to space for more users than the large satellites prevalent over the last 20 years (D.W Thompson, December 1991). Small satellites with sufficient power, pointing and tracking accuracy, on-board data compression, storage and processing capabilities, high-rate data downlinking, and associated ground segments for a variety of applications have been demonstrated by NASA, the DoD, the Centre National d'Etudes Spatiales (CNES), and the European Space Agency (ESA) (Eric Mahr and Greg Richardson, 2002). Despite that, as a result of the craving to use increasingly reasonable dispatch vehicle, advance advances are continuously being combine into small spacecraft to productively decrease mass and increment execution, every so often with immaterial learning into the impacts to cost and anticipated hazard. Cost estimating is the iterative process of calculating the expected cost of a space mission. Just as the space engineer predicts performance parameters for evolving space system design, they can also predict development, production, and operations cost. Elements of cost are essentially the hardware, software, and operations element of the space system, plus necessary management and administrative elements. Costing usually involve two main factor which are non-recurring cost and recurring cost. First, non-recurring costs are associated with the labor and material associated with designing, developing, fabricating, and testing space vehicle qualification test model plus program-peculiar ground support equipment. This often identified as the prototype approach and does not produce a flight unit. For those programs that use the alternative *protoflight* approach, the qualification test unit will later be refurbished to become the first flight unit. This requires an additional 30% (approximate) non-recurring cost for the refurbishment. Second, recurring cost which associated with the labor and material of fabricating, manufacturing, integrating, assembling, and testing of follow-on space vehicle flight hardware plus the effort associated with launch and orbital operations in support of the program (James R.Wertz et al., 2011).

Table 2.1: FireSat II Space, Ground and Launch Segment Cost (James R.Wertz et al., 2011)



Cost Component	CER Input Parameter	Value	Units	RDT&E (NRE) Cost (FY10$K)	1st Unit Cost (FY10$K)	2nd Unit Cost (FY10$K)	Total Cost (FY10$K)	Std Error ($K)
1.1 Spacecraft Bus								
1.1.1 Structure and Thermal**	mass	29.1	kg	6,480	657	591	7,728	1,658
1.1.3 ADCS**	mass	11.6	kg	3,767	3,405	3,065	10,237	3,987
1.1.4 Electrical Power System**	mass	20.9	kg	1,346	678	610	2,634	951
1.1.5 Propulsion**	N/A†							
1.1.6 TT&C and Data Handling**	mass	8.1	kg	26,916	1,680	1,512	30,108	5,419
1.1.7 Integration, Assembly, & Test (IA&T)	S/C Bus and P/L NRE Cost	73,722	FY10$K	14,376	9,142	8,227	31,745	11,943
1.1.9 Flight Software‡	source lines of code	38,100	N/A	20,955	0	0	20,955	6,287
Spacecraft Bus Total Cost				73,840	15,562	14,005	103,407	15,201
1.2 Payload					NRE + 1st Unit Cost			
1.2.2 IR Sensor*		mass(kg)	pwr(W)	Data (kbps)				
1.2.2.1 Fabrication	mass, power, total data rate	30.2	65.0	100	24,120	21,708	45,929	16,040
1.2.2.2 Management	sensor cost	24,120	FY10$K		2,366	2,129	4,496	899
1.2.2.3 Systems Engineering	sensor cost	24,120	FY10$K		3,030	2,727	5,758	1,439
1.2.2.4 Product Assurance	sensor cost	24,120	FY10$K		1,921	1,729	3,650	730
1.2.2.5 Integration and Test	sensor cost	24,120	FY10$K		3,775	3,398	7,173	1,793
IR Sensor Total Cost					35,212	31,691	67,006	16,245
2. Launch Segment	2 Minotaur Launches	50,000	FY10$K	0	25,000	25,000	50,000	5,000
4. Program Level	S/C Bus, P/L, & IA&T NRE Cost	88,098	FY10$K	36,473	28,191	25,372	90,036	29,587
5. Launch and Orbital Ops Support (LOOS)		5,850	FY10$K	0	5,850	5,265	11,115	3,335
6. Ground Support Equipment (GSE)	S/C Bus NRE Cost	38,509	FY10$K	13,627	0	0	13,627	5,042
Total Space Segment Cost to Contractor				123,940	78,966	71,070	273,975	
10% Contractor Fee				12,394	7,897	7,107	27,398	
Total Space Segment Cost to Government				136,334	86,863	78,177	301,373	
Total Cost of Deployment							**351,373**	**37,842**

* IR Sensor CER (1.2.2.1) is from the NASA Instrument Cost Model (NICM), see Table 11-14. **Spacecraft bus subsystem masses shown include a fraction of the spacecraft mass margin of 14 kg. † FireSat II propulsion system is taken into account in the ADCS CER (1.1.3). The 13.1 kg mass value for ADCS mass includes propulsion system hardware mass. The typical USCM CER for propulsion systems are for reaction control systems and apogee kick motors, not standard spacecraft propulsion systems. ‡ Software cost CER (1.1.9) taken from Table 11-20, unmanned flight CER.

2.4 Scheduling

The project scheduling also plays a crucial role for small satellite projects. One of the substantial advantages of small satellite projects is their agility which enables rapid technology demonstration and evaluations in space. The project scheduling for small satellite projects shall be organized to maximize this advantage. Anyhow, planning a time schedule for small satellite project is quite exasperating because of many types of uncertainties, such as personnel resources, financial resources and testing opportunities. Moreover, it is common for small satellites that the launch date is tend to be fixed as a late phase of the project. Therefore, the solution can be either using GANTT chart or PERT chart as the main scheduling method. According to the time duration estimated for each hardware development and their order, a PERT chart can be built as illustrated in Figure 2.6. Based on this chart the critical path can be identified and the progress of the project can be maintained by monitoring this critical path.

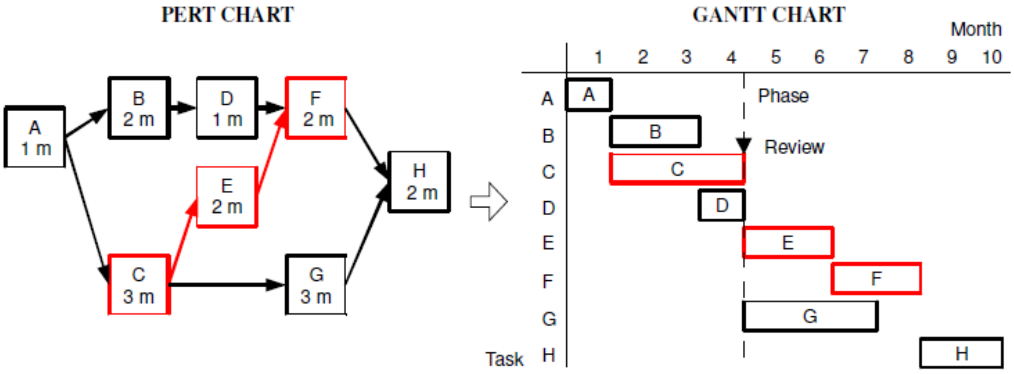


Figure 2.6: Type of Time Scheduling

CHAPTER 3

METHODOLOGY

In designing satellite system, it is significant and vital to actually first understand the mission of the satellite itself so that each step involve in the future development can run smoothly and efficiently. For documentation and the executives part for MYSAT there are a few significant advance should be done all together for the ordering part should be possible in an arrange way. All the information gathering are done in the Microsoft Excel in Work Breakdown Structure (WBS) form. First and foremost, the mission definition for the mission must be crystal clear and comprehend. Figure 3.1 is the linking icon which is hyperlink used to link the information in the Figure 3.2 with another file.

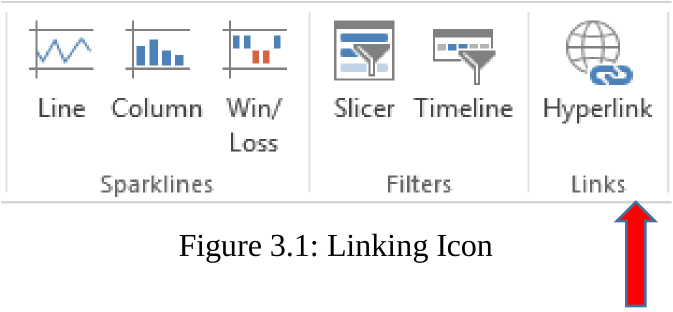


Figure 3.1: Linking Icon

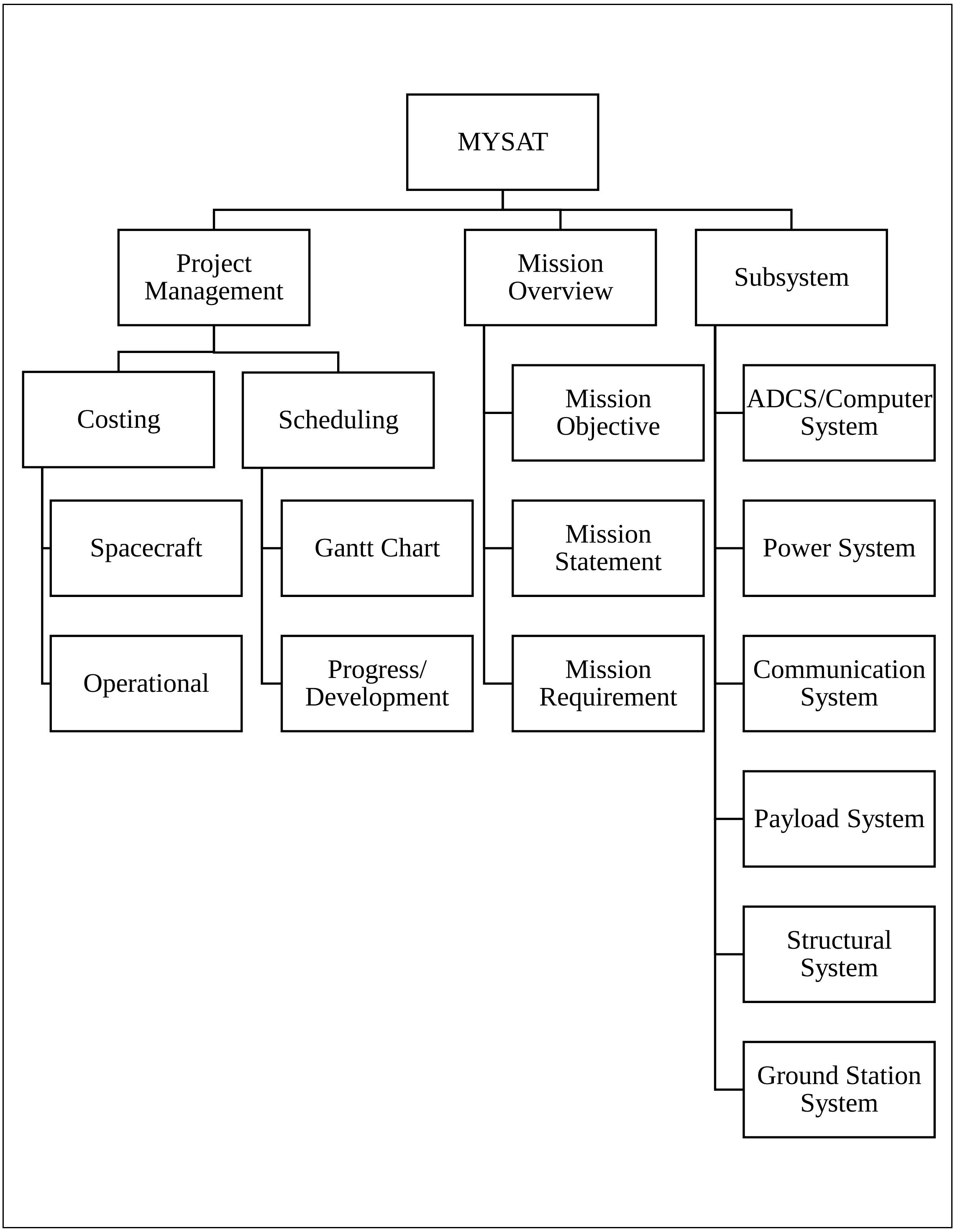


Figure 3.2: MYSAT Work Breakdown Structure (WBS)

For the mission definition there will be three important part that need to be list under which are mission statement, mission objective and mission requirement. These three also can be characterized as the concept studies. First, for the mission statement it is the reason why the MYSAT need to be built at the first place or the reason the mission need to be done. Second, the mission objective is derived from the mission statement which means the objectives are then quantified based on the needs, applicable technology, and cost constraint. These quantitative requirements are suggested to be subjected to trade off to enable some flexibility in satellite development. Third, the mission requirement is the broad objectives and constraint of the mission are translated into well-defined system requirements in final stage where each subsystem can use for the components development.

First of all, the project will be divided into levels as shown in Figure 3.2. The levelling has been done based on the reference by (NASA, 2018) which the purpose is to subdivide the information into manageable form and easy to review. For Level 1 which is the first level is the main part that is MYSAT itself as the main point. After that, Level 2 which contains subdivision which will divide each priority which are project management part, mission overview part and subsystems part. Next is Level 3 which involve detailed information derived from Level 2 for instance costing, scheduling, mission overview (mission objective, mission requirement and mission statement), and subsystems (ADCS/Computer System, Power System, Communication System, Payload System, Structural System and Ground Station System).

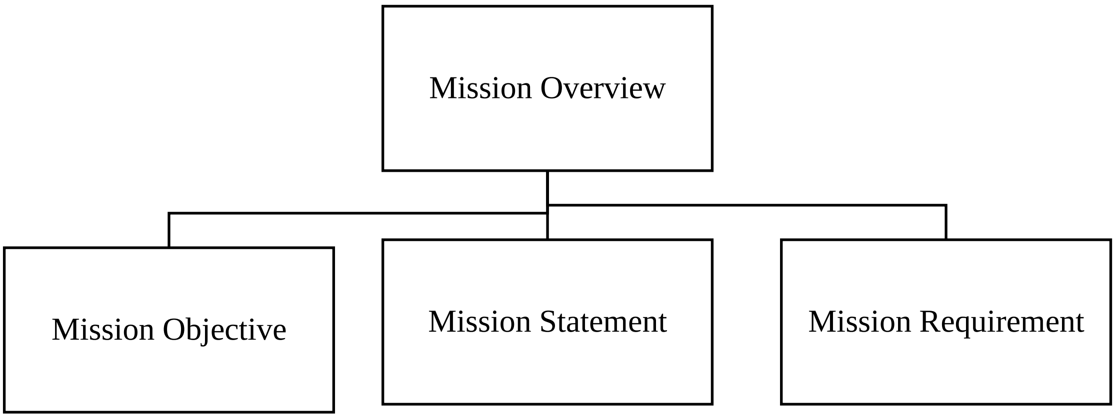


Figure 3.3: Mission Overview in WBS form

Then, after that Mission Overview of MYSAT is listed in WBS form under Level 1. This studies overview display the whole mission and requirement that MYSAT will follow and the whole picture of MYSAT mission. After that, information in the Level 3 is derived from Level 2 which is for the subsystems, the requirement, detailed specification and development progress from each subsystems. As for the detailed specification, it referred to particular important parameter involve in the designing and fabricating process. For example mass budget, power budget, link budget, antenna design, solar array, depth-of-discharge (DOD), data budget, uplink and downlink data.

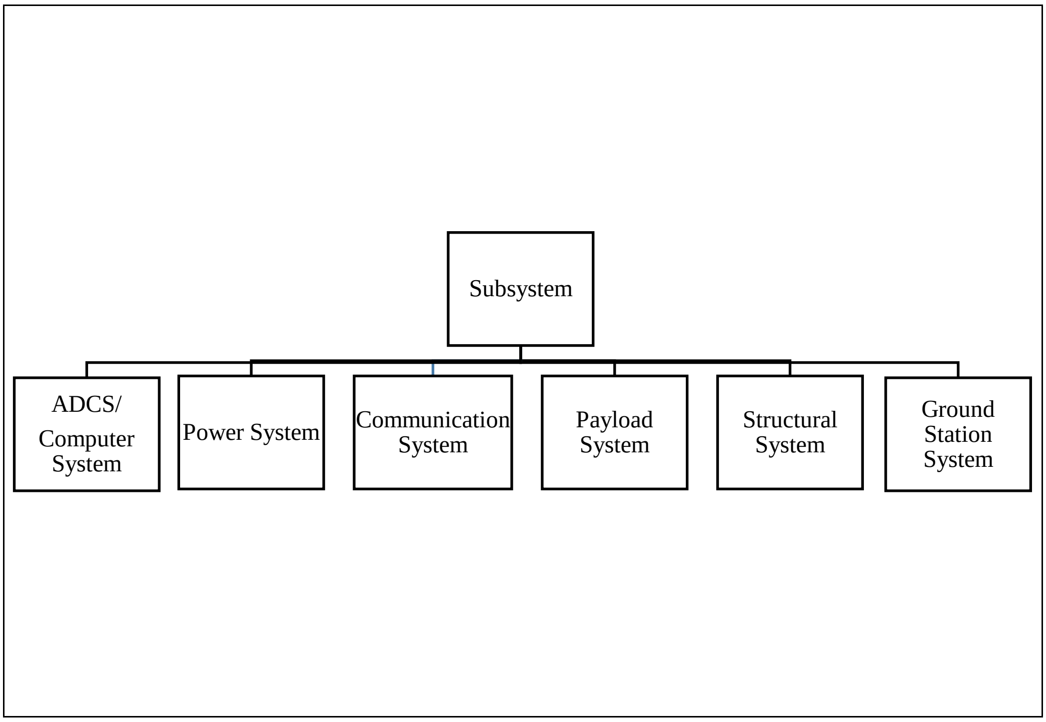


Figure 3.4: Each Subsystem from Each Level Interface in Level 3

Following the subsystems is project management part which includes costing part and scheduling part. Cost analysis and cost budget is described. For the cost analysis, the part encompasses of spacecraft cost analysis and operational cost analysis. Cost budget of spacecraft budget which involve the hardware and component budget and operational budget which involve labour cost from ground station prospective. This means the cost will be calculated based on the hour worked by the operator involve in the ground station including overtime work if any. The costing done followed the Fire Sat II Space, Ground and Launch Segment Cost (James R.Wertz et al., 2011) as stated in costing part in section 4 below. Based on the book the cost divided based on each subsystem involve for easier review rather than listing all the component used all at once which will cause confusion which component from which subsystem.

Next, the scheduling part which in this case the scheduling method used is Gantt chart to monitor and keep track on the progress and timeline of the project. It is easy to present task, sub-task, milestone and project visually. Other than that, it displays clear visibility of dates and times frame while helps the task in progress and pending mode work is clearly visible on stacked bars. Although it has few drawbacks such as it requires more effort for creating and managing the chart but once it is done the managing and updating part will make work simpler and smooth to deal with. In another word, it is still a powerful tool for managing long term project as MYSAT more effectively because of its clarity in visual representation of task and easy to schedule the tasks and understand by different time frames.

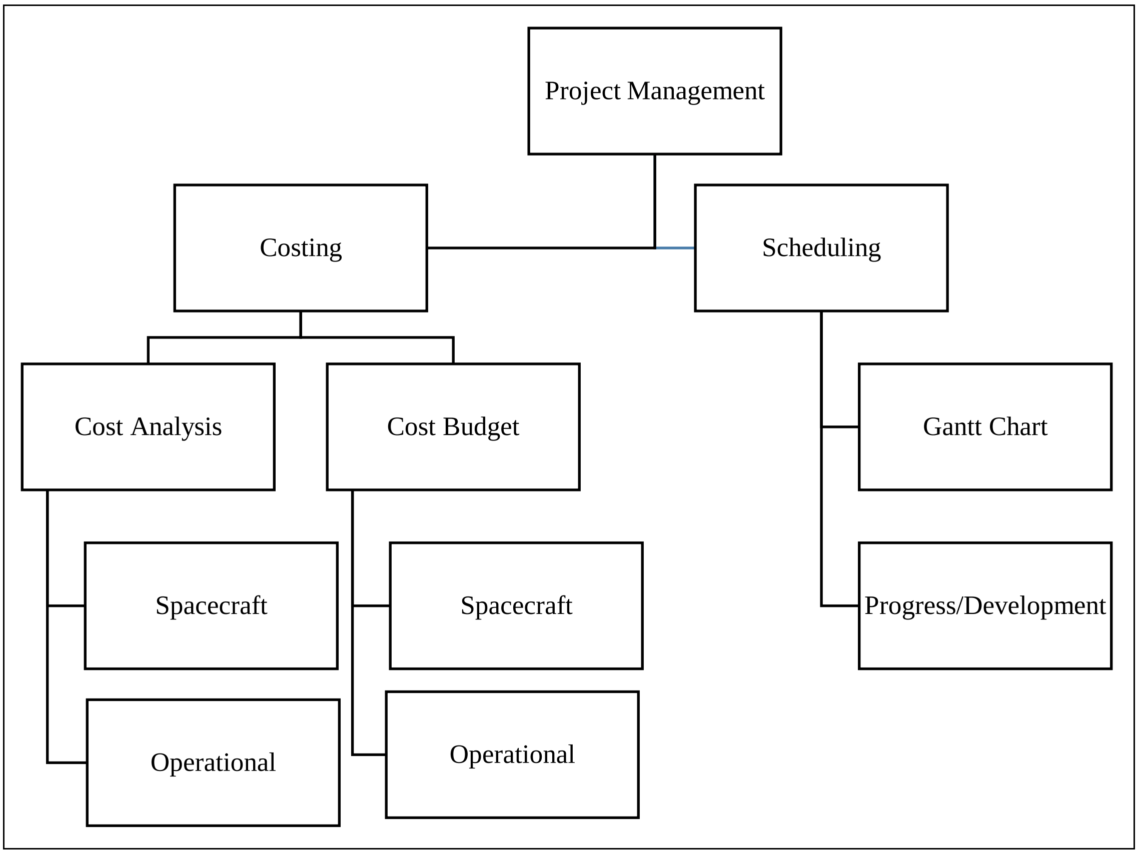


Figure 3.5: Project Management from Each Level Interface