SYSTEM ANALYSIS OF THE LEONIDAS MICROSATELLITE BUS

Zachary Lee-Ho
Department of Mechanical Engineering
University of Hawai'i at Manoa
Honolulu, HI 96822

ABSTRACT

System engineering in a critical role in ensuring that all subsystems are in compliant with the desired mission objectives. A key tool for system engineers to accomplish this task is requirements. Requirements set the procedure, interfaces and the schedule for how the mission will be carried out. Requirements constantly evolve as the definition of the mission becomes more and more clear. The LEONIDAS microsatellite is driven by the set of requirements established by the LEONIDAS concept team in order to perform the desired mission.

INTRODUCTION

The goal of LEONIDAS program, Low Earth Orbit Network Integrated Distributed Autonomous Systems, is to develop a space program with the capabilities to complete an entire microsatellite mission from design to launch and perform operations while in orbit. If the LEONIDAS goal is accomplished it will be a one of the most unique space programs, with the University of Hawaii the only university in the nation with these capabilities. The LEONIDAS program provides valuable work experience and hands on training to UH students that will be difficult attain otherwise due to our geographic constraints. The LEONIDAS microsatellite bus currently being developed will serve as a testing platform for validating experiments in order to demonstrate their capabilities on future missions. In addition, the bus will house two cameras, one equipped with an optical lens for ultra-violet light and the other for visible light. The team working on the LEONIDAS bus will also work in collaboration with engineers from the Jet Propulsion Laboratory (JPL) to assist on the overall design of the microsatellite bus and facilitate in mission tasks to ensure the success of the project.

SYSTEM ENGINEERING

For a given mission typically there are several solutions to accomplish the desired mission goals. It is the job of the system engineer to achieve an overall optimum solution in which the mission objectives are satisfied efficiently. To achieve system optimization the system engineer must be familiar with elements of design, fabrication, testing, assembly, launch and operations. The system engineer is in charge of several critical tasks that entails the monitoring of the mission's progress and ensure that it the guidelines set by the mission objectives and established requirements. Other tasks include the management and maintenance of budgets for mass, power, fuel and other key resources. Definition, monitoring and control of interfaces between all system elements and between subsystems will be done by the system engineer. The system engineer should have a good overall perspective of the system to interpret and explain motivations for requirements to his team members and thereby gain their acceptance and commitment to objectives.

MISSION OBJECTIVES

The mission objectives are imposed on the system by the user(s) of the data and are the broad goals that the system must achieve to be productive. For the LEONIDAS satellite the mission objectives were derived based on the five potential payloads that the bus will house, they are:

1. Active Antenna
2. Camera (Ultra-Violet and Visible Light)
3. Sublimation Thrusters
4. Surrey Satellite Technology Limited GPS Module
5. JPL Autonomous Software

Mission objectives are statements of the aims of the mission, are qualitative in nature and should be general enough to remain virtually unchanged during the design process. The final design of the bus must meet these fundamental objectives. The following is a list of the mission objectives:

1. To send microsatellite into low earth orbit at 400 km in altitude
2. Successfully command satellite to perform basic housekeeping test to ensure components are properly functioning.
3. To successful communication with satellite and downlink all mission data
4. To correctly orient the satellite to take a ultra-violet and visible picture of Hawaii
5. To perform scientific test of atmospheric anomalies through the operation and verification of the Surrey Satellite Technology Limited GPS module
6. To test and validate Scientific technologies developed at the University of Hawaii (Sublimation Thrusters & Active Antenna)
7. To test and validate the Jet Propulsion Laboratory Hardware for autonomous capabilities upon completion upon previous experiments
8. To verify the capabilities of the reconfigurable bus to have the ability to accommodate various payloads

As a system engineer the first task that must be accomplished, is to define the mission requirements from the given mission objectives.

MISSION REQUIREMENTS

Mission requirements are quantitative expressions of how well the objectives are met by balancing what is wanted against what the budget will allow. Throughout the mission lifetime it is common practice to trade requirements as the spacecraft bus is more clearly defined. Mission requirements will largely establish the operational concepts that will meet the mission objectives. The system engineer must identify what aspects of the mission and what elements of the design provide the major influences on the type of satellite that will meet the given mission requirements.

#	Title	Functional Requirement	Comments	Allocation	Accommodation
1.1	Acquisition	Acquire the sun after separation from the launch vehicle		Mission	ACS
1.2	Pointing Strategy	Satellite will maintain nadir pointing to earth in order to perform payload observation		Mission	ACS
1.3	Launch	Launch vehicle must place satellite into 400 km orbit		Mission	Launch
1.4	Communication	All housekeeping data from subsystems and experimental data from payloads must be downlink to ground station		Mission	COMM
1.4.1		Downlink of data must be accomplish within 6 minute viewing window		Mission	COMM
1.4.2		Receiving and Transmission of data must be accomplished within a maximum of 2 orbits		Mission	COMM
1.5	Payloads	Operation of each experimental payload for validation test		Mission	C&DH
1.5.1		Each payload experiment shall run separately during a designated orbit(s)		Mission	C&DH
1.6	Pointing Performance	Satellite must have the ability to pointing within +/- 1 degree to take pictures		Mission	ACS
1.7	Data Processing	All data processing will be performed on the ground		Mission	COMM

Table 1: List of mission requirement for LEONIDAS microsatellite bus

MISSION SUCCESS

A set of milestones must be attain before progress of the satellite can continue. Success of the mission is determine by the completion of several critical milestones. The keys for mission success have been set based on the milestones that are need to be reach to achieve the mission requirements. These keys for mission success have been divided into three different phases and are listed as follows:

- Phase I: Documentation
  - Successful completion of Mission Concept
  - Successful completion of documentation for Preliminary Design Review
  - Approval of spacecraft design
- Phase II: Assembly & Testing
  - Successful integration and testing of each subsystem
  - Successful integration and testing of the entire spacecraft system
  - Approval for launch
- Phase III: Launch
  - Successful delivery into mission orbit
  - Connection of satellite when initially delivered into orbit
  - Satellites completes all housekeeping operations and relays data to ground station

- Payload experiments are tested for validation and results are transmitted to ground station

Completion of each task in a given phase will translate as success for that phase for the team and help in prepertaion for the upcoming phase milestones.

SYSTEM REQUIREMENTS

System requirement duties entail understanding all external interfaces and ensuring the functional architecture correctly captures the mission objectives. The system requirements document should cover every relevant aspect of what the system should do and how well it should do it. In addition, it addresses every aspect of system performance.

#	Title	Functional Requirement	Comments	Allocation	Accommodation
4.1	Mass	The mass of the satellite structure and all subsystem components must not exceed 35 kg		System	All
4.2	Durability	Subsystem components must be able to withstand 400 km orbit		System	All
4.2.1		Structure must be able to withstand forces incurred from launch vehicle thrusters		System	Structure
4.2.2		Structure must be able to withstand forces as result of thermal expansion		System	Structure
4.3	Thermal	All subsystem components must be thermally protected to withstand environment at an altitude of 400 km		System	Thermal
4.4	Power	Subsystem components will be provide a maximum of 110 watts to perform required operations		System	Power
4.4.1		Battery power with the capacity to permit the performing of mission operations for a maximum of 12 hours		System	Power
4.5	Data Transfer	Data will be downlink and uplink using S-band or UHF frequency		System	COMM
4.6	Volume	The volume of structure shall be within the linear dimensions 60 cm x 60 cm x 50 cm		System	Structure
4.7	Data Handling	Processing unit capable of orchestrating mission operations and managing subsystems and data flow		System	C&DH
4.7.1		Unit capable of running the operating system and components software		System	C&DH
4.7.2		Unit that can store all necessary software, housekeeping and experimental data		System	C&DH
4.7.3		Computer capable of managing operating modes		System	C&DH
4.8	Optical Viewing	Camera optics capable of taking a picture from an altitude of 400 km		System	Payload

Table 2: A list of LEONIDAS system requirements

CONCLUSION

From the system requirements a number of key elements are derived from or done in conjunction with system requirements which include system plans, test plans, system interfaces, traceability, budgets, risk assessment, mission lifetime and mission operations. System requirements lay the architecture of how each subsystem will be designed. Test plans will reflect validation and verification of these requirements. Interfaces between subsystems

Through the system requirements interfaces are declared in the interface control document, which state how integration and maintenance of relationships between subsystems will be met. Traceability is also down through system requirements, which indexes the methods that permits traceability upwards as well as across all elements. Budgets numerically list components for any overall system parameters. The Mission Operations Plan describes in users and operator terms the operational attributes of the flight and ground based elements and are written in conjunction with system requirements.

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