

URC97096

**Minority University System Engineering: A Small Satellite Design Experience
Held at the Jet Propulsion Laboratory During the Summer of 1996**

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Introduction

The University of Texas at El Paso (UTEP) in conjunction with the Jet Propulsion Laboratory (JPL), North Carolina A&T and California State University of Los Angeles participated during the summer of 1996 in a prototype program known as Minority University Systems Engineering (MUSE). The program consisted of a ten week internship at JPL for students and professors of the three universities.

The purpose of MUSE as set forth in the MUSE program review August 5, 1996 was for the participants to gain experience in the following areas:

1. Gain experience in a multi-disciplinary project.
2. Gain experience working in a culturally diverse atmosphere.
3. Provide field experience for students to reinforce book learning.
4. Streamline the design process in two areas: make it more financially feasible; and make it faster.

The MUSE program review also provided the primary goals of the MUSE project per university, JPL and students:

1. The university goals were to develop school curricula to reflect system engineering styles so as to keep academia abreast of the changes in industry.
2. JPL's goal is to devise a faster, cheaper and more effective way to design satellites by teaming with academia and industry.
3. The student's goal was to gain experience working in a multi-disciplinary and multi-cultural environment while gaining knowledge of system engineering.

To execute the purposes and goals of the MUSE program, the participants were involved in conceptually designing a satellite, which was named by these same participants as URANIA.

This paper focuses on showing how some students attending UTEP, did during the internship at JPL in order to meet the purposes and goals of the MUSE program as set forth in the MUSE program review. The students participated in the ten week internship held in its entirety at JPL. JPL provided laboratory space for the MUSE participants at one particular location within the laboratory. The classroom provided by JPL was used by the MUSE group as a project central

where all the project activities were discussed and completed with the frequent visits into the different engineering labs at JPL for guidance and advise on the different stages of the project. The project activities included learning about JPL standards and policy, JPL engineering presentations, leadership discussions provided by JPL personnel and the overall activities that went into the conceptual design of the satellite.

A JPL system engineer was always on duty at the MUSE lab providing the proper guidance for the MUSE group in order to achieve the project goals at the proposed timelines. JPL engineers in no way ever took over the project instead these engineers presented suggestions and viable solutions to the different problems and questions encountered by the students and faculty. The students presented their progress, three times during the internship, to reviewing engineers; the final presentation was to an official JPL review board. Each presentation provided the MUSE group with communication experience as well as with technical questions and suggestions directed at improving the quality and extent of the design work.

Program Objectives

Students participating in the internship were handed the MUSE UNISAT Program guidelines (white paper) for informational and planning purposes only for the MUSE Summer 96 workshop at JPL. The guidelines included a description of opportunity, the program objectives, MUSE UNISAT program constraints, guidelines and requirements, proposal submission information and proposal evaluation, selection and implementation. From this white paper the students began to lay the baseline design of URANIA.

URANIA Mission and Science Objectives

URANIA was to be a low earth orbit resource satellite designed to be launched as a secondary payload in order to decrease cost and use off-the-shelf technology in order to decrease design cycle and cost. At the end of the summer program URANIA had the following characteristics:

1. Shape is to be a Hexagonal cylinder of dimensions (30X40X40) cm.
2. Mass- 30 Kg
3. Stabilization- Gravity gradient boom
4. Processor- A80186
5. Memory- 600 Mbit DRAM
6. Power- 17W BOL, 16.5 W EOL
7. Mission Life- 1 year required and 3 year goal
8. Orbit- Inclination 42°
Altitude 1100 Km
Duration 112 min

The science payload instruments for URANIA are as defined in the white paper a cloud imager, a Global Positioning System, and an infrared camera. It was this conceptual URANIA that the MUSE participants had developed at the end of the summer program. Also included in the

design were the organization, schedule and cost plan as well as technical proposal report. These were all prepared and completed by the MUSE participants having only the white paper as a guideline but most of all, having the availability of the expertise provided by the JPL engineers and administrators.

The students divided themselves up in a way in which each student participated in three of the nine subsystems of the satellite while choosing to be a cognizant engineer for one of those subsystems. Each subsystem group was attached to one or two JPL engineers, experts in that subsystem, to provide the necessary advice and tools needed to develop the particular subsystem. While each student was busy developing and designing the particular subsystems assignments it was system engineering which was emphasized rigorously by the JPL system engineers since it played the major role in integrating the subsystems of the satellite and the science instruments. Finally, each of the cognizant engineers was responsible for progress presentations on the assigned subsystem.

The following part of the paper will elucidate a student's experience as a participant in the MUSE program and some technical background on his design involvement with the URANIA satellite providing a conclusion on what the learning experience meant to the student.

MUSE Experience Introduction

This summer my major involvement in the MUSE program came as a system engineer for URANIA where I helped maintain the focus of the design work on the various subsystems of the satellite as well as keeping track of the tradeoffs made of each subsystem and finally developing a satellite power profile graph. I was also involved in the development of the thermal control subsystem of URANIA by being the cognizant engineer which meant that I was responsible for presenting the progress of this subsystem throughout the summer. It also meant that I was the one responsible for making sure that guidelines and deadlines were met as well as to provide information about the subsystem whenever necessary to the system engineers, I also participated in the development of the power subsystem of the satellite by providing the power subsystem cognizant engineer with assistance in trying to define the power consumption and power available to the satellite from the given guidelines and system constraints and by generating a solar incident angle graph. As a mechanisms subsystem engineering assistant I provided help in determining the satellite boom design and its role as an energy provider to the satellite. Finally, I also helped generate a technical proposal report.

System Engineer

The system engineering group met several times during the week to discuss deadlines, project alterations, system implications, tradeoffs and subsystem engineering requirements. The deadlines were measured by using the presentation dates as milestones as to when certain expected work should be completed. Project alterations were brought up to compare to a system restriction or guideline and to make sure that implications of such an alteration only altered the system within the constraints already set. If such an alteration or lack of one had to be made then it had to be documented as a tradeoff. For the subsystem engineering requirements a list of

questions and suggestions was gathered from each of the review board presentations. The list was organized and prepared for each of the subsystems and it was then presented to each of the cognizant engineers for execution and answers.

The system engineering group also met periodically with all the members of the subsystems to update and revise information and requirements of each of the subsystems. The meetings were designed to consolidate subsystem information so that each subsystem would know what the other was up to as far as tradeoffs and alterations were concerned.

Finally, I developed a power profile graph of the system by gathering energy requirements and consumption for each of the subsystems. The power profile becomes one the main tools available to the system engineer because it allows for verification of the power used by any system and thus it acts as a guide in deciding for re-allocation of power as needed. I generated the graph using an excel spreadsheet to make calculations from energy data gathered from each of the subsystems. Another tool I developed as a URANIA system engineer was a table for modes of operation of the satellite. Several modes of operation such as launch, spacecraft stabilization and typical orbit were considered for power consumption, this helped the system engineering group determine if such modes of operation were within power constraints of the system.

Thermal Subsystem

The thermal subsystem design was developed under the guidance of Ray Becker a JPL thermal engineer. Becker provided a presentation on basic thermal physics and design considerations. Becker also suggested that a preliminary thermal analysis be completed by using thermal simulation software and developing a spreadsheet which would house the thermal software output file from which temperature data could be extracted. The thermal constraint as provided by the white paper was to make it a passive system in which no active thermal elements such as radiators and heaters would be used for temperature control of the satellite. Instead the thermal analysis would be used to provide for proper placement of the satellite components and correct usage of thermal paints and heating sensors thus providing passive temperature control.

1. TRASYS Implementation

Using TRASYS thermal software a three dimensional space craft figure is created as input using TRASYS commands.

A space craft external surface layout is then considered where the different materials present in the surface will be considered for solar absorptivity and emissivity.

Worst case orbital angles as well as nadir pointing data and spacecraft altitude is also inputted. TRASYS is now executed and heat fluxes data is generated.

2. Temperature Data Generated

Using an Excel spreadsheet the TRASYS output data is analyzed by manipulating the heat fluxes data and generating spacecraft temperatures for each of the points considered in the TRASYS thermal simulation.

Finally orbital average temperatures are generated and compared against the worst case orbital angles, where the following was true for URANIA :

At an orbital angle of 70° the orbital average temperature was found to be 277K

At an orbital angle of 0° the orbital average temperature was found to be 289K

3. Conclusion and Future Works

The preliminary thermal analysis provided a safe temperature range for operation of the spacecraft, **although** not complete, the analysis was used by the URANIA group as an indicator that passive temperature control could be achieved.

Left to do is a conduction analysis where the internal components of the spacecraft and their heat fluxes will be considered so that with the combination of the conduction and preliminary thermal analysis data may generated which will provide knowledge for the proper placement of thermal blankets and paints and thermal sensors or component rearrangement.

Power Subsystem

My role in the power subsystem was to provide the cognizant engineer with the power profile data needed so that the various calculations to determine solar cell array and battery type and amount could be determined. I also provided the cognizant engineer with a solar incident graph used to determine the amount and duration of sunlight available for the solar cell array. The power profile data was the same as the one used to generate the power profile graph which was used in the power subsystem calculations to determine energy efficiency of the batteries and solar cell array. The excel spreadsheet used to analyze the TRASYS output file was also used to generate a solar incident graph. Since a three dimensional spacecraft had been generated for the thermal simulation there was flux data available for each side of the figure thus each flux intensity corresponded to a certain solar incident angle.

Mechanism Subsystem

The satellite will contain a minimum amount of mechanisms, this is reduce probability of mechanism failure resulting in elimination of redundant or backup systems. As of the end of the summer program the mechanism proposed for URANIA were the cloud imager lens cover, an actuated **pinpuller** which would be used release the third mechanism which is the boom. My involvement with this subsystem came in doing research work for the boom and with making suggestions about how to position the boom and make use of its surface area where solar cells could be positioned to provide added power to the spacecraft.

Conclusion

The MUSE program at JPL provided me the opportunity to gain insight and appreciation for system engineering and its vital role in industry. It also allowed me to perform in the same stage with members of other cultures. It was this cultural diversity which provided the primary element of the learning experience by way of each of the members bringing into the group their own ideas, abilities and scientific mannerisms which left the doors wide open for engaging in an all out effort to execute the project from various cultural angles.