URC97026

The MUSES Satellite Team and Multidisciplinary System Engineering

John C. Chen,[†] Alfred R. Paiz,[*] and Donald L. Young[*]

‘Department of Mechanical Engineering
North Carolina A&T State University

*Jet Propulsion Laboratory
California Institute of Technology

Abstract

In a unique partnership between three minority-serving institutions and NASA’s Jet Propulsion Laboratory, a new course sequence, including a multidisciplinary capstone design experience, is to be developed and implemented at each of the schools with the ambitious goal of designing, constructing and launching a low-orbit Earth-resources satellite. The three universities involved are North Carolina A&T State University (NCA&T), University of Texas, El Paso (UTEP), and California State University, Los Angeles (CSULA). The schools form a consortium collectively known as MUSES — Minority Universities System Engineering and Satellite. Four aspects of this project make it unique: (1) Including all engineering disciplines in the capstone design course, (2) designing, building and launching an Earth-resources satellite, (3) sustaining the partnership between the three schools to achieve this goal, and (4) implementing systems engineering pedagogy at each of the three schools. This paper will describe the partnership and its goals, the first design of the satellite, the courses developed at NCA&T, and the implementation plan for the course sequence.

Introduction

In efforts to encourage the inclusion of courses which focus on systems engineering as part of the curriculum, and also to increase the number of minority engineers graduating with skills in the design and engineering of complex systems in a team environment, the Jet Propulsion Laboratory (JPL) took the initiative to form a consortium composed of three minority-serving institutions: North Carolina A&T State University, University of Texas, El Paso, and California State University, Los Angeles. The consortium is collectively known as MUSES — Minority Universities System Engineering and Satellite. MUSES has a two-fold mission: (1) the development and implementation of systems engineering courses to teach the fundamentals of the design of large, complex systems, such as a satellite, and (2) the design and construction of a small satellite to be launched into low Earth orbit in approximately three years in order to collect data on planet Earth, which will be analyzed by the Consortium.

In the increasingly competitive world today, government and industry have realized the importance of cohesive, multidisciplinary engineering teams for product design and realization, and problem solving. Yet in our universities, there is currently a dearth of courses and activities which call on students from various engineering disciplines to collaborate in achieving a common design goal. Experience with MUSES shows that a diverse groups of individuals motivated to explore new frontiers can self-organize as a team to complete complex engineering project.

Through the efforts of the MUSES team, minority-serving universities are poised to enrich the pool of future systems engineers produced in the United States. Although MUSES created an exciting design experience for the students, the program's intent was to support the universities' goals related to reinventing the teaching of design engineering. In this regard, the summer workshop featured a self-organized product implementation team strongly coupled to a curriculum development process. The MUSES team sowed the seeds for defining how engineering will be taught and practiced.

Project History

The project began in the Summer of 1995, when faculty representatives from the three universities participated in the Summer Design Institute held July 24 to August 4 at JPL. This extended visit provided opportunities for the faculty to: (1) work with JPL personnel to learn methods of concurrent engineering and project management, (2) observe typical JPL design teams working in JPL's Project Design Center, (3) gain familiarization with system design tools developed at the Project Design Center, (4) discuss systems engineering course elements and implementation, and (5) visit with a faculty member and a student at California Institute of Technology to discuss the satellite design course at their school. The objectives for the summer were to gain familiarity with JPL's Project Design Center, both its architecture and philosophy, and to develop plans for activities in the next academic year (August to May, 1995) and the following summer.

'During the following academic year, plans were made to begin the first Summer Satellite Design Workshop held for ten weeks during Summer 1996 at JPL. Participants in the workshop included faculty members and four students from each of the three schools, and a large contingent of JPL personnel who acted as mentor System Engineers or as mentors on satellite subsystem design. The roles of the students were to act as lead engineers on at least one satellite subsystem each, while contributing as engineering team members on several other subsystems. The faculty members were not involved directly in subsystem design, but were present to mentor the students as needed to solve analytical or other technical problems. A second role the faculty members played was in developing Systems Engineering courses to be implemented back on their respective campuses. The following describes the two activities resulting from the 1996 Summer Satellite Design Workshop: (1) the design of the satellite — called Urania, and (2) the development of the Systems Engineering Curriculum at NCAT.

The MUSES Satellite Team

The students' goal for the 1996 Summer Workshop involved the initial design of a small, low Earth-orbit satellite with a mission to study planet Earth. Realistic constraints on size, power consumption, mass, and cost were specified for the MUSES team. These constraints were stipulated by the requirements that the satellite:

1. be launched as a secondary payload on a Delta II rocket to reduce cost, which essentially limits the dimensions to approximately 30 x 40 x 40 cm;

2. weighs a maximum of 30 kg, again constrained by the secondary payload option;

3. uses flight-tested, off-the-shelf technology to decrease risk, design time, and cost;

4. consume no more power than it can collect using the solar panels to be mounted on its surfaces; and

5. cost no more than $5 million, including all hardware, software and labor, but excluding the launch cost, which was assumed to be donated by external sponsors.

Other aspects of the Summer Workshop included regular meetings with technical personnel from JPL to resolve technical issues and to ascertain progress, and with Human Resources personnel for team building and learning conflict resolution. At the end of the Workshop a formal presentation was made by the team to a panel of technical experts from JPL, and a completed technical proposal was reviewed. The satellite will now be described.

Fig. 1: The 1996 MUSES students, posing with a full-scale mock-up of the Urania satellite.

The initial satellite was designed within the constraints described above. The MUSES team named the satellite Urania, which is one of nine muses of Greek mythology. Urania's overall dimensions are 30 x 40 x 40 cm and it weighs just over 28 kg. Its shape is that of a six-sided cylinder covered on five of the six sides and the top with solar cells. The remaining side is always pointed away from the sun in order to provide a low-temperature surface on which to mount heat radiators for the electronics and instruments. The bottom surface is mounted with the two imaging instruments — one imaging in the near- to mid-infrared for cloud imaging, and one imaging in the visible spectrum for earth resources studies — and thus will always be directed toward earth. The satellite will be stabilized with a 4-m long, gravity-gradient boom which will be deployed after the satellite is released from the launch vehicle into its orbit. The power consumption of the satellite is limited to 17 W maximum, which will require all subsystems, including the instruments, to share this power, and to be placed into "sleep" modes until it is needed. The on-board computer for command and data handling is an A80 186 processor with

600 Mbit DRAM memory for data storage. The satellite has a minimum design life of one year, with a goal of three years.

The mission designed for Urania, as mentioned earlier, is to study planet Earth, and as such its launch is planned to be at an inclination of 42 degrees and at an altitude of 1100 km; this results in a single orbit of 112 min. Three science instruments will be carried as payload: (1) an infrared cloud imager for ocean color mapping and measurements of distributions of water vapor or ice on Earth's surface; (2') a visible-spectrum camera for measuring mineral matter distributions, population densities, and vegetation variations; and (3) a global positioning system (GPS) receiver for the satellite's navigation purposes, and to perform scientific measurements in conjunction with other GPS receivers of other satellites. Science information gained from the satellite provides insight into the geological and environmental phenomena affecting our planet.

The engineering subsystems of the satellite include:

1. Structure/packaging:
2. Mechanisms;
3. Power;
4. Thermal control;
5. Command and data handling-software and hardware;
6. Telecommunications; and
7. Attitude control.

Each of theses subsystems, along with their integration into the satellite, is described in detail elsewhere [1, 2].

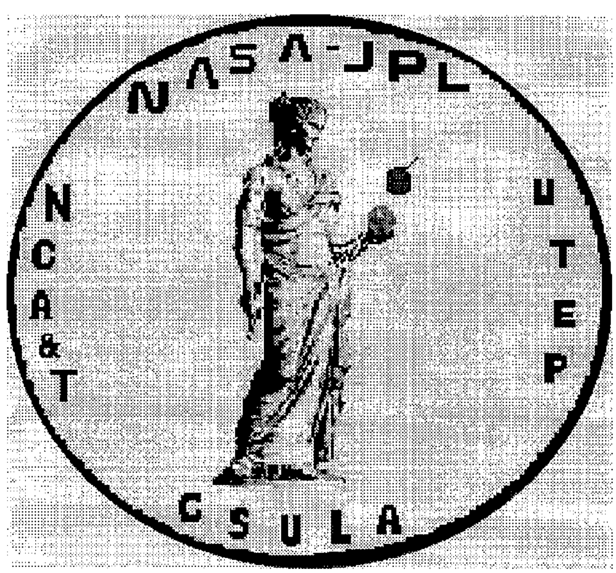

Fig. 2: Logo of the MUSES team, showing the Muse, Urania, holding the Earth as the satellite Urania orbits above.

Multidisciplinary Systems Engineering at NCAT

Due to the fact that the System Engineering curriculum developed is different for each school because of programmatic and administrative constraints. the following is a description of the curriculum to be implemented at NCAT only.

A two-course sequence will be offered in consecutive Fall and Spring semesters of each year. The courses will be open to seniors and graduate students of any engineering major, since the emphasis is on multidisciplinary system design. The first course can be taken as a Technical Elective, while the second will substitute for the Capstone Design course, which is a graduation requirement for the undergraduate curriculum of all engineering majors at NCAT.

Contents of the first course will consist of topics necessary for Systems Design and Engineering but will not be specific to any one system, while the second course will be purely the technical design of a system. The purpose of this is so that the course sequence maybe used to teach the design and engineering of any system, which will most likely change from year to year. Topics of the first course will include team building, technical communications, creative problem solving in multidisciplinary teams, selected issues from total quality management (TQM), and engineering design tools (e.g. software tools). Substantial time will also be devoted to the definition of systems, and analysis of common engineering systems.

The second course in the sequence will focus solely on the design of a single system. In addition to satellite design, other topics may include a solar boat design for a competition sponsored by the American Society of Mechanical Engineers, or the design of experiment modules to be launched with sounding rockets for scientific purposes. The current plan is to implement the courses under the General Engineering division, so that students of any major, in the College of Engineering may take these courses for credit, and to highlight their multidisciplinary nature,

Future Plans

The 1996 Summer Workshop culminated in September with the MUSES team traveling to the Small Satellite Conference sponsored by Utah State University in Logan, Utah. A poster presentation of Urania was made by the team, and favorable comments were received from the attendants.

The immediate plans of the MUSES team is to forge ahead with planned curricular activities for the coming academic year, and to plan for a follow-on Summer Workshop for 1997. It is hoped that several members of the original team will return to refine the initial satellite design. Most importantly, the MUSES team, along with JPL mentors, is seeking to promote the team's activities to private industry and government in hopes of obtaining funding to actually construct the final satellite designed, and to realize its launch, perhaps by 1999. The team's best hope is to compete and win against other universities in future NASA-sponsored satellite design and construction opportunities.

Acknowledgment

We gratefully acknowledge the leadership provided by Ms Bettie White at NASA's Office of Equal Opportunity Programs, Dr. Yvonne Freeman, formerly with NASA, and the Jet Propulsion Laboratory's Minority Science and Engineering Initiatives Office. These programs agreed with our vision of how engineering education can be broadened and improved by the project described in this paper, and provided the necessary funding for its conduct.

We would also like to acknowledge those who participated and are continuing to participate in this venture:

North Carolina A&T State University: Professors Esther Hughes, Eric Cheek, Ganelle Grace, Robert Li, Yong-Duan Song, Shih-Liang Wang, and students Nicole Wright, Kimani Silva, Edgar Masters, Darryl Parker;

University of Texas, El Paso: Professors Mary Clare Robbins, Bryan Usevitch, Scott Starks, and students M iguel Ordaz, Ivan Munoz, Guillermo Velasquez, Joe Riccillo;

California State University, Los Angeles: Professors Kamran Karimlou, Anjan Bhaumik, and students Zoila Herrera, Veronica Lacayo, Luis Rodriguez, Steve Hopkins;

Jet Propulsion Laboratory: Kim Leschly, Cecilia Guiar, Ann Dalton, and other scientists and engineers;

Industrial partners: Mr. Ray Shibata, Hughes Space and Communications Systems, El Segundo, California, and Mr. Richard Croxall, TRW, Redondo 'Beach, California.

References

1 MUSES Program Review Presentation, presented to the Program Review Panel, Jet Propulsion Laboratory, Pasadena, CA (1 996).

2 MUSES Technical Proposal, presented to Jet Propulsion Laboratory, Pasadena, CA (1996).