Design and Test of a Tethered Pair of Satellites: Equipment Requirements

A Summary of Research Report
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Dr. Jesse A. Leitner, Technical Officer
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by

Henry J. Pernicka, Associate Professor
Mechanical and Aerospace Engineering and Engineering Mechanics
1870 Miner Circle
University of Missouri-Rolla
Rolla, MO 65409-0050

Phone: (573) 341-6749
Fax: (573) 341-4115
Electronic mail: pernicka@umr.edu

Summary of Research

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Introduction

A recent development in spacecraft mission design involves the increasing use of Distributed Spacecraft Systems (DSS). Several key technologies must mature sufficiently to facilitate these missions, including the use of spacecraft flying in tightly controlled formations. Such formations may be controlled using "free flying" navigation schemes, or alternatively may use tethers to constrain the formation geometry. An investigation has been initiated here to further develop this technology using two small spacecraft connected by a short tether. After insertion into orbit, the tether will be extended and various data collected on the performance of the dual-spacecraft "formation." At some later time, the tether will be cut, and the spacecraft pair will be navigated in a manner to maintain a geometry as closely as possible to that of the tethered configuration. Comparisons and evaluations of the two modes of operation can then be made so that the merits of both approaches are available to mission designers.

The spacecraft pair is undergoing design, construction, and test by students and faculty at the University of Missouri-Rolla (UMR). This approach closely matches one of the objectives of NASA's Strategic Plan which states as a goal to "motivate students to pursue careers in science, math, and engineering." The education of engineering and science students for employment in the space industry requires that the university provide the workforce with capable entry-level personnel who understand the basics of spacecraft design, manufacture, test, and operation. By partnering with NASA to use students to develop and fly a mission of interest to NASA and the space community, it is hoped these students will become highly motivated and will go on to successful productive careers in astronautics and aeronautics.

This grant was instrumental in the acquisition of basic equipment needed to complete the design, construction, and test of the tethered spacecraft pair. Preliminary discussions held with the DSS lead at NASA-GSFC (Dr. Jesse Leitner) identified mission concepts that will advance spaceflight technology areas of current interest. As a means to initiate this project, this grant resulted from a proposal requesting funding to augment funding received from the University of Missouri system and the Department of Mechanical and Aerospace Engineering and Engineering Mechanics. As detailed in the *Equipment Purchases* section, this funding was used for various equipment purchases currently being used in the design and construction of the satellite pair.

Background

The education of engineering and science students for employment in the space industry requires that the university provide the workforce with capable entry-level personnel who understand the basics of spacecraft design, manufacture, test, and operation. The main goal of this effort is to achieve such an objective by initiating an effective and innovative hands-on educational and research project at the University of Missouri–Rolla that will directly benefit NASA and its mission.

In educating engineering and science students, one of the key challenges is formulating meaningful senior-design projects and thesis topics for graduate students. To address this challenge, this effort has initiated a project with the main goal of having students design, construct, and test a satellite (named "MR SAT" for Missouri-Rolla Satellite) to be launched into low Earth orbit. A key objective of this project is to provide students with a valuable culminating design experience that emulates all of the critical elements they will encounter in industry. Thus one emphasis is to educate students on working together in an interdisciplinary team environment with the goal of producing a functional spacecraft meeting given design, budget, and time constraints. At the same time, another equally important emphasis is to define a mission purpose for the satellite that will advance scientific and engineering state-of-the art knowledge of interest to NASA.

Research Plan and Progress

In formulating the research plan, goals and objectives were first summarized. The two main goals of equal importance are:

- Advancing scientific and engineering state-of-the art knowledge of interest to NASA;
- Effective spacecraft design education of graduate and undergraduate students.

Specific project objectives are listed below with a brief statement for each regarding the progress made to-date in meeting each objective:

- Establishment of a multi-disciplinary team of both students and faculty that spans the campus. *Progress*: Completed. The MR SAT team has approximately thirty students, including graduate and undergraduate students from aerospace, mechanical, computer, and electrical engineering.
- Development of a laboratory to fabricate and integrate small spacecraft and their payloads. *Progress*: The lab is functional and is outfitted with a clean room, workbenches, two computers dedicated to the MR SAT project, and various hand tools.
- Development of a ground station on campus to receive telemetry from the spacecraft after launch into Earth orbit. *Progress*: Currently researching hardware to be acquired. Candidate locations for the antenna have been identified.
- Modification of the curriculum to facilitate the (meaningful) use of both graduate and undergraduate students in a team setting. *Progress*: A dual-level course has been created that senior design students and graduate students can take fall, spring or both semesters.
- Initiating collaborations with NASA, industry, and other researchers in government facilities in spaceflight-related areas. *Progress*: A cadre of mentors has been established from NASA and industry with which MR SAT team members can and are actively consulting.
- Emphasize the use of systems engineering in completing a project of this nature, including team building, good technical writing and documentation practices, and development of good oral communication skills. *Progress*: This approach has been integrated into the management of the MR SAT project.

- Development of professionalism and ethics in students as they relate to engineering. *Progress*: This approach has been integrated into the management of the MR SAT project.

In striving to achieve these goals and objectives, this grant was used to augment existing start-up funding. Numerous purchases of miscellaneous items for use in designing and building the pair of spacecraft were made and are detailed below in the Equipment Purchases section. This equipment is being used in a new lab (named "Space Systems Engineering") dedicated to this project and the study of astronautics.

Currently, the conceptual design of MR SAT has been completed. Design documentation will soon be uploaded to the MR SAT website (www.umr.edu/~mrsat). When the upload process is complete, the mentoring group will be solicited to review the conceptual design and provide feedback and further guidance. The team is now focusing on performing more detailed design work, leading to a Preliminary Design to be completed before the end of the current semester.

Equipment Purchases

During the two-month performance period for this grant, the following purchases were made:

Miscellaneous Equipment and Supplies:

Hand tools: Screwdrivers, wrenches, ratchets, sockets, torque wrenches, wire cutters, saws, knives, multimeter.

Power tools: Drill, Dremel, soldering irons, glue gun, cordless screwdriver.

Clean Room: A 6' x 6' x 6' Class 100 clean room was purchased and installed in the UMR Space Systems Engineering laboratory. This clean room is composed of an A 6-36 vertical flow hood supported by a C-frame and is enclosed by vinyl strip see-through curtains.

Materials: Solar cells, aluminum sheets (for construction of mock-up/prototype satellites), Teflon, magnetic wire.

Other: Two workbenches, tool chest, safety glasses, earplugs, bulletin board.

Permanent Equipment:

Computer Hardware: A Dell Precision Workstation containing dual Pentium Xeon processors and one gigabyte of RAM. It is also equipped with dual SCSI hard drives, a CD-RW drive and a Zip drive as well as Firewire capabilities.

Computer Projector: An Epson computer projector

Concluding Remarks

The successful launch and operation of the MR SAT spacecraft undergoing design and construction will be of great value to NASA and UMR. NASA will benefit from engineering and scientific return obtained at a very modest cost. Students at UMR will benefit from the hands-on experience of designing and building a satellite. NASA will also have easy access to these students for possible hiring after graduation. The funds expended in this grant have been used to purchase equipment that is proving very useful in designing and constructing the satellite pair, and hopefully, will also be useful in future spacecraft projects undertaken at UMR. The MR SAT project is very grateful to NASA and the Technical Officer, Dr. Jesse Leitner, for the support provided by this grant.