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1. Scientific/Technical/Management [20 pages limit!!]

This proposal is submitted to the Suborbital Program as the consequence of a letter from Mr. Kenneth W. Ledbetter, Mission and Payload Development Division, dated 21 April 1998, in response to our submission of a Form 1628 to the Office of Space Science on 2 February 1998.

This proposal seeks the scientific sponsorship of the Suborbital Program for our request for NASA's commitment to launch a satellite by the Hitchhiker Ejection System (HES), *i.e.*, the approval of our Form 1628. We seek no funding other than the expenses required by the Shuttle Small Payloads Project (SSPP) in the preparation and the launch. Therefore, no budget is included in this proposal.

The satellite, UASat, is being designed and to be fabricated, assembled and tested either by or under the supervision of the students of the Student Satellite Project (SSP) at the University of Arizona (UA) under the guidance of volunteering experts from UA and near-by industries, including Evergreen, Honeywell, Kaman, Motorola, and Raytheon. The operational expenses, student support, facilities, and equipment have been provided by UA, local industries, private organizations and individuals. The industrial support for the fabrication, assembly, testing, and delivery of UASat to SSPP for launch, is contingent upon NASA's approval of this proposal.

The learning process began at the very start of the project in February 1997, when students, graduate and undergraduate, were asked to respond to an announcement of opportunity, followed by the formation of teams, the writing and submission of proposals by the teams, and the selection and evaluation of the proposals by a panel of experts in space science and engineering. What followed was a student-run organization doing the planning and execution, passing a Conceptual Design Review in November 1997, and into the present Preliminary Design Phase.

The approach of SSP towards the completion of the UASat mission is unique in its student-centeredness and its university-community-industry collaboration. Consequently, the role of NASA will also be different from all its previous and existing ones. The following sections will present the case of SSP in its attempt to develop and operate a scientific satellite, UASat, in the hope that its mission can be accomplished with the approval and support of NASA to launch the UASat by the Hitchhiker Ejection System (HES) or its successor some time in 2001.

1.1 *Objectives*

The objectives of the Student Satellite Project (SSP) at the University of Arizona (UA) are divided into scientific ones for the UASat mission and educational ones for the entire endeavor. While the educational objectives laid the groundwork for the whole project, the scientific objectives were the result of a competitive selective process that began with the choice of the launcher -- NASA's HES. The reasons for choosing HES are given in § 1.2.2.5.

1.1.1 Scientific Objectives

Unlike the usual space missions, the SSP selected the orbit and constraints on the platform before selecting the science objectives. This approach is rooted in the difference between a student project and the usual missions (see § 1.2.2.5). Through a process described later in this proposal, the Evaluation and Selection Panel found three complementary science experiments, proposed by the studetn teams, that can take full advantage of the HES-injected orbit, the expertise on campus, the technology in the community, and the feasibility of success within the student ranks; these are: 1) Lightning Experiment, 2) Sprite Experiment, and 3) Stellar Photometry Experiment.

1.1.1.1 *Lightning experiment*

The primary science mission is the lightning experiment, consisting counting lightning discharges in the atmosphere. The objectives of this experiment are:

a. Characterize convective storms and their spatial distribution;
b. Improve the global climatology of lightning by mapping lightning strikes;
c. Constrain global climate and cloud microphysical models and tropospheric gas production; and
d. Supplement data sets of similar missions.

1.1.1.2 *Sprite experiment*

In 1989, a group of researchers, using a low-light-level video camera at high altitude, captured an electrical discharge that propagated from the top of a large thunderstorm into the ionosphere. Later termed "red sprites," because of the general color of the phenomena and its fleeting nature (hence the reference to William Shakespeare's creatures of the same name). Further observations have led to more quantitative information about sprites. Their size is on the order of 10-20 km horizontally and about 50 km vertically, and their brightness has been compared to a bright auroral arc. They occur in the mesosphere from about 50-100 km in altitude, well above the 20 km of the highest thunderclouds that produce these sprites.

Past sprite research has focused on statistical data needed by modelers to develop theories on sprite development. Since most of the current research has been localized to regions in the Central Plains of the United States, a satellite platform offers a global perspective to the activity of sprites. The objective of the sprite experiment is to map the occurrence of sprites according to:

a. Latitude (tropical vs. extra-tropical);
b. Season (summer vs. winter);
c. Storm size, for example single-cell storms versus mesoscale systems;
d. Maritime or continental based storms; and
e. Lightning flash rate.

1.1.1.3 *Stellar photometry experiment*

The UASat will be uniquely positioned to perform measurements of the brightest Johnson UBVRI photometric standard stars with unprecedented accuracy. Standard star measurements are used extensively to correct for air mass and atmospheric effects in many different astronomical applications. The objective of our space-based measurements is to improve the accuracy of ground-based UBVRI data for a selected set of standard stars by producing a highly accurate internally-consistent data set of UBVRI measurements spanning a range of magnitudes and spanning both the Northern and Southern hemispheres.

1.1.2 Educational Objectives

The educational objectives of SSP are to offer the students, the university, and the community the following benefits:

a. A hands-on experience in the design, fabrication, testing, and operation of a complex system with a well-defined objective through teamwork;
b. A needed channel for many students to gain self-confidence and employable skills;
c. An example of intercollegiate, inter-departmental, and interdisciplinary collaboration;
d. An avenue to enhance beneficial interactions among university, industry and community; and
e. A test-bed for innovative ideas in a wide variety of areas.

Each of these objectives is delineated below.

1.1.2.1 *A hands-on experience in the design, fabrication, testing, and operation of a complex system with a well-defined objective through teamwork*

There is no substitute for experience. Bad experience may teach us caution and good experience courage; but no experience teaches us nothing.

Complexity and specialization are inseparable. As individual and societal goals become harder to achieve, more complex systems and devices are sought. The more complex the system or device becomes, the more specialized skills and techniques in a wide variety of fields are needed. The whole process of making a complex system work, from conceptual design to fully operational, demands closely coordinated large-scale teamwork. Such teamwork requires people skills as much as technical skills. The development of a complex system also demands time -- a duration longer than the average dwell time of its participants. Such a disparity in time-scale spurs the challenge for patience and dedication to the continuity of a larger self. A modern university can and should provide its students the opportunity to face these challenges and to develop these skills.

Test-oriented courses, result-driven research projects and departmentally-confined programs are the existing building blocks of a university. They alone do not provide the kind of learning just described. Talents already nestled in these building blocks, however, can indeed be organized to provide a "hands-on experience in the design, fabrication, testing, and operation of a complex system with a well-defined objective through teamwork" to the students to gain the experience and the varied skills that are more and more demanded of them upon graduation.

1.1.2.2 *A necessary channel for many students to gain self-confidence & employable skills*

Realistic self-confidence enables new endeavors, and it grows out of excelling one's performance along the way. The opportunity to excel is essential for gaining such self-confidence.

Not all motivated and talented students excel in classroom-confined and test-oriented learning. Thomas Edison, Albert Einstein, Steve Job, and Bill Gates come to mind. As a state university that serves a large number of students with a wide range of interests and abilities, we must try to provide additional modes of learning to attract and retain a larger cross-section of students to become future productive workers and leaders in a variety of fields.

1.1.2.3 *An example of intercollegiate, inter-departmental, and interdisciplinary collaboration*

The knowledge and skills required for SSP threads through departments and colleges. The breadth of experience surpasses all existing interdisciplinary programs. What is learned in the process of making SSP a success can be beneficial to other interdisciplinary programs addressing other complex systems. An example of a more practical, but far more complex system, could be the design, construction and operation of a model water-supply system that could adequately, safely and economically serve a community living in a delicate environment.

While much of the problem-solving along the way utilizes analytical tools and approaches, the entire project offers a holistic view and an integrating process of working together towards a common goal. Such kinds of projects re-affirm the concept of "UNI" in our "university" on the one hand, and provides leadership training for the students in systems and organizational skills.

1.1.2.4 *An avenue to enhance productive interactions among university, industry and community*

A holistic view of the university must include the community. From the community, the university draws its life-giving resources in the form of money, goods, employees, and most of all, its students. To the community, the university returns life-enriching truth, beauty and goodness in the form of profound and innovative ideas, useful technology and services, and most of all, responsible and productive graduates.

The University of Arizona is a state institution located in a city that is equipped and working for economic development through "high-tech" industries, especially in optical- and aerospace-based science and technology. The Greater Tucson Economic Council’s “Strategic Economic Plan” (see GTEC website <http://gtec98.rd.net/gtec/economic/summary.htm>) sets the stage for educational programs like SSP. In carrying out its mission, SSP will naturally intensify the interactions between the community and the university. For example, mutual benefits are expected when the Mechanical Structure & Analysis (MSA) Team of SSP interacts with the Composite Airframe Program at Pima College. Another example could be SSP's use of test facilities and expertise at Raytheon as SSP trains skilled potential employees. The selection of the instrument and scientific objectives for SSP's UASat stands as an example of the electro-optics based science and technology linking the University of Arizona with the local industries.

1.1.2.5 *A test-bed for innovative ideas in a wide variety of areas*

Generating and testing new ideas are intrinsic to our mission as a university. Unlike most of the research projects -- each conducted by a faculty and professional staff plus one or two graduate students -- SSP is conducted by undergraduate and graduate students. In addition to new ideas generated or stimulated by students, rigid rules and regulations can also be made more rational and tolerant to allow testing new ideas under much less external pressure. This is in obvious contrast to the way many institutions run their missions. SSP can truly serve as a test-bed for ideas in a wide variety of disciplines, in a manner these institutions could not afford or willing to pursue.

The test-bed is also available to participating industries. As an example, Tucson Electric Power Co.'s newly developed thin-film solar battery is being considered by SSP for UASat. SSP offers other industrial partners similar opportunities to test their ideas or products.

1.2 *Approach*

The scientific objectives of UASat and the educational objectives of SSP require respectively a technical approach and a programmatic approach. We note that the entire approach of UASat is based on the choice of HES as the launcher. The reasons for choosing HES are given in § 1.2.2.5.

1.2.1 Technical Approach

To achieve the mission goal of UASat, an appropriate instrument supported by a suitable spacecraft will be necessary. We first describe the instrument and then the spacecraft. We took the holistic approach that the design of the instrument and that of the spacecraft proceed as a whole.

1.2.1.1 *The instrument*

In order for these three experiments to be carried out on the same orbital platform, the design integrates them into a single optical system. While this causes us to compromise the design slightly for each of the separate experiments, the cost, space, and weight savings of such an approach is well worth any compromise. A block diagram of the science instrument[iv] is shown in Figure 1.2.1.A.

The heart of the instrument is an f/7.0 cassegrain telescope with a 15-cm primary mirror. A hyperbolic secondary mirror is mounted with curved diagonal vanes, chosen to minimize diffraction spikes. The 45-cm focal length is expected to provide a 5.0° x 5.0° field of view (FOV). This FOV was selected so as to be small enough to allow the use of reflective optics, thus reducing weight, cost, and problems with chromatic aberration. This FOV, however, is still large enough to fully image large a mesoscale convective system at midlatitudes from the planned orbit of 425 km at 51.6° inclination. In addition, the signal-to-noise ratio and resolution will be sufficient for the stellar photometery experiment. The sensor has a single primary mirror with a fold mirror to reduce the size of the platform. The fold mirror is also used for minor pointing adjustments and directs light from the primary mirror to three separate focal planes, one each for the three separate experiments of the mission.

1.2.1.1.1 Lightning Experiment

The focal plane for the lightning experiment contains a 2-D CCD. From Figure 1.2.1.A, it can be seen that light on the CCD array is filtered by dichroic beam splitters. These beam splitters allow light of wavelengths longer than 777 nm to pass to the array. The current design of the system uses a 1024 x 1024 array with virtual shuttering to allow multiple images to be held in memory at a given time. The data will also be binned to improve signal to noise and the expected spatial resolution is approximately 1 km in the center of the field for the 40-km tangent height of the view of the system.

1.2.1.1.2 Sprite Experiment

The primary detector for the sprite experiment is a linear photodiode array and a cylindrical lens as shown in Figure 1.2.1.B. The array and lens are oriented perpendicular to the Earth's limb so that the lens collects light from across the entire field and focuses it onto the array allowing vertical discrimination of the source of the energy. Since the energy from sprites is predominantly at shorter wavelengths, all light with a wavelength less than 777 nm is diverted using a dichroic beam splitter. Even after blocking a significant amount of energy from lightning discharges, energy from lightning will still be 500 times that from sprites at the photodiode array. We avoid confusion between the two phenomena using the spatial location of the event on the array. Additionally, we will also use the lightning experiment's CCD array to image sprite events. Because the energy from sprites is so much less than that of lightning, the gain of the upper portion of the array will be different from that of the lower portion so as to equalize the signal from the two phenomena.

1.2.1.1.3 Stellar Photometry Experiment

The stellar photometry experiment uses the same collection optics as the other two science experiments. Light from the primary mirror is deflected to the photometry focal plane via a flip mirror through a focal reducing lens and a filter wheel. The filter wheel contains a set of standard UVBRI interference filters used in stellar photometry. A single photodiode is used for this experiment.

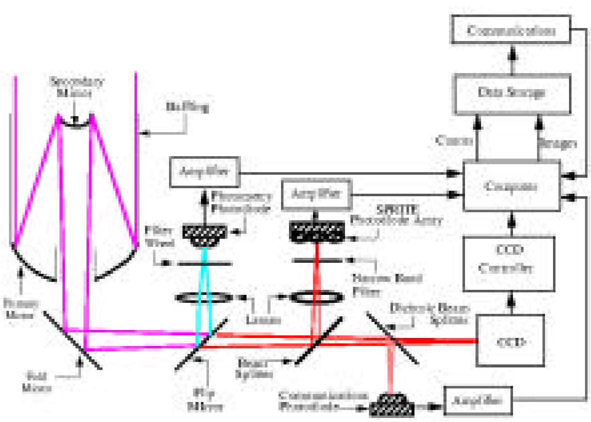

Fig. 1.2.1.A Science Instrument Block Diagram

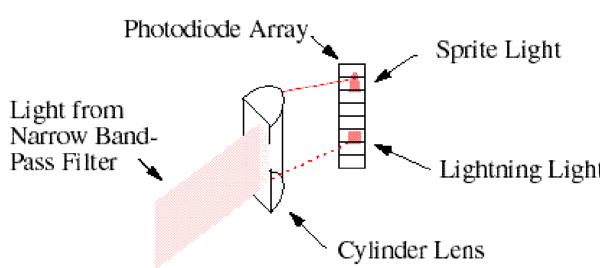

Fig. 1.2.1.B Cylindrical Sprite Detection Lens

1.2.1.2 *Spacecraft design*

The choice of HES as the launcher for its availability, reliability, and flexibility, also conveniently provided a set of well defined design constraints (shown in Table 1.2.1.A), within which the inexperienced students could exercise their creativity. This gave the SSP a good start. Also serving as a guideline for design was the Shuttle's "standard" orbit of 28.5° to 57° inclination and 185km to 400km altitude[i]. (With the upcoming construction of the International Space Station (ISS), there are currently 34 Shuttle missions between December 1998 and January 2004[ii] to the ISS orbit of 407km and 51.6° inclination[iii].) The consequent orbital lifetime of ≤ 1 year is also a favorable factor considering the quality assurance costs and the transitory nature of the students.

Table 1.2.1.A Hitchhiker Ejection System Characteristics

Maximum spacecraft weight	68 Kg (150 lb)
Maximum spacecraft height re separation plane	52 cm (20.5 in)
Maximum spacecraft diameter	50 cm (20 in)
Maximum CG location re canister centerline	1.27 cm (0.5 in)
Maximum CG location re separation plane	26 cm (10.25 in)
Ejection Velocity (at 68 Kg)	0.6 – 1.2 m/s (2 – 4 ft/s)

With these constraints given, over 80 volunteering students were assembled into 17 teams, comprising 6 design subsystems that constitute an entire satellite: Science, Mechanical Structures & Analysis (MSA), Power Generation & Distribution (PGD), Data & Command Handling (DCH), Guidance, Navigation & Control (GNC) and Tracking, Telemetry & Command (TTC). The student teams were asked to find a faculty mentor and submit a "Letter of Intent to Propose" one month later. Full proposals were submitted on 14 April 1997. Out of the 17 proposals, the Evaluation & Selection Panel (ESP) recommended on 24 April 1997 the most suitable concepts for each of the 6 subsystems. These recommendations and the regrouping of the students into the respective teams marked the beginning of UASat. Here we describe the approaches taken by the respective teams, based on the result of the Semester Review in May 1998.

1.2.1.2.1 Mechanical Structures & Analysis (MSA)

The Mechanical Structures & Analysis (MSA) team is tasked with designing the body, to which all other subsystems and experiments are to be mounted. This team is also responsible for routing the subsystem interconnect cables throughout the spacecraft. The MSA team's current preliminary design is a 12-sided satellite that fills most of the volume and mass outlined in Table 1.2.1.A. The basic design includes body-mounted solar panels, a 15 cm aperture at the "top" face of the satellite, the sensors in the "lower" part of the body, primary downlink antennae on the top face, and the marmon plate interface to the HES on the "bottom" face of the satellite. Positions of other components are described in the following subsystem descriptions. The basic layout for the design is illustrated in Figures 1.2.1.C and 1.2.1.D.

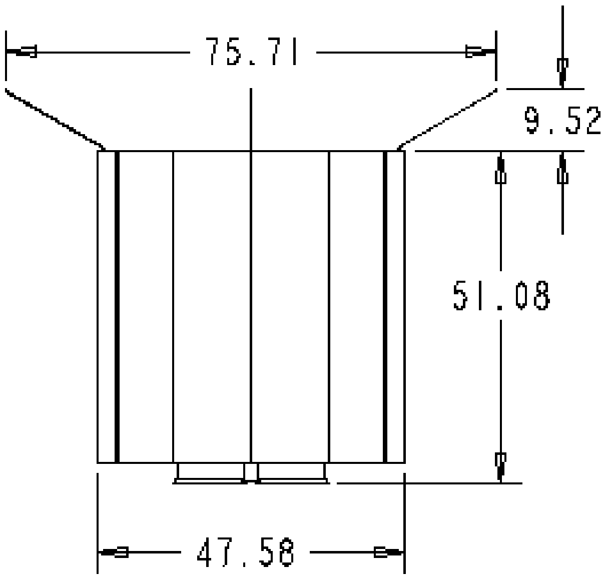

Fig. 1.2.1.C UASat Preliminary Structure Design (dimensions in cm)

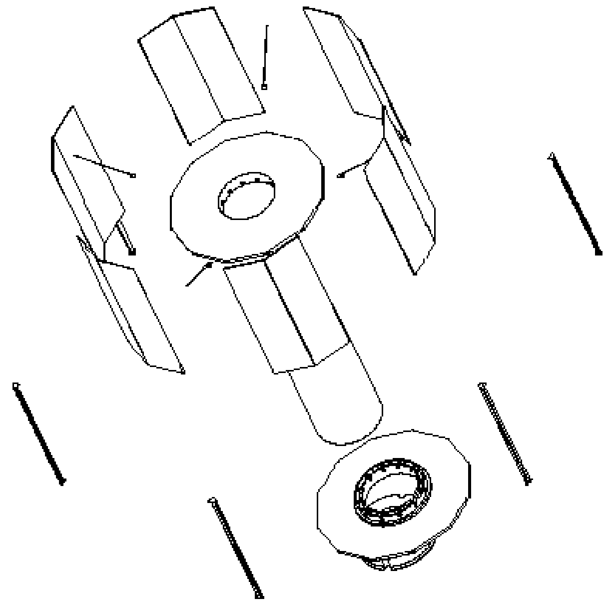
Fig. 1.2.1.D UASat Preliminary Structure Design (Exploded View)

The MSA team uses the parametric design capabilities of Pro-Engineer (ProE) in the design of UASat. ProE allows easy visualization of concepts and quick design studies on the components. The students will perform both the mechanical and thermal analyses of the entire structure.

1.2.1.2.2 Data & Command Handling (CDH)

The DCH team is tasked with command detection, verification, distribution and execution. They must interpret, store and carry out all commands uplinked, as well as perform general internal housekeeping functions. Typical processes will include executing attitude determination and control algorithms, interacting with the science instrument computer to pass data and commands, and relaying commands and data to and from the TTC subsystem. Essentially, they are the spacecraft computer. Presently, the DCH team is studying the utilization of an Intel 386EX class processor. The trade-off between building this processor from scratch and using a commercial single-board-computer is under study. The team is internally organized to include a software group and a hardware group.

Also under investigation is the choice of approach for the spacecraft operating system (OS). Due to the nature of the computing tasks aboard UASat, the following traits are desirable for the eventual OS, whether it is coded in-house, or adapted from commercially or publicly available sources:

- Multitasking
- Priority oriented
- Real time (as schedule and budget permit)
- Runs on a simulator

UASat has selected the ORCAD suite of design, layout and simulation tools for its design of the DCH system and other circuit design tasks. ORCAD was chosen as it allows us to seamlessly interface with our AMSAT advisors Lyle Johnson and Chuck Green, who live in Tucson.

1.2.1.2.3 Power Generation & Distribution (PGD)

The PGD team is tasked with selecting, designing and integrating components for the solar arrays, battery subsystem, and distribution of power throughout the satellite on standard regulated buses. Silicon or Gallium Arsenide (GaAs) solar cells will be body-mounted circumferentially on the facets of the satellite, potentially allowing radiating surfaces if necessary. Isolation diodes will be used in the solar cell strings to protect against cell shadowing and failure. A peak power tracker approach is also under study to maximize power obtained from the solar cells. The current power storage approach utilizes 72 NiCad D-Cells -- 24 units in series, each unit comprised of 3 D-Cells in parallel -- for redundancy. The batteries will be mounted in a pressure vessel near the marmon plate at the bottom of the satellite. While in sunlight, UASat's activities and positioning will be optimized for maximum power generation; and other activities (science and telemetry) will be carried out as power permits.

1.2.1.2.4 Tracking, Telemetry & Command (TTC)

The TTC team is tasked with providing the communications link between the spacecraft and the ground. They must provide both the spacecraft and the ground station with radios, modems, and antennae. The TTC team is pursuing the use of amateur radio bands for communications for the following reasons: availability of inexpensive commercial hardware, existing equipment, local expertise, and the opportunity to provide a service to the amateur radio community.

Current plans are for communication on three radio bands. The primary high-speed data downlink will be on S-band (2.4 GHz), and command uplink will be on 70 cm (428 MHz). As a service to the amateur radio community, UASat will offer a PACSAT-style store-and-forward system with an uplink on 2 m (145 MHz) and downlink on 70 cm. Base communications will be at 9600 baud , and the primary downlink will use quadrature-phase-shift-keying (QPSK) modulation in hopes of obtaining data rates in upwards of 2 Mbps. An illustration of the proposed antenna locations on the UASat is shown in Figure 1.2.1.E. The 70 cm and 2.4 GHz antennae are fixed, and the 2 m antenna would be a deployable "carpenter tape" antenna released on orbit.

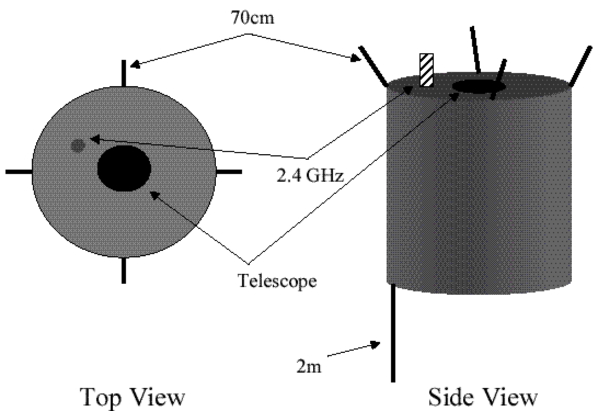

Fig. 1.2.1.E UASat Antenna Locations

Fig. 1.2.1.F SSP Project Manager, Chris Lewicki, assembling UASat/SEDSAT-1 ground station

The ground station for UASat had already been under construction for some time at the inception of the SSP. The Project Manager is shown in Figure 1.2.1.F assembling the ground station tower. Members of the University of Arizona Students for the Exploration and Development of Space (SEDS) and Amateur Radio Club (ARC) are collaborators on a project to provide SEDSAT-1[iv] with a ground station and an Internet data center.[v] UASat plans to use a ground station approaching that is currently being developed for SEDSAT-1, which uses the Internet and distributed amateur radio ground stations interacting with a relational database at the University of Arizona for increased downlink capability, and worldwide near-real-time coverage. Users worldwide can use a world-wide-web interface to retrieve data from the database, as well as place requests for data to be retrieved at the next uplink opportunity. All of the ground station software is currently being developed in Java with some C for the best portability and upgrade capability.

1.2.1.2.5 Guidance, Navigation & Control (GNC)

The GNC team is tasked with determining the absolute position and attitude of UASat, and controlling the pointing of the satellite at specified targets. This is perhaps one of the most ambitious and technically challenging design aspects of UASat. Due to the pointing requirements (Table 1.2.1.B) of the high-speed telemetry downlink, laser uplink experiment, and stellar photometry experiment, a passively stabilized platform will not suffice. Therefore, the GNC team is pursuing the design of a three-axis stabilized platform utilizing reaction wheels for attitude control; coarse sun sensors, horizon sensors, global positioning system (GPS) receiver, micro-mechanical gyros, and a magnetometer for attitude determination; and magnetic torquer coils for momentum dumping. (The compatibility between the magnetic torquer and the magnetometer is under study.) This multi-parameter control system is summarized in Figure 1.2.1.G. Except for the GPS receiver and magnetometer, all of the GNC components will be built in-house, as it is economically infeasible to purchase the components commercially.

Table 1.2.1.B GNC specifications

Pointing Accuracy (Earth based)	1°
Pointing Accuracy (inertial)	0.1°
Slew rate	1°/sec.

1.2.1.2.5.1 *Reaction wheels*

A major design focus of the GNC team is that of the reaction wheels. Since satellites of this size typically are not three-axis stabilized, there currently are no reaction wheels on the market that are small enough to fit UASat's needs. Design of such reaction wheels has been undertaken by small projects before, and we are utilizing as much of that experience as possible, as well as working with Honeywell's reaction-wheel assembly group. The ground rules for design of the reaction wheels are: low in cost, use standard components and common materials, small in size in order to fit 4 of them in UASat, low in power consumption to allow their operation, and reliable enough to last the 1-year planned mission lifetime. On the advice of Honeywell, the GNC team continues to design the assembly and the flywheel itself, while outsourcing the design and fabrication of the brush-less DC motor. More design details are found in the UASat Technical Notes.[vi]

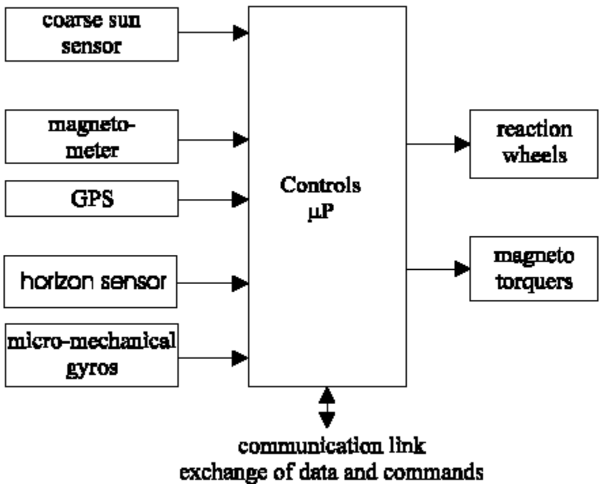

Fig. 1.2.1.G GNC block diagram

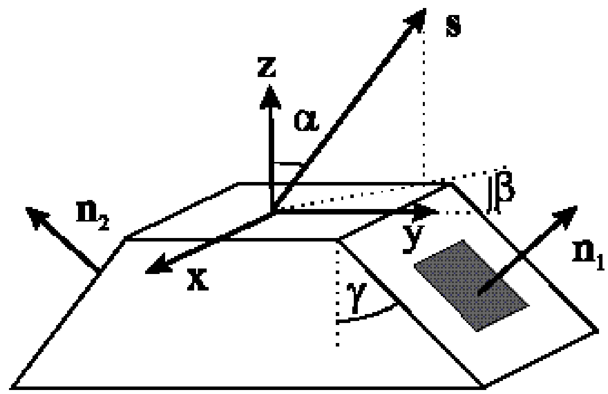

Fig. 1.2.1.H GNC Sun Sensor Concept

1.2.1.2.5.2 *Sun sensors*

A concept for the UASat sun sensors is currently in the prototyping stages.[vii] The design utilizes a Texas Instruments TSL230B programmable light intensity-to-frequency converter. The TSL230B digital output is easily interfaced to a microcontroller, and several of these placed strategically around the spacecraft can provide the two angles necessary to locate the Sun with respect to the spacecraft. The present design for the sensor block is a 4x3 cm parallelepiped with two TSL230Bs mounted normal to each other (Figure 1.2.1.H). Up to six sensor blocks can be mounted in the six directions of the coordinate system for greatest redundancy.

1.2.1.2.6 Strategic Technology Initiative (STI)

Originally one of the proposals for the TTC subsystem, the laser communication concept was kept by the ESP as an engineering experiment, dubbed "Strategic Technology Initiative". The baseline for the experiment is for a laser uplink. The receiver will be integrated into the science experiment (Figure 1.2.1.A). The STI team has already prototyped both ends of a communications link using a Manchester encoding technique, and has tested it successfully with a direct serial link as the transmission medium. Currently the team is ready to test the optics with lasers.[viii]

1.2.2 Programmatic Approach

The workings of SSP can be understood in terms of its internal structure and procedures, and its relation to the sponsors. We shall first describe the organization and operations of SSP, then the roles of the sponsors.

1.2.2.1 *The organization and operations of SSP*

SSP is a student-oriented interdisciplinary project. Table 1.2.2.A shows the wide distribution of students in their fields of study and their years in school. (Double majors are counted as halves.)

Table 1.2.2.A Distribution of Student Majors and Years in School (Spring 1998)

Major	*Fresh.*	*Soph.*	*Junior*	*Senior*	*Grad.*	*Total*
Aerospace Engineering	1.0	1.5	1.0		1.0	*4.5*
Astronomy	1.5		1.5			*3.0*
Atmospheric Science					1.0	*1.0*
Biology				0.5		*0.5*
Chemistry				0.5		*0.5*
Computer Engineering		0.5	3.0	7.0		*10.5*
Computer Science		1.0	1.0	0.5		*2.5*
Creative Writing				0.5		*0.5*
Electrical Engineering	1.5	1.0	8.5	6.5	0.5	*18.0*
Engineering Mathematics			1.0			*1.0*
Engineering Physics		2.0		1.0		*3.0*
Management					1.0	*1.0*
Material Sci. & Engr.		0.5	1.0			*1.5*
Mathematics				0.5		*0.5*
Mechanical Engineering		0.5	5.0	4.0	2.0	*11.5*
Microelectronics Engr.					0.5	*0.5*
Nondegree			1.0		1.0	*2.0*
Optical Engineering		1.0	1.5			*2.5*
Optical Science					1.0	*1.0*
Physics			1.5	1.5	1.0	*4.0*
Pre-Med				0.5		*0.5*
Total	*4.0*	*8.0*	*26.0*	*23.0*	*9.0*	*70.0*

SSP is a teamwork-oriented project. Figure 1.2.2.B presents its organizational structure. Its base is the pool of interested students, faculty and staff, from which teams are organized. There are seven teams, corresponding to science, the 5 subsystems, and the Strategic Technology Initiative. Each team, with its Team Leader and Team Mentor, is autonomous, but the Team Leader is responsible to the Project Manager for the running of the team and all tasks to be accomplished by that team. The current Team Leaders are listed in Table 1.2.2.B.

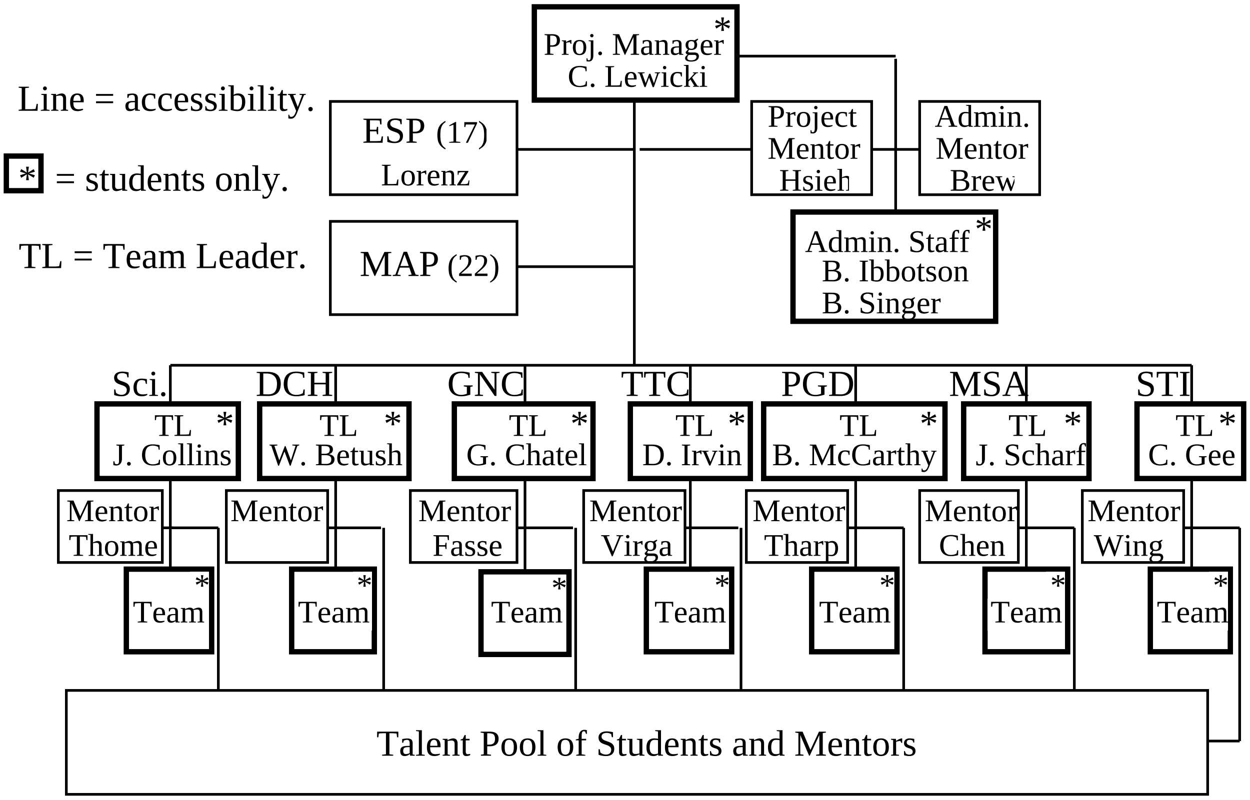

Figure 1.2.2.B Organization chart of the Student Satellite Project (current).

Table 1.2.2.B Current Team Leaders of the Student Satellite Project.

Team	*Team Leader*	*Status*
Science	Jim Collins	Grad., unclassified.
Data & Command Handling	William Betush	Soph., Computer Eng. & Material Sci. & Eng.
Tracking, Telemetry & Command	Dana Irvin	Soph., Computer Science
Guidance & Navigation Control	Greg Chatel	Sr., Mechanical Eng.
Power Generation & Distribution	Brad McCarthy	Sr., Electrical Eng.
Mechanical Structure & Analysis	John Scharf	Sr., Physics
Strategic Technology Initiative	Christopher Gee	Sr., Computer Eng.

Each week, all the Team Leaders meet with the Project Manager on a systems level to ensure the teams are functionally connected to reflect the interdependence of the instruments and all the subsystems and of the complex satellite. If conflict or inconsistency arises within a team or between the teams, the Project Manager may form an ad hoc committee of mentors to help resolve the problem. Although we have now only one student in the Project Management (PM) as the Project Manager, in the coming year we shall have the more complete Project Management consisting a Project Manager, Project-Manager Elect, and Past Project-Manager. This moving scheme protects the continuity and consistency of SSP as students join and later graduate during the life time of the project. The Project Manager is responsible for the entire Project. The Project Manager is assisted by the Project-Manager Elect and Past Project-Manager in carrying out that responsibility. The Project Manager receives advice from the Project Mentor, Administrative Mentor, the Mission Advisory Pool (MAP) and the Evaluation & Selection Panel (ESP). It is the Project Manager's responsibility to keep all advisory bodies informed of the Project's progress and difficulties. Presently, Chris Lewicki is the Project Manager. A Project-Manager Elect is expected to be selected in the fall of 1998. Chris is the natural choice for the Project Manager. When SSP was organized, he was the national chair of the Students for the Exploration and Development of Space (SEDS). His enthusiasm, familiarity with satellite projects and ability to lead give SSP an excellent start. Because of SSP, he entered the AME graduate program with a Space Grant Graduate Fellowship in the fall of 1997.

To carry out the heavy load of the Project Management (PM) and to keep the growing technical and financial documents in order, an administrative staff is necessary. The tasks and size of the Administrative Staff is defined by the PM at the advice of the Administrative Mentor. Presently, there are two staff members, Brian Ibbotson, a junior in aerospace engineering with previous administrative experience, and Brandon Singer, a freshman majoring in electrical engineering and planning to go into management.

1.2.2.2 *The role of the sponsors*

The relationship between SSP and its sponsors can be represented by a tetrahedron, the polyhedron of least number of vertices and sides, with SSP in the center and the sponsors at the four vertices, as shown Figure 1.2.2.A. We describe the roles of the sponsors below.

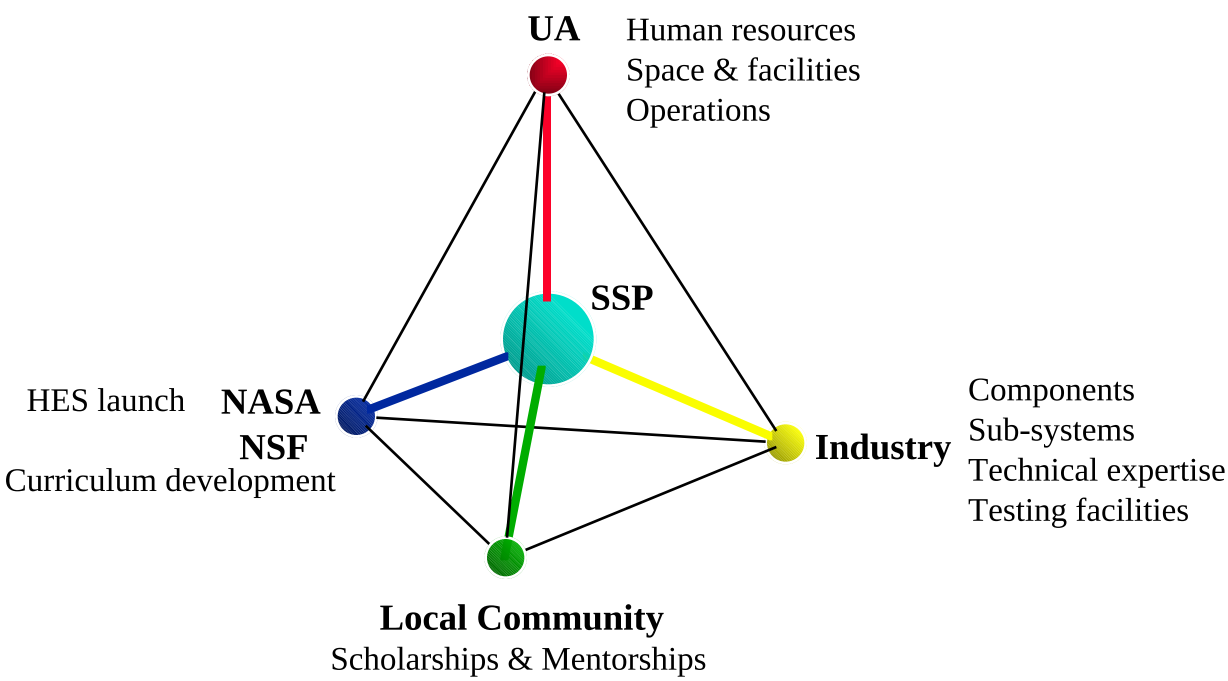

Fig. 1.2.2.A Tetrahedron illustrating the relationship between SSP and its sponsors.

1.2.2.2.1 The role of the University

SSP is a student project on a complex system. It requires an enormous amount of guidance, advising and technical assistance from the more experienced faculty, staff and other experts on and off campus. The University of Arizona is favorably endowed with many of these talents. SSP has been fortunate to have from the start the highest caliber human resources at no cost. Here we present four groups of mentors and advisors, without double listing. The mere number of supportive experts in all the fields encompassing a scientific satellite, a truly complex system, is SSP's most important asset that matches the enthusiasm of the students. All menotrs and advisors work for free.

The first group is the Team Mentors (TM; see Appendix A). Each TM is chosen by the respective team to provide advice and support to that team. The TMs work most closely with the students.

Next to the Team Mentors is the Mission Advisory Pool (MAP; see Appendix B). These research faculty and staff of diverse talents -- astronomy to management -- have been helping SSP on specific topics when needed. Some industrial partners have also offered advisory help.

The Evaluation & Selection Panel (ESP; see Appendix C) does the major evaluation and recommendation at the end of each phase to set the direction and pace of the next phase. The ESP was responsible for setting SSP on its course in conceptual design, completing the Conceptual Design Review with recommendations for the preliminary design. The ESP will also conduct the Preliminary Design Review, Critical Design Review, and Pre-delivery Review.

Finally, there are the Project Mentors and the Administrative Mentor. The Project Mentors consist of two faculty members, whose duties are to assure the healthy development of SSP as a whole. Presently, there is only one Project Mentor, K. C. Hsieh, the initiator of SSP. He is expecting a faculty member from the College of Engineering to join him in the fall of 1998. The Administrative Mentor, Susan Brew, Program Coordinator of Arizona Space Grant Consortium, offers guidance and advice to the SSP Administrative Staff.

In addition to invaluable human resources, different units of the University also provided funds, facilities and equipment to enable the operation of SSP thus far. The funds received from the different units of the University as of this writing totaled $97,352 (itemized in Appendix D).

For the support given in-kind, we give some examples. The Department of Physics provided the crucial service from the very beginning of SSP: establishing a communications capability through its computer network, a website that made publicity and out-reach possible, and the use of a lab space as the SSP Headquarters. The Aerospace & Mechanical Engineering Department also provides the use of two teaching labs for the MSA and the GNC teams, and the use of the Department's machine shop facilities and computers equipped with software such as ProEngineer for mechanical design. The Remote Sensing Group of the Optical Sciences Center provides lab space complete with optical and electronic equipment and a 4' x 8' optical table and supports one SSP student at 20 hr/wk and offers access to the Group's technical staff and research faculty. The Lunar and Planetary Lab provides the service of its Senior Staff Engineer, Steve Bell, a member of MAP, for 1 hr/wk for consultation without charge. Dr. W. Bickel, University Professor of Physics and member of MAP, has also offered to train the students for basic machining skills and shop safety. The University Research Instrument Center gave SSP access to its stocks and the use of its machines by qualified machinists. *The dollar equivalent of these services and facilities in the past year runs easily in the six digits.*

SSP can expect continuing support from the University, because of the enthusiasm exhibited by the students, faculty, staff, and administration. The President of the University, Dr. Likins, a specialist in spacecraft guidance and control, put it in perspective: "The Student Satellite Project at the University of Arizona is the best evidence I have discovered anywhere of the creative initiative of Americans committed to the Space Program, which has been an important part of my life for forty years."

1.2.2.2.2 The role of the Industry

The University of Arizona has an excellent record in space research, especially in the design and construction of sophisticated space instruments, but it is not experienced in or equipped for the construction and testing of a complete satellite. Fortunately, UA is situated in the vicinity of established aerospace companies, such as Honeywell, Kaman, Motorola , and Raytheon, which have the expertise and facilities to complement what UA lacks. As indicated in Appendix C, these industries have been providing SSP with technical advice at the top level from the start.

After the Conceptual Design Review in November 1997, as SSP entered the preliminary design of UASat, local industrial firms such as Burr-Brown, Breault Research, Evergreen, and Honeywell pitched in to donate components and engineering advice in the construction of prototypes of the payload instrument and spacecraft subsystems.

Todate, the industry has provided the support to SSP as the need arose. Support for the completion of a deliverable UASat will depend on the promise of a launch. This proposal is, therefore, crucial to the continuation and realization of the dream of SSP. [REFER TO § 6?]

1.2.2.2.3 The role of the Community

The University of Arizona is favorably situated in Tucson, a city fascinated by space. The space research at UA and the presence of aerospace industries and museums certainly contribute to this aspiration. The Greater Tucson Economic Council (GTEC) considers SSP a grassroot program that resonates with its vision of development for the area. [AN ENDORSEMENT?]

Pursuant to the enthusiasm of the community, two members of GTEC, Dorothy Finley and Bob Walkup, lead the way to help SSP in raising $110K this year from the community to provide scholarship to student leaders and financial aid to students in need of support participating in SSP and operational funds for Team Mentors. By July 1998, even before the drive has started, the following contributions have already arrived:

WAESO (Western Alliance to Expand Student Opportunities)	$3,386.	Two Undergraduate Grants. $1100 Materials & Supplies $286 Admin. Fee $2000 Student Stipends
Research Corporation	$5,350.	$2600 S/C structure & control $1500 Proto-typing photometry $1250 Proto-typing sprite detect.
Foundation Cariñoso	$2,000.	Two SSP scholarships.
Clint Ludke (Retired UA machinist)	Free labor as needed.	Machining precision parts.
Wes Weisheit (Private machinist)	Three-four days of labor.	Machining precision parts.

The SSP also has its education and public-outreach activities in the community. Through the Bridge Program, founded by the National Science Foundation, SSP has accepted students from the local Pima Community College to participate in the SSP during the summers of 1997 and 1998. Such participation is, in principle, not limited to the summer session but depends on the students' availability during the academic year. Extending to the general population, especially children in elementary schools, SSP is working together with the Pima Air and Space Museum to establish an on-going exhibit on SSP as its work on UASat progresses into more tangible and visible phases. A letter of commitment from the Museum is found in § 6.

1.2.2.2.4 The role of NASA

As shown in Figure 1.2.2.A, NASA and NSF share the fourth vertex of the tetrahedron. The SSP will seek support from NSF's Curriculum and Course Development Program for the development and implementation of the senior design courses based on the activities and topics of interest to SSP. It should be apparent that NSF and NASA will have distinctly different roles.

The role of NASA, sought by us, is to have the Shuttle Small Payload Project (SSPP) receive from us UASat -- a student satellite designed, built and tested by SSP to fit the Hitchhiker Ejection System (HES) -- then perform all the pre-launch procedures and eventually launch it at some suitable time. In other word, we seek NASA's approval of our Form 1628 and its consequent preparation and launch of UASat by HES at an mutually agreed time, which is presently estimated to be in the fall of 2001. An approval for a HES launch with a tentative launch date would be sufficient at this time.

We are fully aware of NASA's suborbital program for university student experiments in balloon and rocket flights, and of NASA's student satellite programs, such as SEDTI, SEDSat, and others. Our SSP differs from all the existing projects in at least five distinct ways: 1) SSP is completely student driven; 2) UASat is a complete orbiter being designed and to be fabricated and tested either by or under the supervision of students; 3) SSP does not seek NASA funding for the development of UASat; 4) UASat will be a student satellite produced through an unprecedented experiment in university-industry-community collaboration without federal funding; 5) SSP seeks a NASA-supported launch by the existing and proven HES.

Descriptions of SSP and its UASat in the previous sections have clarified the above points, except the justification of our choice of HES for the launch. From the experience of other student satellite projects, such as the CatSat of the University of New Hampshire, the SEDSat of the University of Alabama at Huntsville, and the ASUSat of the Arizona State University, we have learned that it is important to settle for a launcher before designing the satellite. We have heard of the need of changing mission objectives and instrument designs due to changes in either the launchers or in the primary payloads, all frustrating to the powerless students. We have noticed that while either waiting for the development of a "cheap launcher" (estimated at $1M per launcher) or a "free ride" that would suit our preconceived mission objectives, we taxpayers have already paid for the development of a reliable launcher with a frequent and predictable launch schedule and delivers orbits that could be used for student satellites to do meaningful science. No other existing launcher offers the flexibility in setting a launch date, a crucial feature to accommodate learning-oriented projects. We are astonished that NASA does not have such an option in its student suborbital program and that we are the first to exploit this avenue in the manner being proposed here.

Our request clearly does not fit any of the existing NASA programs, thus providing NASA and ourselves a dilemma. We are optimistic, however, based on Administrator Dan Goldin's vision of NASA presented to us on 15 May 1998 at our University -- NASA is a "can do" organization, opening new possibilities and willing to take risks -- that the role of NASA sought by us in this proposal can indeed be realized and that HES can be better used for educational purposes in the absence of any "cheap launcher".

1.3 *Impact*

1.3.1 Scientific Impact

The impact of simple counting research is that lightning is intimately related to storm convection dynamics, and can be correlated to the global rates, amounts and distribution of convective precipitation (Davis et al., 1983). While ground-based data collections significantly contribute to these studies, space-borne measurements of lightning have the advantage of near global coverage, especially over data-poor regions such as the middle Pacific region. Space-borne systems are also not limited to observing cloud-to-ground strikes as are typical ground-based systems. Lightning observations provide information to locate areas of deep convection and to test prevailing hypotheses for the relationship between lightning and graupel/hail. Because of lightning=s crucial role in the global electric circuit, the lightning counts from this work can be used to better understand the generation of the the Earth's fair weather electric field. Other areas of research include correlating lightning counts with studies of tropospheric ozone formation and nitrogen fixation from lightning discharge and studying the relationship between thunderstorm electrification and tornadogenesis.

In general, detailed studies of sprites are expected to reveal important new information about the microphysical processes by which these phenomena transfer energy from underlying thunderstorms and to the upper and middle atmosphere. Numerous models related to the causes of sprites have been developed in recent years. However, the lack of a global mapping of sprite occurrences inhibits fully testing these models. The simple act of mapping the spatial frequency of sprites will significantly impact the science of sprite modeling.

In light of the ubiquitous use of standard star measurements in stellar photometry, this portion of the primary science mission will provide an important. Such a contribution will have far-reaching long-term benefits to the astronomical community.

Reference: Davis, M.H., Marx Brook, Hugh Christian, Brian G. Heikes, Richard E. Orville, Chung G. Park, Raymond G. Roble, and Bernard Vonnegut. "Some scientific objectives of a satellite-borne lightning mapper", Bulletin of the American Meteorological Society, vol. 64, No.2, February
1983.

1.3.2 Programmatic Impact

The approval of this proposal would prove the willingness of NASA to support a pilot project, a new and innovative approach to the education and training of future space scientists and engineers, that could serve as a model of how university, industry, community, and NASA could work together to produce the effects none of the participants could do on its own. This model of broadly based collaboration can be translated into other fields of endeavor nationwide.

The immediate impact would be on all the participants -- the students, their menotrs and advisors, the industries, and the supportive community -- who have shown their enthusiasm and abilities. They will be encouraged and enabled to complete their commitment for the success of UASat, to set an example for future industry-university-community collaborations that takes advantage of national capabilities already developed by the taxpayers. This impact is expected in maintaining the competitive edge of this nation (§ 1.4.2.)

The approval of this proposal would also take NASA’s education and public-outreach efforts to new frontiers, where its exiting capabilities, such as launching small payloads by the HES, or its successor SPRITES, can be more fully utilized and appreciated for the benefit of the taxpayers.

1.4 *Relevance*

1.4.1 Scientific Relevance

The lightning detection experiment will supplement data collected by Marshall Space Flight Center's Lightning Imaging Sensor (LIS) and Optical Transient Detector which were launched in 1997 and 1995 respectively. The lightning monitoring data we obtain will also be combined with the LIS and OTD data to contribute significantly to the global lightning climatological database currently under development as part of NASA’s Office of Earth Science. This database is currently being used for studies of Earth's water cycle, sea-surface temperature variations, electrical coupling of thunderstorms with the ionosphere and magnetosphere, and modeling of the global distribution of electrical fields and currents in the Earth's atmosphere. The sprite experiment has similar relevance. However, there does not exist at this time a centralized database of sprite counts, thus we will ensure that our data are available to the modeling community through ftp and world-wide-web distribution.

The relevance of the stellar photometry experiment is that past research done between the northern and southern hemispheres will not have to rely on convoluted use of multiple of standard stars for comparison purposes. Rather, the results of this work will allow direct comparisons improving the accuracy of this past work. The results should also provide an additional check on more recent experiments such as the Hipparchos mission.

1.4.2 Programmatic Relevance

The educational objectives and programmatic approach described in § 1.1.2 and § 1.2.2, respectively, speak clearly what SSP has begun to do is of great relevance to the future of America. Earlier this year, the National Innovation Summit, an impressive assembly of American leaders that included the Vice President of the United States, members of Congress from both sides of the aisle, governors, university presidents, and the leaders of our most prominent corporations, was held at the Massachusetts Institute of Technology to discuss the means to maintain the competitive edge of America in a world of globalization. Dr. Peter Likins, President of the University of Arizona, who attended the meeting, observed, “The deepest and most nearly intractable problems in keeping our competitive edge involve our talent pool, the most critical element for success in the global economy.” He also noticed, “With economies and opportunities improving throughout the world, however, we can no longer rely on immigrants to satisfy the needs of our high tech economy. We must grow our own scientists and engineers, ...”

There are many ways to grow our own scientists and engineers; and SSP is an unique example. Only in American can a project like SSP be possible. Only NASA can put a student satellite in orbit by an existing and proven ejection system at minimal cost and effort. We choose to take on this possibility and to make use of this national capability. The relevance of SSP and the new role of NASA on the national competitive edge cannot be over emphasized.

1.5 *Work Plan*

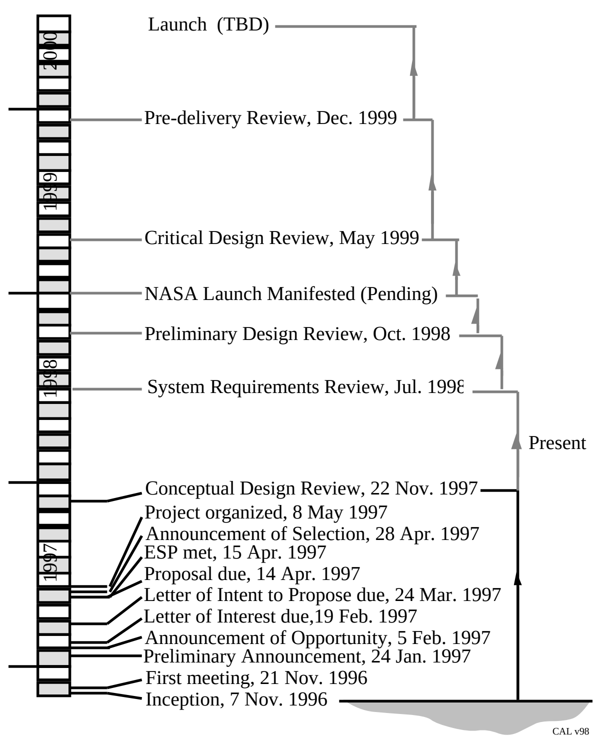

Fig. 1.5.A UASat Milestones and Goals

The progress made and the milestones ahead are depicted in Figure 1.5.A. This is a new project, testing new waters as it progresses. Thus far all its plans were executed successfully, *i.e.* , tasks were carried out as planned, with all the supports from different resources. Most recently, there is one postponement in the schedule -- the Systems Requirements Review has to be delayed for a month. This is due to the unavailability of most of the members of the ESP during the summer months in Tucson. One should keep in mind that all members of ESP are busy persons who volunteer their precious time to SSP! This is the first time this body could not meet. In the previous two reviews, the ESP had 100% attendance!

The dates of the milestones beyond the present are only tentative. In the meantime, the teams are learning to make realistic schedules -- first to make sure that all necessary tasks are considered and then learn to estimate more accurately the time required of each task. All this takes experience, and this is where the mentors and advisors become useful to the students. The weekly meetings of the teams with their respective Team Mentors, and of the Team Leaders with the Project Manager and Assistant have been successful in keeping the schedule.

In addition to the major reviews shown in Figure 1.5.A, are the Semester Reviews, which are attended by selected members of the Mission Advisory Pool (MAP) to keep the project on track. This is a natural periodic function that follows the basic academic rhythm -- the semester.

As shown in Figure 1.5.A, more time is assigned to the design phases, because carefully planned good design can save time in later fabrication and testing. The enthusiasm of the students, the dedication of the mentors, and the caring of the members of MAP and ESP, together make the project move smoothly. Nevertheless, the learning nature of this project requires patience and flexibility in setting schedules. The choice of HES as the launcher becomes clear. The milestone ahead will become more certain, if NASA would give soon its green light to launch UASat on the HES sometime in 2001.

1.6 *Collaborations*

The SSP and its UASat are an experiment in collaboration. On one level, the different departments and units at the University must work together. This is working well. On another level, the four vital elements of our society: the community, the university, the industry, and the government, must work together (see Fig. 1.2.2.A). The government here is NASA and NSF, of which NASA has by far the most crucial role, *i.e.* to put UASat in orbit. This is the very reason of this proposal. To be successful, it may require the working together of the different programs within NASA!

The roles of the collaborators, the university, the community, the industry, and NASA are described in detail in § 1.2.2.2.1 - § 1.2.2.2.4, and will not be repeated. The collaboration among the University, the community, and the industry has already begun and is growing in pace with the progress of SSP on UASat. The collaboration needed to move UASat forward from its present preliminary design will definitely depend on the decision of NASA on this proposal. Section 6 exhibits the willingness and readiness of the four prime industries that have already began their contribution to the SSP effort on UASat. Such potent resources, only exist in America, are ready to be tapped pending on the decision of NASA on this proposal.

2. Facilities and Equipment

Different phases of the project need different facilities and equipment. Thus far, all needs are met. The University, through its different units, has provided office and lab space in different departments, computers and software for operational and design activities, materials and machine shops. As the project progresses, the many special lab facilities on campus will be made available for fabrication and testing. What the university does not have, namely, spacecraft level testing and handling prior to delivery to GSFC, we expect the industries to let us use their existing facilities and equipment without cost. The SSP will also arrange for transporting UASat to GSFC, without NASA funding. At GSFC, we expect the Shuttle Small Payloads Project Office to provide all the necessary service for a safe and successful launch without cost to SSP. The provision of the last part is what we seek in this proposal.

3. Education and Public Outreach (E/PO)

As described in § 1, the SSP and its UASat are educational endeavors of a new kind. Also mentioned in § 1.2.2.2.3, the SSP has its own E/PO component; *i.e.* working with the Pima Community College students through the NSF funded Bridge Program, and working with the Pima Air & Space Museum to inform the public, especially the students in elementary schools, to be more aware and interested in their local student space project. A letter of commitment from the Museum is found in § 6. If the appropriate program element of the Office of Space Science deems our project worth considering for E/PO funding, we will submit a proposal for such support as soon as we are notified.

4. Curriculum Vitae

Principal Investigator:
K. C. Hsieh: born in Chungking, China, 1940; B. A. in physics, Wabash College (1963);
Ph. D. in physics, University of Chicago under Prof. John A. Simpson (1969).
Physics faculty, University of Arizona, since 1971; Professor of Physics since 1993.
Acting Head, R & D Division of the National Space Program Office, Republic of China, 1993-1994. Initiator and Project Mentor of the Student Satellite Project at the University of Arizona.

Hsieh's research ranges from cosmic-ray composition and modulation, atomic and molecular physics, to cometary coma. He has worked on particle detection techniques ranging from dE vs. E solid-state telescopes, time-of-flight analyzers, to field-ionization and field-emission mass spectrometers. He pioneered the development of techniques for the study of space plasma via energetic neutral atoms (ENAs) in the energy range of 10 to a few hundred keV. He proposed the use of ENAs to study space plasma as early as 1980 for the NASA's OPEN. Only the launch of ESA's SOHO in 1995 gave him his first chance to use this new technique and detected heliospheric energetic hydrogen atoms for the first time. His recent activities, in addition to teaching, include participation in SOHO, Cassini and IMAGE as co-investigator.

Publications Relevant to this Proposal:

K. C. Hsieh and C. A. Lewicki, "A Student Satellite Project" an invited talk at COSPAR Colloquium on Scientific Microsatellites "Microsatellites as Research Tools", National Cheng Kung University, Tainan, Taiwan, ROC, 14-17 December 1997, to be published in COSPAR Colloquium Series (Elsevier, 1998).

Co-Investigators: (In alphabetic order)

Jo Dale Carothers:
Data & Command Handling Team Mentor, SSP.

Weinong (Wayne) Chen: born in ZheJiang Province, China, 1961; B.S. and M.S. in Aircraft Engineering from Beijing University of Aeronautics and Astronautics (1982; 1985); Ph.D. in Aeronautics, California Institute of Technology (1995).
Industrial experience includes senior design engineer at McDonnell Douglas (now Boeing). Assistant Professor of the Aerospace and Mechanical Engineering Dept., University of Arizona since 1995. Elected by students as the Most Supportive Junior Faculty in AME (1996; 1997);

recognized by the College of Engineering and Mines for Excellent Student Interface (1997; 1998). Mechanical Structure & Analysis Team Mentor, SSP.

Chen's research concentrates on the fatigue and dynamic response of engineering materials. His current research projects include: control of microstructure and fatigue of automotive aluminum castings; development of superior materials for layered solid oxide electrolyzers based on mechanical and thermal failure testing and analysis; dynamic response of elastomeric materials; dynamic behavior of geomaterials; and material failure formulation and modeling.

Ernest D. Fasse: born in Burlington, Colorado, in 1963; S. B. (1985), S. M. (1987) and Ph.D. (1992) in Mechanical Engineering from M.I.T. under Prof. Neville Hogan.
Postdoctoral researcher with the Electrical Engineering Dept., University of Twente, the Netherlands (1993-1995; one year as an NSF NATO fellow); Assistant Professor of the Aerospace and Mechanical Engineering Dept., University of Arizona, since 1995.
Navigation, Guidance & Control Team Mentor, SSP.

Fasse's research is generally in the area of modeling, state estimation, and control of space mechanical systems. Specifically he has developed intuitive, Euclidean geometric techniques of controlling the mechanical impedance of spatial robotic devices. The mechanical architectures of these devices include serial kinematic chains; parallel kinematic chains; and free-floating, electromagnetically levitated platforms. Similar mathematical techniques have been applied to the modeling of elastically coupled rigid bodies. Thus far the methods have been implemented on a serial robot. He is collaborating with a group at CMU to control a levitated platform.

Fasse is the faculty mentor of the Guidance, Navigation and Control (GNC) team of the Student Satellite Project. Current activities of the group include (1) design and fabrication of low-cost reaction wheels, (2) quaternion-based attitude estimation using extended Kalman filtering methods, (3) sensor design and fabrication, including a photodiode-based solar sensor and a linear-CCD-array-based horizon sensor, (4) design and fabrication of magnetotorquers, and (5) attitude control for inertial pointing and Earth pointing.

Ten Publications Relevant to this Proposal:

Fasse, E.D. & P.C. Breedveld. "Modeling of Elastically Coupled Bodies: Part I: General Theory and Geometric Potential Function Method," Accepted for publication in ASME J. of Dynamic Systems, Measurement and Control (1998).

Fasse, E.D. & P.C. Breedveld. "Modeling of Elastically Coupled Bodies: Part II: Exponential- and Generalized-Coordinate Methods," Accepted for publication in ASME J. of Dynamic Systems, Measurement and Control (1998).

Fasse, E.D. & C.M. Gosselin. "Spatio-Geometric Impedance Control of Gough-Stewart Platforms," Accepted conditionally for publication in IEEE Trans. Robotics and Automation (1998).

Fasse, E.D. "On the Spatial Impedance Control of Levitated Platforms," Proc. 4th IFAC Nonlinear Control Systems Design Symposium NOLCOS 98 (1998).

Fasse, E.D. & C.M. Gosselin. "On the Spatial Impedance Control of Gough-Stewart Platforms," Proc. 1998 IEEE Int. Conference on Robotics and Automation (1998).

Fasse, E.D. "On the Spatial Compliance of Robotic Manipulators," ASME J. of Dynamic Systems, Measurement and Control, 119:839-844 (1997).

Fasse, E.D. & J.F. Broenink. "A Spatial Impedance Controller for Robotic Manipulation," IEEE Trans. Robotics and Automation, 13:546-556 (1997).

Fasse, E.D. "On the Spatial Compliance Control of Parallel Manipulators and Levitated Platforms,"
Proc. of the ASME Dynamic Systems and Control Division, ASME DSC-Vol. 61:511-518 (1997).

Goeree, B.B., E.D. Fasse, M.J.L. Tiernego & J.F. Broenink. "Sliding Mode Control of Spatial Mechanical Systems Decoupling Translation and Rotation," Proc. of the ASME Dynamic Systems and Control Division, ASME DSC-Vol. 61:545-554 (1997).

Fasse, E.D. & N. Hogan (1996). "Control of Physical Contact and Dynamic Interaction", Robotics Research: The Seventh International Symposium, G.Giralt and G. Hirzinger (Eds), Springer Verlag, 28-38.

Uwe Fink:
Science Team Mentor (Stellar Photometry portion), SSP.

Fink has spent most of his academic career on solar system investigations using ground based and airborne observatories. He has developed and built a variety of photometric and spectroscopic instruments. His main research interests include planetary atmospheres, satellite and asteroid surface composition and the study of comets.

Hal S. Tharp:
Associate Professor
Electrical and Computer Engineering
College of Engineering

Power Generation & Distribution (PGD) Team Mentor, SSP.

Tharp's research area is in the general area of Control Theory. He has worked on a gyroscopically stabilized movie camera platform, calorimeters for Mars missions, controlling tumor temperatures during hyperthermia cancer treatments, optical disk drives, automated interferometry equipment, and control laboratory demonstration mechanisms. Besides these research activities, He has supervised many students (probably over 100) on their senior projects in electrical and computer engineering. The various activities associated with the Student Satellite Project represent a natural extension of his research and supervision activities.

Kurtis J. Thome: born in Milwaukee, Wisconsin, in 1963; B. S. in Meteorology, Texas A and M University (1985); M. S. in Atmospheric Sciences, University of Arizona (1989); Ph. D. in Atmospheric Sciences, University of Arizona under Prof. Benjamin M. Herman (1990).
Assistant Professor, Optical Sciences Center, University of Arizona since 1994.
Science Team Mentor, SSP.

Thomes' research activities includes work in support of NASA's Office of Earth Sciences as a member of the Landsat-7 and ASTER Science Teams, Associate Team Member of MODIS, and Science Advisory Team Member for New Millennium Project's EO-1. His research focuses primarily on developing algorithms for the absolute radiometric calibration after launch, but also includes work on the preflight characterization and design of these systems. Since this work exposes him to the entire process of developing an earth-orbiting sensor, from design to data processing, he is able to pass this experience on to the Science Team, SSP.

Five Publications Relevant to this Proposal:

K. Thome, S. Schiller, J. Conel, K. Arai, and S. Tsuchida, "Results of the 1996 joint, EOS vicarious calibration campaign to Lunar Lake, Nevada," in Metrologia, in press.

M. Sicard, K. J. Thome, B. G. Crowther, M. W. Smith, "Shortwave infrared spectroradiometer for atmospheric transmittance measurements," Journal of Atmospheric and Oceanic Technology, vol. 15, 174-183 (1998).

K. Thome, B. Markham, J. Barker, P. Slater, and S. Biggar, "Radiometric calibration of Landsat," in Photogrammetric Engineering and Remote Sensing, vol. 63, 853-858 (1997).

P. N. Slater, K. J. Thome, K. Arai, H. Fujisada, H. H. Kieffer, A. Ono, F. Sakuma, F. D. Palluconi, and Y. Yamaguchi, "Radiometric calibration of ASTER data," Japanese Journal of Remote Sensing, vol. 15, pp. 16-23 (1995).

K. J. Thome, M. W. Smith, J. M. Palmer, and J. A. Reagan, "Three-channel solar radiometer for determining atmospheric columnar water vapor," Applied Optics, vol. 33, pp. 5811-5819 (1994).

Kathleen L. Virga:
Tracking, Telemetry & Command (TTC) Team Mentor, SSP.

William H. Wing:
Strategic Technology Initiative (STI) Team Mentor, SSP.

5. Current and Pending Support

Information on each of the investigators is listed separately below.

5.1 *Current Support*

Pincipal Investigator: K. C. Hsieh

- Subcontract from Applied Physics Lab of Johns Hopkins University
  MODA of Magnetospheric Imaging for Cassini Saturn Orbiter
  Funding Period: 1 November 1998 - 30 September 2008
  Amount: $ 36,290.
  P. I.: Hsieh works at no cost.

- Subcontract from Southwest Research Institute
  Pre-launch Phase of Imager for Magnetopause to Aurora Global Explorer
  Funding Period: 23 May 1996 - 31 January 2000
  Amount: $158,992.
  P. I.: Hsieh works at no cost.

- NSF Solar-Terrestrial Research Program

Studying the Energetic Particles at the Termination of the Solar Wind via Energetic Neutral Atoms
Funding Period: 1 January 1998 - 31 December 1999
Amount: $ 87,694.
P. I.: Hsieh works at no cost.

- SOHO Guest Investigator Grant from NASA
Funding Period: 1 November 1997 - 31 October 1998
Amount: $ 38,129.
P. I.: Hsieh: 4/5 summer month at $4,952.

Co-Investigators: *(In alphabetic order)*

Jo Dale Carothers:

Weinong (Wayne) Chen:

- Control of Microstructure & Fatigue of Automotive Aluminum Castings, DoE
Funding Period: 1 September 1996 - 31 July 1999
Amount: $405,000
P. I.: Chen: 1 summer for 1997 and 1998 at ~$12,000.

- Development of Superior Materials for Layered Solid Oxide Electrolyzers Based on Mechanical and Thermal Failure Testing and Analysis, NASA
Funding Period: 1 May 1998 - 31 September 2001
Amount: $265,000
P. I.: Chen: 1 summer for 1998-2001 at ~$25,000.

- Dynamic Response of Elastomeric Materials, Sandia Natn'l Lab
Funding Period: 1 May 1998 - 31 January 1999
Amount: $30,000
P. I.: Chen: 1 summer for 1998 at ~$6,000

- Dynamic Behavior of Geomaterials, U. S. Army
Funding Period: 1 January 1998 - 31 January 1999
Amount: $10,000
P. I.: Chen works at no cost.

- Material Failure Formulation and Model, Allied Signal
Funding Period: 1 August 1998 - 31 December 1998
Amount: $20,000
P. I.: Chen works at no cost.

Ernest D. Fasse:

Hal S. Tharp:

Kurtis J. Thome:

- Absolute Radiometric Calibration and Atmospheric Correction of Landsat-7 Thematic Mapper, NASA

  Funding Period: 15 October 1996 - 14 October 1999

  Amount: $487,840

  P. I.: Thome: 25% of academic salary & 33% of summer salary

- Feasibility of developing an atmospheric correction routine for operational use in a commercial environment, Boeing

  Funding Period: 15 May 1998 - 15 September 1998

  Amount: $32,110

  P. I.: Thome: 1 month summer salary

- Absolute Radiometric Calibration of EOS, NASA

  Funding Period: 15 January 1992 - 14 December 2001

  Amount: $11,665,266

  P. I.: Thome: 25% academic salary and 67% summer salary

Kathleen L. Virga

William H. Wing

5.2 *Pending Support*

Pincipal Investigator: K. C. Hsieh

- SOHO Guest Investigator Grant from NASA

  Funding Period: 1 November 1998 - 31 October 1999

  Amount: $ 45,261.

  P. I.: Hsieh: 1 summer month at $6,190.

Co-Investigators: *(In alphabetic order)*

Jo Dale Carothers:

Weinong (Wayne) Chen:

- Mechanical Response and Failure Behavior of Pure and Toughened Polymers under Dynamic Multiaxial Loading at Various Temperatures, NSF (CAREER)

  Funding Period: 1 January 1999 - 31 December 2002

  Amount: $206,000.

  P. I.: Chen: 1 summer month 1999-2002.

Ernest D. Fasse:

- CAREER Grant from NSF

  Funding Period: 1 January 1999 - 31 December 2002

  Amount: $200,000.

  P. I.: Fasse: 1 summer month 1999-2002.

Hal S. Tharp:

Kurtis J. Thome

- Combined Lidar and passive sensing techniques for characterization of aerosol radiative effects, NASA Research Announcement 97-MTPE-16

  Funding Period: 1 June 1998 - 31 May 2001

  Amount: $322,787.

  Co-I.: Thome: 1 summer month 1998-2001.
  P. I.: J. A. Reagan

Kathleen L. Virga:

William H. wing:

6. Letters of Commitment from Collaborators

7. Budget Details

This proposal seeks the scientific sponsorship of the Suborbital Program for our request for NASA's commitment to launch a satellite by the Hitchhiker Ejection System (HES), *i.e.*, the approval of our Form 1628. We seek no funding other than the expenses required by the Shuttle Small Payloads Project (SSPP) in the preparation and the launch, can best be provided by SSPP. For informational purpose, we show the estimated cost for SSP's effort in delivering a completed UASat to SSPP/GSFC and the post-launch MODA. None of the expenses listed in this estimated budget will come from NASA. We don't have all the money we need, but a commitment from NASA to provide a HES launch would give us the opportunity to continue our quest. We started with nothing but an idea. We have won all the support as we went on doing what we thought to be consistent. There is no reason it will not continue as we move towards our set goal.

References

[1] Hitchhiker Customer Accommodations and Requirements Specification, Goddard Space Flight Center, 1994

[1] NSTS 1988 News Reference Manual

[1] International Space Station Assembly Sequence (5/31/98: Revision D)

[1] International Space Station Fact Book

[1] A Student Satellite Project, K. C. Hsieh, C. A. Lewicki, COSPAR Colloquia series Microsatellites as Research Tools, Elsevier Science 1998.

[1] Student Satellite Project Conceptual Design Review Document, November 22, 1997.

[1] UASat Spring 1998 Semester Review Book

[1] The Role of Space Shuttle Videotapes in the Discovery of Sprites, Jets, and Elves; W. Boeck, et al.

[1] Fishman, G.J., Bhat, P.N., Mallozzi, R., Horack, J.M., Koshut, T., Kouveliotou, C., Pendleton, G.N., Meegan, C.A., Wilson, R.B., Paciesas, W.S., Goodman, S.J. and Christian, H.J., Discovery of intense gamma-ray flashes of atmospheric origin, Science, 264, 1313-1316, 1994.

[1] STI-002 Laser Uplink Experiment Overview, UASat Technical Note online at http://www.physics.arizona.edu/ssp/documents/technotes/

[1] Read more about SEDSAT-1 at http://www.seds.org/sedsat/

[1] Students for the Exploration and Development of Space Satellite 1 (SEDSAT-1): A Student Designed and Built Satellite and Ground Data System, C. Lewicki, A. Tubbiolo, H. Knoepfle, T. Bressi, G. McArthur, American Astronomical Society, Division of Planetary Sciences Conference Poster, 1996.

[1] GNC-005 Reaction Wheel Overview, UASat Technical Note

[1] GNC-006 Coarse Sun Sensor Overview, UASat Technical Note

[1] SSP Listservs online at: http://www.physics.arizona.edu/email/

[1] SYS-001 Technical Note Overview, UASat Technical Note

Appendices

Appendix A: Team Mentors (Spring 1998)

Team	*Mentor/Title*	*Department*
Science	Kurt Thome, Asst. Prof.	Optical Sciences
	Uwe Fink, Prof.	Planetary Sciences
Data & Command Handling	Jo Dale Carothers, Assoc. Prof.	Electrical & Computer Eng.
Tracking, Telemetry & Command	Kathleen Virga, Asst. Prof.	Electrical & Computer Eng.
Guidance & Navigation Control	Ernie Fasse, Asst. Prof.	Aerospace & Mechanical Eng.
Power Generation & Distribution	Hal Tharp, Assoc.. Prof.	Electrical & Computer Eng.
Mechanical Structure & Analysis	Wayne Chen, Asst. Prof.	Aerospace & Mechanical Eng.
Strategic Technology Initiative	Bill Wing, Prof.	Physics and Optical Sciences

Appendix B: The Mission Advisory Pool (MAP)

Name	*Current Position*	*Expertise*
Steve Bell	Senior Staff Eng., LPL	Space-borne electronics
Bill Bickel	Prof., Physics	Particle accelerator for detector calibration and radiation effects on space-borne instruments
Lyle Broadfoot	Senior Res. Scientist, LPL	Space-borne EUV imagers. PI on numerous space missions.
Matt Cheselka	Res. Specialist, Steward Obs.	
Elliot Chu	Asst. Prof., Physics	Particle detection & digital electronics
Charles Curtis	Res. Assoc. Prof., Physics	Space-borne particle & EUV detectors.
Roger Davies	Assoc. Prof., Atmospheric Sci.	Cloud physics from space
Eustace Dereniak	Prof. Optical Sci.	IR detector & imagers.
C. Y. Fan	Prof. Emeritus, Physics	Space physics
Uwe Fink	Prof., LPL	Stellar photometry
Sy Goodman	Prof., Managem. & Info. Systems	Management
Larry Head	Asst. Prof., Sys. & Industrl. Eng.	Complex systems.
Keith Hege	Assoc. Astronomer, Steward Obs.	Opto-electronics
Ben Herman	Head, Atmospheric Science	Remote sensing via GPS
Jeff Jacobs	Assoc. Prof., AME	Fluid dynamics
Philip Krider	Prof., Atmospheric Science	Lightning & sprites
Larry Lebofsky	Sr. Res. Sci., LPL	Solar system small bodies
Alfred McEwen	Assoc. Res. Sci., LPL	Remote sensing surfaces
Kumar Ramahalli	Prof., AME	Space-borne new materials
Bill Sandel	Sr. Res. Sci., LPL	Space-borne EUV imaging
K. R. Sridhar	Assoc. Prof., AME	Spacecraft engineering
Tom Vincent	Prof., AME	Control & guidance.

Appendix C: The Evaluation & Selection Panel (ESP)
(Names followed by * are representatives from the industry.)

Name	*Current Position*	*Expertise*
Ralph Lorenz (Chair)	Res. Assoc. LPL	Nine years of experience on small satellites at Univ. of Surrey, Univ. of Kent, & ESA. Mars probe.
Jill Bechtold	Assoc. Prof., Astronomy	Active in space-based astronomy. Member of NASA selection panels.
Bob Brown	Prof., LPL	Planetary surface science. Mars missions.
Chuan F. (Tony) Chen	Prof., AME	Fluid dynamics & complexity
Don Huffman	Regents Prof., Physics	Optical properties of matter. Nobel nominee for his work on C_{60}.
Don Hunten	Regents Prof., LPL	Senior member of space physics & planetary aeronomy communities. Member of National Academy of Sciences and various national panels.
Matthew Jones	Asst. Prof., AME	Radiative heat transfer
Ron Jost*	Chief Engineer, IRIDIUM Project, Motorola	Systems engineering, integration and testing. DoD & NASA programs since 1969.
Bill Kerwin	Prof. Emeritus, ECE	Analog & digital circuits
Pitu Mirchandani	Head, System & Industrl. Eng.	Complex systems
James Palmer	Assoc. Res. Prof., Optical Sci.	Spacecraft solar-cell engineering.
Ed Pierce*	Adj. Assoc. Prof., ECE Senior Engineer, Hughes	Microwave specialist. 34 yrs. with Hughes from design to project management.
John Reagan	Head, ECE	Space radiometry & remote sensing.
Rich Van Riper*	Chief Engineering Fellow, Honeywell Satellite Systems	Attitude control & guidance, data handling systems. 35 yrs. in space engineering.
Don J. Ruedy*	Director of Knowledge Center, Raytheon	Systems engineering, coordinating collaborations with universities
Richard Schotland	Prof., Atmospheric Sciences	Space-borne LIDAR experiments.
Bobby Ulich*	Vice-Pres., Kaman Aerospace Res. Prof., Astronomy Chief Engineer, MMT	Electro-optics development. First space-borne adoptive optics.

Appendix D: Funds Received from Different Units within the University of Arizona (as of June 1998)

Source of Funding	*Amount*	*Remarks*
Department of Planetary Sciences, Lunar and Planetary Laboratory	$4,000.	For hardware for Satellite Ground station (Challenge grant to ECE). Given under auspices of SEDSat. (Before inception of SSP)
Department of Electrical and Computer Engineering	$4,000.	For hardware for Satellite Ground station (Challenge grant from PTYS/LPL). Given under auspices of SEDSat. (Before inception of SSP)
Department of Physics	$5,000.	Summer student stipends; office supplies; and partial support for student travel to AIAA in Utah.
Prizes from Student Showcase, 1997	$500.	SSP won first place in engineering undergraduate and first place in engineering graduate.
Department of Atmospheric Sciences	$5,000.	Summer student stipends
Space Grant	$38,187.	$6785 5 undergraduate students $25402 1 graduate fellowship $6000 Cash and 486 computer $68 Joel Rademacher's airfare to informational meeting at UA $1000 Partial travel to AIAA in Utah
UA Research Small Grants	$5,000.	Awarded to Prof. Wing for STI use.
Remote Sensing Group of the Optical Sciences Center	$2,000.	For optical-sensor prototype hardware.
Dean of Science	$5,000.	Operational and student support.
Dean of Engineering	$6,000.	Engineering mentor support.
Vice President of Research	$10,000.	Operational and student support.
Provost’s Office	$12,665.	Instructional equipment & software.

For in-kind support, see § 1.2.2.2.

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[i] NSTS 1988 News Reference Manual

[ii] International Space Station Assembly Sequence (5/31/98: Revision D)

[iii] International Space Station Fact Book

[iv] Read more about SEDSAT-1 at http://www.seds.org/sedsat/

[v] Students for the Exploration and Development of Space Satellite 1 (SEDSAT-1): A Student Designed and Built Satellite and Ground Data System, C. Lewicki, A. Tubbiolo, H. Knoepfle, T. Bressi, G. McArthur, American Astronomical Society, Division of Planetary Sciences Conference Poster, 1996.

[vi] GNC-005 Reaction Wheel Overview, UASat Technical Note

[vii] GNC-006 Coarse Sun Sensor Overview, UASat Technical Note

[viii] STI-002 Laser Uplink Experiment Overview, UASat Technical Note online at http://www.physics.arizona.edu/ssp/documents/technotes/