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UMES-AIR: A NASA-UMES Collaborative Experiential Learning Project

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Abstract

UMES-AIR (**U**ndergraduate **M**ultidisciplinary **E**arth **S**cience-**A**irborne **I**maging **R**esearch) project which was partially funded by NASA Goddard Space Flight Center (GSFC) in the fall of 1999 has provided a platform for involving a group of undergraduate students in mathematics, science, engineering and technology (MSET) curricula at University of Maryland Eastern Shore (UMES) in an "out of classroom" active learning and exploratory research experience in the field of remote sensing and its applications. The project involves flying an instrumented payload on a tethered blimp filled with helium to a height of upto 2000 feet. The payload includes monochrome and color cameras attached with different band-pass filters, transmitters, and the power supply for all on-board power requirements. The transmitters are used to transmit the acquired images to the ground where they are received at the ground station and displayed and recorded on a Video-Cassette Recorder cum Television unit. The scientific objective of the project includes aerial imaging in the visible and infrared region of the electromagnetic spectrum, land survey, study of shoreline erosion, research in agricultural land use patterns, and environmental studies pertaining to algal blooms in the Chesapeake Bay. The project also has a strong focus towards educational objectives and involves more than twenty students from different MSET curricula at UMES.

UMES administration has strongly supported the activity by providing space for the blimp shed, and encouraging student and faculty involvement. The initial phase of the project has drawn significant student participation. The project has also received additional funding from the University System of Maryland for promoting recruitment and retention of minority and economically disadvantaged students. The first phase of the project has been a success. The blimp with the instrumented payload has been flown over the UMES Campus to a height of 500 feet. The acquired images are currently being analyzed. Subsequent launches for the blimp are scheduled to be at UMES agricultural fields and the Wallops Flight Facility of NASA.

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I. Introduction

The term "Remote Sensing" is attributed to the collection of information about an object without being in physical contact with the object. Aircraft and satellites are the common platforms from which remote sensing observations are made. The two modes of remote sensing may be broadly classified as *active*, where the sensing is achieved by transmitting energy to, and receiving energy from the sensed target (e.g., radar, lidar etc.), and *passive*, where the energy source is the sun. This paper describes a NASA-UMES collaborative project primarily involving passive remote sensing experiments using reflectance patterns in the visible region of the electromagnetic spectrum using color and monochrome cameras on board a payload attached to a tethered blimp.

The spectral information captured by the cameras has been successfully transmitted via onboard transmitters and has been received on the ground using a receiver and displayed on television monitor. The captured images are currently being analyzed using Multispec[1] an image analysis package developed at Purdue University. A commercially available software package called ERDAS[2] will also be used for image analysis in the future. Future plans also include experiments/applications in the infrared region as well. The scientific objectives include generating information concerning vegetation growth, shoreline erosion, changing land use patterns and wildlife management. Initial tests are being performed on surfaces that have distinctly different spectral signatures such that pattern classification can be done with relative ease.

More than twenty students involved in the project are working in different teams involving various aspects of the project. While freshman and sophomore students in the UMES Engineering Program have shouldered majority of the responsibilities they have received significant support from students in Construction Management Technology, Mathematics and Computer Sciences and Engineering Technology programs in the UMES campus. Weekly meetings of the entire group supervised by faculty at UMES, NASA Engineers and Safety Officers are helping to keep the project on track. Besides project planning, design, analysis, and manufacturing to design specifications, the students are learning to work in multi-disciplinary teams which is considered to be a critical skill for success in the professional world in the new millennium [3]. This is also strongly emphasized by the Accreditation Board of Engineering and Technology (ABET Criteria 2000) [4,5].

The highlights and objectives of the project can be described as follows:

- Improve retention in MSET curricula for minorities and economically disadvantaged students under an experiential and active learning[6,7] framework.
- Complement and reinforce knowledge provided in classroom settings.
- Boost student motivation and improve study habits.
- Integrate some of the project activities with pre-college enrichment programs to assist recruitment.
- Introduce students to career pathways at NASA and provide a resume-building experience that is likely to be considered favorably by NASA and other employers.

- Stimulate development of skills necessary in the workplace (such as ability to perform in multidisciplinary teams, project planning and execution in accordance with time schedule [8], conflict resolution skills [9], leadership skills etc.)
- Provide avenues for faculty to develop interdisciplinary undergraduate/graduate research projects involving applications of remote sensing technology to the broad field of earth system science.
- Participation of NASA GSFC's Wallops Flight Facility engineers and safety officers in an active advisory capacity;
- Implementation of ideas delineated in a memorandum of understanding between University of Maryland Eastern Shore (UMES) and NASA GSFC.
- Provide opportunities for developing junior/senior design projects for Engineering/Engineering technology majors as well as thesis topics for students in the graduate programs offered in the Department of Mathematics and Computer Science and the School of Agriculture and Natural Sciences at UMES.

II. UMESAIR Project Teams, Vision and Mission Statement

The undergraduate students participating in the UMES-AIR project have been divided into teams of four to five students. Each team is responsible for specific subtasks such as gondola design and layout, tether and blimp selection, site survey, development of project website, camera selection, winch selection/design, weather monitoring, construction of blimp shed, telemetry, electrical power and wiring, image analysis, safety and other tasks related to project management. A student leader and faculty supervisor have been assigned for each team. A student has also been given the responsibility to coordinate activities of all the teams and communicate information to the advisory group consisting of UMES faculty, NASA professionals and UMES administration.

Subsequent to the receipt of partial funding from National Aeronautics and Space Administration in October 1999 weekly meetings were held every Friday during the semester. Such meetings continue to be held as of date, as the project team continues to direct their efforts to work on refining the project for the second phase.

During the initial meetings the participants including students, faculty and NASA personnel brainstormed over the project goals and objectives and identified the acronym for the project as well as a *Vision* and *Mission* statement. The expanded form of the acronym UMESAIR mentioned earlier in the paper was found to appropriately capture the project theme. The vision and mission statements that were identified are as follows:

(i)*Vision*: The vision of the UMESAIR project is to provide experiential learning primarily for undergraduate Mathematics, Science, Engineering and Technology (MSET) students. Students will interact in teams to investigate multi-disciplinary problems associated with applications of remote sensing.
(ii) *Mission*: The mission of the UMESAIR project is to design, build, and fly an instrumented payload to remotely determine coastal topographic and vegetation features.

III. Design Specification, Information Gathering and Selection of Purchased Items.

With the guiding principles established, the group proceeded to identify specifications for project goals and objectives that allowed identification of parameters associated with critical items that needed to be purchased.

Blimp, tether, winch, camera, filters, ground support equipment, telemetry equipment, weather monitoring equipment and other necessary items were all identified by student teams under supervision from faculty and NASA Engineers and Safety officers that participated in the project. The World Wide Web and manufacturers catalogs were extensively used to identify each item.

The first item to be identified was the blimp. It was decided to purchase a 21ft. long blimp with a diameter of 7 ft. Students did calculations to verify that when filled with helium the blimp would give a lift of approximately 16 lbs. as given in the manufacturer's data sheet. This also allowed discussion on Archimedes' principle which some of the students were getting exposed to in the Physics course they were taking. Since along with exploratory research education is one of the major goals of this project whenever appropriate such discussions were encouraged during the weekly meetings. The choice of the blimp was determined by the lift, the space constraints and the budget. The identification of the blimp laid the groundwork for obtaining the specification for the blimp-shed as well as the gondola or the payload that would carry the camera and transmitters for remote imaging. At this stage a team of students in the "Construction Management Technology" program proceeded to design and construct the blimp shed to house the blimp under the supervision of a faculty member in the program. The shed development proceeded in parallel with the other design, identification and purchasing activities described below.

It was decided to limit the payload to 6-7 lbs. so as to save enough buoyant force to accelerate the blimp rapidly as it went up to 2000 ft. The weight of the tether was also taken into consideration. The tether selection was based on the weight, the diameter and the load carrying ability. Although, ideally the blimp would be flown under favorable weather conditions as a safety measure the calculations were performed for relatively gusty wind speeds. In consultation with an appropriate vendor the tether selected was 0.07 in. in diameter, 0.14 lb/100 ft weight and 750 lb. of allowable breaking/tearing force which was sufficiently higher than the calculated load due to the combination of buoyant force and wind force under severe weather conditions. The tether diameter enabled the students to estimate the spool dimensions for the winch. For the initial phase it was decided to raise the blimp to a height of 500 ft. An appropriate manual winch was selected for the purpose. Since weather plays a critical role in determining whether conditions are appropriate for flying weather monitoring equipment were also identified. The selection of the cameras and transmitters were primarily based on desired function, availability, size and weight considerations since these items were the most essential components of the payload. The power requirements were also part of the selection process since the power supply for these items also had to be carried on the payload. It was decided to use rechargeable Nickel-Metal Hydride (NiH) cells for the power supply for a flight time of approximately 2 hours. At the initial phase it was decided to fly two cameras with their individual transmitters. The power requirements for these units coupled with the estimated time of flight allowed students to calculate the number of NiH cells rated at 1.2 volts each necessary to perform the task. The selection of the receiver / parabolic antenna was based on compatibility with the transmitters. Ten filter ranges that split the visible spectrum into ten frequency bands were chosen for future experimentation with multi-spectral imaging. Student teams assigned to the task identified the vendor for the filters and the ranges in consultation with UMES Natural Science faculty members. The ground support equipment consisted of a cart to attach the parabolic antenna appropriately directed to the transmitters, the receiver unit, the television cum videocassette recorder unit and the power supply for these units. A "Critical Design Review" was conducted at this stage before proceeding with the purchasing. Faculty members from various MSET programs, NASA Engineers and Safety officers critically reviewed the items that were identified by the student teams and the design consideration associated with them. Federal Aviation Administration (FAA) regulations [10] were raised at this review meeting. Some safeguards that needed to be built in to destroy the blimp if it were to escape the tether were discussed. The safety features that have been included in the project to comply with the FAA regulations have been discussed in a separate section.

IV. Electrical System Design, Gondola Development and Layout

As identified items were requisitioned through the UMES procurement department student teams concentrated on designing the structure for the payload, electrical system and the layout of the components within the payload structure. It was decided to build the structure in the form of a truss out of balsawood (See Photograph [1]). The load on the structure was not significant hence the space requirements for the housed items which included the two cameras, two transmitters, the power supply, switches and wiring arrangements were primarily considered. Other factors that were also taken into consideration in determining the shape and size of the structure were aerodynamic stability and ease of attachment to the blimp.

Each transmitter draws 0.25 and each camera draws 0.12 resulting in a total amperage of 0.74. The battery pack consists of 10 NiH batteries each 1.2 Volts. They are wired within a pack in series with one another and shrink wrapped together. The battery pack can supply the necessary current and last for more than two hours while maintaining a bus voltage of 12 Volts. While NiH batteries are less susceptible to problems associated with memory as compared to Nickel Cadmium (NiCad) batteries they can be damaged due to overheating during charging. To avoid this problem a small thermistor was taped to the pack so that while charging the temperature could be monitored. This allows immediate discontinuation of the charging process as soon as a sharp change in temperature is noticed signaling that the pack has been fully charged.

Two main areas were allocated on the gondola. One was dedicated to the power distribution and the other was utilized for the items that used the power. The power distribution portion of the electrical system consists of the wiring, current sensing, batteries and switches. The switches are blade type and are mounted in a small enclosure. Six switches are used in all, one for each camera and transmitter, one master and one for the GPS unit that may be added later. The switches are used to connect and disconnect supply power to individual components and to switch between sources internal and external.

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Power distribution system consists of a main board that is used as a junction point between the umbilical, switch box and the various components. It houses the discrete components that are used to regulate and alter the voltage coming in from the battery when appropriate. The circuit diagram for the electrical system is shown in Figure [1]. Some portions of this circuit are currently unutilized. Photograph [1] shows a picture of the complete gondola with all electrical components. It also shows the tether lines for attaching to the blimp.

V. FAA Regulations and Safety Measures

The commercially available 21 foot tethered blimp is typically operated in accordance with Federal Aviation Administration (FAA) rules and guidelines, specifically Federal Aviation Regulations (FAR) Part 101 "Moored Balloons, Kites, Unmanned Rockets and Unmanned Free Balloons"[10] outlining limitations regarding the time of day, and maximum altitude of operations, FAR Part 101 also stipulates the use of a "Rapid Deflation Device" that will automatically deflate the blimp if it were to "escape from it moorings". The blimp manufacturer pre-installs a "Seam Splitter" system that opens a large hole in the blimp envelope if it were to reach an altitude significantly higher than normal – typically between 10,000 and 20,000 ft. This Seam Splitter is quite simple, relying on atmospheric pressure reduction with increasing altitude. The run-away blimp expands as it ascends, resulting in an increase in the circumference of the envelope. This increase in circumference causes a pair of lines attached to the blimp's surface in the vicinity of a seam, to create opposing forces that cause a large hole for rapid venting of Helium. The operation of this system has been verified in tests conducted at NASA GSFC WFF.

To further enhance the reliability of compliance, a second system has been added to the UMES-AIR blimp for redundancy. This second system, an active "Blimp Blower", uses a barometric switch that is set before flight to a pre-determined altitude, typically 5000 ft above the surface. The barometric switch closes at this predetermined altitude, and allows current to flow from a Ni-Cad battery pack through a Ni-Chrome wire filament. This filament heats up and melts a hole in the blimp, allowing the Helium to escape and resulting in a loss of buoyancy. Activation time is a few seconds, and the system requires less than 5 amps of current to function. This system has been developed in collaboration with the manufacturer, and is also in use at NASA GSFC WFF.

VI. Accomplishments

The first flight of the blimp was conducted in April 2000 without the payload but with the appropriate safety measures, so that the student team got some experience with filling the helium and raising and lowering the blimp. The blimp shed had been completed by this time by the Construction Management Technology student team. They built the shed as a class project for the Spring semester of 2000. The inflated blimp could be stored in the shed after it was lowered. This avoided deflating the blimp for storage purposes and allowed helium that leaked over a period of time from the blimp to be topped of during subsequent flights. The Photograph [2] shows the completed blimp-shed.

The blimp was flown with the payload and all necessary instrumentation for the first time in July 2000. During this launch one color camera was used to acquire images from the blimp and transmitted the ground to be received, displayed and recorded on the television cum videocassette recorder included in the ground support equipment. Photograph [3] shows the ground support equipment housed on a wheeled cart. Photograph [4] shows the television monitor displaying a remote image that is being transmitted live from the payload on the blimp. This flight date overlapped with the NASA supported Summer Engineering Bridge Program [11] at UMES allowing students that would join as freshman in the fall semester to be exposed to the project. Photograph [5] was taken during this launch.

The third launch was conducted in November, 2000. The Photograph [6] was taken during this launch. Both a color camera and a monochrome camera were flown on the blimp on this day. Although the color camera successfully transmitted the remotely acquired images from the blimp, the transmission from the monochrome camera ran into some glitches. A filter changing device designed and developed by a student participant was flown on this flight. The filter changer could be activated remotely from the ground to change the filters in front of the monochrome camera to acquire images with different pass-bands. The transmission problem for the monochrome images is currently under investigation.

Students worked in teams during all these launches performing various tasks associated with the launch. A NASA engineer who is also the co-author of this paper supervised the student teams during all launches.

All the launches conducted so far has been using the manual winch with 500 ft. tether line. The Photograph [7] shows the winch mounted to the back of a pick up truck during one of the launches. The Photograph [8] shows members of the UMESAIR team attaching the gondola to the blimp via the winch and Photograph [9] shows the blimp with the gondola while it is ascending upwards.

The students have also presented the progress of the project at two conferences. At the HBCU retention summit in Ocean City, Maryland in March 2000 a significant number of students gave a team presentation with the primary author of this paper. Photograph [10] shows one of the team members giving portion of the presentation at the summit. Also at the Joint Minority University-Space Interdisciplinary Network (MU-SPIN) 10th Anniversary Users' Conference and the Minority University Research and Education Division (MURED) 2nd Annual Education Conference in Atlanta Georgia, in September 2000 one of the team members presented the project on behalf of the entire group. Her presentation was adjudged the best presentation at the conference. Both these presentations are available online [12, 13] for the interested reader. Students are also preparing a webpage for the project. The URL for the site is http://hawk.umes.edu/bbrs.

The University System of Maryland (USM) has also provided additional support to the project for its scientific scope and promise for involving and retaining students by way of active learning. While the funding from NASA has primarily provided for the equipments the USM support is directed towards student stipends and summer internships. Seven undergraduate students were hired in the summer of 2000 to work on the project. Significant progress was made over the summer. At the end of the summer the students also got an opportunity to present the project to a group of visitors from NASA.

VII. Future Plans

The project has significant merits both from the educational and scientific perspective. The immediate future plans include flying the blimp with both a monochrome and a color camera with the filter changing arrangement and transmitters appropriately functioning. Image analysis has been started however more attention needs to be devoted to this area to identify the capabilities of the software packages that have been identified for the purpose.

Also a hydraulic winch has been ordered which is being custom built for the project with a spool capacity of 2500ft. This will enable the project to meet its proposed objectives. While the manual winch performed adequately for 500ft. launch the hydraulic winch is being designed so that it is able to retract the blimp within 20 minutes from a height of 2000ft.

Investigations are underway for using GPS (global positioning system) in conjunction with UMESAIR project. One of the several uses of the GPS unit will be to ascertain the precise height and coordinates of the blimp as it ascends.

Also discussions are underway with Natural Science faculty members at UMES and NASA scientists to refine the scientific objectives of the project and develop a long term and meaningful research agenda. Significant attention continues to be paid on the educational objectives for the students as well.

VIII. Learning Outcomes

The project has provided a platform for application of knowledge and complements formal education efforts that goes on in classroom environment. The format allows students to conduct active research, cultivate leadership and learn cooperatively. It allows integration of "soft skills" as well as "technical skills" to provide a holistic learning environment. The learning outcomes for the project can be summarized as:

- Ability to apply knowledge of mathematics, science and engineering;
- Ability to work in multi-disciplinary teams;
- Ability to integrate knowledge from many different fields;
- Ability to design a system, component or process to meet desired needs.
- Improved skills of utilizing internet technology for information gathering as well as information dissemination.
- Exposure to modern software tools for image processing, remote sensing and Geographical Information System (GIS)
- Improved critical thinking skills;
- Experience with project planning and execution;
- Improved communication and presentation skills;

- Exposure to NASA’s Earth Science and Aerospace research.

It may be worthwhile noting that the learning outcomes for the project is not only consistent but parallels the educational "outcomes" proposed by ABET in their Engineering Criteria 2000 [4].

The project has also allowed UMES faculty members to get an exposure to growing field of remote sensing and explore research efforts that will utilize the technology and infrastructure for conducting meaningful scientific research that is being developed with the progress of the project.

IX. Impact on Student Retention and Motivation

The project promotes student learning by motivation rather than by imposition. Also since there is no direct influence on their grades the students cooperate more effectively in the project. While retention of students has a lot of factors that contribute to it, the, involvement with the project is certainly a contributing factor. The impact on student motivation and retention may be summarized as follows:

- Student teams and student leadership have moved the project forward with guidance from faculty and NASA engineers and officers. Twenty to twenty-five students have regularly participated in group meetings (including a critical design review) on all working Fridays subsequent to partial funding of the project by NASA GSFC in October 1999.
- Faculty members are getting an opportunity to observe student performance in an active learning environment. This is providing an additional dimension for evaluating student ability and performance that is likely to improve retention of students with poor “test-taking” skills.
- The “out of class room” informal setting of the project is allowing students to learn according to their individual “learning styles”.
- Involvement with the project is allowing students to get exposed to career opportunities at NASA.

X. Conclusion

UMES-AIR project is providing a valuable learning experience to pre-dominantly minorities and economically disadvantaged students in the MSET curricula at UMES. The 'out of classroom' active learning framework is allowing the involved students to learn according to their individual learning styles. The project involves students through all four phases of the experiential learning cycle involving *concrete experience(CE)*, *reflective observation(RO)*, *abstract conceptualization(AC)*, and *active experimentation(AE)* as shown in Figure 2. Initial enthusiasm among students is encouraging and is an indication of improved motivation level.

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XI. Acknowledgement

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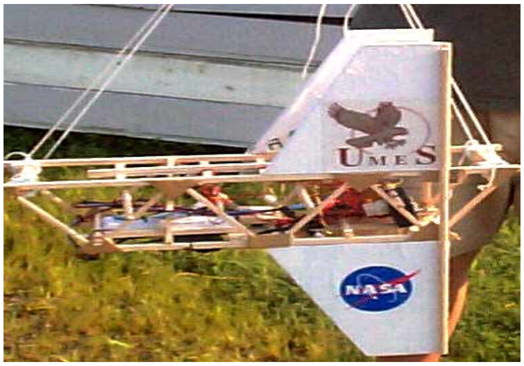
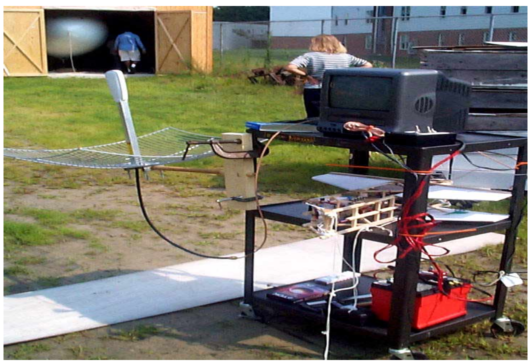
GEOFFREY BLAND
Geoffrey Bland received a BS degree in Aeronautics and Astronautics Engineering from Purdue University in 1981. Bland is a member of the NASA Goddard Space Flight Center, Laboratory for Hydrospheric Processes, Observational Science Branch, located at Wallops Island VA. Primary research activities are focused on the development and utilization of uninhabited aerial vehicles (UAVs) and associated sensors for Earth science related measurements. Previous assignments include mission management and engineering support of sub-orbital sounding rocket and aircraft borne experiments. Bland has also served on the UMES Engineering and Engineering Technology Advisory Committee since 1995.



[PHOTOGRAPH 1]

[PHOTOGRAPH 2]

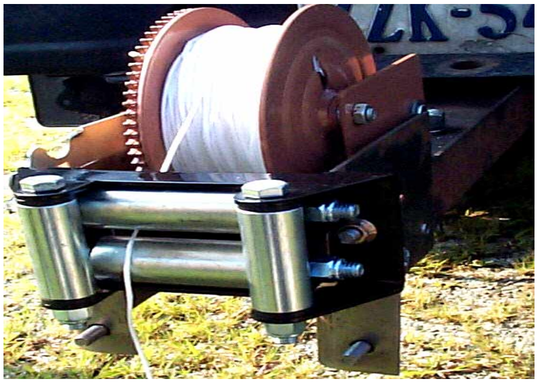


[PHOTOGRAPH 3]

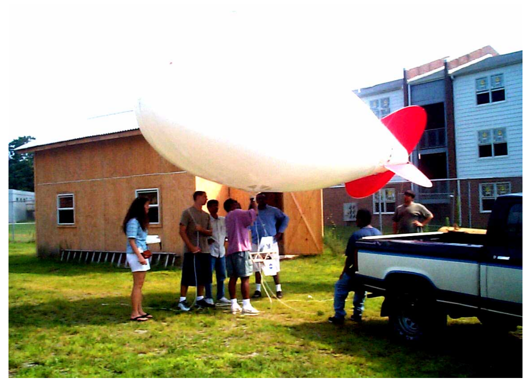
[PHOTOGRAPH 4]

[PHOTOGRAPH 5]

[PHOTOGRAPH 6]



[PHOTOGRAPH 7]



[PHOTOGRAPH 8]

[PHOTOGRAPH 9]

[PHOTOGRAPH 10]

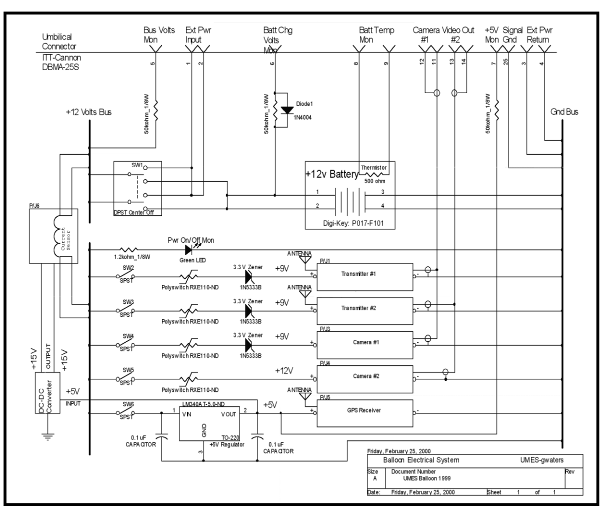


FIGURE 1

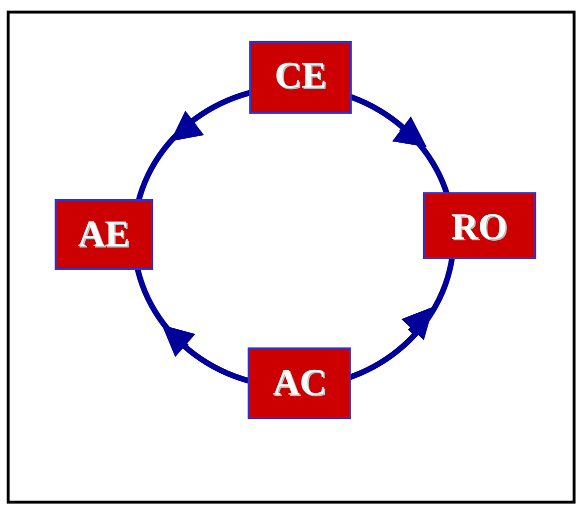


FIGURE 2