

# The Louisiana ACES Student-Built BalloonSat Program

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## Abstract

A major concern of many aerospace industries and space agencies worldwide is the continuing decrease in undergraduate student enrollment and graduation from aerospace and closely related degree programs. With a decreasing number of new aerospace workforce candidates, expanding or sustaining our exploration of the universe over the coming decades could be at risk. In Louisiana, we have developed the Aerospace Catalyst Experiences for Students (ACES) program to address this issue by attracting new students to aerospace related programs and providing interdisciplinary training on how to design, build and manage aerospace payloads. Based upon the National Space Grant Student Satellite Program “Crawl, Walk, Run, Fly!” methodology, ACES closely ties cross discipline content knowledge with extensive hands-on experiences to instill skills that are then applied by the students to design, document, build, test and operate a small balloon-borne scientific payload. The ACES concept was initially piloted during 2002-2003 and now includes a semi-formal “Student Ballooning Course”, five Louisiana institutions and serves ~45 students.

## 1. Introduction

Early in 2004, President Bush unveiled a new vision of space exploration, directing NASA to develop the technology, tools and expertise necessary to establish human missions to the moon, to Mars and beyond. Further, the President created the *President’s Commission on Implementation of United States Space Exploration Policy* to examine and make recommendations on implementing this vision. This Commission conducted dozens of hearings reviewing input from academia, industry, teachers, entrepreneurs, labor unions, state and federal government agencies as well as the general public. The Commission’s report (Aldridge, Fiorina, Jackson, et al., 2004) concluded that “...a workforce of great technical skill in their chosen disciplines will be required to implement the system of systems that will accomplish the space exploration vision” and that “The workforce required for the United States to prosper as a nation is not being trained adequately.” Similar concerns have been echoed earlier in reports ranging from the future of the U.S. aerospace industry (Walker, Peters, Aldrin, et al., 2002) to assessments of U.S. national security (Hart, Rudman, Armstrong, et al., 2001). Further, during testimony before the “Walker Commission”, Mr. Elliot G. Pulham (President & CEO, The Space Foundation), observed that between 1993 and 1998 graduate enrollment in the U.S. in science and engineering programs dropped by almost 8% and declined in Aerospace Engineering by more than 25%!

Such concern is not surprising. A typical aerospace engineer or scientist is a highly trained, experienced individual who can call upon multiple practical skills, is familiar with teamwork, must effectively communicate the results of the effort by writing numerous reports, documents and presentations and is intimately involved in the daily management of people, money and time. Yet many students entering a university have few practical skills, have problems with writing and “computer literacy” (limited to web usage), and are just beginning to understand the concept of time management. Bridging the gap between these two extremes at the university level has mostly been focused, particularly in science curriculum, on providing content knowledge with little emphasis on how to integrate and apply this knowledge to real world problems. Some engineering departments address this issue by including a “capstone” or design course in the last year of their curriculum, but most science departments have no such organized method and assume that students will “pick up what they need along the way”. To provide a more interdisciplinary learning experience for students interested in an aerospace career, the

*President's Commission* recommended that NASA partner with universities to develop a "virtual" *space academy* the "goals of which are: 1) to provide tangible experiences that prepare students for a future in a space-related field, and 2) to bridge the divide between engineering and science training." In Louisiana, the Aerospace Catalyst Experiences for Students (ACES), a part of the National Space Grant Student Satellite Program, is designed to provide such "tangible experiences" and cross the engineering / science boundary to build skills that students will find useful during a future career in the aerospace industry (Guzik and Wefel, 2004b; Guzik, 2003).

## 2. The Aerospace Catalyst Experiences for Students Concept

The long-term goals of the Aerospace Catalyst Experiences for Students (ACES) are to 1) attract new students to aerospace related science and engineering programs, 2) provide students with a background to develop and manage modern aerospace projects, 3) give students practical experience with sensors, electronics and "spacecraft" systems, and 4) assist in retaining these students by exciting their imagination and fostering their innate curiosity. The ACES program centers on exposing students to the aerospace project development life cycle using the design, fabrication, testing and operation of small payloads (i.e. 500 – 700 grams) launched on a latex sounding balloon "vehicle" to carry the payloads to the "edge of space" (~ 32 – 35 kilometers altitude). Based upon the National Space Grant Student Satellite Initiative "Crawl, Walk, Run, Fly!" methodology (Reed, 2003) the students "Learn," "Do" and "Experience" in a variety of settings including producing reports, establishing schedules / milestones and undergoing reviews similar to the kinds of metrics used to track NASA projects. In this fashion ACES models a modern aerospace development program, and provides students with a preview of the excitement, effort and experiences associated with an aerospace career.

The initial ACES concept was first tested during 2002-2003 under a pilot program funded through the NASA National Space Grant College and Fellowship Program Aerospace Workforce Development program. The yearlong pilot program involved undergraduate student participants from Southern University (SU) and Louisiana State University (LSU), both located in Baton Rouge. The first semester focused on building basic skills in electronics and programming utilizing simple electronic circuits. One of these circuits, the *CricketSat*, was based upon a 555 chip with a thermistor to input a temperature dependent frequency to a UHF transmitter and provided students with experience in parts identification, soldering, circuit troubleshooting, sensor calibration and basic data collection and analysis. A second circuit, the *CanSat*, incorporated a Parallax, Inc. BASIC Stamp microcontroller and involved students in real-time programming, sensor signal conditioning and readout, data formatting and storage and "ground control" software development. During the second semester the students were grouped into four teams of 3 to 4 students each, were provided additional lectures on project management and began to design



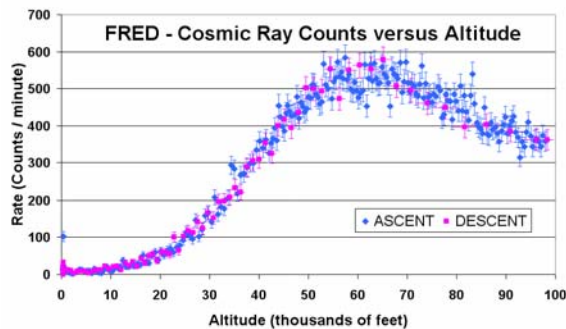
**Figure 2:** ACES-01 view from ~60,000 feet.



**Figure 1:** The 2002-2003 ACES student group at NSBF

their balloon payload. Over the course of the semester the teams needed to develop and defend a Preliminary Design Review (PDR) of their payload concept, followed several weeks later by a Critical Design Review (CDR). Both reviews required the student teams to develop a written document specifying all aspects of the payload including management issues and an oral presentation summarizing the design. A review panel composed of LSU faculty members critiqued the documents and identified issues with the design that needed to be addressed by the students. Once the payloads were complete a final Flight Readiness Review (FRR) was held to assess whether each payload was safe and operational. Launch operations took place at the NASA National Scientific Balloon Facility (NSBF) in Palestine, Texas (Figure 1) where the student payloads were launched, operated during flight, recovered and the data analyzed.

The payloads developed by the students included the “Temperature – Infrared – Camera (TIC)” experiment that measured infrared radiation and temperature as a function of altitude and returned some stunning images taken during flight (Figure 2). The “Flux Reliant on Environmental Density (FRED)” experiment measured the cosmic ray intensity as a function of altitude. The “Student Made Ultraviolet Radiation Detector (StuMURD),” a collaboration between SU and LSU students, measured the transmission of ultraviolet radiation through the atmosphere as a function of altitude. Finally, the “Ozone Measuring Equipment at Given Altitudes (OMEGA)” payload was developed to study the concentration of ozone in the atmosphere as a function of altitude. Three of these four payloads received final flight approval (OMEGA suffered a major failure the day before launch) and were launched from the NSBF facility on May 21, 2003 at 12:20 UTC. The balloon climbed to an altitude of 98,179 feet prior to balloon burst at 14:09 UTC. Figure 2 shows an image returned by the TIC payload from an altitude of ~60,000 feet. Following burst, the payload descent was slowed by a parachute to a final landing at 14:44 UTC



**Figure 4:** FRED measurements of the galactic cosmic rays

### 3. Lessons learned during the ACES pilot

The ACES pilot was very successful, and in the process we learned several valuable lessons. First, all students appeared to significantly gain from the experience. For many of them, ACES was the first time they were required to think a problem through from beginning to end, and most were surprised to learn that obtaining data from a sensor was not “plug & play”. The students understood that the



**Figure 3:** Recovery of the joint SU, LSU StuMURD

approximately 60 miles from the launch site. Figure 3 shows the recovery of the StuMURD payload.

After payload recovery the teams returned to the NSBF where they began the process of downloading and analyzing their data. Figure 4 shows the cosmic ray data returned by the FRED experiment. Here the FRED team included the flight profile information to relate their data to altitude plus performed an error analysis to correctly assess their uncertainties. The resulting plot clearly shows the Pfozter maximum peak in intensity at about 60,000 feet and good agreement between the datasets collected during ascent and descent.

experiences obtained during ACES would be valuable to them throughout their career. In fact, during a recent LSU / SACS Program Review of the Department of Physics and Astronomy, students interviewed by the external review committee expressed their strong support for the ACES program.

Second, the informal presentation approach used during the ACES pilot was inadequate. The ACES pilot was primarily an informal, hands-on program emphasizing the two electronic circuits and payload construction as discussed in section 2. During payload development in the second semester, it became clear the most students were not fully grasping particular basic concepts (e.g. signal conditioning, task definition and time estimates, connection between documentation and implementation). A more structured program, with a series of focused lectures and targeted activities prior to payload construction, would likely facilitate student assimilation of the required concepts.

Third, due to the interdisciplinary nature of a program like ACES, there are virtually no prepared materials that are appropriate. Development of an aerospace payload requires knowledge and skills from a spectrum of disciplines such as electronics, programming, mechanical structures, design, thermodynamics, and project management as well as the science investigated by the payload. In ACES we must cover such topics, plus design and build the payload within an academic year, requiring that only the concepts most relevant to the task at hand be selected and effectively presented. There are numerous, excellent textbooks available, but these generally focus on a single topic in depth. There are also multiple institutions across the country which offer aerospace courses based upon a payload-building theme, but these are either not focused on ballooning or have not attempted to organize and disseminate their class materials (i.e. lesson plans, lectures, activities, etc.).

Fourth, the ACES pilot was an extracurricular activity, but to improve impact and assure long-term viability, such a program must be incorporated into the regular curriculum. A typical student will have multiple activities, including classes, study time, a job, sports, academic clubs and social events, that will demand their attention. While students may be highly interested in aerospace this motivation, exclusively, may not be sufficient reason to cause a student to dedicate time from their busy schedule. As ACES is not yet part of the formal LSU curriculum, we chose to pay the students a nominal wage for their participation in the program. This approach worked well, allowing students to allocate time they would normally spend on some kind of a job to ACES. With this approach, however, the number of student participants will be directly related to the availability and amount of student support funds. By implementing ACES as a laboratory, “capstone” or design, course the program could become part of the curriculum, and students would be provided with college credit.

#### **4. The Louisiana ACES (LaACES) second generation program**

During 2003, Space Grant offered a second round of funding in the Aerospace Workforce Development program and we developed a follow-on project called Louisiana Aerospace Catalyst Experiences for Students or LaACES. This new project builds upon the ACES pilot program and extends it to multiple institutions across Louisiana. We developed a new “Student Ballooning Course (SBC)”, held a workshop to train potential institution leaders in the SBC material, and are now piloting this material at five institutions in Louisiana. Following completion of the SBC material, student teams from all institutions will develop payloads culminating in flight operations, with the assistance of the NASA National Scientific Balloon Facility (NSBF), during May 2005.

##### **4.1 The LaACES Student Ballooning Course**

The motivation for developing the Student Ballooning Course is derived directly from the lessons learned during the ACES pilot program. In particular, getting students to absorb the skills required for developing a balloon payload will be enhanced by a systematic presentation of focused lectures and targeted activities. In addition, a collection of integrated course materials targeted for intermediate undergraduates that cover the interdisciplinary skill set necessary for payload development did not exist.

Our goal, therefore, was to develop a complete course package that would allow ACES to be more effective and provide institutions new to ACES with a quick start-up solution.

The SBC contains a number of components including a course syllabus that summarizes the course contents, expectations and requirements, a set of PowerPoint lectures on focused topics, a collection of activity descriptions that provide hands-on experiences with particular skills or concepts, and a list of materials required for the course activities.

The most recent version of the SBC lectures and activities are summarized in Table 1. This version includes 33 activities and 29 lectures in 4 major content units plus 2 introductory lectures. The introductory lectures provide an overview of the ACES program, the SBC structure and contents and what the students will do over the academic year. The four major units in the SBC (electronics, programming, ballooning, project management) cover topics ranging from soldering techniques, sensor signal conditioning, and reading a real-time clock to mechanical design, thermal control and risk management. Each lecture includes one or two activities that illustrate a concept or build a skill. For example, during the project management unit the student teams gradually build a PDR document, similar to what they will produce for their payloads, including requirements, system design, task definition, cost estimates, work breakdown structure, time schedule, milestones and risk assessment for a project consisting of producing a pizza dinner from scratch for the entire group. The culminating event of this set of activities is the implementation phase where the teams are required to build to the specifications described in their document.

**Table 1: LaACES Student Balloon Course v1.5 Summary**

<b>Units</b>	<b>Num. Of Lectures</b>	<b>Num. Of Activities</b>	<b>Themes</b>
Introduction	2		Overview of ACES & SBC
Electronics	8	10	Components, prototyping, soldering, assembly, CAD tools, data acquisition, A to D converters, power
Programming	7	8	BASIC Stamp, BalloonSat, digital I/O, serial I/O, RT clock, memory, peripherals, debugging
Ballooning	6	6	Vehicle overview, flight environment, payload construction, materials, thermal calculations, mechanical drawing, design guidelines, launch ops
Project Management	8	9	Project life cycle, system design, WBS, estimating costs, scheduling tasks, risk management, documentation

Activities for the electronics and programming units make use of two new circuit boards, *SkeeterSat* and *BalloonSat*, based upon the circuits used during the ACES pilot, but enhanced and tailored to provide experience with key skills. *SkeeterSat* is a simple data collection system that presents its data as audio tones. If connected to an inexpensive Family Radio Service (FRS) handheld "walkie-talkie" it forms a rudimentary radio telemetry system. Temperature and light intensity are the two physical parameters monitored. The frequency (pitch) of the audible beep produced by *SkeeterSat* depends on the ambient temperature. The time interval between beeps depends upon the intensity of light falling on the unit. Computer software (Spectrogram) can be used to convert the tone frequency and interval into numerical values that can be used to calculate the actual temperature and light intensity in SI units (kelvin or celsius degrees, and watts per square meter). *BalloonSat* is a simple micro-controller based development board, which serves as the platform for learning to use and apply the Parallax BASIC Stamp micro-controller. *BalloonSat* includes additional memory, an analog-to-digital converter, a real time clock and large prototyping area. Learning to build, troubleshoot, and operate both circuits as well as to

program the *BalloonSat* provides skills that will be used again during payload development. Further, the *BalloonSat* can be integrated as the flight computer into a student designed balloon payload. Thus, students will already be familiar with a major component of their system prior to beginning their design effort.

The course is designed as a two semester unit assuming 14 weeks per semester and two sessions per week. The first semester includes the formalized lectures and activities to guide development of student skills, while the second semester is focused on having these students apply these skills during the design, development and operation of their balloon payloads. The SBC materials are distributed on a CD along with public domain software and the *SkeeterSat* and *BalloonSat* electronic kits

#### 4.2 Expansion of the ACES program

Another major goal of LaACES is to expand the program beyond LSU to other institutions in Louisiana. As of this writing five institutions are involved including Southern University, University of New Orleans, University of Louisiana – Lafayette, Louisiana Tech University and LSU with about 45 undergraduate students total engaged. The SBC has been distributed and is being piloted at each institution. Evaluations of the SBC material by the students and instructors will be returned to LSU and used to assess the course and update it as necessary. Following completion of the SBC material each institution will develop at least one student team (and possibly more than one at some institutions) and begin the design / development of the balloon payloads. Similar to the ACES pilot each team will be required to complete a PDR, CDR and FRR prior to flight. These documents form part of the course evaluation.

Similarly we are currently engaged in expanding ACES to institutions across the U.S. southeast region. We are planning to hold a short workshop session at a Space Grant Southeast Regional meeting to present the ACES program, the SBC lectures and activities and demonstrate aspects of the *SkeeterSat* and *BalloonSat* controller components of the electronics kits. Following the workshop, we will offer assistance to any consortium interested in establishing an ACES-like program in their state including providing the SBC and electronic kits, access to the ACES website FAQ and online SBC, interfacing with the NSBF as needed and mentoring project leaders via e-mail, teleconference or possibly video conference. Several states in the southeast already have student ballooning efforts, but may still be interested in our LaACES approach in combination with their current effort.

Finally, we are in the process of developing an Advanced ACES program. This program will deepen the skills of those students who have completed the SBC and continue to engage their imagination by involving them in larger, more complex balloon experiments or student-built satellite missions. Advanced student balloon experiments may be launched as attached payloads on NSBF supported scientific balloon experiments or on a platform dedicated to student payloads such as the High Altitude Student Platform (HASP) reported elsewhere in this volume (Guzik and Wefel, 2004a). Louisiana has also recently joined the “Magnetic field Investigation of Mars by Interacting Consortia (MIMIC)” which currently involves close to 200 students across 12 states to build a small satellite that will be carried to Mars circa 2011 ( <https://spacegrant.colorado.edu/tiki-index.php?page=MIMIC> ). MIMIC, or similar programs, can provide an excellent opportunity for engaging Advanced ACES students.

#### 5. Outcomes and future effort

Of the 13 students that completed the ACES pilot, one has graduated and is currently working in the chemical industry, eight remain in an aerospace related degree program, three have moved to another degree program and one is currently on extended leave from the university. In addition, three of these students are also currently engaged in an Advanced ACES pilot program including developing a prototype attitude determination system for balloon flight during 2005 and participating in the MIMIC program. We will continue to track these as well as the ~45 students now engaged in the LaACES SBC through graduation.

With the success of ACES there has been growing interest at both LSU and SU to incorporate the program as part of the regular Physics curriculum. Southern University has recently obtained continuation of its' NASA Minority University Partnership Project which includes an ACES component and plans to develop a course for its curriculum that is based upon ACES. Further, the LSU Department of Physics & Astronomy is in the early stages of developing a *capstone* course that would include design and development of a balloon experiment with elements of the SBC incorporated into several laboratory courses.

As support for future Advanced ACES programs and new courses in the curriculum in Louisiana and elsewhere in the southeast, LSU is planning to develop the HASP balloon platform (Guzik and Wefel, 2004a). This platform will accommodate at least eight student payloads, provide a common power and telemetry bus and be based upon flight proven technology to minimize cost. Flights of HASP would take place yearly from the NSBF facility at Palestine, Texas or the launch site in Ft. Sumner, New Mexico. If HASP is approved for construction, the NASA Balloon Program Office will commit to three flights starting as early as 2006.

Further details on ACES, including recent presentations on the program, can be found at <http://laspace.lsu.edu/aces>

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