Developing Student Ballooning Research Programs at Minority Institutions

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"Physics & Aerospace Catalyst Experiences in Research (PACER)" sponsored by the National Science Foundation at Louisiana State University (LSU), uses the development and flight of small sounding balloon experiments as a focal point for assisting minority institutions to attract and retain students from underrepresented groups into STEM (science, technology, engineering and math) programs. In particular, PACER is intended to provide students with a research experience that builds skills, techniques and methodologies applicable throughout their career, to help establish a core of expertise at multiple minority serving institutions around which a local, sustainable student research experience program can develop, and to partner with these institutions as they implement their local program. We describe the PACER, summer program and preliminary results in attempting to establish ballooning programs at multiple minority institutions.

I. Introduction

The nation's high technology workforce is aging rapidly, and there has been steady decline in the number of students entering the workforce as scientists and engineers over the last several decades. Studies identifying the problem range from assessments of U.S. national security[1] to reports on the future of the U.S. aerospace industry[2] and the Aldridge Commission's report on implementing the Vision for Space Exploration[3]. Further, in 2004 the National Science Board released a report that indicates "an uncertain future because of a troubling decline in the number of US citizens who are training to become scientists and engineers"[4,5]. Across all science and engineering (S&E) fields more than half of the degreed workers are aged 40 or older[5]. Attracting and retaining students into science and engineering careers is, therefore, of paramount importance if the U.S. is to maintain its technological lead.

Figure 1. A sounding balloon launch with student payloads attached.

Concern about the S&E workforce is not surprising. A typical engineer or scientist is a highly trained, experienced individual who can call upon multiple practical skills, understands teamwork, effectively communicates results via reports, documents and presentations and is involved in daily management of people, money and time. Yet many students entering a university have few practical skills, have problems with writing, have "computer literacy" limited to web usage, and are just beginning to comprehend time management. To bridge the gap between these two extremes, universities often focus on providing content knowledge with little emphasis on how to integrate and apply this knowledge to real world situations. Some engineering departments include a "capstone" or design course in the last year, but most science departments have no such organized method. This lack of nurturing may account for the National Science Board's observation that while interest in science is high among freshmen, there was a 10% decline in graduate science & engineering enrollments by US citizens between 1994 and 2001[5]. Thus, institutions of higher education need to incorporate programs that emphasize practical skills and experiences that are directly applicable to the development of future science and engineering projects, products and careers.

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Figure 2. The 2007 PACER team from GSU Dr. M. Ware (left), J. Bass (center), H. Neal (right)

Finally, in attempting to address these issues there is a question of what target audience should be the focus of limited resources. The trends apply across the existing workforce and student population, but the U.S. Council on Competitiveness has observed that the greatest opportunity to expand the technical talent pool lies in participation of women and minorities in the workforce[6]. Sakimoto and Rosendhal[7] observe that the best way to incorporate minority institutions into mainstream science research is to encourage partnerships between research institutions and minority universities, enabling the minority institution to establish its own research capability and reputation. Therefore efforts focused on minorities that establish sustainable capability at Minority Serving Institutions (MSI) may have the greatest long-term payoff.

The "Physics & Aerospace Catalyst Experiences in Research (PACER)" program was developed by our group at Louisiana State University as a test project to evaluate how best to address the issues raised above. In particular, PACER uses the development and flight of small sounding balloon experiments to help minority institutions attract and retain students into STEM curricula. Figure 1 shows the launch of one such sounding balloon vehicle with student payloads attached. In this context PACER has a set of specific objectives including 1) attract students from the ranks of minorities to science and engineering programs; 2) provide students with a research experience that builds skills, techniques and methodologies applicable throughout their technical career; 3) establish a core of expertise at multiple MSI institutions with a sustainable student research experience program; and 4) nurture and mentor these institutions as they implement their program. In 2007 we obtained funding from the National Science Foundation (NSF) Physics Division Education and Interdisciplinary Research program and additional support from the Louisiana Space Consortium (LaSPACE) in order to implement the program. The first PACER team from Grambling State University is shown in Figure 2 recovering their payload. Since then we have involved five more institutions in the PACER program and continue to mentor them. Here we report on the PACER program implementation structure, how minority institutions were recruited and involved in the program and, finally, the kinds of lessons that we learned along the way.

II. The PACER Program Structure

The PACER program includes a 9-week summer research experience plus an academic year follow-up / mentoring component. Since 2007 we have recruited one or two MSIs to participate in PACER and each of these institutions sent a team consisting of a faculty member plus three students to LSU for the summer. The summer program uses established materials to guide the teams in building skills in electronics, real-time programming, design and management. These skills are then applied to develop and operate a small science experiment carried to high altitude by a sounding balloon. Following the summer, we partner with each institution for up to three years providing some financial support, advice on recruiting students, mentoring on implementing the skill building program at their institution, suggestions on community involvement in their program and transferring knowledge on balloon flight vehicle development, operation and recovery. As institutions develop their program, we also offer an advanced training program to previous PACER institutions in order to provide an additional incentive for commitment and growth.

A. Recruiting and the Application Process

During the design of PACER, we recognized that to be successful the faculty and student participants as well as the institution administration must be committed to the program. During the summer the faculty and student team must be on-site at LSU for 9 weeks, and during the academic year the institutions must support these participants as they develop their local student ballooning program. Thus, identifying and recruiting appropriate institutions into the program is very important.

To facilitate this process we developed proposal guidelines for PACER[8]. These guidelines were incorporated into a document that included sections describing the PACER program, anticipated timeline, summer program and academic year support provided by PACER, eligibility requirements, deliverables, application content, evaluation criteria, deadlines, award processing as well as standardized forms for the cover page, project summary page and academic year budget. The application schedule included two "Q&A" teleconference sessions at different times in January, a "Notice of Intent" (NOI) due in February and final application due in March.

The PACER proposal guidelines were distributed as far in advance of the summer session as possible. Typically, we could distribute the guidelines in January and sometimes in December of the previous year. Distribution was accomplished with the assistance of LaSPACE and their access to the NASA Space Grant e-mail list that contacts STEM program coordinators in all 50 states plus D.C. and Puerto Rico. In addition, we identified the Physics or Engineering department chairs at 63 Historically Black College and University (HBCU) institutions across the country and sent personalized emails with the guidelines to each chair.

The response to the call for application was underwhelming. For a typical year we would get four to six NOI letters and a few final applications for one to two entry level slots. This general lack of response was a source of constant consternation during the entire program, and is regardless of the fact that each institution that completed the summer program had a very positive experience. In an attempt to improve response we requested existing PACER institutions to urge other institutions to apply, we placed personal telephone calls to the HBCU department chairs and received permission from NSF to open the eligibility requirements to any non-research intensive institution primarily from EPSCoR states. This additional effort helped, but response was still poor.

It is difficult to quantify the exact reasons we received such a poor response to our application process, but we can speculate that much of it may be due to economic conditions. Minority institutions are generally under greater economic stress that majority institutions and, therefore, have few resources to invest in a new program. Of these resources faculty time is the most precious and a stressed MSI administration finds it very difficult to release faculty from standard teaching duties to attend a 9 week summer session as well as to devote class time to a new, untried program during the academic year.

B. The Summer Session

Much of the PACER program is actually based upon our previous experience with the Louisiana Aerospace Catalyst Experiences for Students (LaACES) program that was developed by LaSPACE and ported to multiple institutions across Louisiana[10,11,12]. A key PACER component inherited from LaACES is the Student Ballooning Course (SBC), which contains a set of instructional materials designed to guide students as they build practical research project skills in electronics, real-time programming, instrument design and project management plus a series of electronic kits used to provide hands-on learning of key electronics and programming concepts. A full description of LaACES, the SBC and our associated balloon system electronics can be found elsewhere at this conference[13].

The LaACES program takes place over two semesters during the academic year, with the first semester making extensive use of the SBC and focusing on skill building while balloon payload design, development, fabrication and

Table 1: Major Summer Program Activities by Week

Week	Formal Activities	Informal Activities
1	Introduction, Begin Electronics, Construct SkeeterSat and BalloonSat, Begin Programming	Science Lecture
2	Sensor Interfacing, Serial Communications, Testing & Debugging, Power, System Design	Science Lecture, ham Radio Class, St. George Observatory Tour, Bar-B-Q
3	Mechanical Design, Thermal Issues, Near-Space Environment, Project Management	Science Lecture, Communication across the Curriculum (CxC) Resources, ham Radio Class
4	Work on payload, Prepare PDR document and Presentation	Science Lecture, Pennington Planetarium Tour, ham Radio Class, Highland Road Park Observatory tour, ham Field Day, LIGO tour
5	PDR, Work on payload, Prepare CDR document and Presentation	Science Lecture, ham Radio Class, July 4th Party, Free Weekend
6	CDR, Construct, Calibrate and Test Payload	Science Lecture, ham Radio Class, Mary Bird Perkins Cancer Center Tour (Medical Physics), ham Radio APRS "fox" hunting
7	Construct, Calibrate and Test Payload	Science Lecture, Lockheed Martin Space Systems Tour, ham Radio License Exam
8	Complete Payload, Prepare FRR Document and Presentation	Center for Advanced Microstructures & Devices (CAMD) tour, Science Lecture
9	PACER Flight Operations at the NASA Columbia Scientific Balloon Facility	

testing takes place during the second semester. For PACER we compress this schedule down to eight weeks with flight operations taking place during the ninth week of the summer session. The major formal and informal program activities that occur during the summer are listed in Table 1.

The formal summer session program is focused on skill building and balloon payload development. Activities in the first three weeks are taken up with the skill-building lectures and activities associated with the SBC. There are four major units in the SBC which cover topics in electronics, real-time programming, ballooning and project management that are designed for the intermediate college level. Each lecture includes one or two activities that illustrate a concept or build a skill. During the first week initial topics and activities include electronic component identification, soldering skills, electronic circuit quality control, validation and debugging, detector sensitivity and how sensors or electronic sensors can be used to measure the environment. Figure 3 shows a group of PACER students engaged in these activities. Toward the end of the first week the participants construct a simple micro-controller based development board, which serves as the platform for learning common real-time control applications (e.g. digital I/O, serial I/O, sensor signal conditioning and analog to digital conversion) as well as being integrated as the flight computer into the student designed balloon payload. In the third week participants learn about mechanical design, thermal and vacuum issues associated with the near-space environment, as well as how to identify and manage risks, task scheduling, cost estimates, documentation and other project management topics. At this point the team should be ready to develop their own balloon flight payload.

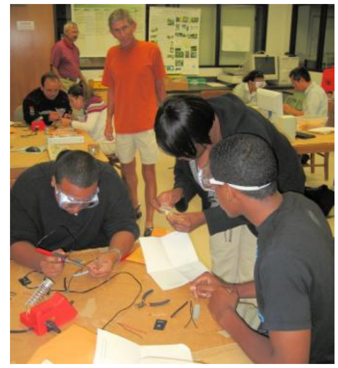

Figure 3. PACER students learning basic soldering techniques.

Over the next five weeks the team designs, constructs, calibrates, tests and validates a balloon payload to measure temperature, pressure and humidity as a function of altitude as well as take pictures throughout the flight. Such a payload allows a rich scientific investigation of the structure of the atmosphere that almost all undergraduate students have never experienced and correctly measuring such parameters is not necessarily easy. Throughout this period the payload development process is guided and monitored through a series of reviews, very similar to those that take place during real world projects. The Preliminary Design Review (PDR) occurs at the beginning of week five and presents the initial payload design concept. The Critical Design Review (CDR) occurs during week six and, in essence, should include final details on how the payload will be constructed, tested, calibrated and operated. The Flight Readiness Review (FRR) occurs at the end of week eight, providing documentation of the 'as-built' payload configuration and evidence that it is safe and ready to fly. For each review, each team must produce a written document and an oral presentation. The written document is based upon a template that contains a detailed outline, descriptions of content for each section, as well as suggested figures and tables. Producing a 50 to 90 page long detailed documentation for a science project is a new concept to most PACER participants and is usually perceived as the hardest part of the summer program. For the most recent PACER summer sessions, LaSPACE has supported a graduate student majoring in English/Communications to help mentor the students with their writing and oral presentation skills. The results of this mentoring are usually quite dramatic over the course of the summer with the team ending up with very professional FRR documents and presentations. Nevertheless, all teams are generally elated to be finished with this portion of the program as is evident in Figure 4.

Figure 4. The 2008 PACER teams upon completion of their FRR from left to right, from NSU D. Baker, J. Mathis, Dr. W. Hinton, L. Caraway and from IUPR V. Gonzalez, Dr. H. Vo, A. Espinal and J. Diaz

The summer session informal activities take place throughout the summer program during evenings and weekends and provide a break from the intense formal part of the program. Once a week, a LSU Physics & Astronomy faculty member provides a lecture on their particular area of research and we include tours of local science facilities such as the Center for Advanced Microstructures & Devices synchrotron x-ray source and the Laser Interferometric Gravitational wave Observatory (LIGO) and its new Science Education Center in nearby Livingston parish. In addition, we offer the PACER participants a ham radio licensing class in the evenings as another informal activity. Ham radio is one of the enabling technologies for institutions who want to do their own balloon launches, including using lightweight transceivers coupled to a GPS receiver to transmit the latitude, longitude and altitude of the balloon vehicle over amateur frequencies in real time. This kind of information during flight is required by the FAA and is essential if one is planning to recover the payloads. In addition, most communities have a group of amateur radio operators whose practical electronics skills complement the SBC and can help support the local PACER program. Thus, our informal activities complement the payload development activities and together provide a very full summer schedule.

C. The Advanced PACER Component

To build upon the student research capabilities started at the institutions and to provide additional incentive for commitment and growth, we offer current and previous PACER institutions the opportunity to participate in an advanced training program. This advanced program would make use of the High Altitude Student Platform (HASP)[15] that provides student experiments with flight time, altitude and resources well beyond what is possible with sounding balloons. The HASP system, shown in Figure 5, uses a "few" million cubic foot, thin film polyethylene, helium filled balloon to carry multiple student built payloads to altitudes of ~120,000 feet (~36km) for durations of ~17 hours. As shown in Figure 6, this flight duration and altitude is significantly more than that achieved with a sounding balloon, thereby opening up the number of science topics possible for a student payload. These student payloads can mass up to 20 kilograms and a standard interface includes support for power, serial telemetry, commanding and analog output. Since 2006, HASP has had four flights during which 34 student payloads from 17 institutions across 11 states were flown. Among these payloads were investigations on cosmic dust, rocket nozzle performance, balloon thermal characteristics, cosmic rays, gamma rays, neutrons, atmospheric ozone, remote sensing as well as testing spaceflight power systems and magnetic field sensors, as discussed elsewhere at this conference[16].

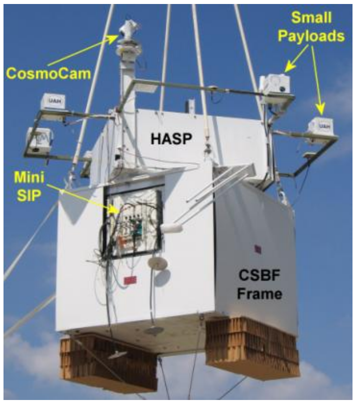

Figure 5. The HASP platform designed to carry complex student payloads.

Similar to the entry level team, the advanced PACER team arrives in early June and has eight weeks to complete with payload design, fabrication and system testing. This is a challenge as we expect that a HASP payload will be more complicated than a “simple” sounding balloon experiment and take advantage of real-time commanding and downlink data capability. Following completion of their payload by the end of July, we travel to the NASA Columbia Scientific Balloon Facility (CSBF) in order to fly the entry level teams sounding balloon payload and integrate the advanced team payload with HASP the following week. Following integration, HASP is shipped to Fort Sumner, New Mexico where flight operations take place the first week in September. This is during the normal school year, and it is difficult for students to fully participate in flight operations. HASP is, therefore, designed so that all telemetry from the student payloads, as well as balloon tracking, status information and live streaming video from a webcam (CosmoCam) on the HASP vehicle, is available to students at their home institution through the HASP website. We also provide a sub-award augmentation to the advanced PACER institutions to support team members travel to HASP flight operations if they wish to do so, as well as to support payload data analysis and preparation of papers/presentations.

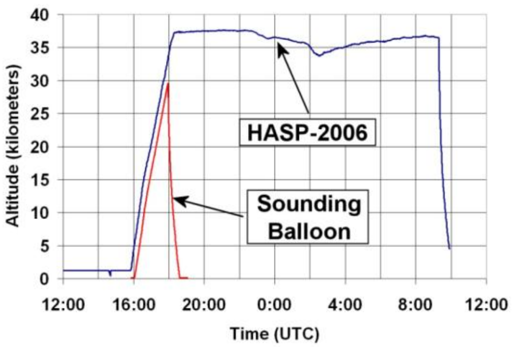

Figure 6. Comparison of the flight duration and altitude reached during typical sounding balloon and HASP flights.

D. The Academic Year Program

Following the summer of entry into the PACER program, the institution is supported for the next three years as they attempt to establish a student ballooning research program of their own. Preparation for the academic year program begins during the summer when we work with the team faculty member to develop an implementation plan. This plan provides a written document of how the faculty member intends to establish the ballooning program at the institution and includes sections on student recruiting, how the program is intended to be incorporated into the curriculum, administration support, available equipment, community involvement, major milestones and institutionalization of financial resources.

To help ease the financial burden of starting up the program we provide a sub-award to the institution of $10,500 the first year, $5,250 the second year and $2,500 the third year. In addition, we also provide SBC electronic kits for

12 students the first year, 8 students the second year and 4 students the third year. The declining award and electronic kits over the years is intended to encourage the institution to become independent of PACER.

Throughout the year we maintain contact with, at least, the faculty member of the institution team through frequent teleconferences and regular email status reports. In addition, an annual report is required in order to receive the following year funding. Much of this contact involves answering questions about the SBC materials that might not have been addressed during the summer, providing assistance with electronic or software problems, providing advice on how to develop and fly their own balloon vehicle, discussions about involving communication organizations in their program and other related topics. In addition, we mentor and encourage institutions to participate in the advanced PACER component.

Figure 7. The HATPaC payload developed by GSU in 2007.

Further, during the spring we generally visit each institution and participate in the student payload Critical Design Review. These site-visits provide us with an opportunity to interact with students involved in the program, meet other faculty participants, assess the facility and equipment used to support the program and discuss the program with institution administrators. Most recently we assisted with one of the first balloon vehicle launches by a PACER institution during a site visit.

Our intention with this program is that by the end of the three year mentoring period each PACER institution will gain enough experience and have developed sufficient internal support so that they can operate independent of our assistance.

III. Results from the PACER Implementation

To date we have involved six institutions in the PACER program. These include Grambling State University (GSU) who started in 2007, InterAmerican University of Puerto Rico – Bayamon (IUPR) and Norfolk State University (NSU) in 2008, Central State University (CSU) and Albany State University (ASU) in 2009 and Knoxville College (KC) in 2010. In addition, IUPR returned to LSU in the summer of 2010 as the first advanced PACER team, and during the summer of 2011, the advanced PACER team will have members from CSU, KC and NSU. A team from each of these institutions participated in the summer program described above; successfully completing a payload and all of the reviews. A typical such payload is the HATPaC instrument developed by GSU in 2007 as shown in Figure 7 and an example of the payload electronics developed by Knoxville College is shown in Figure 8. By the end of the summer the payload is fully functional, the sensors have been calibrated, all system tests have been completed and documented and the payload is ready for flight.

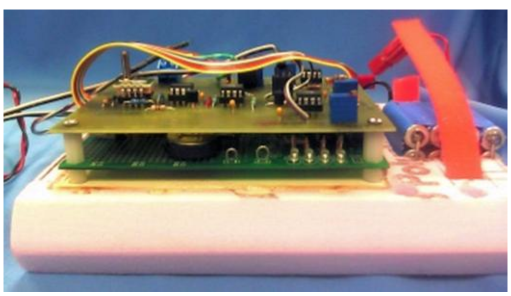

Figure 8. The Knoxville College payload controller and sensor interface electronics built during the 2010 summer session.

The last week of the summer session is devoted to flight operations at NASA's Columbia Scientific Balloon Facility (CSBF) in Palestine, TX. CSBF supports professional scientific balloon flights around the world and has been operating from their Texas site for about 40 years. The Facility has supported PACER by providing hanger space to stage the student payloads, helium for the sounding balloons, trained personnel to manage the launch operations, and interfacing with the FAA during flight operations.

The launch trip generally lasts four to five days. Monday is spent on setup in the hanger, preparing the payloads for flight, configuring the flight string and chase vehicle radios, as well as other pre-flight activities including a weather briefing from CSBF personnel about

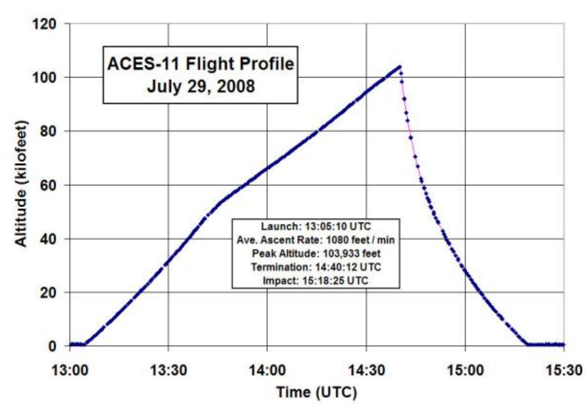

Figure 9. Typical PACER balloon flight profile.

flight conditions the next day. Before sunrise on flight day, final payload checks are made, the balloon is filled with helium, attached to the payload string and the entire balloon vehicle is readied for launch in a nearby field and released. The flight profile (altitude vs. time) for the ACES-11 flight last July which carried both the NSU SPARTA and IUPR ABITA payloads to an altitude of about 104,000 feet is shown in Figure 9 and is similar to other sounding balloon flights. Throughout the flight we received GPS latitude, longitude and altitude information in the chase vehicles allowing us to track the balloon in real-time and follow the payloads to their landing site within minutes of touch down. After recovery we return to CSBF so the students can download the data recorded by their payload and begin their data analysis. On Wednesday the students have all day to complete their data analysis, interpretation of results and science presentations. Their presentation of results is then delivered the following morning (Thursday) to an audience of CSBF engineers and staff. CSBF personnel are very interested in hearing from the students, and we typically have 40 to 50 (or > 60% of all base personnel) in the audience. This enthusiasm encourages the students and provides them with realistic, yet sympathetic, questions and comments. Following the last presentation we return to LSU, and the following day the students and faculty advisors return to their home institution.

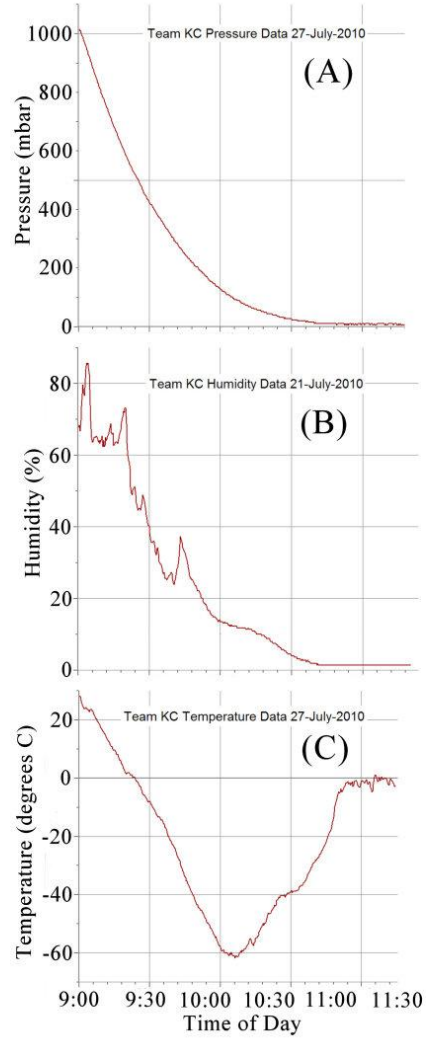

Figure 10. Pressure (A), humidity (B) and temperature (C) data returned return by the Knoxville College payload during its flight on 7/27/10

Example results are shown in Figure 10 for the KC payload temperature, pressure and humidity data and an image taken by the GSU payload at high altitude is shown in Figure 11. The KC data is plotted in terms of time during the day 7/27/2010 with launch occurring at about 9:00 am and float at about 100,000 feet was reached at about 11:00 am. In panel (A) a steady decrease in pressure is observed as the balloon rises in the atmosphere and in panel (C) the temperature decreases in the troposphere until the coldest point in the tropopause (~-60°C) was reached at about 10:15 am. This was at an altitude of about 55,000 feet. In the stratosphere the temperature then increases as altitude increases. Further, the relative humidity as measured by team KC during their flight is shown in panel (B). An interesting observation is that there is measureable humidity even into the stratosphere. Finally, images taken during the flight are used to interpret the temperature and humidity data by determining, for example, whether the payload traveled through a cloud and what are the surface albedo conditions below the payload that might affect the temperature measurement. In addition, seeing an image of the black of space, the curvature of Earth and the tops of thunder clouds from above conveys to the students a sense of excitement and accomplishment.

Figure 11. Image at ~105,000 feet taken by the GSU HATPaC payload in 2007.

In parallel with the entry level team effort, during 2010 we also hosted a team from IUPR as the first advanced PACER team. The payload proposed for HASP by IUPR was an attitude determination system intended to provide accurate knowledge of the direction in which the payload is pointed. This payload consisted of magnetic compass, gyroscope and accelerometer sensors and associated software to read and interpret the sensor data and provide a derived direction. The group spent the first few weeks of the summer specifying their system requirements and completing their critical design review. Fabrication and testing of the payload was finished by the end of summer and the IUPR team assisted with the KC flight and then went on to HASP integration. Integration proceeded smoothly and the IUPR payload performed will during the thermal / vacuum stress test. HASP, with all student payloads attached, was then prepared for shipment to Ft. Sumner, NM for flight in September. Unfortunately, we found out the following week that NASA had to cancel the fall 2010 Ft. Sumner campaign so that the 2010 HASP flight is now scheduled for September 2011. In the meantime, the IUPR group proposed an additional payload for HASP, independent of PACER, and their proposal was accepted. The IUPR team will now be on both HASP flights, 2010 and 2011, scheduled within a week of each other during this coming fall.

Figure 12. Filling the ASU balloon prior to launch.

At the end of the summer session we solicit feedback from each participant using a standard form. The first part of the form requests a rating on a scale of 1 (poor) to 5 (excellent) on the content, clarity and delivery of the Student Balloon Course lectures, the content, clarity and guidance during the SBC activities, the payload review content, feedback and utility, the extra-curricular activities as well as an overall rating. The second part of the evaluation form requests written comments. Averaging over all participants our average rating for the summer program is about 4.5 and many participants wrote that the most important thing they learned was how to work in a team and how to document their work. Many also "grumped" about the intensity of the summer, but then provided general comments such as *"This is a very ambitious and rewarding program.", "Keep providing these experiences to the students and faculty!", "Great preparations for senior projects.", "Valuable program. Students need more opportunities like this to expand their understanding of what science and being a scientist is all about.", "I learned a lot of information that I think will be useful to me in the future.", "I learned work ethics and how to work with others.", "It was a very intense program and very helpful in many ways", "I really enjoyed my time in the PACER program. I will not falter if I was offered another opportunity",* and *"PACER ROCKS!!!!"* Getting this kind of feedback allows us to conclude that we must be close to "getting it right"

While the PACER summer program appears to be highly successful, we have had mixed results for the academic year mentoring component. All institutions have had problems with recruiting local students into their program and keeping the students focused on the payload development. A typical academic year cohort appears to be about 3 to 4 students almost regardless of whether the institution implements PACER as an extra-curricular activity or a for credit course. In addition, the students appear to have great difficulty completing the SBC and payload development activities within one academic year. However, in the four years since PACER began, only one institution, GSU, has completed the three year mentoring. Thus, it may still be premature to evaluate how successful PACER is in establishing a student ballooning research program at minority institutions.

Figure 13. Launch of the ASU balloon vehicle on 4/11/11

There are, in fact, very encouraging signs. Grambling State University completed the full PACER program last year and during the 2010-2011 academic year was successfully able to recruit and retain 4 students into their ballooning program. These students have completed development of a payload and participated in the yearly Louisiana student balloon flight campaign during May 2011. The payload successfully collected data on temperature and pressure as a function of altitude up to an altitude of 23,000 feet before filling available memory. This kind of success can only help encourage more GSU students to become involved in the program. In addition, IUPR has used PACER to expand the aerospace training opportunities available to its students. While it is difficult for them to launch balloon payloads from Puerto Rico, we have included their payloads on our balloon vehicles and IUPR is working with other groups on the island to support local launches. Further, IUPR has procured additional grants to support their involvement with the development of a CubeSat[17,18,19] satellite. The IUPR payloads on the HASP 2010 and HASP 2011 flight are, in fact, designed to flight test a prototype attitude determining system for their CubeSat satellite. IUPR states that this year there are more than ten students engaged in their ballooning and satellite projects.

Another encouraging sign is the ASU first flight of a balloon vehicle this spring. In previous years, most PACER institutions engaged in some kind of payload flight, either with a tethered balloon or with a balloon vehicle developed and supported mostly by another institution. For the flight this spring, however, we helped ASU develop a tracking beacon,

Figure 14. Recovery of the ASU balloon vehicle.

provided them instruction on the infrastructure needed to launch, track and recover a balloon vehicle, and assisted them with their launch. Figure 12 shows the ASU team filling their balloon with helium after first laying out the payload string, powering up the student payload and making sure the tracking beacons are fully operational. Figure 13 shows the launch of the ASU balloon vehicle at about 10:15 the morning of April 11, 2011. The balloon vehicle climbed to an altitude of about 88,000 feet before the flight was terminated and the payload safely parachuted to the ground. The ASU team along with one of the authors (J. Giammanco, center) is shown, in Figure 14, following the recovery of their payload string. The ASU payload functioned well throughout the flight returning valid temperature, pressure and humidity data into the stratosphere. This is the first time that a PACER institution has acquired all the equipment, skills and training necessary to develop, fly and recover their own balloon vehicle. It is hoped that this capability will enable ASU to perform balloon flights on their own schedule and attract more students into their program.

IV. Conclusions

The PACER project was implemented at LSU to test a concept for helping to establish a student ballooning research program at multiple minority serving institutions across the country. The concept included a summer training program and three years of follow-up mentoring. During the summer an institution team, usually consisting of a faculty member and three students, is engaged in a nine week intense workshop where they are exposed to basic electronics, software, mechanical and management skills and then use these skills to develop a balloon payload to take images and measure temperature, pressure and humidity as a function of altitude. After completing a Flight Readiness Review the payload is flown to an altitude of about 100,000 feet using a helium filled sounding balloon. Participants are very enthusiastic about the PACER summer program and typically state that the summer helped them learn some major life lessons.

The success of the academic year program is not as clear cut. Institutions generally have problems recruiting students into their program and retaining them throughout the academic year. However, one PACER institution has expanded its program to include CubeSat satellite develop with component testing on balloon platforms, another institution after several years of incomplete projects has successfully retained a team during the full academic year and designed, built and flown a complicated balloon payloads, and one institution appears to be well on its way to establishing its own balloon launch capability. Thus, it may still be premature to evaluate how well PACER can migrate a student ballooning program into a minority institution.

There are some major advantages for minority institutions to establish their own PACER-like program. The infrastructure necessary to support PACER at an institution is significantly less than what is necessary to establish a state-of-the-art research project capable of supporting tens of students each year. However, PACER provides students with skills and experiences applicable to a very wide range of science and engineering fields. While we emphasize that each student payload must be focused on scientific research and "discovery", these discoveries might not be new to the entire scientific community **but they are always new** to the students. PACER is typically the first time that most student participants encounter the think-for-yourself environment of scientific research and are usually ill prepared for it. Consequently, many of the PACER research experiments may, on the surface, appear contrived. Yet obtaining, understanding and explaining results from an experiment built from scratch based upon an initial "science goal" is both a difficult and rewarding experience for most students.

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