SPIRIT I and II: A Progress Report from Penn State's long-duration Undergraduate Sounding Rocket Project

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Introduction

The Student Projects Involving Rocket Investigation Techniques (SPIRIT) Undergraduate Sounding Rocket Program will have launched its second student payload this spring. In its seventh year, SPIRIT has been a successful exploration of non-traditional methods of engineering education. A final SPIRIT payload highlighting an international collaboration with Norway is under development.

At the time of this writing, SPIRIT II is ready to launch. We are hopeful that a launch opportunity will be offered in early April. We present preliminary conclusions about the outcome of that project and lessons learned from the manifold differences between these two efforts. We resist the temptation to ascribe value judgments such as "success/failure". Work on a program evaluation is ongoing. Rather, our purpose is to compare the two very different outcomes of SPIRIT I and SPIRIT II. In addition, we present the current evolution of the characteristics and goals of this unique program.

Characteristics of a "SPIRIT Project"

The SPIRIT projects are designed to provide a supportive environment[1,2] for students to demonstrate newly acquired skills and to learn about themselves. Membership is open to engineers and non-engineers of all levels of experience. The project begins with a stated scientific objective and the suggestion of a complement of instruments to meet that objective. Student interest is a strong determinant of what instruments are actually built. A companion course provides a forum for presentation of new material and discussion of project issues. The project follows a standard formal project timeline with a series of at least three pre-launch review meetings held with engineers at the NASA Wallops Flight Facility[3].

Project work is organized in the confines of five work teams. These teams are defined by function (TM, publicity, Power & Wiring, Structures, and Experiments). Due only to the nature of the various tasks, the teams represent very different learning environments. Each is led by a student

leader who is responsible (after consultation with faculty) for setting and achieving semester goals. Though student accomplishment is achieved within a team, the social fabric of the project extends across teams.

The projects last for approximately three years. The long duration, the firm launch date, and the open membership without regard to academic departments set SPIRIT apart from other project courses at Penn State. Participation typically remains at about 40 students until the last semester, when numbers tend to drop as time demands increase significantly. We include approximately 75 students during the course of the project.

There has been collaboration with students at another institution in both projects. The collaboration not only broadens the capability of what we can do, but also requires students to learn to relate as professionals to peers, who are not necessarily friends.

The SPIRIT program has evolved from experience in the Penn State Aerospace Department with an ongoing Sailplane Project[4]. Both programs are ongoing and several students participate in both. Other project-based courses at Penn State are similarly popular, including the SAE car, Future Truck project for developing efficient vehicles. Community service projects are also available to engineering students in increasing numbers through Engineers Without Frontiers and Engineering Projects In Community Service (EPICS). Nevertheless, the SPIRIT project is unique and continues to be popular at roughly the levels of participation of six years ago when it began.

Learning Goals for SPIRIT

SPIRIT is an educational program. When scientific requirements conflict with the educational agenda, education must take precedence. The objective is to deliver a successful experience for the students, as they transition from students to professionals[5]. Our scientific agenda is an important element of the payload, but only as it serves the educational objectives.

An important part of professionalism is the ability to work independently toward a firm deadline. This is a tough lesson for these students since they must learn both the process and the particular expertise as they go. They must also deliver a product that is absolutely reliable. Such is the unforgiving character of the sounding rocket. However, the ability to meet a deadline is particularly important to our corporate stakeholders (NASA, NSROC and our private sector sponsors)[6].

Central to the educational agenda is increased cognitive awareness. Project-based courses are generally seen to lend themselves to cognitive development[7]. Since SPIRIT students in general demonstrate a high level of initiative and motivation, cognitive development (defined as the ability to monitor and direct one's own development according to personal interests and skills) is an important progress toward professional excellence. The criteria used to evaluate this development include, fulfilling leadership potential, attacking open-ended tasks in logical and

disciplined way, and understanding when outside help is needed and then finding that support.

Promoting responsibility (to each other and to the project) is another objective of professional development. The students must be able to meet commitments they make. They must also be able to set reasonable short-term goals that will lead inevitably to the fulfillment of the long-term goal. Students can only learn to do this in a long-duration project. Again, this is a difficult task given the many and varied demands made of students. Student work in the project is performed in the context of the work team. So, students' first responsibility is to the team leader (a peer).

The above enumerated behaviors relate to development of personal discipline and professionalism. In addition, SPIRIT students must learn teaming skills. The payload is complex enough that it must be a group effort to succeed. Group dynamics skills relating to communication, conflict resolution, social skills and accountability must become second nature. We look for signs of positive interdependence, peer mentoring and other forms of cooperative behavior as indicators that this objective is being met[8].

In addition to these developmental goals, we try to meet the needs of the students in:

- … fostering an awareness of space-related industry norms.
- … introducing them to a specific expertise that will set them apart from other undergraduates. For most, this means the areas of atmospheric science and rocketry, but it might also be public relations or a specific area, such as GPS technology.
- … building relationships and support mechanisms both among SPIRIT peers and with the NASA engineers and vendors.

Student initiated experiments

In both projects, the student initiated portion of the payload was a source of great pride to the students. The process for encouraging such initiative is quite informal. In general, it grows out of the daily experience of the students. On SPIRIT I, a student conceived of the idea of flying a camera that would use polarized lenses to ocean surface roughness. Since our primary aim was education, this project was not judged on scientific merits. Rather, it was seen as a means to encourage the students who would be working on it and to provide insight into the process of designing an instrument for the rocket environment. This student discussed the merits of the experiment with one professor and submitted a proposal to the PA Space Grant Consortium. This proposal was funded. The control electronics was the basis of the student's required capstone course. He provided documentation and accountability for the experiment throughout. Since he had other students working with him in his capstone group, this was a way to leverage the value of SPIRIT to the core curriculum. Though the camera worked flawlessly, the scientific goal of measuring surface roughness was not achieved.

On SPIRIT II, the Aerospace students were eager to find a way to introduce composite materials

to the payload. The initial plan was to build a rocket skin of composites. On the basis of benefit analysis, this was changed to building a nosecone. During the planning stages, the students involved several of their professors in considering the suitability of composites, determining which composite to pursue, planning the fabrication and performing preliminary performance analyses. One professor was invited by the students to address the class in order to consider these issues as a group. The result has been an object of great pride among the SPIRIT students – and interest on the part of NASA.

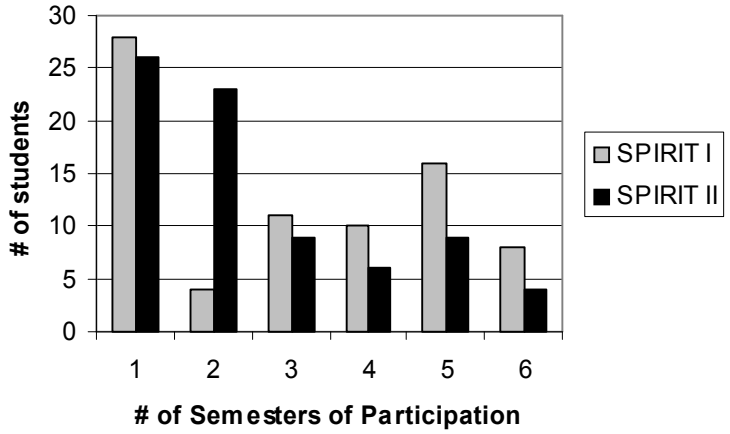
Unplanned student-initiated additions to SPIRIT Project payloads have increased the sense of "ownership". They were significant sources of pride even for students who were not involved in student-initiated projects themselves. The program should remain flexible as long as possible, in order to include such ideas[9].

Project length

The duration of a SPIRIT project was set at three years because of the guidelines set for the original funding opportunity. This length of time coincides with an undergraduate career so the opportunity is there for students to grow with the payload. By this model, students would join as sophomores and would be developing their design skills as the payload takes shape. It is observed that for those who follow this path, the project is particularly meaningful. Their dedication and commitment tend to be solid. In general, these are the students who form a core group around which the social organization of the project evolves.

However, this core group is a minority of the participants in the project. The accompanying figure (Figure 1) shows that most students stay involved with the project for a few semesters.

Figure 1: Duration of Participation



Students leave the project for a number of reasons, including:

- Schedule conflicts with required departmental courses
- Graduation
- Preference for job experience and/or co-op experience to the "club" atmosphere of SPIRIT.
- Completion of the particular portion of the payload the student is working on.
- Loss of interest in the objectives of the project

Those who stay are generally responding to:

- Commitment to a particular project
- Varied opportunities for hands-on experience in a space-related field
- Opportunities for responsibility and leadership that seniority brings.
- Professional and personal relationships that grow in the context of SPIRIT work.

This data has led us to consider the ideal length of a project-based course in an undergraduate university setting. Might our educational goals be better met with more frequent launches of less complicated payloads? A shorter duration would be less risky because struggling students would get another chance on a subsequent payload. However, cohesion of project teams, as well as accountability might suffer if we tried to have projects at different stages of development side by side. It would be expected that students identify with a single project instead of the larger payload. We would thus lose a dimension of teamwork that is an important motivator for completing the payload. We would also lose the opportunity to use their individual project as a means for introducing them to broader issues of atmospheric science and space-related industries. Sponsorship for such a *program*, rather than for a cohesive payload, might be harder to arrange.

Succession

The SPIRIT II group has had the advantage of several SPIRIT I veterans who were available for consultation. Several SPIRIT I students continued to actively participate as mentors and coaches with the program well after their graduation from Penn State. Despite this, cohesion in the SPIRIT II group has been much less apparent than SPIRIT I. Project loyalties have seemed to fracture roughly along departmental lines. Several students worked on SPIRIT II without being a part of the class. It was hoped this would allow us to make use of the skills of these students, despite schedule conflicts. As it turned out, the result was to dilute the camaraderie among the core students with students who were only marginally involved in the project.

For SPIRIT III, we have encouraged younger students to become involved in the final stages of SPIRIT II. This promises to be a much better way to pass on the expertise of one group to the next. It had been feared that such newcomers would detract from the concentrated efforts of the

"expert" teams as the deadlines neared. Instead, it is clear that these new recruits inject energy and enthusiasm at precisely the time it is needed most. The older students seem genuinely eager to pass on their experience and they are grateful for the help provided by the newer students.

Conclusions

Several conclusions can be drawn from our experience on the first two projects as we develop the third SPIRIT project. First and foremost, it is evident that sounding rockets are a superb teaching tool. The excitement of rockets reaches across traditional barriers of age, gender and academic major. A diverse group of students will indeed be attracted to rocket projects. In my opinion, rocket projects are superior to satellite projects as a teaching tool, since the duration of a project can coincide closely with an undergraduate career. In addition, the engineers and technicians at the sounding rocket group of the Wallops Flight Facility have shown themselves to be superb mentors and professionals. They have patiently dealt with the SPIRIT students, encouraging them and listening respectfully to their ideas. This working relationship has been a vital element of the success of these projects.

The place of education as the central mission of the project is fundamental to SPIRIT. It gives the students a degree of freedom to reach beyond themselves and to mold each payload to their own purposes[10]. This level of "ownership" is important in motivating the students over the long duration of the effort. The students take seriously this educational dimension. It appears that this is a reason that they work so enthusiastically to bring the educational outreach programs to local schoolchildren.

College students do not easily distinguish between professional and social contexts. Professional relationships are fundamentally social relationships, governed by social cultural norms. Professional interaction is much reduced or non-existent without social interaction. A strong social fabric may be needed in the project for a satisfactory professional outcome to occur.

Sounding rockets present a challenging and unforgiving engineering environment for these inexperienced students. This is appropriate as it forces the students to acquire habits of diligence and reliability that might not be so emphasized elsewhere. They know that they get only one chance to make the payload work.

For the faculty who are involved with the project, the excitement of atmospheric research motivates our work with rockets[11,12]. Not so the students. For them, the opportunity to work with NASA and rockets is reward in itself. Few students embrace the scientific challenges once they have defined the engineering requirements. It is our hope to attract students to the rockets, but to leave them with an appreciation of atmospheric science and space-related professions. More effort is needed in this area.

Another area of concern for SPIRIT III is to make inter-institutional collaboration more fruitful.

In the first two projects, students did not easily develop relationships with students at our collaborating institutions. This is likely a reflection of low professional self-confidence. In the upcoming project with Norway, cultural differences might contribute to the uneasiness of collaboration. We expect to expend considerable time and energy to creatively encourage meaningful relationships[13].

Finally, the roles of student leadership and social cohesion are vitally important for the completion of a reliable payload. In the first project, the leaders formed a tight-knit group of committed and determined comrades. They supported each other socially and professionally. In the second project, this cohesive coterie did not form until very late in the project. The leadership of the teams was uneven and as a result, the younger students exhibited uneven commitment to the project. This made it very hard to know the status of the various projects at any particular time. Routine requests often required persuasion at critical times.

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References

[1] Walberg, Herbert (1974). Models for Optimizing and Individualizing School Learning. In Marjoribanks, Kevin (Ed.), *Environments for Learning*. Sussex, England: NFER Publishing Company, Ltd., pp 19 – 38.
[2] Johnson, D., Johnson, R.(1991). Cooperative Learning and Classroom and School Climate. In Fraser, B.,Wahberg, H. (Eds.), *Educational Environments*. New York, NY: Pergamon Press, pp 55 – 74.
[3] *Sounding Rocket Users Handbook*. NASA Goddard Space Flight Center. 1988
[4] Maughmer, M.D., and Jensen, D. (1992). Enhancing the Aerospace Educational Experience With a Multi-Year Sailplane Design Project. Toledo, OH: Proc. of the 1992 ASEE Annual Conference, pp 714-717.
[5] Branford, J., Brown, A., Cocking, R. (Eds.) (2001). *How People Learn*. Washington, DC: National Academy Press, pp 60 – 78.
[6] Jackson, Jan (2002). Personal correspondence from NSROC sponsor.
[7] Op. Cit., p 67.

[8]Wheeler, T. (2002). SPIRIT II Companion Course Assessment, Part 3. (Unpublished)
[9]Marra, R.M., Wheeler, T.F., (2000). The Impact of an Authentic, Student-Centered Engineering Project on Student Motivation. Submitted to *30th ASEE/IEEE Frontiers in Education Conference.*
[10]Wheeler, T. (2001). Theoretical Context for a Formative Assessment Model Applied to the SPIRIT Companion Course. (Unpublished)
[11]Larson, M.F.(2000), Coqui II mesospheric and lower thermospheric wind observations over Puerto Rico, *Geophys. Res., 105,* 24931-24940,
[12]Mitchell, J.D., Wheeler, T.F., Croskey, C.L., Meisel, D.M. (1999). SPIRIT: Student Projects Involving Rocket Investigation Techniques, *ESA SP-437*
[13]Wheeler, T. (2003). SPIRIT III: International Collaboration in an Undergraduate Research Program. Submitted to Schreyer National Conference: Innovations in International Education

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