EDUCATIONAL ADVANTAGES AFFORDED BY THE ESPRIT PROJECT

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ABSTRACT

The goal of this paper is to provide an overview and assess the educational value from conducting a space science related design project, such as the ESPRIT program, and examine the special issues related to conducting such student projects. About 100 undergraduate engineering students from Penn State University and from Norwegian universities (groups of graduate students from Universitetet i Oslo, Høgskolen i Narvik, and Universitetet i Bergen) participated in preparing and launching the ESPRIT rocket payload. Almost all of the tasks for mechanical and electrical design, fabrication, testing, and calibration of the payload and instruments, as well as the analysis of the results have been carried out by the students. More than twenty students participated in the launch activities during a four-week field campaign in June–July 2006. The ESPRIT student project served to meet several goals for advancing the educational process and training while preparing young people for careers.

1. INTRODUCTION

The ESPRIT (Engineering/Scientific Project for Research and International Teamwork) program has provided a great learning experience for a large number of engineering students at Penn State University and at Norwegian universities in Oslo, Narvik, and Bergen. The value of the experience is measured in the hands-on learning experiences in engineering and science that go well beyond the classroom. Also valuable is the teamwork between several different technical disciplines with an emphasis on strong international cooperation to accomplish this very sophisticated project.

The project advanced educational needs by providing both teaming and hands-on learning experiences. The activities provided opportunities for hardware design, instrument and payload fabrication, scheduling, instrument and payload testing, formal and informal communications, goal setting, field work experiences, interaction with many aspects of government regulation and international cooperation, and many other important topics that cannot be experienced in a classroom environment [1]. From our point of view as the faculty advisors of the students, we now summarize the strengths and concerns associated with conducting such projects. In this paper, we will discuss the goals of the ESPRIT project, including the scientific, engineering, and educational goals. Both the advantages and the less desirable factors will be considered in retrospect, from the standpoints of the faculty advisors and the students. We have prepared this report in order to evaluate this effort by assessing the outcomes one year following the launch, and seeking to improve our future endeavors.

The ESPRIT project continues at this time with the data analysis and interpretation. Several papers have reported preliminary results from the ESPRIT project at this 18th ESA Symposium on European Rocket and Balloon Programmes and Related Research [2–6]. One of the challenges, especially for engineering students who prefer to move toward the next hardware activity, is to maintain a focus and follow through on the tasks of reporting the scientific results, describing the engineering achievements, and documenting the procedures, test results, mechanical drawings, electrical schematics, etc. These activities are of extreme importance so that these items will be available as a resource for subsequent projects, and can provide a documentation of results to justify the expended resources. When payload is launched, the project is only half complete, and this factor is not so easily grasped by students, which requires a bit of reminding by advisors.

As faculty advisors of the students who actually did all of the "heavy lifting" in carrying out this project, we approach our task with a special philosophy. First, we are charged with setting the level of education for the next generation of engineers and scientists. Second, we need to try to pass along to the next generation the key learning experiences that we have had, together with specialized knowledge for success in accomplishing far-reaching goals—information not found in textbooks. A good approach for the philosophy of teaching was espoused by Galileo many generations ago:

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**"You cannot teach a man anything,
— you can only help him to
find it within himself"**

Following this idea leads naturally to providing many interesting hands-on opportunities for the students to experience.

2. ESPRIT PROJECT INTRODUCTION

As an example of the several PSU student project experiences, the ESPRIT program will be described. We have fostered several programs within the university to enable students to conduct space-related scientific investigations and engineering developments; these have included space shuttle experiments using the GAS (Get Away Special) payloads (1986, 1996, and 2001), rocket payloads (SPIRIT-1 in 2000, SPIRIT-2 in 2003, and ESPRIT in 2006), and instrumented high altitude balloons (CATS in 2005). The recent efforts include opportunities for students to build satellite payloads for nanosatellites [7, 8]. The ESPRIT project was the first with major international involvement, but additional activities are planned [7–9]. Each of these projects involved relatively large numbers of students (typically 50 to 100) working collectively over several semesters to design, fabricate, test, launch, and analyze results.

As an example of a recent major student project, the ESPRIT program provides a focus for describing the experiences with student space research in the university. More than one-hundred undergraduate PSU students and ten Norwegian graduate students conducted the ESPRIT program. The ESPRIT payload, which is shown in Fig. 1, was built by the PSU undergraduate students and included instruments prepared by Norwegian students. The PSU students are mostly from the Electrical Engineering and Aerospace Engineering Departments. While participating in the program, they developed their technical talents, practiced their interpersonal skill, learned reliance on others, experienced the commitment and responsibility as a team member, and appreciated the sense of accomplishment. This program also provided the special experience of international cooperation with ten Norwegian students as co-investigators from Universitetet i Oslo, Høgskolen i Narvik, and Universitetet i Bergen. The promises of long term friendships, as well as appreciation and understanding of another culture, were additional benefits during this program. The ESPRIT students designed, fabricated, and tested the payload, experiments, and supporting subsystems that were part of this payload. Twenty students, fifteen from PSU and five from Norway, participated in the launch preparation activities during the month of June 2006 at the Andøya Rocket Range (ARR), Norway. The successful launch on 1 July 2006 has been followed by intensive efforts on analysis of the data during the past year [2-6]. Fig. 2 shows the launch of the Terrier Improved–Orion rocket carrying the ESPRIT payload.

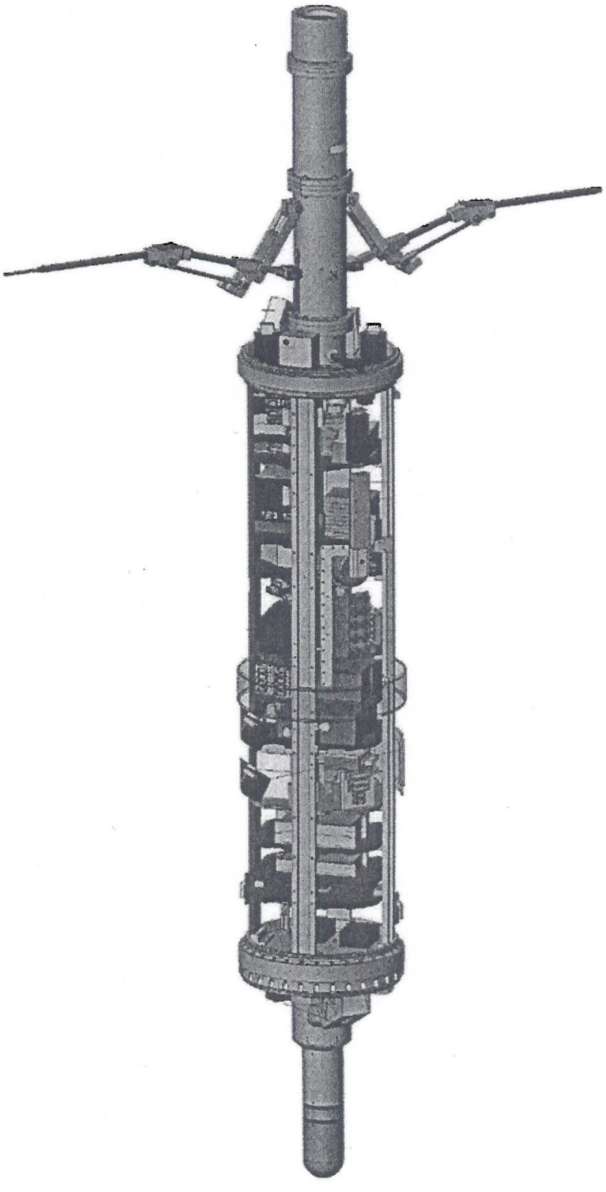

Figure 1. The ESPRIT payload was 3.45 meters (136.6 inches) long and 36.6 cm (14 inches) diameter, weighed 193.3 kg (425 lbs), and included seven scientific experiments and eight engineering performance demonstrations.

3. GOALS OF THE ESPRIT PROJECT

The ESPRIT goals focused on three areas: science, engineering, and education. The multi-facetted activities of a project to launch instruments on a rocket or other platform provide many learning experiences.

3.1 Science Goals

The science goals of the project were selected to be:

(1) Investigate the high latitude ionosphere during a geophysically interesting period (NLC, PMSE, X-ray or particle event) using plasma frequency probe (PFP), Langmuir Probe (LP), and X-ray instruments to improve our scientific understanding.

(2) Investigate the physical characteristics of mesospheric aerosols (NLC) and/or PMSE conditions using Multi-channel Photometer, Imager, Aerosol Detector instruments.

In both of these efforts, we have a particular interest in coordination and collaboration with lidar, radar, and other measurements conducted at ARR (ALOMAR, ALWIN and HOTPAY).

3.2 Engineering Goals

The engineering goals included several efforts to provide a flight test as a part of the process of developing new instrument sensors and capability for future applications. These activities included:

(1) Develop and test a composite nose cone and composite deck construction.

(2) Develop and test a pyro-less separation mechanism.

(3) Develop and evaluate a new Plasma Frequency Probe (PFP) for future satellite and rocket investigations.

(4) Test a new design for a sun sensor for attitude determination.

(5) Develop and test boom deployment system.

(6) Test flight of accelerometer and mini-gyro instruments.

(7) Test a simple and inexpensive imaging system for future rocket and balloon flight.

(8) Develop and test a new photometer instrument for future aerosol studies on balloon and rocket flights.

The ESPRIT payload included seven scientific experiments; Langmuir Probes (one fixed-bias and one swept-bias potential), NLC Photometer (a ten-channel instrument with three wavelengths), Plasma Frequency Probe, NLC Imager, Solid State Detectors (for energetic particles), Aerosol Detector (to measure the noctilucent cloud particles), and X-ray Detector (to measure the bremsstrahlung radiation resulting from energetic particle precipitation). The payload also included eight engineering demonstrations to develop future space systems; Carbon Fiber Composite Nosecone, Carbon Fiber Composite Deckplates, Auto-zero Strain Gauges, Boom System (to extend probes beyond the shock generated by the payload), Magnetometer (for attitude determination in conjunction with the sun sensor), Solar/Horizon Sensor, SMA (shaped memory alloy) actuator for Door Deployment (to demonstrate pyro-less door ejection), and a Digital Solar Sensor.

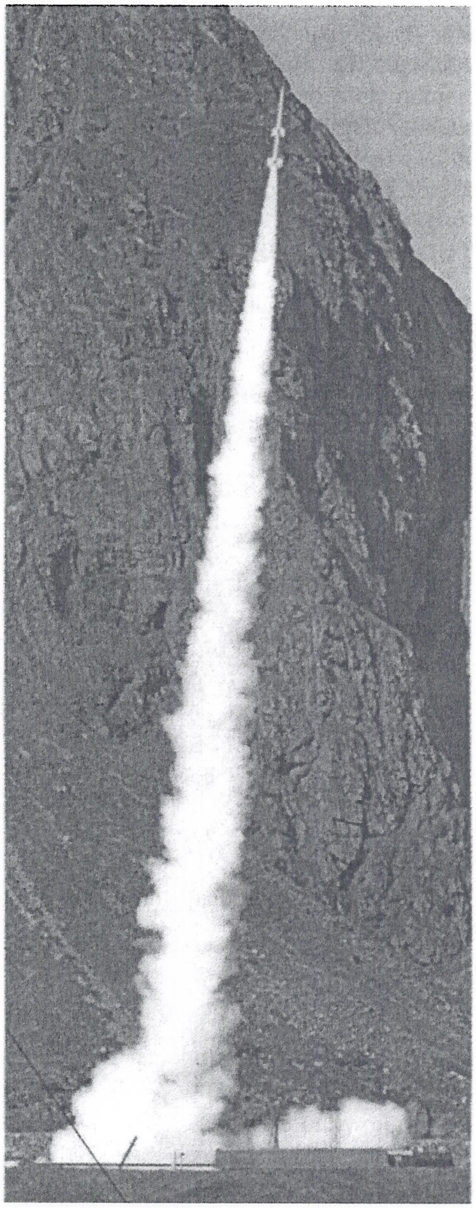

Figure 2. The launch of the ESPRIT payload on 1 July 2006 from the Andøya Rocket Range.

3.3 Educational Goals

The goals from the point of reference of a student's education include the following items:

(1) Prepare the next generation of scientists and engineers for research activities in the space sciences by providing challenging opportunities to gain hands-on experiences in a wide range of topics that go well beyond the classroom environment.

(2) Develop teamwork and professional skills through

participation in complex multi-facetted projects that include experiences in design, testing, launch, data analysis, and technical reporting of engineering and scientific results.

(3) Foster a global view of the human quest to understand the world around him by adding to our common store of knowledge, while developing an understanding of other peoples, countries, and cultures to build international cooperation among the next generation of engineers and scientists.

4. STUDENT PERSPECTIVE

Most of the feedback on an informal level from the students was very positive. The factors that seemed to raise the most concerns for the students involved planning and communications, also there was concern regarding project funding, since not all of the travel expenses could be covered for each of the necessary activities, which limited some students' participation. In an effort to attempt to gain a more formal assessment of this experience, all of the students were asked to write a project evaluation at the end of the 2006 Spring semester, after the launch campaign, and one year later as the first publications of results are assembled. Several of the comments received one year after the launch are summarized here (without attribution). The questions that the students were asked were:

1. What were the most positive results from your participation?
2. What was the most negative and/or disappointing outcomes?
3. What recommendations would you suggest for future projects?

4.1 Positive Comments

The primary points that students raised are listed (extracted from student write-ups— not ordered).

- collaboration with PSU and Norwegian students
- big team working to meet a common goal
- overall learning experience
- increased interest in related topics
- project prepared me for future career
- experience from being able to work along side scientists and professionals from many countries
- satisfaction in seeing the results of the project and analysis with ground based data comparisons
- the fact that it was a student run project - faculty helped us most by giving just enough guidance for the students to move into the next phase
- lessons learned from mistakes important for career
- major project undertaking for undergraduates
- technology developed has promising future
- allowed me to experience leadership positions
- it was a project that people enjoyed doing

4.2 Negative Comments

- incomplete payload for initial integration
- funding for travel was not sufficient
- last minute purchasing of critical components
- don't think there was a negative outcome
- people were sometimes poor team players
- mistakes in my early effort to lead a group
- disappointing struggle with project timeline

4.3 Recommendations for Future Projects

- more advice on engineering part selection
- dimensions: inches or mm, use common standard
- component buying: 3000 on a wheel costs the same as 500 single components
- funding for travel should be part of project costs
- improve training in project management, communications, and budget planning
- rocket projects provide good balance between technical challenge, project length, and open-endedness for introduction to the space industry
- emphasize accountability and professionalism
- amount of paperwork required is seriously impeding the "fun factor"—important for a volunteer project
- the shop schedule was so tight impacted making parts (only with the CNC machine)
- student leaders should make their respective meetings more productive

5. FACULTY PERSPECTIVE

The ESPRIT project provided the faculty an opportunity of working with a group of enthusiast young engineers and scientists from two countries, and was a special experience. It demonstrated that the challenges of communications can be handled on a trans-Atlantic scale. Differences in language, technical design approaches, clock time, social customs, and educational backgrounds were overcome through use of email, phone, and infrequent video conferencing among the participants. The teams that formed at Penn State and at the three Norwegian universities worked well together and have developed bonds for group and individual collaborations in the future. Most importantly, many students from both the US and Norway were able to understand and appreciate each other, both on technical and social levels. These experiences should be useful to each of the students in their future careers. The overall result of the project has been a spectacular success with valuable data gathered from all of the scientific and engineering experiments on board the ESPRIT payload. Several efforts are underway to analyze the data and report the results from the measurements [2-6]. Factors that guide our planning for the future include these thoughts:

1. Space projects are a natural platform to teach students about systems engineering. They can start with a science/engineering goal and flow the requirements down to the box level, which has been the focus in the past. This also helps the students "to understand the larger picture."
2. There needs to bring synergy between platforms and in opportunities. Students can work on rockets, spacecraft, balloons, instruments, data analysis, satellite control, etc.
3. For the more complex projects, an on-ramp is needed so that younger students are not scared off and are not sure how they fit in the larger project. They need to first be shown that they can do it.
4. Students desire credit for their work, and employers are looking for such a credential (Space Systems Engineering Certificate), [8].

The ESPRIT Project, third in the series of SPIRIT undergraduate student rockets, was highly successful by the measures of the scope of the payload, in-flight performance of student-built hardware, and post-flight production of student papers. A distinguishing feature of this project is that it was an international collaboration, consisting of students from Penn State and three Norwegian universities. The rocket was launched on schedule from Andøya Rocket Range in northern Norway (1 July 2006).

The SPIRIT rockets have clearly demonstrated that committed undergraduate students, with proper guidance, are capable of rising to the level of professionalism demanded by a sounding rocket project. A critical factor for the timely success of the project is developing the rising core group of effective student leaders. These leaders organize and motivate productive teams that provide the on-time delivery of well-functioning rocket hardware. Since the students participate with little or no compensation, leadership by suasion is key. This comes from student leaders who are closely involved with their team members and know details of the efforts in their technical areas.

The international dimension of ESPRIT was important for many reasons. It raised the importance of the project in the eyes of the students and motivated them to dedicate themselves further to their work. ESPRIT became an example for possible future joint student projects between PSU and Norwegian universities through the Andøya Rocket Range. The international collaboration required extra commitment, time and money. We are grateful to our Norwegian partners for their commitment in supporting this project. The friendships that began here will persist through the long careers of these students. The goals of the partnership are experience and international exposure to scientific and engineering practices in another country and development of contacts across national boundaries.

From the point of view of the Andoya Rocket Range and the Norwegian groups involved, ESPRIT was indeed a great success, and we should endeavor to continue this kind of collaboration. There are several specific points in this connection:

1. ESPRIT gave our students a taste of real international collaboration. Being part of an international team of experts in space science and technology caused them to learn much faster and more efficiently than in their normal, local university environments.
2. ESPRIT provided a unique social setting as a basis for professional networking as well as for personal friendships.
3. ESPRIT gave visibility in the media for our field. Such visibility is very important for the research groups in their search for funding for space research. The Norwegian Space Centre, Andoya Rocket Range and its daughter company NAROM benefit from such publicity in their work to secure a firm basis for future activities.
4. ESPRIT provides a very good example of an implementation of the MOU on collaboration in space activities between the US and Norwegian governments.
5. The question is now how we can exploit the success of ESPRIT to fund a continuation of our collaboration.

6. PROJECT EVALUATION

A critical look at the ESPRIT project leads to several factors that are worthy of note.

1. Students constantly overestimate their capability for accomplishing tasks; this occurs when they over simplify, underestimate time involved, tend to procrastinate, and attempt to catch up with last minute and late night efforts.
2. Young engineers like to work with hardware, but must be reminded the success is not measured by the BOOM of the rocket, but by the analysis, evaluation, interpretation, and reporting after the launch.
3. Educational values included:
    - "Hands-on" learning experience,
    - Confidence building for complex problems,
    - Motivation for success,
    - Communications skill development,
    - Teamwork skill building,
    - Planning and scheduling,

International and cultural understanding,
Valuable scientific data obtained,
Useful engineering technology demonstrations.

4. Student evaluations focused on the ideas:
   Hard work and success yield a special sense of satisfaction,
   Project was a great preparation for career,
   Leadership training at this level was most valuable,
   Student driven project is valuable,
   Opportunity of learning from mistakes,
   Overall learning experience gained,
   International collaboration has built relationships,
   Value of working together on a big team.
5. Students felt the problems included:
   Projects need better defined and controlled timeline,
   Better business model for budget and ordering lead-time items,
   Improve communications within/between teams.
6. Conclusions and recommendations included:
   Rocket experiments are best student training,
   Need more accountability to be sure tasks are accomplished,
   Improve project management to avoid problems,
   Develop time management skills to meet deadlines.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

1. Philbrick, C.R., "Education in Space Sciences," *Proc. 17th ESA Symposium on European Rocket and Balloon Programmes and Related Research*, ESA SP-590, pp. 25-32, 2005.
2. Escobar, A.C., Bilén, S.G. and Philbrick, C.R., "Preliminary Langmuir Probe Analysis from ESPRIT," Ibid. 2007.
3. McKeever, K.R., Greenert, K.R. and Philbrick, C.R., "Characterization of Noctilucent Clouds Utilizing a Ten-Channel Photometer," Ibid. 2007.
4. Edwards, P.S., Philbrick, C.R., Surdal, L.H., Johnsen, M.G., Latteck, R., and Baumgarten, G., "The ESPRIT Rocket Payload Launch: Initial Comparison with Ground Based Atmospheric Measurements," Ibid. 2007.
5. Reichard, G., Cochrane, C., and Fortin, W., "ESPRIT Sun Sensor: Results and Future Use," Ibid. 2007.
6. Brouwers, E., "Advanced Boom Systems for Sounding Rocket Research," Ibid. 2007.
7. Bilén, S.G., Philbrick, C.R., Escobar, A.C., Schratz, B.C., Thrane, E.V., Gausa, M., Dahle, K., Honary, F., Marple, S., Smith, R., Friedrich, M., and Zilaji, T., "NittanySat – A Student Satellite Mission for D-Region Study and Calibration of Riometers," Ibid. 2007.
8. Schratz, B.C., Bilén, S.G., and Philbrick, C.R., "The Student Space Programs Laboratory: Fostering Student Space Systems Education and Research within a University Environment," Ibid. 2007.
9. Wheeler, T.F., Bilén, S.G., Haugland, K. and Philbrick, C.R., "A Broader Vision: Space Projects and International Collaboration," Ibid. 2007.