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Evaluation of NASA's ESMD Space Grant Project: A Descriptive Analysis

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Chapter 1. Introduction

The National Aeronautics and Space Administration (NASA)'s commitment to education spans NASA's Office of Education (OE), NASA Centers, and the NASA Mission Directorates, including the Exploration Systems Mission Directorate (ESMD). Each group makes investments in education programs to contribute to the nation's efforts "to achieve excellence in science, technology, engineering, and mathematics (STEM) education."[1] NASA's education investments are organized around three education goals, to:[2]

1. Contribute to the development of the STEM workforce in disciplines needed to achieve NASA's strategic goals, through a portfolio of investments;
2. Attract and retain students in STEM disciplines through a progression of educational opportunities for students, teachers and faculty;
3. Build strategic partnerships and linkages between STEM formal and informal education providers that promote STEM literacy and awareness of NASA's mission.

ESMD supports NASA's overall education goals as they relate to ESMD's mission to develop the next generation of vehicles and technologies for space exploration. ESMD's education efforts seek to "educate the explorers who will lead us back to the moon."[3] Its investments in higher education are intended to develop systems engineers who can integrate across discipline-specific engineering (e.g., chemical, electrical, mechanical) to ensure successful completion of design projects.[4] Currently, ESMD's largest education project is ESMD Space Grant, operated in partnership with the National Space Grant College and Fellowship Program.

[1] NASA Exploration System Mission Directorate Higher Education Project: Background Information for the ESMD Space Grant Project (10/28/10). Retrieved on March 25, 2011, from http://education.ksc.nasa.gov/esmdspacegrant/NASA_ESMD_Space_Grant_Project.htm

[2] NASA Education Fact Sheet (07.18.06). Retrieved on March 25, 2011, from http://education.nasa.gov/about/factsheet/index.html

[3] *Education in the Exploration Systems Mission Directorate.* Retrieved on March 25, 2011, from http://www.nasa.gov/directorates/esmd/aboutesmd/education/index.html

[4] Hartman, J. and Murphy, G. (August 2008). *Explorations Systems Mission Directorate: Higher Education*. SEED Presentation. Retrieved on March 25, 2011, from http://national.spacegrant.org/meetings/presentations/SpaceSE/6.SEED-PresentationAug08-2-1%20Hartman.ppt

In April 2010, ESMD Education began its efforts to evaluate the ESMD Space Grant by contracting with Abt Associates, Inc. to conduct a descriptive analysis of the project's activities that occurred between FY 2007 through FY 2009. This study has three main purposes:

1. To learn whether stakeholders (i.e., students, faculty, and NASA mentors) are satisfied with their ESMD Space Grant experiences;
2. To collect stakeholders' perspectives of whether the project is meeting its goals; and
3. To generate insight into how the project's performance might be improved.

This report describes the study's findings, and is based largely on interviews with students, mentors, and partners involved with Space Grant. It begins with an overview of ESMD Space Grant's goals, and follows with brief descriptions of its activities. It also includes a brief review of the literature regarding the effect of senior design courses and internships (similar to those funded by ESMD Space Grant funds) for students. Finally, it introduces the project's key partnership with NASA's National Space Grant College and Fellowship Program (Space Grant). Data for this first chapter come from the engineering education literature, ESMD Space Grant monthly and annual reports, ESMD Space Grant solicitations, conversations with the project staff, and the NASA and ESMD Space Grant websites.

ESMD Space Grant Project Goals

Initiated in 2006, ESMD Space Grant contributes to NASA's first desired education goal to contribute to the development of the science, technology, engineering, and mathematics (STEM) workforce in disciplines needed to achieve NASA's strategic goals." [5] The purpose of ESMD Space Grant is "to train and develop the future's highly skilled scientific, engineering and technical workforce needed to meet ESMD's overall goals." These workforce needs span four areas critical to space exploration: spacecraft, propulsion, lunar and planetary surface systems, and ground operations. [6] Ultimately, the intent is to develop engineers nationwide.

To accomplish this goal, ESMD Space Grant partners with NASA's National Space Grant College and Fellowship Program (Space Grant) to support student and faculty STEM activities across the country. For undergraduate and graduate students, the project provides funding for university senior engineering design courses, as well as internships, engineering challenges, and writing competitions focused on ESMD-provided mission challenges. Each of these activities grants students the opportunities to develop the systems engineering skills needed to fulfill ESMD's mission. Recognizing that university engineering faculty may lack the curriculum and technical knowledge needed to lead these ESMD senior design courses, ESMD Space Grant also funds qualified faculty to develop a curriculum for ESMD senior design courses for use at universities across the country. Space Grants also support multi-week fellowships at

[5] National Aeronautics and Space Administration. (April 16, 2010). *FY 2010 NASA Exploration Systems Mission Directorate (ESMD) Space Grant Innovative Project Competitive Cooperative Agreement Notice (CAN).* Announcement No. NNK10ZXA002C.

[6] *NASA Exploration System Mission Directorate Higher Education Project: Background information for the ESMD Space Grant Project*. Retrieved on March 25, 2011, from http://education.ksc.nasa.gov/esmdspacegrant/NASA_ESMD_Space_Grant_Project.htm

NASA Centers and two-day summer workshops for faculty that prepare faculty members to implement ESMD senior design courses. Each of these activities will be described in greater detail in Chapters 3 and 4 of this report.

Partnership with NASA's Space Grant

ESMD's partnership with Space Grant is the key asset that has enabled the project to achieve its goal of a national presence. Space Grant was established by Congress in 1988 and comprises 52 consortia located in every state plus the District of Columbia and the Commonwealth of Puerto Rico. Each consortium is itself an association of organizations interested in science and engineering within the state, including universities, museums, science centers, state and local agencies, as well as industry; today, more than 850 organizations are Space Grant members. Since its inception in 1989, Space Grant has sought to support and improve science and engineering education, research, and outreach efforts across the country to expand the opportunities for Americans to participate in NASA's mission.[7] It funds education opportunities for students pursuing work in science, mathematics, engineering, and technology (STEM) and opportunities for faculty to continue the development of their skills and improve curriculum.

Recognizing the close alignment of their goals, ESMD education and Space Grant have partnered for the ESMD Space Grant project. ESMD education provides an additional funding source for the Space Grant consortia's student and faculty activities. At first, ESMD provided a pre-determined allocation to each Space Grant Consortium. However, as a result of reduced funding, ESMD now offers competitive awards to maintain consortia interest: because all states do not apply, the project can provide larger grants even though the total ESMD dollars distributed are fewer. Space Grant continues to develop relationships with its affiliates and leverages them to generate interest in ESMD Space Grant opportunities via targeted student recruitment and identifying industry partners willing to host ESMD Space Grant interns.

Evidence from the Literature

Studies have shown that both senior engineering design courses and engineering internships like those funded by ESMD are associated with positive student outcomes, including improved learning, skills acquisition, and early career success.

Senior Engineering Design Courses

In 1997, the Accreditation Board for Engineering and Technology (ABET) adopted the Engineering Criteria 2000 (EC2000), which refocused accreditation requirements for engineering programs on "what is learned rather than what is taught" to promote innovation and program improvement; these requirements continue to shape today's accreditation evaluation.[8] The EC2000 requires that students

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[7] *National Space Grant and Fellowship Program.* Retrieved on March 26, 2011, from http://www.nasa.gov/offices/education/programs/national/spacegrant/home/index.html

[8] http://www.abet.org/history.shtml

"be prepared for engineering practice through the curriculum, culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic restraints."[9]

To meet the ABET standards, as well as to better prepare students for workforce positions,[10] engineering programs are increasingly implementing senior design courses.[11] These one- or two-semester capstone courses "bring the practical side of engineering design back into the engineering curriculum" by engaging students in hands-on class projects focused on a design challenge.[12] Sometimes, engineering programs heighten the stakes of these courses by providing a competition at their conclusion, in which the strongest student designs are awarded cash scholarships or other prizes. Evidence from case studies of engineering design competitions demonstrates that these competition events serve to further motivate and excite students as well as create real deadlines for the process. [13]

Education researchers argue that in general, students learn more when they are involved in well-defined, interrelated, and challenging assignments.[14] When compared with subject-based learning, researchers contend that problem-based learning is more effective in enhancing student learning as it "prepares students for formulating and solving problems they have never been exposed to before"[15] while requiring that students "exercise engineering judgment and apply it to a practical problem."[16]

In their extensive review of the literature on engineering design courses, Dutson et al. (1997) found many studies that described the qualitative benefits of these courses.[17] However, they reported limited findings based on empirical analyses:

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[9] Paulik, M.J., & Krishnan, M. (February 2001). A Competition-Motivated Capstone Design Course: the Result of a Fifteen-Year Evolution. *IEEE Transactions on Education*. 44(1), 67-75, p. 67.

[10] Knox, R.C., Sabatini, D.A., Sack, R.L., Haskins, R.D., Roach, L.W., & Fairbairn, S.W. (January 1995). A Practitioner-Educator Partnership for Teaching Engineering Design. *Journal of Engineering Education*. 1-7.

[11] Dutson, A. J., Todd, R.H., Magleby, S.P., and Sorensen, C.D. (January 1997). A Review of Literature on Teaching Engineering Design through Project-Oriented Capstone Courses. *Journal of Engineering Education*, 17-28.; Ibrahim, E.S. (2004). Student Design Projects in King Abdulaziz University for Power Engineers. *International Journal of Electrical Engineering Education*, 41(3), 216-444.

[12] Ibid., p.17.

[13] See for example, Labossiere, P., and Bisby, L.A. (January 2010). Lessons Learned from a Design Competition for Structural Engineering Students: The Case of a Pedestrian Walkway at the Universite de Sherbrooke. *Journal of Professional Issues in Engineering Education and Practice*, 48-56. Paulik, M.J., & Krishnan, M. (February 2001). A Competition-Motivated Capstone Design Course: the Result of a Fifteen-Year Evolution. *IEEE Transactions on Education*. 44(1), 67-75.

[14] Slavin, R.E., Karweit, N.L., Madden, N.A. *Effective Programs for Students at Risk.* Boston: Allyn and Bacon, 1989.

[15] Elahinia, M. H., & Ciocanel, C. (2008). A Problem-solving Approach for Teaching Engineering Laboratories. *International Journal of Mechanical Engineering Education*, 36(2), 140-159, p.142.

[16] Ibrahim, E. S. (2004). Student Design Projects in King Abdulaziz University for Power Engineers. *International Journal of Electrical Engineering Education*, 41(3), 216-444, p.218.

[17] Dutson, A. J., Todd, R.H., Magleby, S.P., and Sorensen, C.D. (January 1997). A Review of Literature on Teaching Engineering Design through Project-Oriented Capstone Courses. *Journal of Engineering Education*, 17-28, p.17.

> The literature is filled with positive comments from students, instructors, and industrial sponsors...The nature of capstone design courses, however, often leads to a purely subjective evaluation with little or no 'hard evidence' of actual benefits.[18]

One article published since this review was released begins to address this gap and quantify the benefits of these courses' active and collaborative teaching approach. Terenzini et al. (2001) used survey results from 480 students across six universities to compare the effects of conventionally-taught engineering courses to those taught using "active and collaborative approaches." These surveys collected information about students' backgrounds, the instructional characteristics of the course in which they were enrolled, and the extent to which that course had enabled them to make progress towards their learning goals. After controlling for observable pre-course differences using multiple regression analyses, they found that students in "active and collaborative" design courses acquired greater skills in design, communication, and group work that were "both statistically significant and substantial."[19]

Engineering Internships

ESMD Space Grant also funds internships that enable students to take on temporary engineering positions at space industry companies to work on professional engineering projects. These internships are similar to the cooperative education (co-op) opportunities that universities frequently offer (i.e., programs that integrate coursework with paid work experience), which also provide students with industry experiences in engineering. Several studies have examined the effect of co-op work experiences, finding positive relationships with both student learning and early career outcomes.

Literature supports the theory that industrial work experience helps students learn about the design process. A recent study found that the industrial experience significantly improves students' knowledge that documentation throughout a project is an important activity in design.[20] Work experience is also related to higher student achievement. For example, Blair et al. (2004) collected data on the 773 engineering majors who graduated from Mississippi State University between fall 2000 and spring 2002. After controlling for student race, intellectual ability (as measured by their American College Test (ACT) scores), gender, and age, they determined that engineering graduates who had participated in a three-semester long co-op while in university finished their degrees with higher cumulative grade point averages (GPAs) and earned higher starting salaries than graduates who had not participated in co-ops; co-op participants did, however, take longer to graduate. [21] Using data from the exit survey

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[18] Dutson, A. J., Todd, R.H., Magleby, S.P., and Sorensen, C.D. (January 1997). A Review of Literature on Teaching Engineering Design through Project-Oriented Capstone Courses. *Journal of Engineering Education*, 17-28, p.24.

[19] Terenzini, P.T., Cabrera, A.F., Colbeck, C.L., Parente, J.M., & Bjorklund. S.A. (January 2001). Collaborative Learning vs. Lecture/Discussion: Students' Reported Learning Gains. *Journal of Engineering Education*, 123-130.

[20] Bailey, R. (July 2007). Effects of Industrial Experience and Coursework during Sophomore and Junior Years on Student Learning of Engineering Design. *Journal of Mechanical Design*, 662-667.

[21] Blair, B.F., Millea, M., J. Hammer (October 2004). The Impact of Cooperative Education on Academic Performance and Compensation of Engineering Majors. *Journal of Engineering Education*, 333-338.

administered at Pennsylvania State University's College of Engineering between 2001 and 2004, Schuurman et al. (2008) reached a similar conclusion regarding GPAs. Additionally, Shuurman et al., found that students with undergraduate work experiences were more likely to receive full-time job offers prior to graduation.[22] Furthermore, Wessels and Pumphrey (1996) concluded that students with co-op experiences advance more quickly once they begin their careers.[23]

Organization of This Report

Chapter One introduced the ESMD Space Grant project and provided a brief review of the literature. Chapter Two describes the study design, outlining the evaluation questions, data sources, data collection and analysis techniques used for this report. Chapter Three focuses on the ESMD Space Grant student activities; it describes the activities and participants, presents the study's findings regarding the perceived benefits and challenges, and describes the general feedback provided by the study's respondents. Chapter Four parallels Chapter Three to provide the study's findings regarding faculty activities and their feedback. Finally, Chapter Five summarizes the findings and offers recommendations.

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[22] Schuurman, M.K., Pangborn, R.N., and McClintic, R.D. (April 2008). Assessing the Impact of Engineering Undergraduate Work Experience: Factoring in Pre-work Academic Performance. *Journal of Engineering Education*, 207-212.

[23] Wessels, W.J., & Pumphry, G. (1995). The Effects of Cooperative Education on Job Search Time, Quality of Job Placement and Advancement. *Journal of Cooperative Education*, 31(1), 42-52.

Chapter 2. Evaluation Design

This evaluation marks the first independent assessment of the ESMD Space Grant project. Its chief objectives are to determine whether the project is meeting its goals and whether its customers, defined as students, faculty, and NASA mentors, are satisfied with what the project offers. It also explores the relative value of the project's activities and considers why some activities seem to be more successful than others. The findings from this evaluation will assist ESMD in its management of the ESMD Space Grant Project.

Evaluation Questions

This evaluation of NASA's ESMD Space Grant project is designed to address the following evaluation questions:

1. To what extent has the project met its goals and objectives?
    - Has the project contributed to the development of the STEM workforce in disciplines needed to achieve NASA's strategic goals?
    - Has the project promoted student and faculty learning relevant to current NASA ESMD activities?
    - Has the project produced innovative and novel ideas that could complement those under development at NASA?
    - Has the project contributed to students' retention in STEM?
    - Does the project improve the prospects for graduating seniors to pursue graduate studies and seek careers in the space industry?
2. Has the project successfully leveraged the expertise of NASA engineers to meet its objectives?
3. Across the activities that the project has offered, which do its participants perceive as providing the greatest value? Which seem to be of least value? Why?
4. How might activities be changed to enhance the project's ability to meet its goals and objectives?

Data Sources

The evaluation takes a case study approach; it triangulates data from multiple sources and interviews to provide a qualitative description of the project's past performance and participants' recommendations.

ESMD Project Materials

A variety of project-related materials from various sources were collected and reviewed. In addition to the documents that the ESMD project team shared, such as the project's monthly progress reports and annual performance summaries, independent web searches were also conducted yielding press releases and information sheets. The research team closely examined these materials, deepening its understanding of the project in preparation for the original data collection effort, interviews with Space Grant students, faculty, and mentors.

Interviews with Stakeholder Groups

We conducted semi-structured telephone interviews with seven stakeholder groups who play an important role in the project or are intended to benefit from the project's activities: students, faculty, NASA mentors, university administrators, Space Grant consortium administrators, participating students' employers and the NASA education points of contact at the NASA Centers, who are responsible for logistical support of student interns and faculty at NASA Centers (e.g., ID badges for entry, computer access, center tours, housing and transport information). Members from these different groups were contacted to allow the research team to understand commonly perceived project benefits and hurdles, as well as to understand how perceptions vary across the stakeholders' positions.

The interviews were tailored to the stakeholder's position and relationship with the project. Sample interview protocols for the various stakeholder groups are provided in Appendix A. Broadly, the questions focused on the following areas, stakeholders':

- Expectations regarding ESMD activities;
- Perceptions of the benefits to student participation in ESMD activities;
- Perceptions of the benefits to faculty participation in ESMD activities;
- Perceptions of the challenges to participation in ESMD activities;
- Perceptions of the importance of specific project activities; and
- Reactions to recent ESMD changes and their impact on the student and faculty experiences.

Data Collection

Respondents were selected from lists maintained by the ESMD Space Grant. When possible (depending on the available information), respondents were selected with attention to diversity of activities they were engaged in, as well as their home states and institutions. Additionally, the research team attempted to include respondents from institutions that the project team indicated as key sites. Up to nine individuals were interviewed in each group. In total, 53 individuals[24] participated in the data collection between June 2010 and January 2011, including:

[24] Note that several respondents had multiple roles in the project (e.g., one Space Grant contact is also a university administrator), so that the total number of interviews is less than the total number across the role categories.

- 3 interns at NASA Centers;
- 9 senior design project participants;
- 7 engineering challenges and paper competition participants;
- 6 faculty workshop participants;
- 3 faculty fellows;
- 3 faculty funded to design senior design project curricula;
- 6 faculty implementing senior design projects;
- 4 administrators at participating universities and colleges;
- 9 NASA mentors;
- 9 representatives from Space Grant Consortia, typically executive directors;
- 5 of the project's points of contact at NASA Centers; and
- 3 employers of ESMD student participants.

Detailed notes were taken during the conversations, which were augmented by audio recordings of the conversations (as agreed to by the respondent).

Data Analysis

During the data collection period, the evaluation team met regularly to discuss what they had learned and identify common themes across respondents. Interview notes were uploaded into NVivo—a qualitative analysis software program that facilitates the search and retrieval of data—and coded using themes derived from the interview protocol and the team's discussions. We then created data reports organized by these coded themes (e.g., benefit to internships, challenge to creating curriculum) and stakeholder group (e.g., student, faculty, Space Grant contact). We systematically reviewed these reports to produce descriptions of how the different stakeholders addressed the evaluation's key concerns and then synthesized the data to answer the evaluation questions.

Study Limitations

The evaluation collected data that provides valuable feedback for the program about individuals' experiences with the programs, their perceived value, and recommendations for modifications. However, there are limitations to the study that constrain the conclusions that can be drawn, in terms of the ability to generalize the findings across all ESMD Space Grant participants. As quantitative data regarding the project's outcomes of interest, such as tracking data of students' education and career choices over time, were not available, the evaluation took a qualitative approach to answer the study's questions. It used interviews to collect rich, detailed descriptions of respondents' experiences with the project. As it is not feasible to interview all participants, the information collected is limited to the experiences of those who responded, which may differ from other ESMD Space Grant participants.

The generalizability of the results may also be limited by difficulties encountered in finding ESMD Space Grant participants. Students were particularly difficult to reach, possibly because NASA's contact list contained many university accounts, which students may no longer check after graduating. In addition, locating university administrators and participant employers was a challenge. To engage participants in these groups, respondents were asked for referrals; while allowing the evaluation team to find individuals across all stakeholder groups, this “snowball” sampling approach could have introduced bias if respondents were more likely to recommend certain contacts over others (e.g., faculty referring students who they believed had only positive experiences with the project). The evaluation mitigates this risk by synthesizing the responses of the stakeholders with the responses of the other four groups.

Chapter 3. ESMD Space Grant Student Activities

ESMD Space Grant funds two primary types of activities for students. The first, senior design courses, are team-based, “real world” capstone courses typically required by engineering programs. During these courses, students learn about NASA’s systems engineering process and gain hands-on experience addressing an ESMD-related challenge. Sometimes these courses include competitive events to enhance student benefits. The second activity, internships, allows students to engage in ESMD-related projects through off-campus working experiences. In this chapter, we describe each of the activities and their participants, identify the benefits reported by the different stakeholder groups, list the challenges they described, and present the feedback they offered.

ESMD Senior Design Engineering Courses

Description of the ESMD Senior Design Courses

Typically, undergraduate engineering majors must complete a semester-long or full-year senior design course to meet graduation requirements. These courses are intended to provide students with “real world” opportunities to gain hands-on experience in engineering, whereby students apply the skills and knowledge gained through their earlier course work to produce design solutions to real engineering problems.

ESMD Space Grant sponsors senior design courses that integrate ESMD-generated mission challenges into their curriculum. ESMD provides funding so that student teams may purchase the materials and resources they need to build and test their design prototypes as well as allow their faculty advisors to bring in subject matter experts who assist in the successful completion of the projects.[25] In addition to financial support, ESMD Space Grant also provides access to a NASA scientist or engineer whose work is related to the course topic; this NASA staff person provides mentorship and shares technical expertise with the faculty advisor. Students usually complete the design challenge over two semesters at the end of which they present their results to NASA scientists and engineers. If they choose, students may also write papers based on their senior design course to enter the ESMD systems engineering paper competition. Furthermore, students whose senior design courses focused specifically on lunabotics mining may enter the ESMD Space Grant annual design competition. These competitive activities are discussed later in this chapter.

Each year, ESMD generates a list of NASA senior design project ideas from which interested faculty advisors and student teams can choose; these project ideas are challenges that NASA engineers and scientists across Centers have identified as relevant to their work. The projects all focus on aspects of space exploration, including spacecraft (e.g., guidance, navigation and control, power systems, avionics, spacecraft material, crew monitoring life support), propulsion (e.g., methods to use resources found in space as propellants, fuels), lunar and planetary surface systems (e.g., landing hardware and software,

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[25] NASA Exploration Senior Design Projects. Retrieved on March 26, 2011, from http://education.ksc.nasa.gov/esmdspacegrant/Sr_Design.htm

navigation systems, radiation protection, space suits, power systems), and ground operations (e.g., pre-launch, launch, communications, command and control software systems, landing and recovery).[26] [27]

These courses are expected to expose students to the principles of systems engineering, an interdisciplinary approach that integrates the different engineering domains, such as mechanical, electrical, and materials engineering, in a structured design process to move a concept through development and into production successfully.[28] The senior design courses are intended to provide students the opportunity to follow a systems engineering process that usually includes seven key steps: 1) state the problem; 2) investigate alternatives; 3) model the system; 4) integrate; 5) launch the system; 6) assess performance; and 7) re-evaluate.[29]

Study respondents who participated in these courses described a variety of design challenges that serve as a foundation for the senior design courses; a description of one follows. One student discussed a project that involved recreating a smaller version of the Apollo capsule and measuring its pressure distribution as it fell into the ocean. Today, spacecraft land on pads placed on earth, but the student reported that some engineers are interested in exploring the use of the ocean for landing. The objective was to estimate the pressure on heat shields as the capsule landed. The respondent and his team members designed a pressure-sensitive film, built a 95-100 pound capsule and dropped it into their university's pool for testing. They found that the film was not precise in its assessment of pressure but did provide a reasonable estimate that could be used to confirm measurements made by other tools.

Senior Design Course Participants

Between the project's inception in 2007 and 2010, 2,897 students have participated in ESMD senior design courses (see Appendix A). Over these years, the project has maintained an impressive national reach even as funding decreases: in 2008, students participated in ESMD senior design courses in 43 states, most frequently in universities located in Texas, New Jersey, and Montana;[30] in 2009, students participated in ESMD senior design courses in 31 states, most frequently in universities located in Michigan and Washington;[31] in 2010, students participated in ESMD senior design courses in 18 states, most frequently in universities located in North Carolina and Texas.[32]

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[26] *Background Information for the ESMD Space Grant Project.* Retrieved on March 26, 2011, from http://education.ksc.nasa.gov/esmdspacegrant/NASA_ESMD_Space_Grant_Project.htm

[27] A complete list of the current 116 project ideas is available at ESMD Space Grant's website: http://education.ksc.nasa.gov/esmdspacegrant/Documents/ESMD_Senior_Design_Project_List.pdf

[28] International Council on Systems Engineering. *What is Systems Engineering?* Retrieved on March 26, 2011, from http://www.incose.org/practice/whatissystemseng.aspx

[29] International Council on Systems Engineering. *A Consensus of the INCOSE Fellows.* Retrieved on March 26, 2011, from http://www.incose.org/practice/fellowsconsensus.aspx

[30] *2008 ESMD Space Grant Project Final Report.*

[31] *ESMD Space Grant Project 2009.*

[32] *2010 ESMD Space Grant Project Final Report.*

The percentage of underrepresented and underserved students (i.e., minority, low-income, and/or female students) has varied across the years, ranging from 15 to 25 percent. In FY 2007, 25 percent of the participants were female and 20 percent were underrepresented and underserved;[33] in FY2008, 20 percent of senior design courses were female and 20 percent were underrepresented and underserved.[34] In FY 2009, 15 percent of the senior design participants were female and 24 percent of participants were underrepresented and underserved students. [35] Note: demographic data for student participants in 2010 is not available.

Senior Design Course Recruitment

ESMD senior design course opportunities are advertised by Space Grants through their networks via emails to list-servs, engineering department heads, and related student clubs. They also disseminate information about the program through word-of-mouth and by approaching individuals they think might be interested when they make their presentations on university campuses. Faculty advisors typically find ESMD Space Grant opportunities through web searches, emails forwarded by their state's Space Grant consortia, or through recommendations from colleagues. Interested faculty members apply for the funding through their state's Space Grants. Once funding is awarded, the faculty members generally recruit students to their ESMD senior design courses. Students commonly select the ESMD senior design courses at their universities because they are interested in space exploration and are excited by the opportunity to tackle a real design challenge that might be of use to NASA. Some also enrolled because they thought it would help them professionally. As one student stated:

> I wanted to do this NASA project. Trying to build hardware that could go into space -that's what piqued my interest! Our teacher showed us the people who we will probably be working with. [I saw myself] being able to network… [and] put myself out there to get experience that some people may not be able to get…It put me a prime position to get experience for the future.

All students reported that their expectations for the senior design course were met and that they would recommend the ESMD Space Grant senior design course to other students.

Benefits for Student Participants in Senior Design Courses

Overall, respondents described the ESMD senior design course experience as highly beneficial for students, serving as a bridge between college coursework and post baccalaureate experiences. They reported benefits for students that fall into three areas: student interest in engineering; skills-building; and pathways to space exploration careers.

Student Interest in Engineering

Students reported that the senior design experience influenced their interest in or thinking about future job aspirations in engineering. For example, one student stated that he appreciated "the concepts that I learned through the project, as well as the interest that it gave me in pursuing more work in the field [by

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[33] *Year End Reporting 2007 ESMD Space Grant Project.*

[34] *2008 ESMD Space Grant Project Final Report.*

[35] *ESMD Space Grant Project 2009.*

showing me] how interesting it is." He thought the course "could really spark those same interests in other students." Another student reported the experience was "pretty much a validation of everything I had hoped engineering would be" and it "validated my decision to go into engineering." These sentiments were echoed in yet another student's comments: "This project [has] been the highlight of my academic career up to this point." One faculty member commented that this increased interest may be related to the fact that students in the design course feel that they have "an intimate, individual experience" working with a team of a few students as compared to the usual experience at universities of projects involving 50 to 70 students.

Respondents also indicated the ESMD Space Grant experience increases the likelihood that students will pursue engineering careers. One university administrator conjectured that senior design courses may be more likely to change student career aspirations than internships because many students who may not have considered a profession in aeronautical engineering (and thus, would not apply for an internship in the field) must complete a senior design project for graduation; through the ESMD senior design project, they can discover interests that were previously unknown to them. As an example, this university administrator shared a story about a student who was planning to get a job after finishing her bachelor's degree, despite urging from her professors to continue her education in graduate school. It was only after participating in a senior design course and winning the lunabotics competition that she changed her mind and decided to pursue a graduate degree in engineering. Student comments at least partly supported this administrator's hypothesis, indicating that the senior design courses can change career directions. For example, one student commented, "I know that the point of this [course] was to [provide] insight on skills for systems engineering and interest in the NASA program, and I think it did a great job. I didn't think of engineering as a career before and now I am considering it."

In some cases, working on the challenges provided students with information about systems engineering that led them to make choices to pursue careers they felt better suited them. For example, one respondent noted that the ESMD Space Grant senior design course experience taught him that he is less interested in pursuing a systems engineering approach; another student agreed, "I realized there was more paperwork involved than I would enjoy…[there would be] less working with hardware and more working with people and presenting ideas…talking about stuff instead of doing stuff." For these students, the value of the experience is the discovery that systems engineering is not the career path they want to pursue, which helps them to reformulate their career strategies. This greater self-awareness not only benefits the students, but NASA as well, as it can help avoid recruiting students who are capable but ultimately not a good fit for the work environment.

Skills-Building

In addition to reporting increases in students' interest in engineering and its related careers, respondents indicated that students also acquired multiple skills through their senior design projects. These skills fall into two areas: substantive skills in engineering and technology as well as more the generalizable skills critical to succeeding in a work environment.

Respondents discussed how the senior design projects expanded students' engineering skills. Students reported that the projects encouraged collaboration among students with different specialties, which helped them synthesize work from a variety of previous courses. Students also learned new software that NASA “actually uses” on a daily basis. One faculty member reported that the best aspect of the Space Grant project is that it challenges students to apply what they have learned, turning them into “real engineers”, rather than asking them to regurgitate information on a test as they had for their first three years of university.

Many respondents also discussed growth in skills with general applications in the workplace, including the ability to manage projects, work in teams, communicate clearly, set timelines, monitor budgets, and manage their time. These skills were developed as students were expected to complete “real world” projects. One student commented: “I’ve gotten experience in the real world…It’s like we are getting part of the workplace. It’s making it a smooth transition from the education environment into the actual workplace.” As students were expected to “run” the projects, a few students reported that it necessitated them taking on more personal responsibility than in other courses. Successful teamwork too was a priority. One student described:

> As a group we had to learn how to mesh. In the industry, teamwork is a big part of a lot of projects. So we had to define our roles within the group and stick to those roles and help out the group as best as we could. That was a big challenge, but in the end, I learned a lot from it.

Pathways to Space Exploration Careers

The third common benefit reported by respondents was the perception that the ESMD senior design courses provided “real world experience” that improved students’ career prospects. Many respondents saw the NASA experience as a significant resume builder, as it demonstrated that students have actual experience doing relevant work as part of their college curriculum at a highly reputable agency. One student commented that “it was helpful to have an experience on my resume where I used the skills that I wanted to use at work.”

Anecdotal evidence suggests that the experience may be related to future career prospects; for example, one faculty member reported that three of his students who participated in the ESMD Space Grant senior design project were hired by NASA upon graduation. Interviewed employers also noted that the ESMD experience played a large role in their decision to hire the participating students.

Benefits of Senior Design Courses for Other Stakeholders

The ESMD Space Grant courses also provided benefits for NASA, the Space Grants, and the participating universities. These are described below.

Benefits for NASA

A few respondents indicated that NASA also derives benefits from the ESMD Space Grant design courses. Student respondents discussed how the projects themselves created data that NASA found valuable. One student discussed that several NASA engineers told him that they were impressed with his work and were interested in using something similar on the shuttle; his project gave them more data on the viability of using a particular type of sensor film. Another respondent felt that the project also benefited the Space Grants, helping them to extend their networks and develop relationships. She noted how the positive experiences that one professor had with these courses has encouraged him to become more active with the Space Grant Consortium.

Benefits for Participating Universities

The final beneficiaries that respondents described are the universities where these courses are taught. The universities benefited through the "warm glow" of NASA's brand equity and through the integration of the systems engineering approach into their engineering programs. University administrators and faculty members reported that these projects' affiliation with NASA "lent prestige to the course" and also to the university. They noted that they are proud to be affiliated with NASA and believe that this connection reflects positively upon the quality of their engineering program. Several respondents mentioned that they use these courses to attract students to their universities. For example, one university administrator reported that the NASA-funded course has attracted women to her university program who want to work for NASA while another university more actively uses the NASA-funded course as a recruiting tool.

Several universities also attributed changes to the structure of their overall engineering programs to their experience with the ESMD senior design courses. One faculty member reported that it inspired her school to create more formalized courses that emphasize the engineering design process, moving away from their previous use of students in senior capstone projects simply as support for professors' research. The same school also integrated systems engineering into their course work, something which previously was not part of the curriculum. Yet another school adopted the systems engineering model throughout all of its capstone projects, which has allowed for more interdisciplinary work at its institution.

Challenges to Senior Design Courses

Challenges for Students

The challenges related to the senior design courses, as described by students and their faculty, were related to specific skills. Above all, time management was the most prevalent hurdle, followed by team work and communication. As one student reported:

> I'd probably have to say time was the biggest challenge. When you're in school, you don't take one class per semester…. We wanted to do our best as a team, so we felt it was necessary to spend a lot of time…It was just kind of hard to get everything the way we wanted…but then again, when we get out into the workplace, you don't have all the time in the world.

Several students mentioned needing to scale back their initial expectations in order to meet deadlines. Faculty members also recognized this challenge, and noted that the students had to put in more time for the NASA ESMD senior design course than other senior design courses offered at their universities but thought that most students found it to be "well worth it."

Getting everybody to work together as a team proved challenging; one student noted, "One or two people did not really contribute, and that really hurt us." Another student described the project as "big and difficult" and getting everyone to work on something was hard, as there were parts that no one wanted to do. Related to teamwork were the challenges of communication, as this student continued, "learning to communicate so everyone knew what they needed to do, what other people were doing, and what was expected of them was also really hard."

Finally, a few students also reported being pushed by the rigor of the course, which several Space Grant contacts noted was "just how it should be." For example, one found it hard to learn the software programs needed to complete his design. One Space Grant contact commented that students at smaller universities were more likely to confront this sort of challenges, as they likely have only taken one class in computer science prior to the senior design course. Regardless of these challenges, there was an overarching sentiment that the courses were well worth the effort.

Challenges for NASA Mentors

Several NASA mentors who supported senior design courses indicated that their experiences with the project were not always positive, prompting a few to withhold recommending the project to their colleagues. The chief complaint was that some felt their time was not well used. These mentors reported that the universities did not play as large a role as they had expected and were not committed to the senior design courses. Ultimately, lack of university support required that these mentors take on oversight responsibilities, and as reported by two respondents, they needed to "micro-manage" the courses they mentored.

Respondent Feedback for Improving Senior Design Courses

While all students reported that their expectations for the ESMD senior design courses were met and only a few NASA mentors indicated differently, they provided some feedback on how the experiences could be improved. Several respondents noted that the expectations for the NASA mentor role was not entirely clear, manifesting in "disconnects" between the students' design projects and the NASA mentors, sometimes disappointing both parties. As one student described, "We had an issue with the guy who came from NASA. He didn't really understand what our professor was expecting of us. He was a little disappointed with what our project turned out to be." Responses from some NASA mentors described their disappointment as they felt that too much was expected of them in managing the courses; one has consequently stopped participating in ESMD Space Grant.

For their part, several students wanted more interaction and guidance from the NASA mentors associated with their senior design courses; their professors concurred, several indicating that increased engagement of the NASA mentor with students would be helpful in lending a professional perspective to the students' designs. One professor noted that it was unclear how the course may have benefitted NASA as there was no further interaction with NASA after the students' final presentation. Ideally, this faculty member would like follow-up conversations so that students could learn from previous senior design course experiences and she would have a better idea of whether the designs were useful to NASA.

One faculty member also suggested diversifying the engineering focus of the project ideas to include more topics of interest to materials engineers and computer scientists. She felt that while ESMD offers an extensive list of project ideas, many of these focus on electrical and mechanical engineering. As she does not specialize in either of these fields, she found it difficult to lead these projects without support of mechanical or electrical engineers.

Senior Design Course Related Competitions

ESMD Space Grant also provides two types of competitive opportunities for students who participate in senior design courses, design and paper competitions, intended to further motivate students and enhance their skills. These are described below, along with their specific benefits and challenges.

Paper Competitions

Since 2007, ESMD Space Grant has held an annual systems engineering paper competition, inviting students from around the country to submit a paper about their senior design project, which must be related to one of the four ESMD areas (spacecraft, propulsion, lunar and planetary survey systems, or ground operations) and use a systems engineering process. The intent is to provide students the opportunity to develop their writing skills. Beginning in 2010, papers are scored in four categories: content, intrinsic merit, ESMD relevance, and technical merit.[36] The judges take the highest scoring papers and decide which will be awarded first, second, and third prizes.

In 2007, eight teams entered, with first place going to the student team from Purdue University, while second and third places were awarded to students from Georgia Tech. In 2008, seven teams entered the writing competitions. First and second place prizes went to students from Georgia Tech and third place went to Virginia Tech's team. In 2009, turn out was low with only four teams entering competitive activities. ESMD awarded first place to two teams, one from Virginia Tech and the other from Rice University. In 2010, the project invested more in their advertising efforts and received 11 team submissions; three teams won, with first place going to a team from MIT, second place going to a team from Virginia Tech, and third place going to a team from University of Michigan.

ESMD Space Grant also held a research paper competition in 2010. Students were invited to prepare papers focused on one of the four topics identified by ESMD Space Grant within ESMD's focal areas. For example, students interested in ground operations were invited to submit a paper on "Spacecraft Landing and Recovery Architecture-Historical Approaches and Ideas for the Future;" students interested in propulsion were asked to research the "Loading of Cryogenic Propellant in Space Launch Vehicle." Given the quality of the papers it received, the ESMD decided to cancel this competition.

Design Competitions

Since 2010, ESMD Space Grant has held an annual Lunabotics Mining Competition. This event is a spin-off of the Regolith Excavation Challenge, one of the NASA Centennial Challenges held in 2007, 2008, and 2009, intended to encourage innovation in aerospace research and development.[37] Students are challenged to design and build a lunabot, a remote controlled or autonomous excavator that can dig and move at least 10 kilograms of lunar simulant, a material that is similar to the moon's highly abrasive "soil", in 15 minutes.[38] Students travel to the Kennedy Space Center for the competition, practice in the

[36] 2011 *ESMD Space Grant Systems Engineering Paper Competition.* Retrieved on March 26, 2011, from http://education.ksc.nasa.gov/esmdspacegrant/SystemsEngineering.htm

[37] *Office of the Chief Technologist.* Retrieved on April 18, 2011, from http://www.nasa.gov/offices/oct/early_stage_innovation/centennial_challenges/pastchallenges/index.html

[38] *Lunabotics Mining Competition.* Retrieved on March 26, 2011, from http://www.nasa.gov/offices/education/centers/kennedy/technology/lunabotics.html

"sandbox" for three days and then compete for three days. Awards include monetary scholarships, Kennedy Space Center launch invitations, and up to $1,500 travel expenses for each team member and one faculty advisor to participate with the NASA Desert RATS.[39]

Students who enter the Lunabotics Mining Competition are also required to enter its two paper competitions. First, they must submit a systems engineering paper that is reviewed by a multi-disciplinary panel of NASA engineers. The winning systems engineering paper receives a $500 scholarship award. The second paper is related to the Competition's requirement that students participate in outreach activities to K-12 students, in either formal or informal education settings.[40] Students prepare reports that describe their outreach activities; these reports are scored according to five elements: content, education outreach, creativity, illustrations and media, and formatting and appearance. The winning outreach paper receives a $500 scholarship award.

In 2010, more than 20 teams entered the Lunabotics Mining Competition; winners came from Montana State University, Embry Riddle Aeronautical University, Auburn University, Western Kentucky University, and the University of Southern Indiana. This May, the project expects 46 teams from 27 states and 12 teams from universities outside the U.S., including institutions in India, Bangledesh, Colombia, and Canada to participate in the Lunabotics Mining Competition. [41]

Benefits of Competitive Activities

Competitions produce two additional benefits for students who participate in senior design courses. The lunabotics event generated significant excitement that was palpable. As one student reported:

> I cannot count the number of nights that I was down there in that lab soldering stuff together, listening to the radio and just having the time of my life...and then to go to the competition…I mean we went to Kennedy Space Center!...Man, how much more awesome and epic does it get?

Students also reported that the competitions improved their writing skills. As one student commented, the experience "really impressed upon me how important communication is in engineering." Several students felt that learning how to write about engineering design was a key aspect of their experience. As one participant stated, "The most valuable part of my [paper competition] experience was the act of gathering my work in the format needed for the paper."

Challenges of Competitive Activities

Students reported that the chief challenge of the competitive activities was related to the writing requirements, where several noted that their teams had trouble keeping to the page limits. One respondent described her struggle to get her team of 26 students "to write coherently and in one

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[39] An event where NASA-led team of engineers, astronauts and scientists from across the country convene to conduct technology development research in the Arizona desert, to prepare for future planetary exploration missions. For more information, see http://www.nasa.gov/exploration/analogs/desert_rats.html

[40] *Lunabotics Mining Competition – Rules and Rubric*. November 23, 2010. Retrieved on March 26, 2011, from http://www.nasa.gov/pdf/390619main_LMC%20Rules%202011.pdf

[41] *Lunabotics Mining Competition.* Retrieved on March 26, 2011, from http://www.nasa.gov/offices/education/centers/kennedy/technology/lunabotics.html

voice." She, as the project's chief engineer, assigned sub-teams different topics to draft. She and a small group of students then reviewed and edited the paper before its submission.

Respondent Feedback for Improving Competitive Activities

Respondents were positive about their experiences with the competitive activities, and few respondents offered suggestions about how to improve the competitive activities. In terms of the paper competitions, several students indicated they thought NASA should allow them to write longer papers as they struggled to address the topic within the page limits. Student participants in the Lunabotics Mining Competition in May 2010 indicated the event went well, even though there were lots of last minute changes, which did not surprise them as they recognized that this was the first year of the competition. One respondent suggested that as NASA is no longer seeking to go to the moon, the project might want to change the competition's context to Mars. One other faculty member suggested limiting the Lunabotics Mining Competition to "American students, preferably undergraduates," as he observed that there "were teams that not only had graduate students, but often those graduate students were foreign students. It is hard to stop a university that take a 'win at all costs' attitude…but at least removing foreign graduate students would be a big improvement."

Student Internships

Description of Student Internships

ESMD Space Grant funds internships during which students are engaged in hands-on engineering projects to support a scientist's or engineer's explorations-related projects. The intent is to expose and engage interns in the kind of work they would do if they were to pursue a career in the space industry, as well as to provide the mentors and possible employers with a sense of the students' productivity and fit with their organization.

ESMD originally sponsored internships both at NASA Centers and at space industry organizations. In 2009, the project decided to limit internships to industry only. This was a stark shift for the project, as previously most internships had been at NASA Centers. There are two key reasons for this change. First, the funding available to ESMD Space Grant has decreased over time, necessitating that the project reassess its priorities to ensure it invests its resources in a way that provides value to NASA's portfolio of education projects. As a result, the ESMD Space Grant project has chosen to focus on the senior design courses as they are less resource-intensive than internships so that the Space Grant project can use them to reach more students, albeit with a less concentrated mentorship experience. Furthermore, several education projects already fund internships at NASA Centers, while ESMD Space Grant is one of the few –perhaps the only one – that supports senior design courses. Accordingly, more of the projects resources are directed to the courses, and the project is funding fewer internships.

Secondly, NASA has traditionally sponsored internships to recruit the best and brightest engineers and scientists for positions at the agency. However, NASA increasingly uses contractors to fulfill its mission and is hiring far fewer civil servants than it has in the past. This means that students are more likely to find employment in industry than at NASA, so that obtaining hands-on experience at a space industry organization may be more valuable for launching their engineering careers than interning at NASA.

The student respondents who agreed to participate in the study all had interned at NASA Centers. This is not surprising as between 2007 and 2009, more ESMD interns were placed at NASA Centers than in space industry organizations; see Appendix A. Consequently, the discussion that follows focuses on the internship experiences at NASA Centers.

The students and NASA mentors who participated in this study described internship experiences where students were frequently engaged in the design, analysis, and testing phases of a project. The specific content applied in the internships, and the roles fulfilled by the students, varied widely. Two internship opportunities are described below.

1. One NASA mentor brought on several interns to work on his project developing technology that makes it more efficient to sustain longer duration exploration missions in space that are safe for the crew. Specifically, his work focuses on air revitalization, to ensure that the astronauts are working in a breathable atmosphere, where air is provided, purified and maintained in good condition, while its temperature is controlled. A few of his interns worked on designing and testing an oxygen compressor while another focused on testing the ability of a portable breathing apparatus to provide emergency air.

2. Another mentor runs a nondestructive evaluation lab, where he and his student interns assess how microwaves and other high frequency waves impact an object's performance. For example, his lab has performed scans on orbital tile as well as on the foam placed on an external tank. His students help to build mock-up walls, develop the testing and write up the procedures, and perform the testing using a Frequency Modulated Continuous Wave (FMCW) radar system. Students also developed the software that helps prepare the scanning test results and analyzes the data.

In general, respondents indicated that the internships involved "so much beyond research." NASA Center education points of contact who were interviewed for this study described providing the interns with enrichment activities, social engagements, trips, and opportunities to meet other NASA interns. One respondent discussed how she encouraged the interns to participate in NASA's outreach activities. Another held a weekly lunch for her Center's interns where they talked about their NASA work in "lay person" terms (i.e., without acronyms) so that all interns could learn from each other's internship experiences as well as practice presenting research in an understandable way.

Internship Participants

Between 2007 and 2010, there have been 534.5 student participants (ESMD Space Grant paid for half of one student's internship) in ESMD-funded internships, 292.5 at NASA Centers and 242 at space industry organizations (see Appendix A). During these years, the project achieved an impressive national reach: in 2008, ESMD funded internships for students across 47 states, most frequently for students from Delaware and Oklahoma;[42] in 2009, ESMD funded internships for students across 41 states, most

[42] *2008 ESMD Space Grant Project Final Report.*

frequently for students from Michigan and Wyoming;[43] in 2010, ESMD funded internships for students across 24 states, most frequently for students from Illinois.[44]

The percentage of underrepresented and underserved students (i.e., minority, low-income, and/or female students) has varied across the years, ranging from 18 to 27 percent. In FY 2007, 27 percent of the interns were female and 18 percent were underrepresented and underserved;[45] in FY2008, 21 percent were female and 26 percent were underrepresented and underserved.[46] In FY 2009, 24 percent of the senior design participants were female and 27 percent of participants were underrepresented and underserved students.[47] Note: demographic data for student participants in 2010 is not available.

Internship Recruitment

Similar to the recruitment process for the ESMD senior design courses, Space Grants advertise the ESMD internship opportunity through their networks by sending information to their email list-servs and by emailing engineering department heads and related student clubs directly. They also spread the information through word-of-mouth by reaching out to individuals they think might be interested and discussing it during their presentations on university campuses. Students reported learning about the opportunity from emails distributed by their professors and web searches.

Students reported applying because they were interested in, as one student stated, "experiencing what it is like to work at a NASA Center… or just help out and see the environment." The process through which students apply is changing. Between 2007 and 2009, students had the option of completing the more generic Space Grant's application for any NASA internship or one specifically for the project; in 2010, the optional ESMD Space Grant application was dropped as the project no longer funded internships at NASA Centers. By FY2012, NASA plans to offer a "one-stop shop" for internship applications, whereby all prospective NASA interns will complete a common form regardless of the project that would provide funding, including the internships that NASA sponsors in space industry organizations.

Benefits for Participating Students

All students reported that their expectations for the internships were met and that they would gladly recommend the experience to other students. Respondents reported several specific benefits for students participating in internships. They indicated that the internships facilitated pathways to aeronautical careers; and increased student interest in space exploration. Respondents also described social benefits resulting from the student experience. These benefits are discussed in greater detail below.

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[43] *ESMD Space Grant Project 2009.*

[44] *2010 ESMD Space Grant Project Final Report.*

[45] *Year End Reporting 2007 ESMD Space Grant Project.*

[46] *2008 ESMD Space Grant Project Final Report.*

[47] *ESMD Space Grant Project 2009.*

Pathways to Space Exploration Careers

The most frequently mentioned benefit of internships related to students' future professional lives. First, respondents reported that internships helped students focus their professional aspirations. The internships provided "an introduction to the type of work that occurs at NASA," allowing students to assess their personal fit with the agency. This opportunity is important for both the intern and NASA, as a NASA mentor described:

> The most valuable part of the experience is getting to see what kind of work is available at NASA and seeing if it's good for them and if they're a good fit for NASA since it's not for everyone. NASA wants to hire people who are a good fit. That's what it is all about.

Secondly, respondents indicated the internships helped develop the professional networks students need to obtain their professional goals. Students appreciated the "many opportunities for networking," and frequent introductions to others in field, and they reported developing relationships with key contacts that could lead to professional opportunities. For instance, one mentor reported that he puts his interns' resumes into the NASA system to ensure that they are considered when job openings arise at the agency. Another noted that, "When you work with students, you always keep them in mind later when hiring."

The internships also gave students valuable hands-on experience. As a NASA point of contact described, "They experience learning for the sake of learning, not for a grade." Several respondents indicated that this experience helps interns' career prospects: as a Space Grant contact noted, **"**Students get a very unique, hands-on experience and see how the work really happens. They take these real-world experiences with them when they leave and it builds their resumes." Another Space Grant contact concurred, pointing out that what is especially valuable is the chance to "apply the education they are receiving," showing prospective employers they can handle real-world problems.

Whether through the professional networks or the hands-on experience, most respondents indicated the internships did lead to professional opportunities for students. Some felt that it might be the only way into the industry; as one Space Grant contact commented, "if the students are serious about a career in aerospace, this internship is critical and may be the only way they can get it." A NASA mentor concurred, stating that the agency does not "really hire anyone who hasn't had an internship or co-op with NASA. [Participation] is basically a necessary condition on whether they are considered." While several NASA respondents pointed out that NASA's current policies make hiring interns at NASA Centers (other than at the Jet Propulsion Laboratory, which is part of Cal Tech and thus exempt from NASA's civil service employment guidelines) difficult, a few have hired interns permanently. One mentor described how the internship was a trial engagement for one student:

> Her internship was the interview: she impressed them during her internship interview and during the internship and they wanted to hire her. After her internship, her mentors worked behind the scenes to bring her on board. The internship was the determining factor, and also they would not have been able to hire her if she hadn't completed it.

Respondents indicated that interns were especially likely to be hired at the Jet Propulsion Laboratory which reportedly sees their interns as its hiring pool.

Student Interest in Space Exploration

A few respondents indicated that the ESMD internships increase and focus their interest in space exploration. According to one employer, who has also mentored interns at NASA, "…many [interns] come in thinking they want to be a doctor. They learn that a chemist can do things other than go to medical school; sometimes it's career changing." Several of the respondents who entered the internships were already interested in space exploration. One student reported that the experience solidified her plans: "I had a long standing interest in NASA and the space industry before this internship. It confirmed that I wanted to pursue this as a career and work at NASA." For another, it helped him to refocus on aeronautics in space exploration rather than his earlier choice of robotics.

Students reported being inspired by their NASA mentors and their focus on space exploration. Students described their NASA mentors not only as people who "go out of their way to give them the mentoring for technical skills", but as people who truly understood their personal needs. For example, one student described how she "spoke throughout the day, every day" with her mentor who was "constantly available" to give advice or answer questions. A few Space Grant respondents indicated that students felt that the NASA mentors not only invested in their interns personally, but they also engaged them in their first opportunity to work on real problems and apply the substantive knowledge they had gained through their studies:

> The most exciting part for the student is directly interacting with someone who is working in the space program, who is actually involved with flight operations and not just on theoretical or academic matters. The connection between the theoretical the abstract, and the academic and the real operational or mission program management activity is what students frequently don't get the opportunity to see or achieve while they're in school.

Students' responses support this view. For example, one student noted that she "really appreciated the mentorship at NASA" as her mentor crafted an assignment that could be completed during the 10 week internship. As the respondent noted, "Having this project was a lot better than just doing calculations!"

Social Benefits for Students

Students derived social benefits from the ESMD Space Grant internships. Interns participated in NASA outreach efforts and multiple engagements, as one Space Grant representative described, where they "are engaged in poster sessions, picnics, travel, [and] opportunities to work with other interns so that oftentimes [they] develop close relationships with their fellow interns." Students appreciated the opportunities. As one participant expressed, "I saw the value of living and working with other interns. I made really strong friendships during the program." Several respondents noted that students interning at NASA Centers, where significant effort is invested in ensuring a high-quality experience, were more likely to enjoy these benefits than students working in industry internships, which several respondents described as lacking opportunities for interns to interact.

Benefits for NASA

ESMD Space Grant also produces benefits for NASA and ESMD. Just as students benefit from developing relationships with future employers, these internships provide opportunities for NASA to develop their future workforce, recruit employees, and potentially even generate more labor supply by increasing students' interest in aerospace careers.

More immediate benefits were also realized, as interns made substantial contributions to the productivity of the NASA laboratories and offices where they were placed. NASA mentors spoke persuasively about how their interns made it possible for them to work on more projects and complete them more quickly. One mentor reported that his interns have greater dexterity with some software packages than he does and can do the work in a shorter amount of time. Sometimes students do work that NASA's researchers would not themselves take on. For instance, one student reported that as part of her internship, she created a mock-up of the larger project that her mentor's group then used as a showpiece to communicate their project to a wider audience, including during a spotlight on national television.

Beyond simply having an extra set of hands, mentors reported a psychological boost from working alongside interns. One mentor explained: "It was valuable to have someone who is really excited about the work, really brings about a lot of energy to what they are trying to do and makes it a lot of fun. It helps me and motivates me." Another mentor noted that he thinks that NASA mentors are "inspired by [the students] just as much as they inspire the students." Mentors frequently described the "fresh ideas" and the "energy" that interns brought to their labs. Some mentors reported their interns often taught them, both through their knowledge of new technology and simply through the act of having to instruct the intern on their projects.

Internship Challenges

Most respondents had difficulty identifying challenges related to the internships. When pushed, students typically reported that the most common hurdle was learning to navigate NASA while also jumping into the middle of a project. One NASA point of contact described it as follows: "The internship experience is like drinking from a fire hose. Students have to quickly figure out who is who, and learn the NASA culture – its expectations and rules - and how to work within it." Students also reported logistical challenges, like finding temporary housing, arranging for transportation, or adjusting to the professional lifestyle of an eight hour day with morning hours. A few NASA education points of contact too experienced logistical issues, as a couple mentioned not having much time to prepare for the students and consequently having to scramble to find office space, get the intern into NASA's system, etc.

Respondent Feedback for Improving Internships

The chief feedback provided by the NASA mentors, the Space Grants, and the NASA education points of contact was for ESMD Space Grant to again fund NASA Center internships. These respondents argued that there is never enough funding to meet the substantial student interest in spending a summer at a NASA Center. They argued that students are more likely to have a high quality and transformational experience at NASA than in industry, as the Space Grants typically have stronger relationships with NASA Centers and know that the interns will be taken seriously there. Several Space Grants also complained that there were no space industry companies in their state, so that it was nearly impossible to find internship opportunities for their students. Further, as they pointed out, these interns generate benefits for NASA, both for recruiting and by helping the Centers complete projects. However, as one Space Grant contact expressed, if ESMD does not reinstitute funding for Center internships, she would like to see the project create a national network of industry internship opportunities for students that would be posted on a website so that students across the country could apply.

Two NASA mentors also provided some input on the matching process, should the project decide to fund NASA Center internships again. They mentioned that they are often given students whose majors are not appropriate for their work. While they usually request mechanical and/or chemical engineering students, they are often matched with aerospace or civil engineers, or students majoring in math, computer science, or chemistry. These two mentors have had better experiences when they recruited the interns themselves as they have a greater understanding of what skills their projects need. One other mentor wanted the project to recruit students from a greater variety of colleges and universities as most of her interns have come from the mid-west; she would like to see more recruitment in the northeast and particularly at Harvard, Yale, and MIT.

Chapter 4. ESMD Space Grant Faculty Activities

ESMD Space Grant funds three faculty activities to address gaps in expertise and provide curricular materials for space exploration-focused senior design courses. Specifically, the project offers fellowships to develop technical expertise, fellowships to develop curriculum for ESMD senior design courses, and short workshops to teach faculty about systems engineering and provide guidance on how to implement ESMD senior design courses. In this chapter, we describe each of the activities and their participants, identify the benefits reported by the different stakeholder groups, list the challenges they described, and present the respondents' feedback.

ESMD Faculty Fellowships

Description of the Faculty Fellowships

ESMD Space Grant provides fellowships each year to prepare faculty to lead ESMD senior design courses that have the potential of making a contribution to ESMD objectives. More specifically, these fellowships are designed to develop the faculty member's interest in ESMD projects and help them become technical experts ready to support their students' participation in ESMD senior design courses. The ultimate objective is to reduce the burden on the NASA scientist or engineer who mentors the ESMD senior design courses.

Selected ESMD faculty fellows spend six to twelve weeks of their summer at a NASA Center, during which they work "side-by-side" with a NASA engineer or scientist on an ESMD-related project. This experience is intended to develop their understanding of the "requirements, interfaces, and issues" that can affect an explorations-focused design project, particularly one using a systems engineering approach. The experiences of the faculty fellows vary considerably, as do the projects. For example, one faculty member was involved in the Mars Science Laboratory Project, where he worked with a graduate student to develop an organic contaminants database and library for the lab. Another learned how to use NASA's Exploration Toolset for the Optimization of Launch and Space Systems (X-TOOLSS), design optimization software that allows engineers to improve the performance of their engineering designs.

Also during the summer, faculty fellows develop course materials for an ESMD senior design course that leverages what they are learning at NASA. For example, the faculty member who learned how to use X-TOOLSS integrated the software into her senior design course. In the subsequent school year, fellows then integrate the course materials into their senior design courses. Once their students complete the senior design courses, fellows submit a white paper to ESMD that documents their successes and challenges in implementing the ESMD senior design course and identifies the lessons they learned, which may help other faculty improve their senior design courses. Should the students in their courses prepare promising designs, the white paper also describes how these designs can be developed further.[48]

[48] 2011 ESMD Space Grant Faculty Fellowship. Retrieved on March 28, 2011, from http://education.ksc.nasa.gov/esmdspacegrant/2010_Faculty_Solicitation.htm

Today's ESMD fellowship opportunity differs from what the project originally offered in its early years. As the project was launching, the faculty fellows met with engineers and staff across NASA Centers to generate a list of potential topics for senior design courses and internships that were relevant to ESMD and that students could reasonably be expected to tackle. Now that a working list has been developed and approved, the project focuses on developing faculty fellows' ability to implement ESMD senior design courses.

Faculty Fellowship Participants

Between 2007 and 2010, 25 faculty members have participated in ESMD faculty fellowships (see Appendix A). In 2008, the project funded 10 fellows and placed one at each of the ten NASA Centers. These fellows came from universities located in 10 states (i.e., Georgia, District of Columbia, California, New Mexico, Ohio, Virginia, Alabama, Utah, North Carolina, and Mississippi); [49] in 2009, five faculty members from Alabama, South Dakota, Louisiana, California, and North Carolina participated across four NASA Centers;[50] in 2010, five faculty members from Florida, Mississippi, North Carolina, Colorado, and Alabama participated across four NASA Centers. [51] Between 2008 and 2010 (years for which information is available), 20 percent of the faculty came from institutions designated as Historically Black Colleges and Universities and 15 percent from Hispanic-Serving Institutions.

Faculty Fellowship Recruitment

The majority of faculty reported learning about the ESMD fellowship opportunity through contact with their state's Space Grant Consortium. Additionally, some also found out about the faculty fellowship through web searches they were doing to identify clients and sponsors for their senior design courses, and a few also mentioned being referred to the fellowship program by colleagues at their university or through connections with NASA staff. Faculty reported that their interest in the fellowships was primarily based on positive experiences with NASA they had in the past and because they welcomed the "opportunity to get extra help on projects that engages bright students." Faculty fellows first select an ESMD senior design project from the list maintained by the project and then submit an application.

Benefits of the Faculty Fellowships

Respondents reported that their expectations for faculty fellowships were "more than met" and that they would recommend the experience to others. Fellowships were described by some faculty as a "once in a lifetime opportunity" to work with NASA scientists and become involved in an ongoing NASA mission. Faculty reported that they developed expertise and acquired materials that improved their senior design courses, expanded their research interests, and provided an introduction to NASA and its technical experts. As a result of their experiences with ESMD Space Grant, respondents indicated that these benefits helped boost participating faculty's candidacy for tenure at their institutions.

Faculty members reported that they developed new technical skills and obtained many resources they can use in their senior design courses and share with faculty at their home institutions. For instance, the

[49] *2008 ESMD Space Grant Project Final Report.*

[50] *ESMD Space Grant Project 2009.*

[51] *2010 ESMD Space Grant Project Final Report.*

faculty fellow who used X-TOOLSS had to also learn C++ coding. Another faculty fellow reported that he has continued to use the *NASA Systems Engineering Handbook* after the fellowship to further deepen his understanding of systems engineering, design optimization, and software components, and to integrate it in his courses. Yet another faculty member indicated that she completely "overhauled" her senior design course after the fellowship to expand her students' use of a systems engineering approach. Some fellows are already sharing their expanded expertise in ESMD senior design courses with their colleagues at their home universities. For example, one university administrator reported that the ESMD faculty fellows at her university put together a systems engineering workshop so that other faculty could incorporate the approach into their senior design courses.

A few faculty fellows reported that the experiences led them to develop a new interest in multidisciplinary research. The fellowships exposed the faculty to the systems engineering approach, which leverages insights from multiple disciplines for design projects. Some faculty became interested in the approach, and even some, in the words of one fellow "more than I had expected." One faculty member is planning to develop a student version of the *Systems Engineering Handbook* so that students can better access the approach. Several fellows reported that they are now reaching out to researchers in other disciplines at their home universities to write interdisciplinary research proposals.

The fellowships also provided faculty fellows the opportunity to develop relationships with NASA scientists and engineers and learn how NASA works. They reported that these relationships and experiences helped them better understand NASA grant application processes, improving their ability to compete for future funding. For example, one faculty member credited his fellowship with enabling him to win NASA funding for unrelated research project. He described how the people he met during the fellowship at NASA helped him define his research project so it was of interest to NASA. Several respondents indicated that these "NASA relationships and experiences" are most valuable for relatively new faculty who are looking for funding sources and likely have more flexibility in the summer months. In addition, some respondents also reported that this opportunity is particularly valuable to small universities that likely would not be able access NASA centers through other means.

Finally, the fellowships have generated relationships across the faculty fellows themselves. Some of the faculty fellows reported they have maintained contact with other fellows throughout the year with a monthly teleconference and are co-authoring a paper together.

Challenges of the Faculty Fellowships

While there were benefits to the faculty fellowship activities, several stakeholders also reported challenges. Some of these barriers may have prevented faculty from participating; others reportedly impacted the participating fellows' experience during the fellowship.

Space Grants and university administrators noted challenges in convincing faculty to apply. Logistically, participating in the fellowship can be difficult for faculty. In particular, the need to temporarily relocate for a summer is difficult, given faculty members' other university obligations and family commitments. As one faculty fellow noted, "It is really difficult to juggle university commitments with work for NASA. I am the chair of [my department] and currently am a PhD advisor to four graduate students…it is challenging to also work on a NASA project." A few respondents reported that faculty members were not convinced that the fellowship would be worth their time as they were not clear on what they would actually be doing at a NASA Center. Additionally, some contacts reported that the stipends were too low, as universities typically reduce the amount distributed to faculty to cover overhead costs.

A few participating faculty fellow respondents also reported challenges they experienced during their fellowships. Several faculty members indicated that they had difficulty transitioning to NASA's 40-hour work week. NASA expected the faculty fellows to work in their NASA offices for a full day, every day. The increased time in the office constituted a big change from some faculty members' usual practice of working from their homes with flexible hours.

Lastly, one faculty member struggled to implement what she learned during the fellowship in her classrooms. She ran into problems integrating X-TOOLSS, which requires knowledge of C++ computer language, into her courses because it was too time intensive for students to learn C++. This faculty member found a short-term solution by convincing the department to pay for a student assistant with C++ coding experience to help student teams. A long-term solution will be needed, since there may not always be a student available with the necessary skills to assist with the C++ coding.

Feedback from Participants for Improving the Faculty Fellowships

Respondents provided suggestions about how the challenges they experienced could be resolved. The most frequent feedback was to increase the funding for the fellowship and/or expand the funding opportunities for faculty members once they finish the fellowships. As one fellow stated, "I hoped that the experience would open up other research opportunities and that did not happen. I think NASA should think about keeping faculty involved and a good way to do that is to provide research opportunities, beyond developing curriculum." Another faculty member mentioned several times that increasing funding would help the project engage a broader range of faculty. One faculty member also suggested offering flexible work schedules to encourage faculty to participate; she thought that allowing fellows to work from home and make a few short trips to NASA over the fellowship period would allow more faculty to participate.

Faculty Fellowships to Create Senior Design Course Curriculum

Description of Curriculum Development Fellowships

In addition to offering faculty fellowships that develop the skills needed to implement ESMD senior design courses, the project also offers funding to provide faculty with the resources for developing senior design courses with the necessary content and structure. These fellowships are intended to develop curriculum "packages" for senior design courses that professors can use in their classrooms across the country.[52]

The project requires that the fellows develop a curriculum alongside a current NASA ESMD project and obtain written commitment of a NASA technical expert prior to its start. The curriculum must address

[52] Solicitation for the *Exploration Systems Mission Directorate Higher Education: Development of an Engineering Senior Design Course.* Released November 3, 2010. Retrieved on March 28, 2011, from http://education.ksc.nasa.gov/esmdspacegrant/Documents/2010_ESMD_Course_Development.pdf

one of the topics on the current ESMD project list and incorporate a systems engineering approach. Furthermore, the curriculum should be designed for implementation within two semesters and meet the Accreditation Board for Engineering and Technology (ABET) standards for quality. [53]

The project intends for the funded fellows to develop a curriculum during the spring and summer; a NASA panel then reviews it during the summer. Once approved, fellows pilot test the curriculum by implementing it at their institutions during the following academic year. The fellows then lead two-day summer workshop activities for faculty members from across the country (described in the following section) to prepare them to implement their curricula in the next academic year. Additionally, the fellows continue to provide technical assistance to senior design course faculty members to address any issues they may encounter in their first year of implementation. Fellows again revise the curriculum based on the outside faculty's experience and submit final course materials to ESMD.

Since 2007, four courses have been developed; three have been pilot tested and one is currently being tested. Five faculty members have received funding to develop a curriculum across four universities as illustrated in Exhibit 1 on the following page. Their institutions are located in four states across the United States: Louisiana, Utah, Michigan, and Alabama. Fellows interviewed for this evaluation learned about the opportunity through word-of-mouth and an email forwarded by their Space Grant consortium.

[53] Solicitation for the *Exploration Systems Mission Directorate Higher Education: Development of an Engineering Senior Design Course.* Released November 3, 2010. Retrieved on March 28, 2011, from http://education.ksc.nasa.gov/esmdspacegrant/Documents/2010_ESMD_Course_Development.pdf

Exhibit 1. ESMD Space Grant Sponsored Curricula

Curriculum Name	Curriculum Fellow(s)	Description	Status
Lunar Regolith Excavation for Oxygen Production and Outpost Emplacement	David Beale, Ph.D. Daniel Harris, Ph.D. *Auburn University*	The purpose of this course is to investigate concepts for Lunar Regolith excavation equipment and propose solutions in the form of completed designs and prototypes.	Available for use
Small Spacecraft Project Illustration	John Gershenson, Ph.D. *Michigan Technological University*	The purpose of the course is to teach students how to implement a structures design process on a real project in a team (perhaps multi-functional) environment.	Available for use
Demonstration Prototype for Lunar or Planetary Surface Landing Research Vehicle	Stephen Whitmore, Ph.D. *Utah State University*	The purpose of the course is to challenge students to apply systems engineering concepts to define research and training requirements for a terrestrial-based lunar landing simulator.	Available for use
Habitats in Extreme Environments	Craig Harvey, Ph.D. *Louisiana State University*	Student projects include Improving the Sleeping Environment on the Moon and Space, The Lunar Dust Dilemma, Nutrition Delivery System, and Reducing Human Exposure to Cosmic and Solar Radiation in a Lunar Base.	Pilot testing

Source: *Current ESMD Senior Design*. Retrieved on March 28, 2011, from http://education.ksc.nasa.gov/esmdspacegrant/CoursesIndex.htm

Benefits of Curriculum Development Fellowships

The key benefit of developing the curriculum is that it provides tools and technical assistance to implement an ESMD senior design course to engineering faculty who might not have the time, expertise, or inclination to develop a suitable curriculum on their own. The curriculum fellows interviewed for this evaluation did not expect that the experience would make a dramatic impact on their own interests, either in terms of the topics they research or specifically in systems engineering. As one fellow commented, he did not anticipate that developing the curriculum would make him a researcher in systems engineering; rather he wanted to "get to the point" where he could teach it and provide appropriate course materials for the senior design course. Another respondent agreed and stated that the experience allowed him to better understand systems engineering and integrate it into his other courses but that it did not become a research interest for him. The fellows then went on to discuss the benefits their students gain through the senior design courses – increased interest in engineering, new skills, and improved pathways to space exploration careers as described in Chapter 3.

Challenges of Curriculum Development Fellowships

The key challenge for respondents was developing a curriculum that met the project's requirements, including the integration of systems engineering and working within the curriculum's structure. All participating curriculum fellows interviewed for this report encountered difficulty accessing information about systems engineering. One respondent noted that systems engineering is difficult for engineers to grasp as it is “an approach that is not based on equations,” which is how engineers typically think. Respondents reported they encountered difficulty identifying people with expertise in systems engineering who could help them access the material. Several respondents found systems engineering quite challenging as the literature on the topic was often difficult to comprehend, filled with terminology not easily translated. For example, one described NASA’s *Systems Engineering Handbook* as containing so many systems engineering-specific terminology that it quickly became confusing. Further, once fellows felt that they understood systems engineering, they oftentimes had trouble “translating it” into lectures that students would grasp.

Secondly, respondents were also challenged by the fellowship’s timeline. For one faculty member, he struggled with developing the course within the given timeframe as he typically outlines a course and then develops it as the semester progresses. Another had trouble designing the course for two semesters, given the challenges it would pose for students. He would have preferred to have created a two-year curriculum, where students conduct background research in the first year and then use it to build and implement the design in the second year.

Feedback from Participants for Improving the Curriculum Development Fellowships

Faculty members who participated in the curriculum development fellowships made two suggestions for program improvement. They felt that ESMD was particularly “hands-off” in managing the work and recommended the project provide more top-level guidance in terms of a schedule that included key design review dates and design requirements. This would help to better exemplify to students the challenges of working on “real world” projects and the need to meet the expectations and timeline of clients.

The second piece of feedback offered was to invest in developing tools that make systems engineering more accessible. One approach could be to ask field engineers (who do not focus on systems engineering “every day”) to revise *NASA’s Systems Engineering Handbook*, so that the information is presented as a tutorial manual appropriate for individuals new to the approach.

Faculty Workshops

Description of Faculty Workshops

The faculty fellows who are funded to develop curriculum for ESMD senior design courses are required to lead summer workshops at the Kennedy Space Center; the first workshop took place in 2009, when the first curriculum was ready to be shared with and used by engineering faculty across the country. These workshops are intended to provide faculty with information about the systems engineering approach and prepare them to implement the ESMD senior design course in the following academic year. Each workshop lasts two days; on the first day, a NASA engineer leads a tutorial and on the second day, the curriculum developers make presentations. The workshops are offered at no charge, and attending faculty members are reimbursed for their travel as is feasible.[54]

Faculty Workshop Participants

Between 2009 and 2010, 85 faculty members (including 6 faculty fellows in 2010) participated in ESMD summer workshops (see Appendix A). In 2009, 37 percent of the attending faculty came from Historically Black Colleges & Universities, Hispanic-Serving Institutions, or Tribal Colleges and Universities;[55] in 2010, one third of the participating faculty came from these minority serving institutions. [56]

In 2010, participating faculty came from 20 states, including California, Louisiana, Texas, Wisconsin, and from the Commonwealth of Puerto Rico. Interviewed faculty indicated they had learned about the opportunity through their Space Grant Consortia and through recommendations from other faculty members.

Benefits of Faculty Workshops

Respondents reported the workshops provided information that helped them implement their ESMD senior design courses. One respondent reported he learned a lot especially about systems engineering and that he really appreciated NASA sharing its wealth of knowledge with him. Another faculty member indicated that the presentation made by the faculty fellow who developed the curriculum better equipped him to lead a senior design course by providing a model for how a professor can successfully teach a systems engineering course in one year. Furthermore, they appreciated the opportunity to learn about what faculty members at other universities are doing in their senior design courses, information they took back with them to their home institutions that helped inform how they implemented their senior design course.

Challenges of Faculty Workshops

Respondents reported few challenges related to participating in the workshops, besides the need for some participants to cover expenses of their travel and time. However, they did discuss the issues they encountered in implementing the senior design courses during the academic year after the summer workshops. Chief amongst these was insufficient time. While some faculty members were able to hand off some of their course load to other faculty so that they could dedicate more time and energy to developing and implementing a quality senior design project, others struggled to maintain a balance. While Space Grant respondents noted that the provision of a NASA mentor helps alleviate some of the burden, several faculty members reported significant difficulties in finding sufficient time to oversee their senior design projects. They felt that this was particularly true for faculty at institutions with higher concentration of minority students, where they reported facing unique challenges. Some indicated their

[54] *ESMD Course Training.* Retrieved on March 28, 2011, from http://education.ksc.nasa.gov/esmdspacegrant/Faculty_Training.htm

[55] *ESMD Space Grant Project 2009.*

[56] *2010 ESMD Space Grant Project Final Report.*

students at these institutions require more support to succeed in the design projects. Several also noted that they had heavier teaching loads than other universities and cannot afford to hire a lab technician to assist them with their lab work. Some faculty also indicated that additional funding for the courses was needed; however, a few also noted that funding was sufficient.

Feedback from Participants for Improving the Faculty Workshops

Respondents were happy with the workshop experiences and offered only two recommendations. One participant suggested that the project incorporate time to talk with a NASA expert about their particular research during the workshop, to take advantage of the fact that they are at the Kennedy Space Center. He was particularly interested in finding a NASA expert who could talk with him about using the systems engineering approach in his work. He noted that contact between the faculty and NASA expert should happen prior to the workshop, so that the NASA expert could "get up to speed" on the faculty member's work prior to the meeting. And because the experience was so positive, respondents also recommended that the Space Grants and the project advertise it more broadly. As one participant mentioned, only one other faculty member at his institution knew about the opportunity.

Chapter 5. Conclusions & Recommendations

In this chapter, the evaluation's findings are summarized as they relate to the project's objectives across seven areas: student learning, faculty learning, student retention in STEM, development of a STEM workforce, student prospects for STEM careers, use of NASA resources, and contribution to the NASA mission. Then, the comparative value of the ESMD Space Grant activities, as perceived by the respondents, is described. The chapter concludes with the respondents' key recommendations for the project.

Progress towards Project's Objectives

The interviews provided evidence that ESMD Space Grant is meeting its objectives and making progress towards its goals of enhancing student and faculty learning, retaining student interest in STEM, developing the STEM workforce, improving student prospects for STEM careers, and leveraging NASA resources, all while producing benefits for the agency.

Student Learning

Respondents' comments indicated that students are learning and acquiring new skills through participation in ESMD Space Grant activities. Students participating in the senior design courses and the internships both indicated that their ESMD experiences provided the opportunity to apply their engineering coursework to solve "real problems" and in the process, "see how the pieces fit together." Students reported that the senior design courses pushed them "far beyond the scope of what [they] learn in a regular class" and provided rare opportunities to cross engineering disciplinary boundaries. Both interns and senior design course participants reportedly gained engineering-specific skills, for example, learning new software packages and how to run simulations. Participants in senior design courses also reportedly learned key workplace skills, including time management, project and task management, budgeting, team work, and communication, as they completed their projects. Students participating in ESMD competitive activities described developing writing skills that engineers need to communicate their ideas.

ESMD Space Grant activities have also influenced the learning of students who do not participate in ESMD-funded activities. Two faculty fellows reported that their universities have improved their engineering senior design courses based on what they learned during their participation in ESMD Space Grant activities. Rather than focusing the courses on "whatever research support the professors needed," these institutions have formalized their courses to emphasize the design process and include systems engineering content; they now require students to manage a project by setting milestones, preparing deliverables, and meeting deadlines. Furthermore, responses suggested that K-12 students are also benefiting from ESMD Space Grant through the Lunabotics Mining Competition's required outreach efforts. For example, one faculty member who leads a senior design course reported that these activities are engaging the interest and motivating the learning of young students.

Faculty Learning

Respondents indicated that ESMD Space Grant activities improved their ability to implement ESMD senior design courses, especially in integrating systems engineering into their courses. Both the workshops and fellowships "broadened horizons and perspectives" of faculty members, helping them "see the whole picture" and understand systems engineering. The faculty fellow presentations at the workshops were particularly helpful; they provided a model of how a faculty member has successfully taught the systems engineering approach within a senior design course that the workshop participants could use as they implemented their courses the following academic year.

Several faculty fellow respondents described how their ESMD Space Grant experience helped them learn about NASA. Through the fellowships, they became more familiar with the different NASA mission directorates and with the agency's education objectives. Several felt that this knowledge has helped them improve the research proposals they submit to NASA. As one faculty participant noted, his NASA mentors helped him develop specific research questions based on NASA's mission, which NASA subsequently funded.

Student Retention in STEM

Participation in all of the student activities appeared to have generated enthusiasm and increased students' interest in engineering and/or space exploration as well as confidence in engineering. Several students who participated in internships and senior design courses reported that their ESMD experiences confirmed and "rejuvenated" their interest and the Lunabotics Mining Competition was an "epic" experience. For the interns, the ESMD experiences seemed to increase their interest in space exploration more than in engineering, while students who participated in senior design courses reported increased interest in engineering overall. As stated by one senior design course student:

> This (project) was pretty much a validation of everything I had hoped engineering would be. I got into engineering to work on projects …to work with my hands and just get things done…this was the first time I had ever gotten to do that. It validated my entire decision to go into engineering… it was part of the reason why I continued onto graduate school…this showed me a side of engineering that I hadn't seen before. Classes are fine and good, but we got to get this done, we got to make this new thing and see if it will work. I love that stuff. That's why I got into it.

For the NASA Center interns, working with a NASA mentor was "inspirational". However, students in the senior design courses did not seem to enjoy this same benefit as a number mentioned they would have liked more interaction with NASA experts during their senior design course experience.

Respondents also reported that participation increased student self-confidence in STEM; several senior design students reported the ESMD activities showed them they are capable of doing design work. One senior design course and competition participant noted that his experience helped him see NASA-related work as a real option: "Especially in terms of working for NASA or working with things that go into space…it wasn't something I had looked at before. It had seemed out of reach. I had always wanted to do it anyway. But it seemed a lot more attainable after we won the competition."

The experiences also helped retain students in STEM by enabling them to experience how these disciplines can be turned into careers. For example, one student reported that through the senior design course experience, he "learned more about the scope of what engineers do" and became more interested in becoming an engineer. Another student who interned at NASA was "surprised by how well his own work fit within NASA's goals."

Development of STEM Workforce

The ESMD activities reportedly have contributed to the development of a STEM workforce through students' acquisition of skills, as described earlier. The technical skills acquired through internships and senior design courses, such as learning new software or programming languages, are relevant to preparing students for success in a range of STEM careers. In addition, senior design students developed skills essential for becoming systems engineers for employers like NASA, the U.S. Air Force, the U.S. Department of Defense, and Boeing specifically through exposure to the systems engineering approach. Furthermore, participants in the senior design courses acquired more general workplace skills that most employers seek, enabling them to succeed in the STEM workplace and beyond: leadership, communication, time management, the ability to delegate responsibilities, manage budgets, and how to work as a team.

Student Prospects for STEM Careers

Stakeholders indicated that the internships and senior design courses have improved the prospects of students seeking careers in the space industry in additional ways than by developing their skills. The activities provided them the chance to demonstrate their skills to future employers, both NASA and others. All of the student activities were described as resume-builders, as the experiences provided resume content of real interest to prospective employers. For example, one student mentioned that he has recently had a number of job interviews and all the interviewers seemed keenly interested in his internship: "They always come back to this." Additionally, some students also came away with patents and publications.

Internships seem to provide a unique – perhaps even necessary – opportunity to expand student prospects for careers at NASA. While NASA's rules regarding recruiting civil servants makes hiring interns difficult, several of the NASA mentors reported that they used the internship as an opportunity to audition a possible new hire before making a full commitment. One NASA mentor even ensured that the interns' resumes were included in the NASA database so that they could be considered as job openings arise. Plus, the student interns clearly saw the advantages of the professional networking provided by the experience.

Use of NASA's Resources

The NASA resources that many respondents identified as holding greatest value were the NASA engineers and scientists who mentored the interns and the senior design courses as well as the support they provided the curriculum developers. Not only did these mentors share technical expertise, they also served as role models for students (particularly for the interns). The NASA mentors who worked with interns indicated the experience was usually well worth their time. They noted that they gained much from working with interns themselves, both through students' ability to complete the tasks that move a project forward, as well as through their contagious enthusiasm.

However, several NASA mentors who supported senior design courses did not feel the same and reported that their time was not well used. These mentors discussed how they were discouraged by the fact that the universities "were not committed to the senior design courses" and did not play as large a role as they had expected. These mentors indicated that they felt compelled to invest significant amounts of time to oversee and "micro-manage" the projects; one reported that the burden placed on her in "mentoring" the senior design course was so great that she no longer participates in the project.

Contribution to NASA's Mission

While not commonly reported, the evaluation's interviews did reveal evidence that occasionally the designs developed by ESMD Space Grant project's students were relevant to NASA projects. A few students mentioned that the NASA scientists and engineers to whom they had presented their designs, indicated that the students' work informed their own; for example, one student design team's work with pressure sensor films provided greater understanding of how the NASA-designed films (similar to the students) could be used on the space shuttle.

More frequently, however, mentors reported that ESMD students contributed to NASA's mission through the internships. They described how the interns brought "fresh ideas and new perspectives" and worked hard to "get the job done." Several NASA staff who worked with student interns discussed how they learned from their mentees. For example, one NASA mentor reported that the necessity of showing his intern how to use FLUKA, a fully integrated particle physics Monte Carlo simulation package, he developed a deeper understanding of the tool and is now better able to use this package himself.

Comparative Value of ESMD Space Grant Activities

The evaluation was designed to collect respondents' perceptions of the different ESMD Space Grant activities. This approach does not allow for the objective comparison of the different activities' benefits; it does, however, inform the generation of hypotheses that a future more rigorous evaluation could test. Accordingly, the discussion that follows describes respondents' thoughts regarding the relative value of the ESMD Space Grant activities and identifies patterns observed across stakeholder groups. These patterns in turn, are hypotheses for a future evaluation's examination.

Student Activities

All of the Space Grant and the education points of contact at the NASA Centers identified the student internships and the senior design courses as the most critical components of the project overall. Respondents described the design courses and internships as transformative experiences whereby students use the theoretical knowledge gained at their universities to address "real world" problems; through the process, it builds students' confidence, interest, skills, and resumes, albeit in different ways. They argued that the power of the senior design courses is derived from its four key student experiences of: 1) working together as a team; 2) seeing an authentic project through multiple development stages; 3) addressing design challenges of real interest to NASA; and 4) using a systems engineering approach. Internships also engage students in real project work, but not necessarily as team members; instead, interns have the opportunity to develop a relationship with a role model. While interns may not develop skills in teamwork and project management common to the senior design courses, they are more likely to receive an individualized experience customized by the mentor to help meet the goals of the lab.

As for the paper competitions and the design challenges associated with the ESMD senior design courses, most of the interviewed Space Grant and the education points of contact at the NASA Centers felt that they were of minor value. A few respondents described these competitions as “little luxuries” “tangential” to the project’s core and may not be worth the resources invested in them.

Several of the Space Grant respondents reported that while internships can be very powerful for students, they are a “riskier” approach for meeting the project’s goals, particularly now as placements are limited to industry employers. Although they recognized the “reality of space exploration’s commercialization,” most Space Grant respondents still preferred to place students in NASA Center internships. Several of these respondents described their relationships with industry as weaker than with NASA Centers and accordingly, were more confident that students would be engaged in highly substantive and thoughtfully executed internships at NASA Centers. Several respondents argued that space industry companies, more likely than not, would use students to “push paper” and perform administrative tasks rather than engage them in meaningful design projects. Furthermore, a few respondents openly questioned the appropriateness of using NASA funds to provide for-profit companies with free labor.

Faculty Activities

Most respondents reported that the faculty activities were of lesser importance than the student activities; however, their comments sometimes showed that they did not fully understand the purpose of faculty activities. Many of the Space Grant participants and the education points of contact at the NASA Centers were not aware of the faculty opportunities to develop senior design course curriculum or the workshops that prepare faculty to implement these courses. Instead, most focused on the original role of the faculty fellows to identify ideas for ESMD senior design courses, which several described as “an inefficient way to find educational opportunities within NASA” and accordingly, did not think it was a good use of the project resources. Their responses might have been different, however, if they understood how the faculty activities have been transformed to improve the quality of the senior design courses for students.

Recommendations

While the majority of the respondents would recommend the ESMD Space Grant activities to students and faculty, they discussed ways the project might improve its effectiveness, both in terms of its programming and management.

Recommendations Regarding Participant Activities

Respondents made two recommendations that would entail significant change to the project’s activities, plus a handful of smaller suggestions to further enhance the current offerings. Overall, the Space Grants tended to favor the student activities over the faculty ones, with several respondents going as far as to recommend eliminating the faculty activities and redirecting the funding into opportunities for students. Given the current level of funding for the faculty activities and the very real constraints on faculty’s ability to participate, these respondents felt that the funds could produce greater impact if used to support more internships and senior design courses. However, these same respondents did not seem to fully understand that the project is utilizing a “train the trainer” approach, whereby the intent of the faculty activities to provide students with higher-quality senior design courses that use the systems engineering approach. Accordingly, should the ESMD decide that this is a critical element of its ongoing strategy, clarification about the faculty activities and their objectives would likely help to generate buy-in from the Space Grants; this support is important as the Space Grants can direct more faculty to take advantage of these opportunities and expand the project's reach.

Most of the respondents who were aware that internship funding is now limited to industry placements recommend that the project reverse this decision. They argued that there is never enough funding to meet the substantial student interest in spending a summer at a NASA Center, to enjoy the rich benefits these opportunities offer there. Plus, the NASA Center internships provide value to the NASA mentors, more so than what they gain through mentoring a senior design course. Furthermore, many of the Space Grant contacts reported that there are no aerospace companies in their states, or that they have much weaker relationships with industry than the with NASA Centers, which puts their students at a competitive disadvantage.[57] Respondents indicated that the NASA internships provide student benefits that differ from those generated by senior design courses; if these internship-specific benefits are critical, and the project keeps its course by continuing to limit internships to industry, the project should consider how it can better ensure that industry internships are equal in caliber to those offered at NASA. One Space Grant contact suggested that this might happen if the project were to develop a national network of industry internship opportunities and post them to its website so that students across all states can participate.[58]

Other recommendations would necessitate less drastic changes to the project. In terms of the faculty activities, respondents asked for clarification of the project's expectations for follow-up once the activities conclude. Several wished that their participation could continue over the span of several years to deepen their relationships with the NASA mentor. Others suggested making the scheduling for the fellowships more flexible by allowing telecommuting and variable hours, to accommodate faculty's commitments at their home universities and to their families. This strategy may increase the project's ability to recruit "topnotch faculty." Some faculty participants also requested that NASA revise its current systems engineering handbook to increase its accessibility. Finally, several faculty and a few Space Grants wanted the project to increase funding, commenting that current levels are not sufficient to interest faculty. One faculty member suggested that funding be renewable at universities where there is strong leadership of the senior design course.

Recommendations regarding student activities typically focused on the availability of NASA content and resources. Several faculty members asked that the project should offer more material or computer science engineering challenges as ESMD senior design ideas. There were also requests for greater access to NASA resources; students and faculty wanted more interaction among students and the NASA mentors, as well as subsidized trips to NASA facilities. For example, one faculty member stated that several of his students visited the Kennedy Space Center with their own funding sources, and that this experience would benefit all students, including those unable to obtain additional resources.

[57] Note: one of the project's reasons for limiting internships to industry is specifically to encourage Space Grants to strengthen relationships with industry.

[58] At one point, the project provided this service, and posted industry internships at six companies on its website; Space Grants did not use these links and thus the project discontinued the posting.

Recommendations Regarding Project Management

Overall, respondents appreciated the project's management team's efforts, commending them on their accessibility, willingness to listen, and responsiveness to their requests. They suggested a few ways that the project's management could be further improved. These include recommendations for expanding the project's advertising, improving communication, and tracking students to assess the project's impact.

Many respondents suggested that greater efforts be made to advertise the project's opportunities. Several faculty members reported that no one else at their universities had heard of NASA ESMD Space Grant and urged the project to consider publicizing it more widely. One strategy suggested by a Space Grant contact was to have NASA mentors visit university campuses that lack a relationship with NASA; during these visits, they could talk about the ESMD Space Grant opportunities, both fostering a partnership with the institution and generating interest in the project.

A few respondents indicated that the project would benefit from improved communication. Some NASA mentors wanted more personalized contact with the project staff; rather than emails alone, one mentor felt that she would be more engaged in the project if she met one-on-one with the team. Several respondents also mentioned that roles and expectations could be more clearly communicated and that the application process should be simplified. One respondent felt that part of the problem with communication is related to the continual evolution of the project's processes and that she struggled to maintain clarity about the latest changes. She urged the team to "let things settle down" and "steer the course" so that the Space Grants can catch up.

A few Space Grant respondents indicated they were eager to begin quantifying the impact of the project, and suggested that project begin consistently tracking the participating students to ascertain whether the project activities are indeed influencing their career paths. One noted that the Space Grant Foundation, which has taken on some of the project's administrative tasks, has systems that would enable Space Grants to follow the students into the future, producing data that would inform a quantitative evaluation of the project's contributions to the STEM workforce. Without this information, the project must rely on participants' perceptions of influence, which can be biased, rather than data representing participants' actual behavior.

Concluding Thoughts

In closing, the interviews conducted as a part of this evaluation suggest that the ESMD Space Grant project is making progress towards its goals and objectives, whereby the different stakeholder groups reported benefits for students, faculty, universities, the Space Grant Consortiums, and NASA. Evidence emerged indicating that the majority of the project's key stakeholders think it has increased student and faculty learning, positively affected student retention in STEM, developed the STEM workforce and student prospects for STEM careers, while contributing to NASA's mission. With these promising results, and the hypotheses suggested by this descriptive analysis, the project is ready to begin laying the foundation for a more rigorous evaluation of its impact.

Appendix A. Participant Counts

Exhibit A. Participant Counts for ESMD Space Grant Project

	FY2007	FY2008	FY2009	FY2010
STUDENT ACTIVITIES				
Senior Design Courses	744	822	492	239
Total Internships	192	182	97.5	63
NASA Center Internships	126	111	55.5*	0
Industry Internships	66	71	42	63
Design Challenges	534	104	492	315
Writing Competitions	8 teams	7 teams	4 teams	11 teams
FACULTY ACTIVITIES				
Fellowships	5	10	5	5
New Courses	—	*Lunar Regolith Excavator* David Beale and Daniel Harros, Auburn University *NASA ESMD Capstone Design with Small Spacecraft Illustration* John Gerhenson, Michigan Technological University	*Design and Testing of a Demonstration Prototype for a Lunar or Planetary Surface Landing Research Vehicle* Stephen Whitmore, Utah State University	*Extreme Environment Habitat Design* Craig Harvey, Louisiana State University
Workshops	—	—	-43	42

Sources: Year End Reporting 2007 ESMD Space Grant Project, 2008 ESMD Space Grant Project Final Report; ESMD Space Grant Project 2009; and 2010 ESMD Space Grant Project Final Report.

*ESMD co-funded one student with another NASA education project.

Appendix B. Interview Protocols

Questions for Senior Design Course Students

- Do you remember participating in senior design course? Did you know that this senior design course was funded by NASA's ESMD Space Grant Project?
- How did you hear about the senior design course at the ESMD Space Grant Project? What convinced you to participate? Were your expectations met?
- What was the most valuable part of the senior design course? Why?
- What was the most challenging part of the senior design course? Why?
- To what extent did participating in the senior design course affect your interest in engineering?
    - Did it affect your plans for graduate school? If so, how?
    - Did it affect your career plans? If so, how?
    - Do you think it affected your career prospects? If so, how?
        - If the students are currently employed, ask whether we might talk with their managers (or someone they feel would be appropriate) for insight into how the experience may have contributed to their professional growth.
    - Have you continued to engage in work related to systems engineering? If so, how?
- What changes would you recommend to the project's staff that would improve the senior design course? What would you recommend *not* changing?
- Considering your ESMD Space Grant senior design course experience as a whole, would you recommend it to another student? Why/Why not?
- Briefly describe your design project. How was it related to NASA's mission?
- What was the impact of your design project on NASA? Do you know whether they used your design in any way?
- What was your relationship like with your NASA mentor? How frequently did you interact? Did working with the NASA mentor change your interest in engineering? In employment at NASA? Have you stayed in contact with your NASA mentor?

Questions for Student Interns

- Do you remember participating in a student internship? Did you know that this student internship was funded by NASA's ESMD Space Grant Project?
- How did you hear about the student internship at the ESMD Space Grant Project? What convinced you to participate? Were your expectations met?
- What was the most valuable part of the student internship? Why?
- What was the most challenging part of the student internship e? Why?
- To what extent did participating in the student internship t affect your interest in engineering?
    - Did it affect your plans for graduate school? If so, how?
    - Did it affect your career plans? If so, how?
    - Do you think it affected your career prospects? If so, how?
        - If the students are currently employed, ask whether we might talk with their managers (or someone they feel would be appropriate) for insight into how the experience may have contributed to their professional growth.
    - Have you continued to engage in work related to systems engineering? If so, how?

- What changes would you recommend to the project's staff that would improve the student internship? What would you recommend *not* changing?
- Considering your ESMD Space Grant student internship as a whole, would you recommend it to another student? Why/Why not?
- Briefly describe your design project/internship. How was it related to NASA's mission?
- What was the impact of your design project/internship on NASA? Do you know whether they used your design in any way?
- What was your relationship like with your NASA mentor? How frequently did you interact? Did working with the NASA mentor change your interest in engineering? In employment at NASA? Have you stayed in contact with your NASA mentor?

Questions for Students Who Participated in Challenges

- Do you remember participating in an engineering challenge or competition? Did you know that this opportunity was funded by NASA's ESMD Space Grant Project?
- How did you hear about the engineering challenge or competition at the ESMD Space Grant Project? What convinced you to participate? Were your expectations met?
- What was the most valuable part of the engineering challenge or competition? Why?
- What was the most challenging part of the engineering challenge or competition? Why?
- To what extent did participating in the project affect your interest in engineering?
    - Did it affect your plans for graduate school? If so, how?
    - Did it affect your career plans? If so, how?
    - Do you think it affected your career prospects? If so, how?
        - If the students are currently employed, ask whether we might talk with their managers (or someone they feel would be appropriate) for insight into how the experience may have contributed to their professional growth.
    - Have you continued to engage in work related to systems engineering? If so, how?
- What changes would you recommend to the project's staff that would improve the challenge or competition experience? What would you recommend *not* changing?
- Considering your ESMD Space Grant challenge or competition experience as a whole, would you recommend it to another student? Why/Why not?

Questions for Faculty

- Do you remember participating in [DESCRIBE ACTIVITY e.g., internship at NASA in YEAR]? Did you know that this opportunity was funded by NASA's ESMD Space Grant Project?

In the questions that follow, we will refer to that [EXPERIENCE] as the ESMD Space Grant Project.

- How did you hear about the opportunity at the ESMD Space Grant Project? What convinced you to participate? Were your expectations met?
- What was the most valuable part of the experience? Why?
- What was the most challenging part of the experience? Why?
- To what extent did participating in the Project affect your interest in systems engineering?
    - Did it affect your research? If so, how?
    - Did the experience affect your career plans? If so, how?

    - Have you continued to engage in research or teaching related to systems engineering? If so, how?
- What changes would you recommend to the project's staff that would improve the experience? What would you recommend *not* changing?
- Considering your ESMD Space Grant experience as a whole, would you recommend it to another faculty member? Why/Why not?

Questions for faculty participants in design courses and internships only:

- Briefly describe your design project/internship. How was it related to NASA's mission?
- What was the impact of your design project/internship on NASA?
    - Did it improve your ability to teach a senior design course?
    - Did it affect how you taught a senior design course? If so, how?
    - Did it affect the content of your senior design course? If so, how?
    - Did it affect your career? If so, how?
- What was your relationship like with your NASA mentor? How frequently did you interact? Did working with the NASA mentor change your research interests? Your teaching interests? Have you stayed in contact with your NASA mentor?
- Briefly describe your curriculum. How is it related to NASA's mission?
- How did you use NASA resources to create the curriculum?
- How often do you teach the curriculum?
- Given your experience teaching the curriculum, what do you think are its strengths? What are its weaknesses?
- Do you think the curriculum increases student interests in systems engineering? If so, how?

Questions for NASA Mentors

- How did you hear about the opportunity to work with a student/faculty through the ESMD Space Grant project? What convinced you to participate? Were your expectations met?
- How many student/faculty mentees have you worked with?
- Please describe the project you worked on with your student/faculty mentee. How was it related to your work at NASA?
- How frequently did you interact with your student/faculty mentees? Have you kept in touch with them?
- What was the most valuable part of being a student/faculty mentor? Why?
- What do you think is the most valuable part of the experience for a student/faculty?
- What was the most challenging part of being a student/faculty mentor? Why?
- What do you think is the most challenging part for the student/faculty?
- How did the time you spent with your student/faculty mentees impact your work at NASA?
- Do you feel that the Project was able to take advantage of your specialized training to increase student/faculty learning?
- What changes would you recommend to the Project's staff that would improve the student internship/faculty fellowship experience? What would you recommend *not* changing?
- Considering your student/faculty mentorship for ESMD Space Grant as a whole, would you recommend it to another NASA engineer? Why/Why not?

Questions for Administrators at Institutions of Higher Education

- How did you hear about the opportunity at the ESMD Space Grant Project? Why did you want your university to participate? Were your expectations met?
- What do you think is the most valuable part of the experience for your university? For your faculty? For your students?
- How do you think the experience affected the students' career paths? How do you think the experience affected your faculty's careers?
- What do you think was the most challenging part of the experience for your faculty? For your students?
- What changes would you recommend to the Project's staff that would improve the experience? What would you recommend *not* changing?
- Has your institution used one of the curricula designed for the ESMD Space Grant Project? If so, how successful do you think the course was? How would you change it? Would you use it again?
- Considering the ESMD Space Grant experience as a whole, would you recommend it to another university? Why/Why not?

Questions for Space Grant Consortiums

- What are your responsibilities related to the ESMD Space Grant Project? How much time do you spend working on issues related to the ESMD Space Grant Project?
- How have you tried to recruit students for the Project? Faculty? How successful have these efforts been?
- What challenges have you encountered in recruiting participants? How have you worked through these issues?
- What do you think is the most valuable part of the experience for the participating faculty? For the participating students?
- What do you think was the most challenging part of the experience for the participating faculty? For the participating students?
- What changes would you recommend to the project's staff that would improve the project? What would you recommend *not* changing?
- Across the different kinds of student activities – the internships, the senior design courses, the paper competitions, and the engineering challenges – which do you think has the greatest impact on students? Which has the least impact?
- Recently, the Project has changed the process through which it allocates funding to the states so that it is now a competitive process. Do you think that this is a good thing for the Project? For the Space Grant Consortiums?
- Recently, the Project limited internships to those with industry. Do you think that this is a good thing for the students? For the Space Grant Consortiums?
- All things considered, do you think the ESMD Space Grant Project is a good opportunity for students? For faculty? For the Space Grant Consortiums?

Questions for NASA Education Points of Contact at Centers

- What are your responsibilities related to the ESMD Space Grant Project? How much time do you spend working on issues related to the ESMD Space Grant Project?

- What challenges have you encountered in meeting your ESMD Space Grant responsibilities? How have you worked through these issues?
- What do you think was the most valuable part of the experience for the participating faculty? For the participating students?
- What do you think was the most challenging part of the experience for participating faculty? For the participating students?
- What changes would you recommend to the Project's staff that would improve the project? What would you recommend *not* changing?
- All things considered, do you think the ESMD Space Grant Project is a good opportunity for students? For faculty? For NASA?

Questions for Employers of Student Participants

- When you were considering whether to hire [STUDENT RESPONDENT'S NAME], were you aware that he/she had participated in an internship at a NASA center/ in an internship in the aerospace industry sponsored by NASA/NASA-sponsored senior design course/in a NASA-sponsored writing competition/in Lunabotics, a NASA-sponsored engineering challenge?
- [IF RESPONDENT ANSWERS "NO"] Would it have mattered if you had known that [STUDENT RESPONDENT'S NAME] had participated in this NASA activity when you interviewed him/her? If so, how?

  THANK RESPONDENT WHO ANSWERED "NO" to QUESTION 1 AND END CALL.

- [IF YES] As you may know, the [ACTIVITY] was sponsored by NASA's Exploration Systems Mission Directorate. How did you learn of [STUDENT RESPONDENT'S NAME]'s participation in the NASA activity? Probes:
  a. Was it included on his/her resume or CV?
  b. Did he/she discuss it during the interview process?

- To what extent do you think your decision to hire [STUDENT RESPONDENT'S NAME] was related to the fact that he/she had participated in this NASA activity?
- Now that you have had the opportunity to work with [STUDENT RESPONDENT'S NAME], do you think his/her participation in the NASA activity has affected his/her work performance? If so, how?
- If you were considering another job applicant for a similar position, would his or her participation in this NASA activity affect your assessment of their candidacy?