NASA Student Launch Projects: Final Report

A Descriptive Analysis of the Student Launch Initiatives

Contract # GS-10F-086K NNH08CD70Z/NNH10CD62D

January 12, 2012

Prepared for:
National Aeronautics and Space Administration (NASA)
Marshall Space Flight Center

Submitted by:
Abt Associates Inc.
Alyssa Rulf Fountain

In Partnership with:
Education Development Center, Inc
Abigail Jurist Levy

Contents

Acknowledgements

The NASA Student Launch Initiatives Projects Evaluation team would like to thank the programs' partners, educators, mentors and participants for their assistance with and participation in the program interviews and focus groups for this study. We gratefully acknowledge the assistance we received from NASA Marshall Space Flight Facility staff and the individuals affiliated with the projects. Their thoughtful and detailed responses allowed us to gather the necessary information to analyze and describe the activities associated with the Student Launch Programs. We are particularly grateful for the assistance of Julie Clift, Eddie Jeffries, Miranda Martin, and Fred Kepner.

Lastly, we would also like to thank the reviewer of this report, Hilary Rhodes from Abt Associates, for the helpful feedback provided.

Executive Summary

NASA's Exploration Systems Mission Directorate (ESMD) and NASA's Marshall Space Flight Center's Academic Affairs Office is considering whether to expand support for the NASA Student Launch Projects which are designed to engage teams of middle school, high school and undergraduate students in research experiences focused on systems engineering. To inform this decision, ESMD and the Marshall Space Flight Center sought an independent evaluation of the Student Launch Projects. The results of this evaluation will assist NASA in the formulation of new and/or the enhancement of existing efforts to provide middle, high school and college-age students with authentic, hands-on research experience in systems engineering and research.

The evaluation, conducted by Abt Associates Inc, an independent research consulting firm, included interviews with key stakeholders (e.g., program leads, reviewers, student participants, mentors, safety officers, partners, and parents), document and extant data review, observations of participant performance reviews, and participation in Launch Week activities and the Advanced Rocketry Workshop. Findings from the evaluation are outlined below.

Program Influence on Students' Pursuit of STEM Education and Careers

- The USLI/SLI program primarily confirmed students' existing interests in STEM fields. The majority of students arrived at USLI/SLI already interested in or committed to engineering. The experience of participating in the program provided the opportunity for students to reaffirm interest and expand upon it.
- Although the intent of USLI/SLI is to inspire students to pursue education and careers in the aerospace industry, participants reported great value in exposure to and understanding of workplace settings. Participants described NASA's design process of initial concept to testing and launch as an opportunity to learn communication, teamwork, time management, problem solving, leadership skills, the value of learning from mistakes, and increase self-confidence.

Program Strengths and Challenges

Program Strengths

- Program structure, organization and logistics: project leaders were rated very highly by participants for their organization, how they structured the program, and they were lauded for their passion and commitment to the program.
- Opportunities to learn from experts and other participants: opportunities to learn from others during reviews with NASA staff, from mentors, NAR staff, and other students (e.g., rocket fair) were highly valued by participants.
- Value of hands-on experience and emphasis on safety: participants reported the critical importance of hands-on learning. Along with the focus on building rockets came an emphasis on safety throughout the program.

Challenges to the Program

- Size, capacity and growth: according to program leaders and NAR volunteers, the program has reached capacity. Program growth over the past several years has pushed human and financial resources to the limit. The recent addition of staff and potential to share burden with other centers may ease this problem, but consideration will need to be given to program consistency and participant safety.
- Tracking impacts over time: the Paperwork Reduction Act and the Privacy Act make tracking students' future endeavors in STEM fields difficult as these acts do not allow for tracking of students in grades K-16. As a result, participants' pursuit of future STEM endeavors can be only informal as only voluntary communication is possible.
- Availability of reviewers: currently, individuals involved in reviews are interested NASA employees and contractors who volunteer their time. The number of volunteers affects the workload for all reviewers. As the program expands to include a greater number of teams, finding a sufficient number of volunteers may prove difficult.

Challenges of Participating in USLI/SLI

- Launch support services: the competitive bid for launch support services sometimes resulted in the need for launch support staff to pay out-of-pocket for program-related responsibilities during Launch Week. Similarly, tight budgets may have contributed to participants' reports of inconsistencies in the pre-launch reviews and recommendations during final hardware and safety checks. Although launch support services share guidelines, some chose to pursue additional levels of scrutiny – an inconsistency that could be avoided if launch support staff receive additional training regarding minimum requirements.
- Team and institutional capacity: there tends to be great variation in teams' financial support from their home institutions. Some universities and high schools provide greater support by incorporating USLI/SLI participation into coursework while others consider participation outside of the school domain – purely an extra-curricular activity. Since each team receives a set amount of funding from the program, this variation in institutional support creates inequity and thus different degrees of challenges to participants. Further, difficulties navigating accounting bureaucracies sometimes made accessing funds difficult for participants.
- Use of and access to experts: many USLI teams adhered to the minimum requirement of including one participant with level 2 certification, that person often being a team member with little experience beyond the certification process. Because of the limited experience, USLI teams frequently faced unexpected hardships during the design process. In some cases, teams found a shortage of willing, experienced advisors with sufficient content expertise to serve their teams. Participants suggested NASA create a network of experienced volunteers who could be easily accessed for advice and guidance.

Recommendations

- Increase the number of NASA reviewers providing feedback to participants and allocate resources to reviewers to reduce burden.

- Create a database of interested experts, in multiple fields, who are available for consultation to teams.
- Recommendations for National Association of Rocketry (or other safety monitors):
    - Provide orientation to new NAR volunteers to reduce variation in expectation from teams
    - Consider bids of launch support services organizations to minimize out-of-pocket expenses for individuals attending Launch Week
- Increase guidance for team mentors:
    - Provide clear, explicit instructions to mentors regarding content and expectations for team reviews
    - Ensure outside experts (level 2/3 certified mentors) obtain necessary program information by including them on communication distribution lists
- Provide additional guidance to team mentors about reviews – specifically additional clarification about how quality is estimated and how to achieve higher scores.
- Expand handbook to include information about "lessons learned" from veteran/returning teams to provide to new teams. In addition to the Advanced Rocketry Workshop, consider an alternate mini-workshop for new teams to learn about potential pitfalls during the program design process.
- Provide guidance (in the form of financial mentoring) to navigate the often difficult funding process.
- Provide additional clarification about the outreach component of the program. Specifically, that both quantity and quality of the outreach efforts are considered.

In sum, participants, educators, mentors, partners, and parents place high value on the SLI/USLI programs. With little exception, positive endorsements of the program far outweighed what little criticism was encountered. The suggestions for future modification have more to do with the need for expansion to meet increased student interest than with any significant problems associated with the structure or implementation of the program. Program participants, past and present, consistently spoke to the importance of the SLI/USLI programs in affording real-world, hands-on engineering experiences to students and participants systematically praised the efforts of the program staff.

Chapter 1. Introduction

Providing opportunities for students to engage in hands-on, practical research experiences during their middle school, high school, and college years can be an effective way to complement the formal education they obtain through their secondary school and university curricula by nurturing knowledge and skills they don't experience via book work. Exposing students to meaningful "real world" experiences during a time when they are making critical future education and career choices is a promising approach for attracting and retaining students to the scientific and engineering workforce, ultimately benefitting the commercial space industry and the National Aeronautics and Space Administration (NASA), and the nation overall (Seymour et al., 2004; Carter, Mandell, and Maton, 2009; Pender, Marcotte, Sto. Domingo & Maton 2010).

NASA's Exploration Systems Mission Directorate (ESMD) and NASA's Marshall Space Flight Center's Academic Affairs Office is considering whether to expand support for the NASA Student Launch Projects which are designed to engage teams of middle school, high school and undergraduate students in research experiences focused on systems engineering. To inform this decision, ESMD and the Marshall Space Flight Center are seeking an independent evaluation of the Student Launch Projects, which could serve as potential models for expansion. The results of this evaluation will assist the USLI/SLI program leads (NASA employees and contractors whose primary responsibility it is to oversee the program and shepherd participants through the eight-month process) and NASA in the formulation of new and/or the enhancement of existing efforts to provide middle, high school and college-age students with authentic, hands-on research experience in systems engineering and research. The two specific projects of interest are described below.

1. ***NASA University Student Launch Initiative (USLI)*** is a competition that challenges university-level students to design, build and fly a reusable rocket with scientific or engineering payload to one mile above ground level (AGL). The project engages students in scientific research and real-world engineering processes with NASA engineers. Students submit a proposal to USLI during the fall. Once selected, teams design their rocket and payload throughout the academic year culminating with a launch event in Huntsville, AL. The program requires four reviews of student projects during the year, the Preliminary Design Review, Critical Design Review, and Flight Readiness Review are conducted by a panel of NASA scientists, engineers, contactors and external partners. Projects require panel approval at all four reviews before the rockets and payloads are authorized for launch. Afterwards, teams complete a Post-Launch Assessment Review that describes the conclusions based on their science or engineering experiment and the overall flight performance. Although students from any college or university are eligible to participate in USLI, NASA strongly encourages team participation in NASA's Advanced Rocketry Workshop (ARW) prior to submitting proposals for USLI (http://education.msfc.nasa.gov/usli).

2. ***NASA Student Launch Initiative (SLI)*** engages middle and high school-age students in scientific research and real-world engineering processes with NASA engineers by challenging them to design, build and launch a reusable rocket with a scientific or engineering payload to one mile above ground level (AGL). Students apply to SLI during the fall. Once selected, teams design their rocket and payload throughout the academic year. Similar to USLI, SLI requires a NASA panel of scientists, engineers, contractors, and external partners to review the teams' preliminary

and critical designs. The project also requires flight readiness and safety reviews before the rockets and payloads are approved for launch. After launch, teams complete a post-launch report to include conclusions from their science or engineering experiment and the overall flight performance. Teams qualify to participate in the SLI by placing in the top three at the Rockets for Schools competition held in Wisconsin or in the top 20-25 at the Team America Rocketry Challenge (TARC), held each year in Virginia. The decision about how many SLI team to accept into the program varies each year, depending on available funding, and as the program evolves, so too does the funding amounts and project organization. After achieving the requisite placements, teams are required to send one faculty/mentor representative to the NASA Advanced Rocketry Workshop (ARW) (http://education.msfc.nasa.gov/sli).

Roadmap to this Report

This chapter continues with a review of existing literature on the value of hands-on experiences in inspiring students to pursue education and careers in science, technology, engineering, or mathematics (STEM) fields. In the second chapter, we describe the study design. The third chapter discusses findings from our case study based on our data collection efforts. Lastly, chapter 4 presents our conclusions and recommendations based on our findings to NASA ESMD and the Marshall Space Flight Center regarding expansion of support for student education and research experiences.

The Value of Hands-on STEM Experiences—Evidence from the Literature

Undergraduate Experiences

There is a new and growing body of research on the impact of undergraduate STEM research experiences on career and course-taking outcomes. The accumulating literature indicates a promising positive relationship between engagement in undergraduate research experiences and a variety of student outcomes including the completion of a Ph.D. and continuation in STEM careers. At the same time, however, several characteristics of this body of work should be kept in mind when considering its relevance to SLI/USLI programs. First, although random assignment is possible, these studies are primarily non-experimental in design, thus making it impossible to make causal claims regarding the impact of these experiences. Second, the authors frequently provide very general or minimal descriptions of the research experiences themselves. Therefore, it is difficult to know whether programs like SLI/USLI are represented in the literature and further, whether their impacts might differ in meaningful ways from those described.

In general, at least some methodological weaknesses are inherent to these studies, suggesting that their findings should be interpreted with caution. Although none of the individual pieces of research can fully explain the nature and extent of the impact of STEM-related, undergraduate research experiences on students' education and career paths, taken as a whole, they represent the field's understanding to date, and provide a consistent picture of the value of these experiences overall, and particularly for underrepresented and minority students. These cautions notwithstanding, the studies discussed below offer a useful overview of what is known about the effect of undergraduate STEM research experiences within which SLI/USLI can be situated.

According to Carter, Mandell & Maton (2009), one of the earliest studies of this question was conducted by Nagda, Gregerman, Hippel & Lerner (1998); it concluded that participation in the

University of Michigan's Undergraduate Research Opportunity Program (UROP) increased retention rates for underperforming African-American students, as well as for white and Hispanic students who participated in UROP in their sophomore year. Further, Seymour et al. conducted a literature review regarding the benefits of undergraduate research experiences in science (2004), identifying the student impacts that are most often examined in the literature. These are listed below, followed by the number of studies investigating these impacts from the 40 articles that the authors reviewed:

1) Increased student interest in the discipline (22); increased recruitment of students of color into the sciences (5); and increased persistence (5);

2) Greater readiness for more demanding research and for professional careers in the sciences (16); professional socialization (3); and opportunities for networking (2);

3) Clarification, confirmation, interest in, or choice of, a career path (including graduate school) (24);

4) Increased skills including research and lab techniques (13); working collaboratively (8); communication (writing, presentation, and argument) (13); and leadership (3);

5) Gains in: critical thinking and understanding how to approach research problems (13); knowledge (3); and science literacy (9);

6) Increased understanding of the research process (10); how scientists think (5); how scientists work on real problems (18); how scientific knowledge is built (2);

7) Increased self-confidence in ability to do research (11); and self-esteem (2);

8) Shift from passive to active learning (8); and

9) Becoming part of a learning community (10); especially for students of color (4); and bonding with faculty (and, thereby, the discipline/career path) (12).

While the majority of studies include career path interest or choice as an outcome, Seymour et al. are skeptical of their findings regarding the positive relationship between participation in undergraduate research and clarification or declaration of a career path, citing a variety of methodological weaknesses. The authors' own study of apprentice-style research activities in physics, chemistry, biology, computer science, engineering, biochemistry, mathematics, and psychology and more recent research have aimed to address these flaws. In their qualitative examination of 76 interviews of students and faculty in four institutions, Seymour et al. (2008) found that "Overwhelmingly, students define undergraduate research as a powerful affective, behavioral, and personal-discovery experience whose dimensions have profound significance for their emergent adult identity and sense of direction" (p. 530). Furthermore, they described the positive impact of undergraduate research experiences on students "personal/professional transitions" as one of the study's strongest relationships.

In another more recent effort to clarify the relationship between undergraduate STEM research and subsequent career choices, Carter, Mandell & Maton (2009) examined the relationship between on-campus, academic year undergraduate research and enrollment in a Ph.D. program. The authors found that the effect of more intensive research experiences that included conducting original research was greater than the effect of less intensive research experiences that included participating in seminars and research methods courses only. Of particular relevance to this evaluation of NASA's SLI/USLI programs, Carter et al. pay attention to the level of intensity of students' research experiences. They found that participation in on-campus, academic year research was associated with increases in the probability that an "average" non-Hispanic student will seek a STEM Ph.D. by 17.1 to 29.4 percentage points. The authors also found that, although the effects were somewhat smaller for natural science majors compared to engineering/computer science or other science majors, these differences were not significant.

In their study, authors Pender, Marcotte, Sto. Domingo & Maton (2010), reviewed prior research examining the effect of summer research programs on minority students' enrollment in Ph.D. programs and found several studies that provided evidence of their effectiveness. These include Foertsch et al. (1996), who analyzed the experiences of participants in Summer Research Opportunity Programs (SROPs) organized in cooperation with a consortium of 15 Midwestern research universities. Based on descriptive and qualitative analyses of survey responses as well as the demographic, and enrollment data from over 4,500 minority student participants, the authors concluded that SROPs successfully recruited participants to member universities. Their data indicated that half of "SROP's minority participants enrolled in graduate school, while more than 20 percent went on to enroll in professional schools" a decision they found was "driven in large part by the students' research experiences" (p. 9). These findings were echoed by Bauer and Bennett (2003), who found that 43 percent of STEM alumni who participated in summer research entered a doctoral degree, compared to 23 percent of alumni who did not engage in summer research experiences; and Zydney, Bennett, Shahid, and Bauer (2002), found that 35 percent of summer research participants enrolled in STEM Ph.D. programs, while only 8 percent of students without research experiences did. The issue of selection bias was one that both authors attempted to address in their study designs. In particular, Bauer and Bennett randomly selected students from the pools of applicants who were accepted to a summer research program and who were denied due to funding limitations. Zydney et al. chose to match participants to similar non-participants. These approaches notwithstanding, the issue of selection bias remains suggesting caution when attempting to relate findings to SLI/USLI.

Pender et al. (2010) also reviewed the work of Lopatto (2004, 2007) and Russell, Hancock, & McCullough (2007). Lopatto analyzed over 2,000 surveys of students participating in summer undergraduate research experiences for a minimum of six weeks and found that 93 percent of the sample reported that their research experience either supported or enhanced their interest in postgraduate education. Additionally, minority students appeared to report higher learning benefits obtained from research participation than their white, non-Hispanic counterparts. These findings are consistent with Russell et al. (2007), who extended this inquiry into other STEM fields: by reviewing the experiences of more than 4,000 students who participated in National Science Foundation (NSF) programs, they found evidence that students' confidence, motivation and interest in STEM research careers increased as a result of summer research participation.

Pender et al. (2010) also reviewed 14 years of administrative, academic and survey data collected from students participating in summer research internships in one university, and concluded that these experiences encourage participation in Ph.D. programs in STEM fields, particularly for students who participate for more than two summers. Based on the review, the authors posit that the 'frequency effect' may contribute to students' developing higher graduate school aspirations, which have been found to be positively related to graduate school outcomes in STEM, particularly for minorities (Sax, 2000; Pascarella, Wolniak, Pierson & Flowers, 2004).

Experiences for Secondary Students

As with research on undergraduate experiences, there is evidence that authentic science experiences prior to undergraduate work affect student interest in science. Students' interest in a science career has more often been studied among high school students than among middle grade students, largely because this population is further along in their education and has had more time to develop their interests. For example, Roberts and Wassersug (2009) conducted a retrospective study on a program from 1958-1972 in which 11th and 12th graders had the opportunity to conduct original science research. They found that "students who are interested in science and have an opportunity to participate in original scientific research while in high school are significantly more likely ($p<.005$) to both enter and maintain a career in science compared to students whose first research experience didn't occur until university" (p. 251). Abraham's (2002) evaluation of the Earthwatch summer field experiences for high school students also found that students reported an increased interest in pursuing a science-related major in college or a career in science after participation.

However in contrast to the findings above, Sharp et al (1994) in the evaluation of the NASA young scholars program, found no evidence that participation in the program was a predictor of further pursuit of STEM, although it was a positive experience for most participants. For example, participants gained an awareness of the science community and learned about STEM fields. The authors found the program to be especially encouraging for African American students and at least reinforced female participants' pre-existing education and career plans.

Research on student interest and engagement for middle grade students is more often defined as engagement in the particular science experience under study, be it a formal science course or an informal science experience such as a robotics competition. Instructional interventions that teachers implement in their classrooms seem to motivate middle school students, especially the technique of project based learning. According to Blumenfeld et al. (1991), "project-based learning is a comprehensive approach to classroom teaching and learning that is designed to engage students in investigation of authentic problems" (p. 369) which can greatly increase student motivation to participate in the classroom activities and learn the content. Hmelo (2000) did a case study of implementing Learning by Design in a 6th grade classroom where students were studying the respiratory system. Students generated their own questions about how the respiratory system worked and did a design challenge to apply their learning: "Indeed, the students did seem to be motivated by the design challenge. The challenge, plus the teachers' use of the challenge to provide focus, kept students engaged throughout the 2.5 weeks of the design experiment." (Hmelo, p. 275)

Informal opportunities in particular have attracted attention recently for the depth of experiences offered as well as the flexibility in content relative to the science taught in schools (Education Week, 2011). In Weinberg et al's study of a 7-week robotics program (2007), the authors were particularly interested in the effect of the experience on 7th grade girls' interests in science and engineering. They found that the experience may have helped change girls' ideas about traditional gender roles and increased their interest in engineering and science in general, as well as their ideas about pursuing careers in these areas. Similarly, Barak and Zadok (2009) found that students were motivated by a design project at a summer robotics camp. These authors found that students dedicated a lot of time and energy to their projects, including arriving early and staying late, and were able to work with minimal teacher intervention. They found that motivation increased for all participating students, regardless of prior student achievement or socio-economic status (student career goals were not measured in this study).

It is worth noting, however, that studies of programs in informal settings are typically optional, thus there are some limitations to interpreting the findings of these evaluations. The fact that students often self-select into these science opportunities indicates that they are already interested in the program and predisposed to science and engineering experiences.

Chapter 2. Evaluation Design

This evaluation assesses the successes and challenges of the SLI/USLI programs and some potential suggestions for maintenance and expansion of the programs. Its findings are intended to inform ESMD and the NASA Marshall Space Flight Center in the decisions surrounding the potential expansion of the existing programs and makes suggestions to improve the Student Launch Initiatives.

Evaluation Questions

The NASA Student Launch Projects Evaluation is designed to address the following evaluation questions:

1. To what extent are the NASA Student Launch Projects meeting their objectives of providing middle school, high school and college students with valuable hands-on systems engineering and research experience?

2. To what extent are these projects inspiring students to continue their STEM education or pursue STEM careers?

To address the evaluation questions, we focused our data collection on the following outcomes:

a. Students' and faculty's perceived value of the hands-on experience gained from SLI/USLI

b. Students' perceived value of the STEM content knowledge/skills acquired as a result of participation in SLI/USLI

c. Student motivation to pursue further education in STEM field resulting from participation in SLI/USLI

d. Student motivation to pursue a career in the aerospace or other STEM industry resulting from participation in SLI/USLI

Data for the evaluation were obtained through a number of sources; the review of documents and other programmatic material (including extant survey data from prior years), interviews and focus group discussions with project staff, partners, reviewers, mentors, faculty, student participants, and parents, observations of the student project performance reviews (via WebEx), and attendance at the Advanced Rocketry Workshop. Members of the evaluation team conducted a two-day evaluation kick-off meeting in October 2010, and a five-day site visit during launch week in April 2011, at which time we conducted interviews and focus groups with stakeholder groups. Additionally, an evaluation team member attended the Advanced Rocketry Workshop during which prospective participants were educated about the specifics of the SLI/USLI program and built/launched their rockets to qualify for Level 1 certification through the National Association of Rocketry. Broadly, interview and focus group questions investigated the following program areas:

1. Student, mentor, reviewer, partner background and preparation for the program

2. Program context, attributes, logistics and organization

3. Perceived effects of program expansion including potential risks, benefits and demands
4. Reviewer, partner, and mentor responsibilities
5. Program size and capacity
6. Program outcomes
7. Importance of specific program activities
8. Project strengths and challenges

Data Sources

The study used four data sources to address the evaluation questions: (1) review and analysis of programmatic documents and extant data provided by the project organizers; (2) observation of technical reviews (Preliminary Design Review (PDR), Critical Design Review (CDR), Flight Readiness Review (FRR)); and (3) interviews and focus groups with project staff, partners, reviewers, mentors, faculty, participating students, and parents; (4) and attendance at the Advanced Rocketry Workshop.

Document Review

Program-related materials were requested from program staff for review, prior to the interviews, to supplement the information already identified. The evaluation team also accessed information about the program through the NASA website and other publically available sources (e.g. university websites, blogs). The document review entailed a comprehensive examination of the collected data, deepening the team's understanding of the program in preparation for the original data collection effort. Program organizers also provided the evaluation team with summaries of prior years' student and faculty surveys.

WebEx Observations

For the WebEx review process, we identified focal teams at the outset of the evaluation to observe as they went through each of their three program reviews- preliminary design review (PDR), critical design review (CDR), and flight readiness review (FRR). Together with the program organizers, we selected four university teams and two high school teams to follow so that they would be representative of the diversity of participant skill, experience, available resources, and geographical location. The specific selection criteria were as follows:

USLI

- Representation from minority-serving institutions of higher education;
- Universities with strong engineering programs and those without engineering programs;
- Representation from institutions who were new to the program (e.g., in their first year of participation) and those with previous experience; and
- Geographic representation (Northwest, West, South, East)

SLI

- Representation from teams with and without previous SLI experience; and
- Geographic representation (West, Midwest)

The opportunity to observe the reviews provided the evaluation team with a unique understanding of the varied levels of teams' skill and ability as well as the occasion to gain deeper understanding of NASA's expectations. Observing the technical reviews also allowed for greater insight into the work and planning required of project participants as well as the feedback, instruction and management provided to participants by NASA technical staff. The evaluation team observed the participant presentations and subsequent question and answer periods with NASA reviewers. We did not ask questions or interact with participants during the WebEx reviews. However, evaluation team members listened in on reviewers' conversations after the presentations and had opportunity to ask questions and interact with reviewers once the teams exited the WebEx format.

Interviews with Program Staff, Participants, and Partners

The evaluation team conducted semi-structured interviews with programs staff, reviewers, participants (students, faculty, and mentors), parents and partners (e.g., staff from ATK Aerospace Systems and the National Association of Rocketry (NAR) safety officers). Where possible, we talked to stakeholders with different positions and investments in the programs in an attempt to triangulate a common or shared set of perceived successes and challenges, as well as to gain an understanding of how perceptions vary across stakeholder groups. The discussions were tailored to the informant's position and understanding of the program. The data were collected at two points in time. At the project's kick-off meeting, evaluators had the opportunity to speak with program organizers, engineers serving as project reviewers, and previous participants. Additionally, project evaluators traveled to the Marshall Space Flight Center during launch week in April 2011 to conduct interviews and focus groups, participate in launch week activities, and observe the team launches.

Focus groups with student participants were also conducted. Student respondents were placed in groups stratified by education level (i.e., university teams, high school teams) and role (i.e., team leader, teach member). Varied modules from the focus group instruments were utilized as appropriate to the composition of each focus group. In total, we conducted the following student focus groups, using different components of the instruments:

- 4 high school team leader focus groups consisting of team leaders from multiple high schools (3-6 team leaders per focus group);
- 4 high school team member focus groups consisting of team members from multiple high schools (6-8 students per focus group);
- 5 university/college team leader focus groups consisting of team leaders from multiple institutions of higher education (3-6 team leaders per focus group); and
- 5 university/college team member focus groups consisting of team members from multiple institutions of higher education (6-8 students per focus group).

Additionally, we conducted focus groups and interviews as follows:

- 1 focus group with the three primary program organizers;
- 2 interviews with NASA engineer reviewers;
- 2 NAR safety officer focus groups – one group of NAR officers new to the program and one group of NAR officers with five or more years of experience (6-8 officers per group);
- 3 educator/mentor focus groups – one group of USLI educators/mentors, one group of SLI educators/mentors, and one mixed group (6-8 educators/mentors per group); and
- Approximately 9 parent interviews on launch day.

Detailed notes and audio recordings were taken during the interviews, focus groups, and observations. A summary of results was prepared for the case study.

Attendance at the Advanced Rocketry Workshop

One member of the evaluation team attended the Advanced Rocketry Workshop (ARW) to better understand the entire scope of the requirements associated with program participation and to observe the training and preparation required of prospective participants prior to acceptance into the program. Each prospective SLI team is required to send one team representative to the ARW while it is highly encouraged, but voluntary, for USLI teams. The ARW is a combination safety training workshop, Level 1 certification opportunity, and information source from program leaders about rules, expectations, and pitfalls to avoid. The workshop is a three-day event that fully prepares teams for the challenge of the SLI/USLI program, and provides the opportunity for teams to ask questions, obtain answers, and plan for the year ahead. Additionally, the ARW provides opportunities for future teams to meet one another and forge relationships that may prove useful during the program year. Participants are given explicit instruction and guidance, not only about building rockets, but also about the SLI/USLI program in general. Program managers are available to answer technical questions, prepare team members for logistical considerations and help avoid (or at least warn of) frustrations inherent to the process. The program leads deliver detailed presentations about each major aspect of the program, provide examples of prior work, and walk through program rules and requirements, step-by-step. Teams attending the ARW come away very well prepared for the program year ahead.

Data Analysis and Reporting

All data collected in support of the case studies were carefully reviewed and systematically synthesized to address the evaluation questions and explore the outcomes of interest. During the course of data analysis and reporting, the evaluation team held analytic meetings to discuss what had been learned about the program and to identify common themes. Findings from the primary data sources were used to inform the conclusions and recommendations.

Extant Data

All hard copy summary data from 2005-2008 program years were entered summarized further, by program year and respondent type (student/educator). The primary data of interest were responses to satisfaction questions and participant report on the effect of program participation.

Interview Data

Interview and focus group data were reviewed for accuracy shortly after the data collection occurred to ensure accuracy and appropriateness of response to each question. Further, information classified under each evaluation topic area was reviewed and synthesized for each respondent type. These efforts allowed team members to determine if responses to questions provided answers to that specific question, if there was information relevant to another question, and how the responses to the questions overall provided information related to the topic areas and evaluation questions. Reviewing responses to each question, in relation to respondent type, also provided a mechanism for identifying themes as they emerged and contributed to answering the evaluation questions.

To ensure consistency during analysis, team members met to discuss questions and methods of data organization to best facilitate analysis. Once analysis of the data began, staff gathered periodically for analytic meetings to discuss the data and to identify the major themes emerging from the data, and to ensure consistency of treatment. The information we collected from all of the sources was used to inform analysis within and across topic areas and research questions, where relevant.

Limitations

The evaluation of the SLI/USLI programs was limited by two factors that should be considered when reviewing the conclusions and their implications. One limiting factor in the case study is the lack of tracking data that would provide evidence of the educational pathways and career choices of participants over time. A second limitation is that although the SLI and USLI programs have been in existence for approximately 10 years, the available extant data are not entirely consistent (e.g., participant surveys changed from year to year). The changes in annual participant surveys make it somewhat difficult for the evaluation team to triangulate information obtained from the current cohort of participants to previous cohorts, regarding participant satisfaction, interest in STEM fields, suggestions for improvement, and details of participant education and career trajectories. However, the essence of the questions asked from each year's participants is similar enough to get the flavor for general attitudes about the program and qualitative data, captured in the form of quotes and self-reports, portray a relatively consistent picture. For this evaluation, program observations, interviews and focus group data were collected from current participants only, and although this allows the evaluation team to make direct observations of their work, opinions, and experiences, we do not have as consistent information from previous cohorts. Therefore, the information obtained from current participants was complemented with the information we were able to obtain from previous cohorts.

Chapter 3. Student Launch Projects Case Study

The case study discussed below describes two NASA Student Launch Projects, SLI and USLI. The two programs share similar objectives and structures and are designed to provide students the opportunity to participate in designing, building and testing reusable rockets. The Student Launch Initiative (SLI) program was first implemented in 2000 as a small, local opportunity for a handful of teams within the community surrounding the NASA Marshall Space Flight Center in Huntsville, AL. In its first year, approximately four high school teams and two college teams participated in the program, which ran on a schedule that was different and longer than it is today. In 2003-04, the SLI program went national, expanding the opportunity to student teams across the country, in partnership with the Team America Rocketry Challenge (TARC) as a feeder program. The program was designed to engage middle and high school students in NASA's design and review process. In 2005, a university-specific program was created, The Deep Space Test Bed – a high altitude balloon project incorporating the building of payloads. In 2006, the University Student Launch Initiative (USLI) was reinstituted, with eight university teams participating. In both programs, students spend eight months focused on rocketry, culminating in a spring launch day in Huntsville, AL. The primary objective of the two programs is to increase student interest in and exposure to careers and education pathways in STEM and aerospace fields.

Key Components of the SLI/USLI Programs

The SLI/USLI programs guide participating teams of students through a progression of steps during their eight-month projects. Most notable amongst these steps are reviews that occur at four points during the year: the Preliminary Design Review (PDR), Critical Design Review (CDR), Flight Readiness Review (FRR), and Post Launch Assessment Review (PLAR). These reviews require both written reports and oral presentations. Participating teams are also required to design a website where they post their reports and presentation slides. The team websites act as the primary portal for sharing design documents with NASA staff. In addition to the review process and website, the program requires teams to incorporate at least two educational engagement/outreach events through which they reach a combined total of at least 75 members of their local community. This can take the form of activities with local school children, Scouts, or 4H clubs, to name a few.

NASA has stringent safety requirements for participation in the SLI and USLI programs. Because teams design, build, and launch High Power Rockets (HPR), they must conform to the National Association of Rocketry (NAR)'s safety standards and certifications. The NAR has three levels of HPR certification, which correspond to types of motors and quantities of total-impulse within each rocket. To participate in SLI or USLI, each team is responsible for contacting their local NAR or Tripoli Rocketry Association (TRA) chapter and establishing a relationship with a currently certified Level 2 or 3 NAR/TRA mentor. This person's contact information is required to be included as a team member for SLI teams (because USLI participants are over the age of 18, team members possessing a Level 2 or 3 certification can act as the team mentor). The NAR/TRA mentor (or Level 2/3 certified team member for USLI teams) is instrumental in helping the team learn sport rocketry practices and is responsible for safety inspections. The NAR/TRA team member is designated as the individual owner of the rocket for liability purposes and MUST accompany the team to the launch in April. A stipend is provided. Acquiring Level 2 or 3 certification involves building and flying a rocket with a sufficiently-powered motor, taking and passing a written exam, and possessing, initially, an NAR level 1 certification. For teams in middle or high school, the faculty advisor of the team may be level 2 certified.

The NASA design process provides student teams with the opportunity to present their work as well as receive feedback from a panel of NASA scientists and engineers on specific aspects and overall progress of their projects. Below we provide additional details on each of the reviews.

The Preliminary Design Review (PDR) is the review where student teams first present their rocket, vehicle, and payload design and any modifications made to their original proposal. The PDR occurs approximately two months after the beginning of the program year and is the initial opportunity for teams to provide reviewers with insight into their vehicle design, payload selection, and payload objectives. During this review, student teams present their project and demonstrate the feasibility of implementing their design (e.g., timetable, budget, and adherence to acceptable risk).

Two-three months following the PDR, student teams participate in the Critical Design Review (CDR) to ensure that adequate progress is being made toward testing the rocket. Students discuss their rocket's final design presenting data regarding its flight reliability and performance predictions as well as any launch concerns. They also provide specific details about the payload design at a systems level. Teams are provided with feedback from the NASA review panel and suggestions for any necessary changes due to safety concerns. The teams then proceed to the next stage of the design process.

Approximately one month prior to launch day, the final review before launch, Flight Readiness Review (FRR), takes place to ensure that the rocket, software, students and other personnel are ready for launch. Prior to FRR, each team is required to fly their full scale rocket and demonstrate flight and recovery results. The reports prepared for FRR are discussed during teams' presentations to the review panel and include a description of recovery, how the students select the parachute size, how the parachute is attached, and how it will deploy. In addition, the student teams outline the assembly of their rocket for the panel. Additionally, the student teams must provide detailed check lists including but not limited to, recovery, set up, launch, and post flight inspections. During this review, students must present information on the design tests they have performed, sharing any data they have collected during the test flights. The panel of NASA engineers then reviews these data to determine readiness for a safe and successful launch; prepared teams then receive authorization to participate in launch day.

Finally, after launch day, a Post-Launch Assessment Review (PLAR) is submitted to the panel of NASA scientists and engineers, which focuses on in-flight performance. The PLAR does not include a formal student presentation. Rather the student team writes a report which includes key statistics from the actual launch, such as the altitude reached. Students are also asked to include an overall summary of their experience in the report.

Program and Participant Funding

The SLI and USLI programs are primarily funded by the Exploration Systems Mission Directorate (ESMD). They also receive support from NASA's Science Mission Directorate (SMD), which provides awards to individual teams interested in applying for funds to build science payloads on their rockets, and from NASA's Space Operations Mission Directorate (SOMD). Additionally, SLI/USLI receives funds from the Office of Education's Education Flight Projects (managed at Johnson Space Center). ATK Aerospace Systems, SLI/USLI's corporate sponsor, also contributes funding for motor and lodging stipends and the prize for the winning USLI team, among other things.

Once accepted and enrolled in the program, new SLI teams receive a $3,700 grant to develop their projects and their schools' rocketry programs. The program is designed as a two-year venture, therefore returning teams who submit a proposal and are accepted again are awarded a smaller sum ($2,450). The initial award is intended to establish the project at a school or organization, requiring less support from NASA in subsequent years. In addition, each SLI team's mentor or advisor, usually a teacher from the school, is provided a stipend to facilitate their required attendance at the Advanced Rocketry Workshop (ARW), where rocketry safety protocols and procedures are reviewed.

Unlike the SLI teams, USLI teams do not receive an initial monetary award from the USLI program upon acceptance and enrollment. However, USLI teams do often request other available NASA funding. For example, USLI teams are eligible to apply for funding allocated to the USLI program by the NASA Science Mission Directorate (SMD), a grant to build a science payload. Similarly, teams generally request and receive funding from their state's Space Grant Consortium, another NASA-funded program. The Space Grant Consortia were created by Congress, in part, to encourage students to choose courses of study that will lead them to enter the technical work force in fields related to space exploration and research. Team members and faculty mentors are encouraged to attend the ARW, but attendance is not mandatory, and no funding is made available to USLI participants who choose to attend.

Qualification and Enrollment

To participate in the SLI program, NASA requires middle and high school student teams to qualify in one of two ways to ensure they have some prior experience in rocketry. First, they can qualify if they place amongst the top ranked teams from the Team America Rocketry Challenge (TARC) competition, an Aerospace Industries Association (AIA)-funded national rocketry competition that began in 2002 (in past years the number of teams qualifying has ranged from the top 20-25 teams). In addition, they can qualify if they place amongst the top three teams from the Rockets for Schools competition, a nation-wide rocketry program based in Wisconsin but open to teams from anywhere in the country, that primarily serves students from Wisconsin, Michigan, Illinois, and Iowa. In the 2010-2011 school year, 19 SLI teams were accepted into the program and due to withdrawals, 17 teams participated in launch week activities. Another two teams of the 17 that participated in launch week activities did not launch their rockets because they did not meet all necessary requirements.

University teams participating in USLI are not required to qualify prior to the application process, however, unlike SLI, the USLI program itself is a competition. In 2010-2011, thirty one university teams were accepted into the program and again, due to withdrawals and technical difficulties, 27 teams participated in launch week activities, and 24 teams launched their rockets with the SLI teams in Huntsville, AL. An additional three teams, who had successfully participated in earlier years, and who had built larger, more complex rockets, launched from Wallops Flight Facility, a NASA facility in Virginia.

Though enrollment in USLI has not historically been capped or curtailed, in the 2010-2011 year, program organizers limited overall enrollment to 53 teams across both SLI and USLI programs.

Increasing interest in the program in the past years has stretched NASA resources, particularly those associated with the periodic reviews and the launch at the program's end. As a result, in 2010-2011, 53 of the 59 teams who applied were selected to participate.

Participating Teams

Exhibit 1 displays the teams participating in the 2010-2011 SLI/USLI programs. Approximately one-third of USLI teams and over half of the SLI teams were new to the program.

Exhibit 1. 2010-11 SLI/USLI Teams

SLI	USLI (Level 1)	USLI (Level 2)
AIAA Orange County Section, Orange County, CA	Alabama A&M University, Normal, AL	Mississippi State University, Starkville, MS
Clear Lake High School, Houston, TX	Arizona State University, Tempe, AZ	Mitchell Community College, Statesville, NC
Federation of Galaxy Explorers, Chantilly, VA	Embry-Riddle Aeronautical University, Prescott, AZ	University of Alabama in Huntsville, Huntsville, AL
Goshen High School, Goshen, IN	Fisk University, Nashville, TN	
Hart County 4-H, New Team, Munfordville, KY	Florida A&M University, Tallahassee, Fla.	
Hart County 4-H, Returning Team, Munfordville, KY	Harding University, Searcy, AR	
Ingraham High School, Team Adams, Seattle, WA	Inver Hills Community College, Inver Grove Heights, MN	
Ingraham High School, Team Olympus, Seattle, WA	Iowa State University, Ames, IA	
Krueger Middle School, San Antonio, TX	Lafayette College, Easton, PA	
Madison West High School, Team Slime Mold, Madison, WI	Middle Tennessee State University, Murfreesboro, TN	
Madison West High School, Team Bamboo, Madison, WI	Missouri University of Science and Technology, Rolla, MO	
Plantation High School, New Team, Plantation, FL	Massachusetts Institute of Technology, Cambridge, MA	
Plantation High School, Returning Team, Plantation, FL	North Carolina State University, Raleigh, NC	
Presidio High School, Team 1, Presidio, TX	Northwest Indian College, Bellingham, WA	
Presidio High School, Team 2, Presidio, TX	Pennsylvania State University, University Park, PA	
Rockwall-Heath High School, Rockwall, TX	Purdue University, West Lafayette, IN	
Star Splitters 4-H, Manitowoc, WI	Shippensburg University, Shippensburg, PA	
	Tuskegee University, Tuskegee, AL	
	University of Alabama,	

SLI	USLI (Level 1)	USLI (Level 2)
	Tuscaloosa, AL	
	University of Central Florida, Orlando, FL	
	University of Florida, Gainesville, FL	
	University of Illinois – Urbana – Champaign, Champaign, IL	
	University of Michigan, Ann Arbor, MI	
	University of South Alabama, Mobile, AL	
	University of North Dakota, Grand Forks, ND	
	University of Washington, Seattle, WA	
	Utah State University, Logan, UT	
	Vanderbilt University, Nashville, TN	
	Windward Community College, Kaneohe, HI	

Experiences of Former Participants

Each year, NASA asks program participants (both students and educators) to complete surveys. A variety of questions are asked including demographics, areas of STEM interest, and satisfaction with the program. Questions are reported as means on a 5-point Likert scale (1=very poor rating – 5=very strong rating). Exhibit 2 displays a subset of the questions asked of program participants between 2005 and 2008 along with their mean responses. Overall, both students and educators reported the program is of great value to them (means ranged from 4.7-5.0 on a 5-point scale). Similarly, students and educators reported that the program was highly relevant to their school work or teaching (mean ratings of 4.1-4.8). Lastly, students and educators alike were highly likely to recommend the SLI/USLI programs to others (mean ratings ranged from 4.7-5.0). Although data from the 2010-11 program year were not available for this report, they mirrored the sentiments of past years' participants.

Exhibit 2. Participant Survey Responses (2005-2008)

	2005	2006	2007	2008
Student Responses				
Value of the program	4.7	4.9	4.8	4.8
Program relevance to school	4.2	4.5	4.1	4.5
Likelihood of recommending program to other students	4.8	4.8	4.7	4.7
Educator Responses				
Value of the program	4.7	5.0	4.9	4.9
Program relevance to teaching	4.3	4.7	4.8	4.6
Likelihood of recommending program to other educators	4.7	5.0	5.0	4.9

Participants also have the opportunity to give general comments about the program each year. Listed below are examples of participant responses. Students were enthusiastic about the opportunity to have a hands-on, real-world experience and found value in the exposure to science and engineering content, problem-solving, and team work. Similarly, educators reported value in the practical experience it provided their students and the inspirational effect the program had on their students' motivation to continue their pursuits in science and engineering.

Students

The most valuable aspect of the program was exposure to skills and knowledge that are not taught regularly in schools.

Learning how to work as a team, and problem solving was the most valuable aspect of the program.

As a result of participating in this program, I hope to gain more experience in the field of engineering, and set myself up to go to a college to become an engineer.

Being in the program has helped me grow up and learn more about myself, and helped me see that I want science to be in my future.

Launching our rocket was one of the coolest experiences of my life! I will never forget the day I got see all my hard work go up in a trail of smoke, pop a parachute, and coast gently to the ground.

Educators

The most valuable aspect of the program was teaching the students how the real world works. Applying for a contract all the way to the end results. How the team had to cooperate with each other and meet deadlines.

I cannot be enthusiastic enough about how valuable this program was to me and will ultimately be for my students. I feel very strongly that they will continue on with aerospace in some

> *capacity. Thank you so much. I have listened to a lot of professionals speak at my job, however, at MSFC, your professionals on site were very passionate and their passion is infectious. Thank you!*
>
> *The most memorable event during the program was hearing students stating how much they were inspired by the program to enter engineering, science, and exploration. This applies to me also, as a teacher.*
>
> *Continue giving students this opportunity! DO NOT defund this program. Expand it if at all possible. More kids across the country need this.*

Overall, student and educators who have participated in SLI/USLI in previous years have reported great value in the programs, both for the science and engineering knowledge and skills it provides as well as for the unique, hands-on experience. In the next section, we present and discuss the feedback from 2010-11 SLI/USLI stakeholders.

Goals and Importance of the SLI/USLI Programs

In order to better understand the goals of the SLI/USLI programs and the degree to which they are shared among stakeholder groups, the evaluation team interviewed program leaders, as well as the ATK Aerospace Industry and National Association of Rocketry (NAR) partners. Their opinions were consistent, noting the emphasis on inspiring students to pursue their interests in STEM and the aerospace industry by creating an authentic research and development challenge based on NASA's design process. Their views are discussed below.

Goals of SLI/USLI Programs

In a focus group with the program leaders, they spoke of the primary goal of the SLI/USLI programs. In their view, the essential purpose is to inspire students to continue pursuing STEM education and then careers in the aerospace industry in general, and at NASA in particular. Their hope, for example, is that the real-world experience of the SLI projects will motivate younger students to advance to the greater challenges of USLI when they enter college, which could then lead to internships at NASA and ultimately, strengthen the aerospace talent pipeline. This focus is shared by ATK, SLI/USLI's corporate partner and fourth-year sponsor. As the corporation's representative explained, ATK's continued commitment to SLI/USLI reflects its commitment to developing new engineering talent and their belief that SLI/USLI's multi-disciplinary approach for creating "close-to-real world experiences" in which students learn from each other and their mentors is an effective strategy.

This program purpose was echoed by the National Association of Rocketry (NAR) volunteers who oversee the safety and logistics of the launch day. In focus group discussions with both the more experienced NAR volunteers as well as newcomers to the launch experience, they commented on their role beyond ensuring the safety of all involved, is to "pass along the passion for rocketry." Moreover, in keeping with the progression of experiences in rocketry that propel students to further aerospace-related higher education and careers, they saw the Team America Rocketry Challenge (TARC), which NAR sponsors, as a "feeder" to SLI/USLI programs. And in fact, many SLI/USLI students who participated in focus groups reported having participated in TARC, stating that SLI was the next logical step for them.

Importance of the SLI/USLI Programs

NAR volunteers also pointed out how SLI/USLI compares to other rocketry programs that students might experience, and what it is about the SLI/USLI projects that are unique. As they explained, "TARC is for the beginners, the masses; SLI is for the committed ones," and "TARC gets kids interested in engineering, SLI makes them engineers." NAR volunteers observed that the complexity of the SLI/USLI projects, the eight-month duration of the experience, the national scope, and the emphasis on community outreach all set it apart from other programs in rocketry. The value of the authentic, real-world nature of the project challenge is a theme that recurs throughout the interviews, focus groups, and informal conversations that were conducted as part of this evaluation.

NAR volunteers noted that the work these students do with rockets is something that it might take NAR members "3-5 years of experience to accomplish." One volunteer commented on how, during the rocket fair, he gained new ideas and learned from some of the teams' projects. And consistent with NAR's mission of educating and exciting the public about rocketry, all volunteers took opportunities throughout their interactions with SLI/USLI teams, to question students, offer suggestions, and "plant seeds" for future projects. In short, although there are some programs that are valuable and offer aspects of the SLI/USLI experience, in the view of volunteers, "Nothing compares to SLI."

Programs' Influence on Students' Pursuit of STEM Education and Careers

On the whole, respondents described what they see as meaningful and varied effects on students of the SLI/USLI programs. Most notably, respondents reported that the experience reaffirmed students' existing interests in engineering, the aerospace industry, and/or in rocketry; and created opportunities for students to venture beyond the theoretical realm of their coursework to develop important workplace and "real-life" skills such as team work, time management, problem solving, communication, and hands-on, building skills. Additionally, respondents observed that it expanded students' views of the education and career possibilities available to them, and increased their self-confidence. Each of these outcomes is discussed in more detail below.

Reaffirming Existing Interests

When discussing the effect of the SLI/USLI experiences on students' pursuit of STEM education and careers with parents, students, and their mentors, the responses were consistent. The vast majority of students arrived at SLI/USLI already interested in or committed to engineering in some form, the aerospace space industry as a career path for a great many, and even working at NASA for a considerable number. The experience provides a valuable opportunity to reaffirm students' interests, and helps pave the way for them to continue to pursue them. As one USLI mentor discussed, "The impact on their future careers is not enormous because kids come in already knowing what they want. But it gives them a chance to find each other in a big institution, build friendships, and remember this experience."

Parents were clear about their children's history of fascination with NASA and rocketry. For example, one mother and father commented on Launch Day that they recalled that when their daughter was seven years old she declared that she would run NASA one day. Another family described their daughter's promise at nine years of age to build a Rover that would successfully navigate the moon's surface. And a third family had supported their son's interest in rocketry for years, dedicating hours of their own time and money to attend his launches all over the country. Of the nine families interviewed on launch day, seven reported that their children were already committed to studying and pursuing engineering careers in aerospace. For these students, the authentic challenge of SLI/USLI combined with the NASA environment offered a singular experience that confirmed their excitement and propelled them further toward pursuit of their passion for engineering and rocketry.

Students echoed their parents' observation, and gave examples of how they think differently about their future courses, career goals, and NASA as a result of their SLI/USLI experiences.

> *I always wanted to be an engineer. I thought about architecture, but with the rockets now, I'm thinking about space.*

> *This opened my eyes to what I could do after high school and college. I'm more likely to take science, technology, and math courses in high school.*

> *Once you start a launch it's like you can't get rid of it. You just want to do more of it, to learn everything there is.*

> *This is what I wanted to do, aerospace engineering, and I just needed to see how the entire engineering process really works.*

> *I've thought more about aeronautics than ever. It (SLI/USLI) definitely piqued my interest.*

Two mentors commented during focus groups on the positive attitudes toward NASA that students develop during the course of their SLI/USLI participation, and their tendency to become "ambassadors" for NASA. And parents commented on the important role of NASA, and their pride in NASA "to see it's getting the next generation of engineers ready."

> *SLI really encouraged me to really try harder to be an astronaut. I learned about opportunities and careers in space that I didn't know existed.*

Team mentors also described the programs' influence on their students' education and career trajectories as they progressed from one year to the next in SLI/USLI. In one mentors' four years with USLI, he has seen at least 10 of his students go on to jobs in the aerospace industry and others become outspoken "advocates for NASA and aerospace." Another mentor with three years of USLI experience, reported similar outcomes for his students; five have gone on to internships at Goddard, Marshall, Glenn, and the Department of Defense. He noted that every year he has "2-5 good students, and for a majority [of those students], USLI opens their world and they do very well." A third mentor described administering a pre-post survey to his team in 2010, which showed an increased interest in engineering careers and an increased comfort with the science content after the SLI project concluded. He also surveyed 20 TARC participants, and consistent with anecdotal evidence discussed earlier, found that 19 of them were interested in participating in SLI.

Developing Workplace and "Real-Life" Skills

Although the intended purpose of SLI/USLI may be to inspire students to pursue education and careers in the aerospace industry, students and mentors reported a different and equally powerful set of accomplishments. Students and their mentors spoke with conviction about the value of the SLI/USLI experience to students' understanding of/and ability to function in workplace settings. A variety of components of the SLI/USLI experience contributes to this result. Primarily, giving students the responsibility for following NASA's design process for taking an initial concept from the development and testing phases to the launch provides them with an opportunity to learn communication skills, teamwork, time management, and problem-solving skills.

Writing and Presentation Skills

A significant number of students and mentors discussed NASA's review process and the value of preparing the written reports, power point presentations, and presenting their work to NASA's reviewers. Despite their displeasure at having to prepare written and oral reports in the moment, students consistently remarked that the intense amount of work required of these reviews was ultimately highly valuable. When asked what aspects of the SLI/USLI experiences were most important for their future education and careers, these responses were typical:

> *It's easy to think you know everything, but writing a presentation forces you to think things through and explain the concepts.*

> *The reviews are a great component. The fact that it's a complete design process makes it really different from some of the other competitions like TARC. This requires you to support your ideas throughout. You need to support the reasoning for your ideas.*

> *We had a lot of responsibility. We had to keep up our work ethic through the long and difficult process, and it taught us how to present our ideas to real engineers, figure out problems, to really problem-solve.*

Team Work

Although the size of the teams ranged between 1 and 24, and no particular number seemed to be optimal, the SLI/USLI experiences required students to learn to work in teams (with the exception of the one-man team), which students and mentors also recognized would serve them well in the workplace. This quote was typical:

> *The most valuable aspects of the experience for me was teamwork, working with all different kinds of people, learning both from failure and success, responsibility, management, motivation, confidence, delegation, schedule management, how to look at the larger picture.*

Moreover, requiring a variety of activities from each project such as developing a payload, conducting outreach efforts, and creating a website, compelled teams to either recruit students with a variety of skills or have current members learn new ones. As one NASA reviewer commented, "The experience is inter-disciplinary; the value is that it matches what happens in real life. There are very few people who can do it all. You can know a little bit of everything, but no one can be an expert at everything." The following remark illustrates students' recognition of the challenge of working in a team, and the value of learning to do so effectively.

The diversity was very interesting. We had so many people on the team – English majors, PR, AutoCAD design; we almost pulled in an accountant. It becomes something akin to a little company in and of itself.

The experience of developing work place skills also had value for those students who brought non-engineering expertise to their teams. For some of these students SLI/USLI was an opportunity to apply their skills as writers, organizers, graphic or web designers to an interesting project in a new field, while for others it was a chance to indulge their rocketry hobby. Several mentors commented on this aspect of the program as a real asset. As one spoke:

The project requires students with a wide variety of skills and abilities, and can attract very different kinds of students with different interests. The heavy writing requirement, for example, attracts students who might not otherwise get involved in a science or technology project, and they're exposed to NASA, an entity with whom they might not otherwise have the opportunity to be exposed.

Another mentor noted that his "top person" on the team this year was a 20-year old student at a technical college, with the "life goal of becoming a top level pastry chef. She loves rocketry and got her level 2 license, but she has no interest in this as a career." However, the experience she has gained in planning and executing this challenge "will get her far in her career." Similarly, an SLI mentor referred to a young graphic design student who was recruited by her team to work on their rocket's design and decoration. Her team mates helped her learn to use computer graphics, and she is planning to return to the team next year: "She'll never be an engineer, but she'll be a graphic designer, and this experience has helped her to better understand the applicability of her skills." According to these and other mentors, the level of planning, organization, communication, problem-solving and team work were skills that are critically important to successful employment regardless of the career.

Leadership Skills

For those students who took on the role of team leader, the gains in leadership skills, communication, and management were particularly profound. In focus groups with the team leaders, they described their responsibilities; and their comments below illustrate the seriousness with which these leaders accepted this position, the complexity of the job, and the rewards in terms of leadership strengths and self-confidence.

Getting the team started is step one, submitting a proposal, being successful, getting to the launch in Alabama, and inspiring other students to learn more about rocketry. There are a lot of people on the team who would otherwise never do this stuff. Being able to spread the excitement was great.

I had to find a good balance between how much help and support to give the sub-teams; learning how to be an efficient manager of all the sub-teams without micromanaging.

It was about knowing how to allocate talent, understanding what skills people had and how to place them to best benefit the team. Some people on the team had no idea how to do the necessary work.

Keeping the whole team involved, getting the seniors to mentor the younger students – sustaining the program for younger students for future years.

I felt like I had a job, setting deadlines, goals. It was more than I expected – more fun, more hands-on than I thought, and much more work.

Learning from Mistakes

Finally, students inevitably confronted disappointments and failures, and getting to launch was about learning to deal with these unexpected problems. The importance of this aspect of the SLI/USLI experiences was mentioned by several students and mentors. One mentor offered his team as an example. His group chose a very ambitious design, too ambitious given their constraints of time and expertise. This mentor was very proud of his team when they recognized that their rocket was not ready to be launched when the time approached to head to Alabama and they decided to withdraw from the competition: "They learned more from their mistakes than another team from the same school that chose an easier design." They will re-work the rocket and fly it at a later time, and in the process they will have overcome both their lack of knowledge and they will strengthen their ability to overcome setbacks and rebound after an important disappointment.

Like the future pastry chef and her mentor mentioned above, students recognized that gaining experience with any of these workplace and "real-life" skills puts them at a distinct advantage when entering the job market. Students commented on the fact that they feel better prepared for work life, and have more competitive resumes with SLI/USLI programs included. They also recognized that many employers in the aerospace industry – and NASA – will recognize the value of hiring SLI/USLI alumnae because of their familiarity and experience with NASA's design process.

Increasing Self-Confidence and Expanding Views of Future Possibilities

Although the trend of reaffirming students' already strong interest in engineering and aerospace was very clear, for some students the SLI/USLI experience opened up new possibilities that they did not know existed. By exposing students to the entire design process and to working with other team members, they had opportunities to develop skills or interests they did not know they had, and achieve goals they did not think possible. This was particularly profound for students whose access to such challenging opportunities was limited by their geography or income level.

The mentor of one such team spoke eloquently about the alienation his teams' students and families feel from mainstream society due to their isolation and poverty – and how involvement with USLI has shown his students and their families what is possible, and what they can accomplish. "To be able to be here, and compete with you guys, it's huge." Another student commented, "This program has shaped me and my personal aspirations. It made me feel like I can do things that people in rural areas don't aspire to do."

Program Strengths and Challenges

Students, mentors, and NAR volunteers all had an opportunity to share their thoughts on the programs' strengths and challenges. While many of its strengths are indicated in the previous sections, others emerged from the focus group discussions and are described below. In addition, students and others discussed the challenges they face as participants in the SLI/USLI program, and those points conclude this section.

Program Strengths

As the discussions above suggests, the strengths of the SLI/USLI programs are in its capacity to create authentic challenges that require multi-disciplinary teams of students to work together to achieve their goal. The program teaches students not only how to demonstrate and expand their knowledge, but to work with one another, respectfully learn from each other and experts in the field, perform under stress, problem-solve, and own an entire design process. As one student put it,

> *It shaped my life and what I want to do. It gets you to see all the possibilities. This is as real as it gets. It shows a wide range of all the different jobs you could have in aerospace, such as engineering, management, or finance. It's real world.*

Program Structure, Organization, and Logistics

The more routine, but no less important strengths of the programs lie in the structure, organization, and the logistical planning and communication of its leaders. Although they don't necessarily contribute directly to the impact of the program, if these aspects of the programs' operation are not done well, it would certainly detract from the programs' ability to achieve its successes. When students were asked about the program logistics, the clarity and organization of the programs' structure, the time allotted for project activities and the programs' overall length, students—with very few exceptions—gave ratings of 4 to 5 out of a 5 point scale. Several commented on the passion and accessibility of the project's leaders, while others commented positively on having access to NASA's knowledgeable engineers during the review cycles.

Opportunities to Learn from Adult Experts and Other Students

The SLI/USLI programs provide students with opportunities to learn from each other as well as learn over time as they participate from one year to the next. One such opportunity is the Rocket Fair, one of the most prized events of launch week:

> *The rocket fair is the coolest part of the whole thing. Make it easier for everybody to see everybody else's project. Maybe make it a little longer.*

Another opportunity, as one reviewer noted, was the "increased complexity of the projects. Students have the opportunity to look at previous years' projects and expand or improve on them."

Mentors and NAR volunteers were also clear that the diversity of the rockets and of the payloads was a strength of SLI/USLI that promised students new challenges each year of their participation, and also set it apart from other rocketry programs. Additionally, they noted that—not just the inclusion of the NASA review process—but its rigor and the seriousness with which it was taken by the staff and the reviewers made this an authentic and powerful experience for students. Students commented that the reviewers were thorough, and appeared to "have read every word of our report." One student went on to say the following:

> *Promoting engineering – they did a superb job. NASA's knowledge about this process allows them to ask the students the hard questions – the "interrogation" structure was very good.*

Value of the Hands-on Experience and Emphasis on Safety

An aspect of the SLI/USLI experiences that students and their mentors felt was critically important was the opportunity "to get their hands on materials" and actually build rockets. Mentors and students both acknowledged that, without the USLI competition, they could easily have progressed through their college careers without ever having gone beyond a theoretical understanding of the concepts necessary to build and launch a rocket with a successful payload.

> *You get to learn about the process, you learn quickly that nothing ever works the first time around. The hands-on experience is incredibly important. Book knowledge will only get you so far, you need to get your hands dirty.*

> *I've taken aerospace classes for a long time, but never got my hands dirty. What I did was always very theoretical. Putting theory into action was totally the motivator – finally to put my hands on a rocket.*

Several mentors commented that this was a particularly important experience for some of the girls, for whom this was their first experience working with tools; while others found this to be true for many of the boys on their teams, as well. Related to the value of the hands-on experience is the emphasis on safety that came through to students consistently from the beginning of their SLI/USLI activities to the final reviews and launches. Students recognized that becoming conversant in the safety requirements and language was another area of expertise that they would benefit from mastering, and the ongoing emphasis on safety, expressed by project leaders, their mentors, and the NAR safety officers sent a message that was unquestionably clear, understood, and well-received.

Challenges Facing SLI/USLI Programs

Programs' Size, Capacity, and Growth

The most pressing challenge facing the program, acknowledged by its leaders and the NAR volunteers, is that it has reached capacity. The fifty teams participating this year pushed the programs' human and financial resources to the limit. As the level of participation has grown over the last several years, project leaders had to focus increasingly on immediate management and operational issues, and were less able to think as visionaries about expansion and other matters related to program growth and quality. However, with the recent addition of new project staff, program leadership now has more time to think creatively about the future, work on expansion, and conceive of better ways to serve the needs of students and their mentors.

As the projects enter a new stage of expansion, with the great likelihood of operating from multiple NASA Centers, they face the new challenge of maintaining a high level of program quality and safety in a different context. Some of the risks associated with such a shift include, for example, the need to recruit additional program organizers with a unified vision of the program, more team mentors with the necessary expertise and interest to be effective, as well as greater numbers of NAR volunteers to staff additional launch days, across multiple sites. Another risk is in diluting the experience for teams who, for example, may have long-standing relationships and rivalries with other teams. These relationships have added a level of excitement to launch week, and now may be split up by teams participating at different sites.

Tracking Programs' Impacts over Time

Another challenge discussed by program leaders is the difficulty of tracking students' future education and career experiences following their participation in SLI/USLI. Leaders recognized the singular importance of these data as evidence of long-term program effectiveness, but it remains beyond their reach for a variety of reasons. While funding and outreach capacity to track these data are an issue, more fundamental constraints are the ones placed on the program by the Paperwork Reduction Act and the Privacy Act. These two acts do not allow programs that serve students in grades K - 16 to track their progress once they exit the program, and so creating a process to gather these outcome data systematically is beyond the scope of SLI/USLI. Were that not the case, to really understand the trajectories of the students participating in SLI/USLI, the programs would need to develop a mechanism by which they maintain contact with students from year to year. And although collecting this information might not particularly difficult or expensive, it would require staffing to take on this role (both in terms of follow-up for non-responders and appropriate analysis), a data collection system for tracking, and a commitment from participants to report annually on their whereabouts and endeavors, all of which would have budgetary impacts for SLI/USLI. As it is, project leaders keep in touch with many past participants informally, and have positive and powerful anecdotal evidence of the programs' impacts on students' interest in education and careers in the aerospace industry in general, and NASA in particular.

Availability of Reviewers

A final challenge for SLI/USLI is in meeting the continuing need for reviewers. These individuals are primarily interested NASA engineers, who are willing and able to take time out from their workday to participate in the review process. Currently, the individuals involved in the reviews voluntarily take on the responsibility, they do not receive "charge time" for their work associated with SLI/USLI and continue to do so because they recognize the importance of contributing their experience and expertise to the process. They may not necessarily be experts in a particular field, but they are well able to provide constructive, relevant feedback and identify safety issues that must be addressed. The number of individuals who are able to make this level of contribution tends to be limited and affects the workload for all involved (the fewer the number of reviewers, the larger the time commitment to all involved). As the programs embark upon an expansion to a second site, recruiting a sufficient number of new reviewers may not be easy for the program leaders. Although program organizers have indicated they would like to have funding to provide charge time to reviewers, this is another expense that would take away from students' experiences.

Challenges of Participating in SLI/USLI

National Association of Rocketry (NAR) Volunteers

NAR and Tripoli mentors work with SLI/USLI teams throughout the year, playing an important part in the SLI/USLI experience and providing critical support during the launch Week. NASA competitively bids safety services for the launch week and for the past two years, NAR has been awarded the NASA contract. Any budget constraints by entities awarded the SLI/USLI launch week services are directly related to the bid submitted to win the NASA contract. This year, the NAR budget only paid for partial support for volunteers' involvement in Launch Week, and the volunteers themselves covered the remaining cost. As a result, many volunteers reported it was necessary for them to donate some of their time that couldn't be covered by the contract.

Similarly, the limitations to the time they can invest prior to and during launch week may explain some of the inconsistencies in their reviews and recommendations that were mentioned by students and mentors. For example, several occasions arose during the final flight hardware and safety check where one team was given a very general review, compared to another team who received a far more detailed and exacting review and set of recommendations. Focus group discussions suggest that minimal training and orientation are provided for NAR reviewers, and so although all reviewers follow shared safety guidelines (a safety "punch list"), some may choose to pursue additional levels of scrutiny whereas others may not.

Team and Institutional Capacity

Because SLI/USLI are national programs, teams from across the country and from a range of schools and institutions participate. The variation is considerable, from 4H clubs to science magnet schools to technical colleges to ivy-league universities. Variation can be seen in the greater levels of academic and financial support that teams receive when their project has been incorporated into a specific course, compared to teams that are working independently as a club or after-school activity. One mentor noted that his team's participation in USLI accounted for 50% of students' course grade, compared to another school where it is an extra-curricular activity, and another where USLI participation is a requirement of graduation. Because each team receives a set amount of money to support their participation regardless of the size of the team or the assets available, some face significantly greater challenges to taking part than others.

These challenges extend to problems with fund disbursement and the need to raise supplementary funds. As reported by students at many institutions of higher education, navigating the bureaucratic labyrinths of their accounting departments to obtain the moneys allocated by NASA could be an extremely difficult process. Team leaders and members recounted frustrating accounting roadblocks that made it impossible to obtain funds to buy materials necessary to meet program deadlines. In many cases, the financial obstacles required out-of-pocket payments for necessary equipment. As a result, many students reported using their own money, on occasion upwards of $500 - $1,000, because of their schools' inability to process reimbursement checks in a timely fashion. Similarly, the need to raise additional funds to cover program costs was a common theme. According to one mentor, "Our travel alone, just the airline tickets, exceeds the total budget that NASA provides for us." Additionally, middle and high schools that sponsor teams may face the burden of covering the cost of teachers' time, and their substitutes' time while the teacher is away for launch week. Transportation and access to tools, workspace, and a local launch site were all requirements that some teams met far more easily than others. Finally, some institutions were able to support their students' activities while the bureaucratic processes of others made such things as purchasing materials and equipment take longer and cost more than necessary. In many cases, team members paid for expenses out-of-pocket because the funds they received were not sufficient to cover costs. As the programs expand and more schools participate, these issues will multiply as well, perhaps placing a greater burden on program staff as they assist in responding to questions and solving problems.

USLI Teams' Access to Experts

A different type of challenge that many USLI teams experience was their unwillingness to seek out experts in rocketry or their lack of access to them. While the program leaders encourage all teams to seek a mentor who is not affiliated with their project, i.e., an outside expert, many teams can and did choose to work without the help of an experienced professor or expert, and simply met the USLI requirement of having at least one team member who has been Level 2 certified—in many cases the Level 2 certified team member had little or no rocketry experience beyond the certification process. Many mentors reported university students' over-confidence and naïve notions about the complexity of the tasks they were undertaking. Three mentors reported their teams originally estimated the entire task could be completed in hours; another team seemed to feel they could do all the work "without much effort." One mentor recalled, "They don't often want my advice. You can see it in their eyes." In comparison, an SLI mentor observed, "SLI teams are better organized because the students have to have hands-on mentors. As we went through the process, they were more receptive to my input because they saw the value of my advice." USLI students' lack of willingness to seek the advice of experts typically led to poor design decisions and wasted time and materials.

A second reason the USLI teams lacked access to experts was less often due to a shortage of willing advisors, and more often due to their advisors' lack of the needed specialized knowledge. Both mentors and NAR volunteers pointed out that these multi-disciplinary projects call for content knowledge and expertise in a wide range of disciplines, in addition to an understanding of NASA's design process and expectations for reports and presentations. Many mentors, although very knowledgeable in many areas, sometimes lacked specialized knowledge on a topic of particular importance for their team's project. These mentors made their need for additional support or guidance from NASA very clear, so that they could be better prepared to support their teams. They also pointed out the need for ways to network with each other, so that they could more easily and efficiently identify the expertise their teams needed at any given time.

Despite the challenges described by program organizers, partners and participants, the data tell a compelling story about the consistently high quality of the SLI/USLI experience for students, and the positive impact it has on their continued interest in education and careers in engineering, the aerospace industry, and in NASA. The SLI/USLI program is unique in that it offers students an authentic opportunity to design and build a rocket and payload, guided by NASA engineers, following NASA's design process. The multi-disciplinary aspect of the project provides opportunities for students with a variety of interests and experience to make meaningful contributions, and in the process, gain exposure to NASA's culture, the opportunities for work and learning that it offers, and develop knowledge, experience, and work skills that will benefit them regardless of what future directions they take. The programs' leadership is passionate about its mission, and has implemented an extremely complex program in a very well-organized manner. Moving forward, the challenges that face the SLI/USLI program are primarily those associated with growth and expansion and the difficulties it will pose for program leaders in their determination to maintain the quality participants have come to expect.

Chapter 4. Conclusions and Recommendations

The goal of the Student Launch Projects is to provide middle school, high school, and college students with valuable hands-on systems engineering and research experience while inspiring them to continue a STEM education and to pursue STEM careers. These programs, which have been growing and evolving for a decade, are providing students a venue to continue exploring and expanding their interests, knowledge and skills in rocketry and areas of STEM and are intended to further solidify future education and career decisions. In addition to the specific STEM content knowledge program participants gain through the SLI/USLI programs, students also have the opportunity to develop and refine more general, though no less critical, skills such as management, leadership, and communication. These secondary skills also serve to benefit students in any variety of future endeavors, career or otherwise.

One goal of the SLI/USLI program evaluation was to obtain feedback from stakeholders about how the program is currently performing and to solicit suggestions and ideas for future change. Below we briefly outline suggestions from the stakeholders with whom we talked.

Participant Feedback

Students, mentors, and NAR volunteers made suggestions for program improvements. In general, the suggestions fell into three broad categories: program support and guidance, general program information, and program timing and location. Suggestions that were made by one to two people have not been included in this report; only those suggestions that were made by multiple people and seemed to represent a trend are included below. In some cases, individuals making suggestions were unaware that the issue had already been addressed by the programs, either in the program materials or handbook, during the Advanced Rocketry Workshop, or as a matter of course in other communications. Those cases are noted below.

Program-Related Support and Guidance

1. Increase access to or make available greater numbers of NASA staff to provide support and answer questions. Some participants felt the program was "maxed out", making it difficult at times to access necessary supports.

2. Participants were unaware that SLI/USLI provides information about other teams, and there were several suggestions regarding the creation of a library of prior rockets and payloads, and other relevant web reference materials that students could find on their own and use as a reference guide. This information was made available to those teams that attended the Advanced Rocketry Workshop.

3. Provide teams with a gradually more competitive experience as they mature. Some teams suggested that NASA level the playing field for newer teams, and allow more rigorous competitions for more experienced teams. In anticipation of this suggestion, USLI provided a higher level challenge this year for teams that were consistently high performers. A higher altitude and water recovery were required for teams invited to compete at Wallops Flight Facility.

General Program Information

1. Although the programs are full to capacity, several suggestions were made to increase publicity such as including it in the NAR section lists, and in the Tripoli Prefecture list.

2. Provide additional information and resources for future careers. Many students come to launch week with their careers and future employment in mind, and two suggestions were made for adjusting launch week events in order to address career interests. One was to include a job fair associated with the Rocket Fair for university students to get a leg-up on job hunting. The second was to provide more detailed information about the day-to-day jobs at NASA during the launch week facility tours.

Timing and Location

1. Schedule reviews and launch at times that are more convenient for participants. Unfortunately, there were many and conflicting suggestions regarding the review schedule, some suggesting expanding it overall, others satisfied as it was, and several others suggesting holding launch week in May to provide additional time to work on the rockets after the flight readiness review. There were always conflicts with some schools' schedules and vacations, regardless of what suggestions were made for modifying the schedule.

2. Provide opportunities for west coast teams to have a program facility closer to them. Some of the west coast participants spoke to the time and cost of traveling to Alabama for the launch and requested NASA consider a secondary site closer to their home institutions.

Recommendations

Ongoing program growth and success is forcing program leaders to assess various pathways for program expansion. In order to make informed, data-driven decisions about program changes, NASA leaders have elicited feedback from program stakeholders through this program evaluation. The SLI/USLI program evaluation has generated several recommendations based on extensive interviews and focus groups, informal conversations and review of extant data. The emerging recommendations, relevant to ensuring the continued high quality of the SLI/USLI experience for students and their mentors, are discussed below.

1) One of the central components of the SLI/USLI program is the engineering design process that students follow, requiring a series of project presentations by participants and reviews by NASA scientists and engineers. Throughout the evaluation data collection, one of the clear themes discussed by both participants and educators was their appreciation for and understanding of the value of the program's design process. With the increasing numbers of participants, staffing the reviews, a labor-intensive undertaking, is becoming progressively more difficult. Performing the job of a reviewer requires an investment of time taken away from one's work schedule. Increasing the number of reviewers is a concern relevant to future program expansion, as well as to requests for increased feedback to SLI teams (see item 5 below). Providing resources for reviewers to assist in covering their time, such as a specific charge code available for this purpose, would reduce the strain and allow for more reviewers to participate and contribute more hours.

2) Another strain facing program staff involves providing participants with advice and expertise required to succeed. A wide range of knowledge is needed to mentor SLI/USLI teams, often more than one individual can realistically provide. With more teams, especially new and inexperienced teams, more time and more expertise will be necessary to provide requisite guidance. A well-maintained database of interested experts who are available for consultation would help ensure that teams receive the advice they need in a timely fashion and would relieve mentors of the burden of seeking and soliciting specialized help each year.

3) NAR reviewers shoulder a significant responsibility for the safety and success of launch day, the culminating SLI/USLI experience. There were at least two resources-related challenges for NAR that emerged.

   a. NAR reviewers addressed safety issues, however, their level of scrutiny varied significantly. An orientation and training session provided by NAR leadership to prepare new NAR volunteers for the SLI/USLI review process during launch week would ensure that all volunteers are operating under the same assumptions and expectations, and reduce variation in the level of scrutiny that teams experience prior to launch.

   b. NAR reviewers are volunteers who used their own resources to cover the cost of travel and time away from work necessary to oversee safety during launch day. Because safety responsibility on launch day is a competitive bid, it is unclear that anything can be done to provide additional funding to the volunteers, short of increasing the price in the bid. Increasing the financial support to safety officers would eliminate, or at least diminish, the problem of out-of-pocket expenses, but could potentially jeopardize the competitiveness of the bid.

4) Increased guidance for mentors and students related to NASA's rules, regulations, and expectations - specifically those surrounding the required report-writing and presentations.

   a. Report writing and presentations are significant components of the SLI/USLI experience for students and their mentors. Guidelines that provide clear and explicit instructions regarding the content and expectations for the level of specificity would help all teams, and particularly those who are new to the process.

   b. Although all teams—SLI and USLI teams—are required to have at least one member or mentor who is level 2 certified, and the Statement of Work all teams receive stresses that teams must seek an outside expert/mentor from NAR or Tripoli as a team member who is level 2 or 3 certified, USLI teams often choose to have one of their own team members serve that expert/mentor function. Those USLI teams that do choose to have outside experts as mentors control the degree and quality of program-related information they pass on. Information is generally passed from NASA program organizers to the teams and the USLI mentors must rely on their teams for information. Program leaders may consider additional steps that could be taken to ensure that mentors are included in their teams' communications and are aware of their teams' progress. For example, orientation and training materials prepared by program leaders specifically for USLI mentors would provide them with an overview of the USLI program, its mission, their roles and responsibilities, and the particulars of the activities and safety regulations. Mentors are most interested in information on the review phases and on the specific requirements for preparing each report.

5) SLI and USLI mentors and students would benefit from additional guidance regarding report reviews. Of particular interest was additional clarification, in addition to the scoring rubrics, regarding what the reviewers look for and how quality is estimated; or what a team should have done differently to obtain a higher rating. Providing exemplars may be one way to elaborate on the scoring rubrics. Unlike the USLI program which is a competition necessitating that reviewers provide teams with scoring and written feedback, the SLI program is not a competition and the teams do not receive the same kind of extensive oral and written feedback. And although all teams are provided with a summary of suggestions after each review, the SLI teams would benefit from a greater degree of feedback on their reports and presentations. It should be noted, however, that providing feedback to the SLI teams that is in keeping with what is provided to USLI teams would increase the burden for reviewers. This potential for additional burden further underscores the need to provide reviewers with enough "coverage" (either charge time or a greater number of reviewers) to complete their increased workload.

6) New teams with inexperienced students face a steep learning curve; teams with even one veteran student are greatly advantaged from what they have learned in prior years. With the understanding that not all new or interested returning team members will attend the Advanced Rocketry Workshop, where they are given the information needed to prepare for their SLI/USLI experience, it may be helpful to find other avenues to make such information available. For example, adding information that elaborates on the issues experienced teams have encountered over time to the existing handbook would be helpful. Similarly, a mini-workshop over the summer to help orient new teams and provide them with the necessary information would better prepare them for the work ahead. It might be useful to solicit suggestions from teams about the difficulties they faced in their first year, to cover the host of more easily-addressed questions that require large amounts of time and energy due to lack of experience.

7) Managing finances and acquiring additional funding was problematic for many teams. Providing expertise as a resource to teams, perhaps in the form of a financial mentor, could alleviate considerable strain and achieve efficiencies for teams that would likely return savings in real costs as well as time.

8) The educational engagement component of the SLI/USLI programs was not as prominent in students' or mentors' discussions of their program experience. It appeared that several teams were under the mistaken impression that the number of students they engaged in outreach efforts was more important than the quality of their experiences. Since both quantity and quality are considered important factors in the outreach component of the program, it would be important to ensure that this was understood by the teams.

In sum, participants, educators, mentors, partners, and parents place high value on the SLI/USLI programs. With little exception, positive endorsements of the program far outweighed what little criticism we encountered. The suggestions for future modification have more to do with the need for expansion to meet increased student interest than with any significant problems associated with the structure or implementation of the program. Program participants, past and present, consistently spoke to the importance of the SLI/USLI programs in affording real-world, hands-on engineering experiences to students and participants systematically and vociferously lauded the efforts of the program staff.

The data collected for this evaluation tell a compelling story about the high quality of the SLI/USLI experience for students, and the positive effects it has had on their continued interest in education and careers in engineering, the aerospace industry, and in NASA. The SLI/USLI programs are unique in that they offer students an authentic opportunity to design and build a rocket and payload, guided by NASA engineers, and following NASA's design process. The multi-disciplinary aspect of the projects provide opportunities for students with a variety of interests and experience to make meaningful contributions, and in the process gain exposure to NASA's culture, the opportunities for work and learning that it offers, and develop knowledge, experience, and work skills that have the potential to benefit them regardless of what future directions they take. The evaluation team observed a program whose leadership is passionate about its mission, and has implemented an extremely complex program in a very well-organized manner.

References

Abraham, L. M. (2002). What do high school science students gain from field-based research apprenticeship programs? *The Clearing House*, 75(5), 229-232.

Barak, M., & Zadok, Y. (2009). Robotics projects and learning concepts in science, technology, and problem solving. *International Journal of Technology & Design Education*, 19, 289-307.

Bauer, K., & Bennett, J. (2003). Alumni perceptions used to assess undergraduate research experience. *The Journal of Higher Education*, 74(2), 210 – 230.

Blumenfeld, P., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist*, 26(3&4), 369-398.

Carter, F. D., Mandell, M., & Maton, K. I. (2009). The influence of on-Campus, academic year undergraduate research on STEM Ph.D. outcomes: Evidence from the Meyerhoff scholarship program. *Educational Evaluation and Policy Analysis*, 31(4), 441-462.

Education Week. (2011). *Education Week: A Special Report on Informal Science Education. A Supplement to the April 6, 2011*, Issue, Vol. 30 No. 27.

Foertsch, J., Alexander, B. B., & Penberthy, D. (1996). Summer Research Opportunity Programs (SROPs) for minority undergraduates: A longitudinal study of program outcomes, 1986 – 1996. Madison, WI: University of Wisconsin-Madison, LEAD Center.

Hmelo, C. E., Holton, D. L., & Kolodner, J. L. (2000). Designing to learn about complex systems. *Journal of the Learning Sciences*, 9(3), 247–298.

Lopatto, D. (2004). Survey of undergraduate research experiences (SURE): First findings. *Cell Biology Education*, 3, 270 - 277.

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. *Cell Biology Education*, 6, 297- 306.

Nagda, B.A., Gregerman, S.R., Jonides, J., von Hippel, W., & Lerner, J.S. (1998). Undergraduate student-faculty partnerships affect student retention. *The Review of Higher Education*, 22, 55-72.

Pascarella, T. E., Wolniak, C. G., Pierson, T. C. & Flowers, A. L. (2004). The role of race in the development of plans for a graduate degree. *The Review of Higher Education*, 27(3), 299 – 320.

Pender, M., Marcotte, D. E., Sto. Domingo, M. R. & Maton, K. I. (2010). The STEM Pipeline: The Role of Summer Research Experience in Minority Students' Ph.D. Aspirations. *Educational Policy Analysis Archives*, 18 (30). Retrieved May 12, 2011, from http://epaa.asu.edu/ojs/article/view/741

Roberts, L. F., & Wassersug, R. J. (2009). Does doing scientific research in high school correlate with students staying in science? A half-century retrospective study. *Research in Science Education*, 39, 251-256.

Russell, H. S., Hancock, P. M. & McCullough, J. (2007). The Pipeline: Benefits of undergraduate research experiences. Science, 316.

Sax, J. L. (2000). Undergraduate science majors: Gender differences in who goes to graduate school. *The Review of Higher Education*, 24(2), 153 – 172.

Seymour, E., Hunter, A., Laursen, L.S., & Deantoni, T. (2004). Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study. *Wiley Periodicals, Inc., Science Education*, 88, 493 – 534.

Sharp, L., Carey, N., Frechtling, J.A., & Burgdorf, K. (1994). *Short-term impact study of the National Science Foundation's Young Scholars program*. Rockville, MD: Westat, Inc.

Weinberg, J.B., Pettibone, J.C., Thomas, S., Stephen, M.L., & Stein, C. (2007*). The impact of robot projects on girls' attitudes toward science and engineering.* Paper presented at the Workshop on Research in Robots for Education. June 30, 2007. Georgia Institute of Technology. Atlanta, GA.

Zydney, A., Bennett, J., Shahid, A., & Bauer, K. (2002). Impact of undergraduate research experience in engineering, *Journal of Engineering Education*, 91(2), 151 - 157.