***Final Report***

***of the***

# *NASA Program Definition Team*

***for***

# *Student Collaborations (SC)*

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# CONTENTS

## 1.0 RATIONALE

### *1.1 Importance of Student Collaborations to NASA workforce development*

Student Collaborations are compelling vehicles to attract, retain and move students through the higher education pipeline into graduate studies and the scientific and engineering workforce. Student Collaborations represent a wide variety of hands-on student programs, which complement the formal education curriculum through practical training and experiences. Whether focused on engineering, science or missions operations, Student Collaborations involve undergraduate students in an authentic research environment that increases their interest in scientific and technical careers and enthusiasm for space exploration, while equipping them with first-class engineering and science skills.

***NASA is charged by the Administration to support the development of space professionals, seen as vital to the future of U.S. space capabilities[1].*** By exposing undergraduates to the dual thrill and technical challenge of space exploration at the very time many of them are making life-long career choices, NASA and the supporting aerospace industry stand to capture the most inquisitive, brightest students into NASA-related careers. Through meaningful, hands-on, multi-year participation in NASA's quests the brightest individual students see, first hand, the intellectual challenges inherent in the NASA mission. As a result they are attracted to pursue related careers.

Student Collaborations represent an excellent value to NASA and allow NASA to harness the resources and assets of universities around the country to support the space industry's workforce pipeline. The final report by the NRC Committee on Meeting the Workforce Needs for the National Vision for Space Exploration (NRC, 2007) suggests that while NASA has an adequate pipeline to meet its current workforce requirement, NASA needs to play a role in training the potential workforce in the skills that are unique to the work that the agency conducts. The report suggests that hands-on experiences for students that focus on the unique demands of satellite and spacecraft systems, environments, and operations, and the opportunity to acquire early knowledge of systems engineering techniques is an extremely important investment for NASA to make. In specific, the committee recommended that NASA support university programs that provide hands-on training, and identified suborbital programs as one key to this development.

Students involved in Student Collaborations often describe their experiences as 'life-altering', with many of them continuing forward towards careers in science and engineering. Students see these programs as meaningful, particularly in terms of knowledge or skills gained. There is a sense among students that they are a part of something important – a sense of belonging to a team where their participation matters. There is also the sense that Student Collaborations are 'real-world' experiences that will transfer to the future work environment. Finally, one cannot disregard the importance of romance and history. Many students view these programs as *the* brass ring of science and engineering education.

Lastly, the role of innovation and discovery in Student Collaborations cannot be underestimated. Student Collaborations allow students and their professional mentors to

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[1] As part of the U.S. National Space Policy.

'think outside the box', providing an environment that nurtures innovation and alternative approaches for achieving success. As a result, Student Collaborations allow organizations to develop in-house expertise in technological areas that they haven't worked in previously, building credibility that can be used for later programs. Carefully crafted, Student Collaborations can be used to develop heritage for new instruments or technologies.

### *1.2 Role of Universities within the NASA framework*

Since its inception fifty years ago, NASA has developed long-standing partnerships with the nation's universities, using them as idea incubators, the seats of innovations, as well as relying on them for its technical workforce. With the growth of the NASA centers as the sites for NASA science and engineering, the role of universities has diminished over the years. Yet they are still in the position of educating and training the majority of the NASA workforce. Higher education, particularly at the undergraduate level, is a critical juncture at which to entrain STEM workers. As elucidated in the report "Rising Above the Gathering Storm" (NRC, 2006), failure to capitalize on this moment will have serious consequences for America's standing as a leader in science and technology. Engineering and science programs at the university level have recognized the value of integrated, hands-on educational opportunities. New and exciting work on project-based learning, team problem-solving programs, and the influx of entrepreneurial ideas has been shown to attract and retain students from across the science and engineering spectrum (Froyd and Ohland, 2005; Dym, et al., 2005, Eris and Leifer, 2003). The advent of these programs offers an important 'fertile ground' within which NASA can operate, taking advantage of work that has already begun. In addition, opportunities afforded science and engineering through the American Competitiveness Initiative may create a 'perfect storm' of opportunities.

Student Collaborations continue to offer a way for universities to maintain their vitality in supporting the space industry workforce pipeline, offering hands-on training for engineers and scientists who will shortly be joining the workforce. These are not simply endeavors that focus on design processes and procedures. Rather they are designed to engage students from a variety of science and engineering backgrounds in a problem-solving environment where the science objectives are the target and the iterative process of design, test and build in a team environment lead to a high-level understanding of systems engineering processes in a 'real world' setting.

It is important to note that, beyond universities, other institutions can play an important leadership role in Student Collaborations. Many museums, planetaria and science centers have the scientific personnel, as well as the infrastructural capacity, to lead Student Collaboration efforts.

## 2.0 OBJECTIVES FOR STUDENT COLLABORATIONS

### *2.1 Definition of Student Collaborations*

The definition of a Student Collaboration is necessarily broad and flexible to encompass the large range of possibilities these programs entails. Whether one is speaking of engineering, science or mission operations programs – or suborbital, satellite, or data collaboratives, there is an emphasis on high-quality projects that involve students in multiple segments of the mission from scientific formulation, to mission planning, to systems engineering, to design and development of flight hardware, to qualification, test and integration, mission operations, to ground truthing and data analysis. In general, a well-rounded Student Collaboration project should provide each student with experience in/exposure to a) systems design and development, b) technical skills, c) data collection and analysis techniques, and d) documentation, reporting and reviews.

The target audience for Student Collaborations is generally focused at the collegiate level, but broader participation is possible as demonstrated on past efforts. Student Collaborations require individuals possessing both a level of maturity accompanied by capability enabled through education. Both characteristics are resident in undergraduates and graduates, and are occasionally seen at the high school level. Undergraduates are targeted for Student Collaborations because it is at this critical junction of their education that they are making decisions about where and whether to join the STEM workforce.

The university environment is ideal for a Student Collaboration. Experience has shown the importance of teaming as a contributor to success in Student Collaborations. Currently evolving practices and teaching approaches in academia are further reinforcing the importance of the teaming, enabling the students to bridge between the academic and project experience. Student Collaborations are distinguished from traditional undergraduate assistantships or internships on the basis on the level of expected teamwork and collaboration that allows the group to achieve its goals, as well as the role in project management that students play. ***Student Collaborations are primarily collaborative educational experiences, rather than driven by cutting-edge science and technical requirements.***

## 3.0 PROGRAM DEFINITION TEAM RECOMMENDATIONS FOR NASA

### 3.1. Student Collaborations should be encouraged throughout NASA SMD.

3.1.1. *Opportunities for Student Collaborations should be included in SMD missions, as components of suborbital programs, as stand alone ROSES opportunities, and as part of instrument development programs, like the PIDDP program.*

3.1.2. *Student Collaborations should be focused at the undergraduate level, with allowances to enable flow down to high school efforts and/or up to graduate students.*

3.1.3. *Student Collaborations should not be mandatory components for any SMD PI-led primary science mission opportunity, as some projects do not lend themselves well to student involvement and the decision to do so should be left to the PI.*

### 3.2. PIs proposing Student Collaborations should be given wide latitude in defining the program, whose elements may include science, engineering and mission operation components, with an emphasis on the education impact of the effort.

3.2.1. *While many kinds of programs should fit into the definition of a Student Collaboration, hardware programs represent a critical experience not* *easily replicated in other science-based programs. Student Collaboration language in AOs for SMD programs should give priority to programs involving students in the design of valid experiments or the design and development of flight systems that encompass the full NASA mission cycle (Phase A/B/C/D/E).*

*3.2.2. Student Collaborations involving for-flight space hardware on PI-led primary missions should be treated as other professionally built instruments, subject to review and descope. PIs should have the same control and inputs over Student Collaborations as they do over any other aspect of the mission.*

*3.2.3. Student Collaborations should additionally be sought as independent stand-alone investigations outside of NASA's mission Announcements of Opportunity. Existing NRA vehicles such as the Low Cost Access to Space Program, the SALMON program, or the annual ROSES solicitation might include separate solicited program elements as Stand-ALone Student Activities (SALSA).*

*3.2.4. Review procedures for Student Collaborations should weigh their educational/training value and need not necessarily be as technically rigorous as for other instruments on a given mission, depending on the spacecraft configuration and the flexibility of the PI to accept failure of a student instrument.*

*3.2.5. A range of projects, varying in scope and size, should be supported within the environment of Student Collaborations – recognizing the broad range of expertise and capabilities within the community.*

**3.3. Mission programs should be structured so as to encourage the inclusion of a Student Collaboration.**

*3.3.1. Student Collaborations should not be counted against the cost cap of Mission programs. Rather, Student Collaborations should be an* ***additional*** *set of resources awarded to a program by SMD.*

*3.3.2. Student Collaboration resources, as an addition to a Mission's program, should not be available to solve Mission cost overrun issues.*

**3.4. Mentoring is an essential component to a Student Collaboration project and professional scientists and engineering need to be supported in this role.**

*3.4.1. Successful student programs have a wide range of mentoring models. Mentors need not be professionals, but the mentoring structure needs to be well matched to the project complexity and expectations.*

*3.4.2. In situations where expectations for performance and success of Student Collaborations are similar to a professionally staffed NASA program, the foundation for success of the program is set by the organizational structure, both in terms of the management team composition and in terms of how the engineering workforce is incorporated into the program.*

*3.4.3. Student Collaborations should not be viewed as an opportunity for cost-savings on a NASA mission. Rather it should be the expectation* *that a Student Collaboration will fully compensate professionals involved in the program.*

**3.5. Evaluation of Student Collaborations should include the quality of the project and its potential for student training.**

*3.5.1. The evaluation of Student Collaborations should be conducted by a review panel that can assess the scientific and technical aspects of a program, as well as its educational efficacy. In the case of mission-related Student Collaborations, SMD should convene a separate review panel that includes Science and TMCO reviewers, as well as educational professionals.*

*3.5.2. While many kinds of programs should fit into the definition of a Student Collaboration, hardware programs represent a critical experience not easily replicated in other science-based programs. Student Collaboration language in AOs for SMD programs should give priority to programs involving students in the design of valid experiments or the design and development of flight systems.*

**3.6. Access to space remains one of the most critical elements for sustaining Student Collaboration instrument programs. NASA can play a critical role in facilitating opportunities for Student Collaborations, both within and outside the agency.**

*3.6.1. NASA should invest in standardized, robust accommodations on existing US launchers, aircraft, high altitude balloon platforms and sounding rockets.*

*3.6.2. NASA should include accommodations for SC payloads on new and existing NASA-procured launch vehicles and possibly spacecraft.*

*3.6.3. NASA should encourage U.S. launch vehicle suppliers to add standardized provisions for university-based educational payloads to their vehicles.*

*3.6.4. NASA should make surplus and prototype NASA flight hardware available to Student Collaboration projects, and establish policies that encourage non-NASA entities to do the same.*

**3.7. NASA has a key role to play in sustaining a healthy Student Collaboration community, ensuring that students from a wide rage of institutions have the opportunity to participate.**

*3.7.1. NASA SMD should support clearinghouses, community workshops, and other opportunities for the dissemination of information, opportunities, lessons learned, and so on.*

*3.7.2. NASA SMD should invest in the development of a standard set of evaluation tools that will allow the impact of Student Collaborations to be demonstrated.*

*3.7.3. Student Collaboration programs should particularly involve a wide variety of minority serving institutions to ensure that a diverse community of students experience these programs.*

*3.7.4. NASA SMD should establish connections to the broader Student Collaboration community, including the nation-wide Space Grant Consortia, NSF, commercial partners, university groups, etc.*

## 4.0 DISCUSSION

### *4.1 Student Collaborations as a Primarily Educational Experience*

Student Collaborations are an important educational experience for undergraduates. Whether focused on for-flight hardware, science collaboratives or mission operations, these programs represent a unique opportunity to students gain real-world experience that will prepare them for the workforce as scientists, engineers, systems engineers, or program managers. A key ingredient of SCs that distinguishes them from the normal academic experience is that individual students learn the necessity of participating as members of an interdisciplinary team to achieve success in the development of a complex system. Many Student Collaborations fall into the category of Project-Based Learning (PBL). While PBL is often focused on hands-on activities and lends itself well to engineering programs, its primary strength is talking about how to develop and maintain cohesive and functional educational groups. There is a large body of literature on PBL and other kinds of undergraduate learning that is available to inform how to develop Student Collaboration (Dym et al., 2005).

### *4.2 Incentivizing PIs for Student Collaborations*

Recent experiences with the SMEX AO suggest that while PIs want to include Student Collaborations in the mission proposals, as the primary programs approach the cost cap, Student Collaborations compete with Phase E science dollars for dwindling resources. When faced with a choice, PIs feel the need to protect the science budget.

Simple restructuring of the Mission program at the SMD level would provide the necessary incentives to encourage PIs to include Student Collaborations. Resources for Student Collaborations should not be included in the cost cap for a Mission but rather should be added on to the top of the cost of the Mission. In this way, a successful Student Collaboration brings additional resources to the PI and the mission. As an addition to the mission budget, the Student Collaboration should not be available for PIs to solve cost overrun problems.

### *4.3 Mentoring Models*

When looking at Student Collaboration programs, the issue of mentoring models – who mentors and under what circumstances, as well as how and when professionals are involved – clearly emerged as the overriding factor contributing to success. Successful Student Collaborations, whether instrument programs or science projects, have a wide range of mentoring or training models in place.

Some generalizations about mentoring in these widely differing programs can be drawn:

1. Mentors need not be professionals. While professional scientists and engineers provide exemplary role models, mentors can also range from experienced undergraduates to graduate students and postdocs.

2. Mentoring doesn't need to be one-on-one, though sufficient time needs to be dedicated on the part of the mentor to insure the program's educational success.
3. Compensating mentors for their efforts, even minimally, insures that they have sufficient time to keep the SC a priority.
4. Mentors work to strike a balance between guiding the students down a successful path and giving the students enough independence to allow the students to take ownership.
5. Student Collaboration programs can be a way for mentors to extend their own knowledge base and expertise in ways that enhance their own professional development.

For Student Collaborations that involve NASA missions, where there is increased cost, increased risk and increased oversight by NASA, the institutional approach to Student Collaborations become critical. In these situations where expectations for performance and success are similar to a professionally staffed NASA program, the foundation for success of the program is set by the organizational structure, both in terms of the management team composition and in terms of how the engineering workforce is incorporated into the program. Adequate funding for a professional support team (e.g., mentors) is vital. For New Horizon's Student Dust Counter, professional engineers and scientists ***volunteered*** their time to mentor students. The result was that 1) these professionals were draining resources from other programs to cover their Student Collaboration time, and 2) they couldn't move the Student Collaboration high on their priority list because they weren't getting paid to do it. Student programs are often incorrectly seen as a low-cost alternative to a professional program. Where student instruments are being held to the same professional standards as other for-flight instruments, inefficiencies in performance standards offset the lower labor cost. Rather than saving money, the Student Collaboration component of the instrument is an additional cost that the program should anticipate.

### *4.4 Risk Mitigation in For-Flight Student Collaborations*

Given the careful balance between the project's rigor and its educational goals, what level of technical risk can NASA absorb with regards to student instrument programs? The answer depends on the kind of Student Collaboration being addressed. The panel sees the potential for NASA to adopt a spectrum of appropriate risk mitigation strategies for Student Collaborations that depends upon the SC's technical and programmatic relationship to primary NASA endeavors.

We envision two broad classes of SCs: stand-alone, independent SC investigations not directly tied to a larger primary NASA flight mission; and SC's included under a PI-led primary science investigation. Risk mitigation must be tailored to fit the circumstances.

For stand-alone SC investigations that have no programmatic or technical connection to primary NASA missions the appropriate level of risk mitigation is one that preserves the learning environment by encouraging innovation and the implementation of "out-of-the-box" approaches. In such cases it is entirely appropriate to accept the risk that the technical objectives of the mission may not be achieved. Safeguards should be put into place to ensure human safety and appropriate safeguards to prevent collateral damage to unrelated hardware.

When Student Collaborations are manifested as part of the system of a larger NASA mission, risk is introduced and risk-aversion comes into play. Given the careful balance between the project's rigor and its educational goals, what level of technical risk can NASA absorb with regards to student instrument programs? The answer depends on the kind of Student Collaboration being addressed. Student Collaboration involving recyclable launch vehicles, such as aircraft, sounding rockets or high altitude balloon platforms, depend by nature on an iterative process of trial and error and represent little or no risk to NASA. As the sophistication of the launch vehicle increases, along with criticality of the electrical and mechanical interfaces to the mission (i.e., an expensive spacecraft), so should the oversight by NASA.

Scaling the risk mitigation efforts in concert with the project's size and importance is fundamental to managing the risk introduced in a Student Collaboration. In these cases, it is appropriate for technical risk mitigation to resemble that seen for professional programs. In addition to such oversight, there are three keys to technical risk mitigation for Student Collaborations. First, Student Collaboration's technical designs should be simplified to present the lowest possible risk to the principal asset. In addition, the Student Collaboration teams must keep the technical requirements in mind and hold fast to them, despite desires to enhance instrument capabilities. Both of these call for additional rigor in the implementation of sound systems engineering principles.

Second, clear interface definitions must exist, enabling Student Collaborations on for-flight missions to operate as black boxes. NASA's role would be to review the interfaces of the instrument to the rest of the spacecraft, only requiring review of the technical interface with the instrument itself, saving review time and resources.

Finally, at the mission level, Student Collaborations should operate with reserve funds comparable to those allocated to other instruments. Currently, Student Collaborations are often executed without reserve fund allocation, contrary to NASA's guidelines for adequate reserves in costing an instrument. During the course of any instrument build (student or not), scope of work and in-kind support changes strain the workforce. Without the reserve allocation, Student Collaborations become precariously uncertain unless the engineering institution is willing to step up and absorb the cost. This results in an institutional burden that makes it difficult to justify ongoing support of Student Collaborations.

### *4.5 Access to Space*

Although there are a variety of platforms, the ability to access space is of utmost importance in encouraging students and in the development of the next generation. Launching is a key incentive to the student group, providing closure, and driving the mission through the data analysis phase. Access to space would be substantially improved with the development and implementation of a standardized, robust system (such as the DoD ESPA ring adapter or CubeSat P-POD) for carrying secondary payloads on existing and planned launch vehicles. This would take advantage of the significant excess lift capacity that commonly exists and is already paid for in launch vehicle costs.

Several current opportunities for flight have been identified, but a clear progression for access to space needs to be identified and/or developed in order to address even the current need. ***While ultimately there is* no *substitute for access to space in encouraging the next generation,*** there are synergies between flight and flight-like platforms that should be exploited.

1. Near Ground Systems. This class provides access to an environment that is “space like” and that allows many of the aspects of space to be explored as well as for prototypes to be tested.
    a. Environmental Test Chambers. These include a broad array of facilities that are generally not available at most institutions, such as vacuum chambers, plasma chambers, space environmental effects facilities, calibration facilities, to name several. It should be noted that, while these facilities are critical in the development of an instrument or payload, they generally serve in a support role and are not the final venue.
    b. Mid-altitude aircraft. NASA has made an investment in a number of aircraft platforms, including SOFIA and the Dryden DC-8. These provide unique, lower cost platforms and the ability to have several build-fly-test cycles.
    c. Reduced gravity aircraft. These aircraft provide the ability to fly experiments in reduced gravity, with the unique opportunity this provides for experimentation—as well as the fun of being weightless!
        i. NASA Reduced Gravity Student Flight Opportunity Program (RGSFOR), a very popular program sponsored by NASA that has provided flight opportunities for more than 2000 students since 1995.
    d. High altitude aircraft, including NASA’s JSC WB-57s and Dryden ER-2s.
2. Suborbital Systems: These platforms have been used successfully by many universities across the country and have as one of their strengths the ability to accomplish a complete design-build-fly-analyze cycle during a student’s academic program.
    a. Balloon Platforms: These are a very cost effective option for providing students with access to the very edge or space as well as being recoverable, reducing risk and providing students with a rich learning experience. Very simple platforms using a latex sounding balloon have been used by many universities to carry multiple, lightweight student payloads (less than 12 pounds total suspended weight) to an altitude of over 100,000 feet. These platforms provide excellent entry-level programs. The High Altitude Student Platform (HASP), developed by Louisiana State University and supported by the NASA Balloon Program Office, supports up to twelve, more complex student payloads or satellite prototypes with a standard power and telemetry interface for flights in excess of 120,000 feet and durations up to 20 hours. In addition, “Piggy Back” payloads on professional scientific balloon gondolas can provide a student team with even more flight time or capability, but available resources and interface details need to be negotiated with the science program PI.

        b. Sounding Rocket Platforms.  Although other launch sites are available, Wallops has historically provided the largest amount of sounding rocket access and is considering extending this access for educational opportunities.  Flights and support have generally come from E/PO budgets and are "fit in the margins."
            i. Microgravity Enterprises, Inc. (MEI).  The role of commercial companies in microgravity flights is something that should be explored.  For example, MEI offers flight opportunities offset by sales of products marketed as space products.

3. <u>Low Earth Orbit Systems</u>
    a. International Space Station.  With NASA ending the Get Away Special program, access to orbital platforms that can return hardware have been significantly reduced. NASA had proposed a similar platform for the ISS. New opportunities for university-based Student Collaborations on ISS should be developed and existing ISS external attached payload programs such as the Materials International Space Station (MISSE) Program should be made more widely available for SCs.
    b. *ARES* and future flight system test flights.  As NASA is developing future launch capability, there exists an opportunity to fly hardware as part of test flights.
    c. CubeSats and NanoSats.  The CubeSat program has been highly successful, but has primarily relied on non-US launchers to provide access to space.  One of the primary benefits of the CubeSat program is that launch costs are known and if paid, a CubeSat can generally be launched. This is an important incentive to students developing such a mission.  It should be noted that NSF has released a call for proposals for space weather missions using CubeSats, with NSF negotiating and paying for launch.  The Air Force's University Nanosat program provides seed funding to approx. 10 universities every 2 years, with the promise of one satellite being selected for flight, but this flight needs to compete with others on the SERB list.  Although NASA has been a participant in past University Nanosat programs, they no longer participate.
    d. SMEX and other observatories.  As orbiting platforms, these provide an opportunity for long-term missions and can augment the primary payload. Several years ago, NASA implemented (and ultimately cancelled) a University Explorer class of small low-cost orbital science missions to bridge the opportunity gap between sub-orbital capability, and the now >$100M Small Explorers.  This program, based on the successful USRA-run STEDI program, was predicated on the availability of frequent low cost launch opportunities.  The two factors that led to its cancellation, a dearth of launch opportunities and the application of risk aversion practices more appropriate to Class-A NASA missions need to be reassessed in light of current day thinking and current day capabilities.
4. <u>Deep Space Systems:</u>  These platforms have been demonstrated to be effective and exciting for Student Collaborations.  The New Horizon's Student Dust Counter, the first student instrument to ride on a deep space mission, paved the

way for other opportunities. Student Collaborations on Scout-, Discovery-, and New Frontier-class missions have tremendous potential to add to the NASA Space Exploration Visions, the Moon and Mars.

### *4.6 The Role of Competition in Student Collaborations*

Competition may be useful, and it is certainly a reality at all levels in the space industry. However, since Student Collaborations seek to encourage students to enter the field, it needs to be addressed with some thought as to how to minimize the discouragement of not being selected. Hence, competition should not be for the flight opportunity itself. As one example of an interesting competition, a group of educators, government, and industry representatives, led by Prof. Brian Gilchrist of the Univ. of Michigan, have proposed a CubeSat Competition, where all participants are ensured a flight (as long as certain safety and other concerns are addressed), with the competition occurring in space. For example, student teams may compete for the first team to download pictures (at a certain resolution) of the complete coastline of a continent announced after launch.

## 5.0 PROGRAMMATIC ISSUES

### *5.1 Program Selection Criteria*

There is general agreement that currently, the constructs in place for selecting SMD proposals (i.e., Science panel and/or TMCO) are important, but not sufficient for effectively evaluating Student Collaborations. In the case of mission-level Student Collaborations, a separate panel should be convened to specifically address these programs, perhaps following the model that is currently employed by some other segments of E/PO within SMD, namely that a panel is convened ahead of the full panel review to assess E/PO plans and the E/PO panel leads then attend the full review, providing insight and reporting on the E/PO panel’s finding.

In addition to the scientific and technical merits of a Student Collaboration, the programs should also be evaluated on their educational considerations, for example:

- Quality of the project: Is it well defined? Well-planned? Cross-disciplinary? Capable of providing a positive student experience? Does the project include the key features of a SC?
- Level of student involvement, both in terms of number of students and in terms of the quality of experience. Proposals that involve students at all stages of the process (from "cradle to grave") should be viewed positively. Level at which students are involved in the management of the Student Collaboration, as well as the student team management structure.
- Technical experience gained by the individual students. Evidence that good engineering practices are being followed.
- Institutional capability: Does the team have access to adequate facilities? Does the SC team appear to have the appropriate level of infrastructure and logistical support (space, facilities, faculty time, etc)?

- Is the technical task within the scope of the proposing group? Is there a reasonable probability of technical success?
- The potential of the program to impact students' careers, as measured by how far the students are expected to evolve professionally during the experience. How will the SC select an adequate number of students with the required range of skills?
- Quality of the mentoring model for the program, with particular emphasis on mentoring capabilities by professionals knowledgeable of industry standards.
- Infrastructure in place to support student and troubleshoot personnel and/or mentor problems as they arise. Is there a plan to handle student turnover?
- Evaluation model for the program (see section 5.2).
- What is the broader impact of the SC? (Other parts of the proposing institution, local community, regional, national, and international levels?) What outreach efforts are planned, and how will SC participants be involved?

Infused throughout the Student Collaboration programs at NASA should be the awareness that there is a body of educational research available in the areas of engineering education, project-based learning, and mentoring and team-building dynamics. Student Collaboration proposals should clearly demonstrate a familiarity with and understanding of this literature.

It is also recognized that the science and TMCO requirements and reviews for Student Collaborations are going to be different from other kinds of instruments. Because the goal of Student Collaborations is training, the kinds of scientific questions that SCs address may not be of first order importance to the mission. Review of SC proposals must recognize this goal and properly balance risk of diminished technical success and technical or scientific achievement against the potential educational return. This is not to suggest that SCs shouldn't have a standard of science return – in fact, this is a key to an SC instrument success. However, Student Collaborations should be evaluated against other student programs with regards to their science benefit, as opposed to other mission instruments. Likewise, similar examples can be explicated for the TMCO review, where Student Collaborations may not meet the same high TRL criteria as other mission instruments. ***As a result, it is important to convene a separate panel for reviewing Student Collaborations, where the appropriate level of expertise can be brought together to look at these programs with a separate set of evaluation criteria***. This selection model was pursued by USRA during the assessment of the STEDI mission proposals, and there are lessons that can be gleaned from this experience.

### *5.2 Program Evaluation*

It is clear that Student Collaborations can be evaluated along a number of axes, some of them very familiar to educators and others less so. Many of the Student Collaboration programs will be run primarily by PI scientists who have little background in educational evaluation and may see extensive evaluation as an onerous barrier that may be difficult for them to overcome. There may be a place for NASA to help in the establishment of Student Collaboration evaluation models and tools, as a way to facilitate effective evaluation of these programs.

Certainly, the success of the SC program in terms of some basic metrics that are familiar to most:

About the Instrument or Program:

- Did the instrument get built?
- Was data obtained?
- Was the data analyzed?
- Did papers get written?

About the Students:

- How many students were involved and for how long?
- What were their backgrounds?
- Assessment of group dynamics and team building during the program
- Assessment of professional progress during the program

However, in order to truly evaluate the effectiveness of Student Collaborations on the workforce, longitudinal tracking of participants for 3-5 years post-program (longer if possible) is an important component of the evaluation – critical for assessing Student Collaboration impact. Here, the evaluation involves metrics more recognizable to career councilors and are generally assessed as part of a yearly survey where questions a rigidly maintained for survey integrity:

- After the program, what did you do? (e.g., enter the aerospace professional, enter a non-related profession, enter grad school) Was this your first choice?
- How did the Student Collaboration program prepare you for your first job?
- Relative to your first job, what aspects did you find easier than you anticipated? What barriers did you encounter that you did not anticipate?
- What technical areas do you feel most proficient in? Deficient in?
- What specific non-technical skills (e.g., budgeting, planning, quality, program management are you using in your first job?
- How did the Student Collaboration program change your view of science or engineering as a career?
- Five years later, given what you see now in your job, what was the most important thing that you learned in your Student Collaboration that prepared you for your career?

In order to take advantage of the wide array of Student Collaboration programs, NASA could implement a single, online survey that all participants could answer. Student Collaboration programs would be responsible for tracking students and reminding them to take the survey, but data analysis could be handled centrally, to minimize impact on PIs.

### *5.3 Community Support Infrastructure and Program Continuity*

To ensure that the Student Collaboration community thrives, NASA SMD can provide leadership in a number of areas. First is in the area of visibility and support for Student Collaborations. Historically NASA has been challenged to create an ongoing program that supports the inherent nature of uncertainty in these projects. Student Collaborations involve trial and error learning, and identifying an appropriate scope for these programs where they are evaluated on a broad scale is important. Without consistent support it is difficult to create a program with continuity and structure.

There are many institutions that run successful variations of Student Collaborations. Every opportunity to bring them together to talk about what's working and where they need help in the changing the NASA ecosystem is worthwhile. In addition, there is a consensus that finding a way to make exporting successful programs to institutions interested in pursing them would be beneficial to everyone, increasing the presence and role of universities in workforce training. Opportunities to share information also lead to greater coordination and leveraging of Student Collaboration opportunities. SMD can support clearinghouse and workshop efforts in support of Student Collaborations. They can facilitate evaluation of Student Collaboration across the agency, minimizing the effort of any single institution or program. And they can establish connections to the broader Student Collaboration community, including NSF, commercial partners, university groups, etc. to increase communication between entities with the same goal.

Need for diversity: Special emphasis should be placed on securing participation from Historically Black Colleges and Universities (HBCU), Minority-Serving Institutions (MSI), Hispanic-Serving Institutions (HSI), Tribal Colleges and Universities (TCU) and other colleges whose student populations are predominantly underrepresented minorities and communities in NASA mission research and implementation. Studies show that the majority of underrepresented minorities in STEM areas graduate from these institutions. With the declining enrollment of US citizens in engineering and science graduate programs, recruitment and retention of underrepresented minorities is becoming increasingly important in the growth and production of the STEM workforce in the US.

## 6.0 CONCLUSION

Student Collaborations provide undergraduate students hands-on experiences that give them important skills to ready them to enter the space industry. Regardless of the type of Student Collaboration (engineering, science, mission operations), quality projects involve appropriate mentoring and evaluation models, are well defined to ensure success, and allow opportunities for students to take on challenges and work towards completion. Student Collaborations are faced with serious impediments that impede the development of a healthy community – access to space, communication across disciplines, and risk mitigation, to name a few. NASA has a unique leadership role to facilitate student programs both within the Agency and across the community to insure that a broad and diverse group of students are able to participate. A broadly-based Student Collaboration Program is recommended that would involve undergraduate students in authentic research opportunities that increase their interest in scientific and technical careers and enthusiasm for space exploration, while equipping them with first-class engineering and science skills that are unique to the work that the agency conducts.

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## 8.0 LIST OF ACRONYMS

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| AO | Announcement of Opportunity |
| E/PO | Education and Public Outreach |
| ESPA | EELV Secondary Payload Adaptor |
| HASP | High Altitude Student Platform |
| HBCU | Historically Black Colleges and Universities |
| HSI | Hispanic-Serving Institution |
| ISS | International Space Station |
| JSC | Johnson Space Center |
| MEI | Microgravity Enterprise, Inc. |
| MSI | Minority-Serving Institutions |
| NASA | National Aeronautics and Space Administration |
| NRA | NASA Research Announcement |
| NRC | National Research Council |
| NSF | National Science Foundation |
| PBL | Project-Based Learning |
| PI | Principal Investigator |
| PIDDP | Planetary Instrument Definition and Development Program |
| P-POD | Poly Picosatellite Orbit Deployer |
| RGSFOR | Reduced Gravity Student Flight Opportunity Program |
| ROSES | Research Opportunities in Space and Earth Sciences |
| SALMON | Stand Alone Missions of Opportunity Notice |
| SC | Student Collaboration |
| SERB | Space Experiments Review Board |
| SMD | Science Mission Directorate |
| SOFIA | Stratospheric Observatory for Infrared Astronomy |
| STEDI | Student Explorer Demonstration Initiative |
| STEM | Science, Technology, Engineering and Mathematics |
| TCU | Tribal Colleges and Universities |
| TMCO | Technical, Management, Cost and Other Factors |

| | |
|---|---|
| TRL | Technical Readiness Level |
| USRA | Universities Space Research Association |