Virginia Space Grant Consortium Mini-Proposal
"Engineering Biology for Space: Engaging Teachers and Students in the Promise of Synthetic Biology"

Margaret Saha, Chancellor Professor of Biology, College of William and Mary

Introduction: The field of Synthetic Biology is commonly defined as "the design and construction of new biological parts, devices and systems and the re-design of existing natural biological systems for useful purposes" [syntheticbiology.org]. Applying engineering principles to biological systems, there is no question that the field of "synthetic biology" is relevant for NASA's stated mission of pioneering "the future in space exploration, scientific discovery and aeronautics research." Unlike relatively brief space missions that had all necessary supplies onboard or missions in proximity to earth that could be easily re-provisioned, more distant missions of the future will preclude the possibility of re-supplying from earth and will necessitate novel solutions for astronauts' many needs. The field of synthetic biology can effectively address these needs. Indeed, synthetic biology is already being employed by NASA, for example, to design hydratable packets that contain safe microbes that produce essential bio-nutrients for astronauts and for bio-manufacturing of needed components for in-space construction. Now being tested on the ground, there are also plans for implementing on the space station as well. [See, https://www.nasa.gov/content/synthetic-biology]. In addition to these challenges, there are a plethora of other pressing needs for space travel that synthetic biology could potentially address, including sensors to detect low levels of toxins, or devices for disease detection and treatment given that astronauts will be distant from high-tech medical centers.

Rationale: While the field of synthetic biology holds a great deal of promise to address many of the challenges of human space exploration and travel, with all of the applications equally benefiting life for humankind on earth, the field of synthetic biology, particularly as it applies to space travel, is not widely known or appreciated. Moreover, when the name of synthetic biology is mentioned, it is often associated with some degree of alarm and a complete lack of understanding. However, in our previous outreach activities, when the nature and benefits of synthetic biology are explained, the field immediately attracts excitement and interest. This is particularly the case when one mentions its application to space exploration, an endeavor that immediately engages all age groups. The overall goal of our proposed project is to engage the community, particularly the next generation of citizens in understanding and appreciating the field of synthetic biology, particularly as it applied to NASA's mission for space travel and exploration. We intend to accomplish this by an integrated program that crosses traditional boundaries and involves faculty, undergraduates, local teachers, K-12 students, and the broader community.

Preliminary Work: First, some preliminary data on why we suggest that our proposal will be feasible and successful. First, William and Mary has had an extremely successful iGEM (international Genetically Engineered Machine, http://igem.org/Main_Page) team for four years which has performed extraordinarily well in the international competition with over 300 participating teams (including universities such as MIT, Stanford, Harvard), winning first place in 2015 and runner-up in 2017. iGEM is the largest synthetic biology organization and hosts the leading worldwide synthetic biology competition. Importantly for this proposal, our team has also placed in the finalist category for outreach two times. As the faculty advisor for this team, I can attest to a vibrant community of interdisciplinary undergraduate students conducting and disseminating synthetic biology with international accolades. Notably, our team was first started back in 2014 following an inspirational seminar presented at William and Mary by Dr. Lynn Rothschild (NASA Ames, https://nai.nasa.gov/directory/rothschild-lynn/) who directs the Stanford-Brown team. We feel as if this potential NASA funding will have brought us full circle. Secondly, we (particularly the PI), has a long-standing commitment to the importance of outreach. In fact she mentored a high school student many years ago in her lab and that student (Zena Cardman) was selected as one of twelve for the NASA 2017 Astronaut Candidate Program! As part of our enthusiasm and dedication for outreach, we have already made contacts with a number of local schools, namely Williamsburg-James City County, Newport News, and Warwick High school health science program. We are eager to do more and funding would make a huge difference to implementing the following program.

Proposed Program: Here we propose an integrated program that educates and promotes the field of synthetic biology particularly as it applies to NASA's mission, a program that crosses disciplinary boundaries and that also crosses typical organizational boundaries. Our goals are as follows:
Our overarching goal is to educate the broader community particularly local K-12 students and teachers about the field of synthetic biology and its application to NASA, and to how advances for space travel frequently have

immediate benefits on earth. But as part of this goal we also wish: (1) to break down barriers between the university and organizations, such as NASA, and the local K-12 institutions—forming lasting partnerships among these entities showing the power of collaboration to enhance progress; (2) to break down disciplinary barriers. While it is clear to most practitioners of science that multidisciplinary work is essential for all areas of contemporary science, challenging and seemingly impenetrable disciplinary barriers remain throughout the educational system right up through the university level. We aim to break down these silos at all levels. We aim to demonstrate how space exploration will require contributions from all fields, and indeed how biology itself now integrates math, engineering and chemistry into this exciting new discipline of synthetic biology. We aim to convince the next generation that one could pursue biology and still be integral to the NASA mission, a very exciting prospect for all scientists.

Our program will consist of the following.

- Several (~ten) short half day workshops for local teachers that give them theoretical knowledge as well as hand-on experience in the field of synthetic biology. The activities will focus on NASA related themes. These will be held on weekends and at convenient times during the summer.
- More extended workshops, flexibly scheduled to meet teachers schedules, that would offer college credit for lead teachers and STEM co-ordinators patterned after the successful teacher update courses we offered several years ago.
- Developing an online set of activities that teachers could employ related to synthetic biology and NASA that are easily available and inexpensive. An essential aspect of this set of activities will be how each activity will dovetail with and address Virginia Standards of Learning as well as the national science standards. This will encourage and promote the use of these activities.
- Mentorship of 2-4 high school students during the summer allowing them to participate in ongoing synthetic biology research.
- We will also have an outreach day in which we have members of the local community attend for a series of hand-on activities along with a featured speaker.
- Education of undergraduates. Notably our project will entail working closely with undergraduates from Biology, Physics, Chemistry, and Computer Science to develop and implement these various activities. This will not only benefit the broader community, but will also teach them about the fields of synthetic biology and its applications to NASA mission.

Budget:

Our requested budget of $13,010 will be broken down as follows:

- $6,000 for Undergraduate Stipends: As discussed above, undergraduate students involved in the field of synthetic biology (e.g. iGEM team members) will be intimately involved in working closely with the faculty director for this project to develop and implement the project. Two students will be paid $2,000 for work during the summer and $1,000 during the academic year to work closely with the PI.
- $3,210 for six lead Teachers or STEM co-ordinators to receive a W&M graduate credit for participation in the more intense workshop.
- $800 for basic supplies to teachers to implement the programs in their school.
- $3,000 for supplies for the initial outreach events and to try out the various activities to ensure that they “work” and are appropriate for SOLs and teachers.

Outcomes:

Our tangible deliverables include the online compilation of activities for the intersection of synthetic biology and NASA’s mission as well as how SOLs in STEM fields may be taught using these engaging activities. Our more intangible outcomes include: developing an appreciation for importance of outreach among undergraduate students; instilling a sense of the challenging and fun problems and a sense of excitement that permeates the growing field of synthetic biology; communicating the importance of synthetic biology for space exploration and showing the utility of the field for NASA and the spillover to broader society needs. As with all of our projects, we will document these more intangible aspects with appropriate surveys and assessment instruments to demonstrate that the activities did indeed make a difference. We respectfully request funding to jumpstart this exciting program.