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The Sea Air and Land Challenge is a STEM initiative for high school aged students. Nicknamed the SeAL Challenge, this engineering challenge provides teams of students the opportunity to learn about the engineering process through the design of a robotic system relevant to the Navy. Developed under ONR, the program grew from the initial region to 8 regions in 4 states and served over 600 students in its final year. This web-based program is fulfilling the 3 goals of providing students the opportunity to tackle a hands-on engineering task while in high school, giving students insight into technical careers available in the DoD, and helping educators learn to implement a STEM program even given constraints.

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Abstract:

The Sea Air and Land Challenge is a science, technology, engineering and mathematics (STEM) initiative for high school aged students. Nicknamed the SeAL Challenge, it is an engineering challenge which provides teams of students the opportunity to learn about the engineering process through the design of a robotics system relevant to the Navy and Marines. Developed under ONR Award No. N00014-14-1-0847, the program was grown from the initial region to eight regions in four states and served over 600 students in its final year. This program is fulfilling the three goals of providing students the opportunity to tackle a hands-on engineering task while in high school, giving students insight into tremendous technical careers available in the Department of Defense, and helping educators learn to implement a successful STEM program in their schools even given budget, time and resource constraints.

Report:

The Sea Air and Land Challenge is an Office of Naval Research (ONR) funded national science, technology, engineering and mathematics (STEM) initiative for high school aged students. Nicknamed the SeAL Challenge, it provides an engineering challenge to teams of students to give them the opportunity to learn about the engineering process through the design of a robotic systems relevant to the Navy and Marines. The robotic systems are designed and built over the course of a semester and are used to compete in a challenge that mimics missions encountered by the military, national security agencies and first responders.

The Sea Air and Land Challenge was developed in 2012 by Penn State's Electro-Optics Center (now part of Penn State's Applied Research Laboratory) to increase the pipeline of students headed towards STEM careers. STEM fields are where jobs are today and where the job growth will be in the future. Emerging mission requirements pose great STEM workforce challenges, and therefore STEM underpins the Department of Defense's (DoD) ability to provide national security. Developing a highly competent STEM workforce gives us a technological advantage.

Sponsored by the Office of Naval Research starting in 2014, the mission of The Sea Air and Land Challenge program is to inspire high school aged students to pursue education and careers in science, technology, engineering and mathematics, with an emphasis on civilian and uniformed careers that support Department of Defense and National Security activities. The SeAL Challenge is intended to introduce the students to STEM career opportunities they may not have otherwise known existed, especially in rural areas with no or few STEM programs. The program is also intended to help high school educators and administrators, implement a successful STEM program into their school district even with budget, time and resource constraints.

Goals of the SeAL Challenge are to:

1. To provide students the opportunity to tackle a difficult engineering task while still in high school
2. To provide insight into the tremendous technical careers in or supporting the Department of Defense and the armed forces
3. To help educators and administrators implement a successful STEM program into their schools given budget, time and resource

Over the first four years of the SeAL Challenge, the primary goals have been met and the program is fundamentally strong. The program structure and scope for each of the sea, air and land challenges have been increased, refined and improved based on feedback received from organizers and participants.

As an overview of the Challenges, the mission for Sea Challenge teams is to develop a submersible to "search for a sunken unmanned vessel to find clues related to an accident." Students view their submersible's environment via an underwater camera mounted to their vehicle and linked to a monitor. From this screen, the students pilot the submersible and pick up blocks and place them in color coordinated drop-boxes, while showing their ability to navigate through a tank or pool controlling pitch, yaw, roll and buoyancy (see Figure 1-left). The mission of Air Challenge teams is to build a payload that can "release aerial water drops onto a dangerous forest fire." Using a camera mounted on their unmanned aerial vehicle, students pilot their drone to locate targets and remotely release an object to drop on a specified target location (see Figure 1-top center). In the Land Challenge, teams navigate their robots in a manner similar to the Sea Challenge teams. Using imagery from the vehicle-mounted camera, the students must navigate the robot within the ten-foot square course, avoiding obstacles, to "deliver supplies to people trapped in an unstable city building after an earthquake." In reality, blocks represent the supplies and color coordinated drop boxes represent the buildings (see Figure 1-right). Of course, each of these "missions" must be completed within a specified time. The sourcing of materials to develop the robotic systems is "open" so the students can be as innovative as they wish. Robots can be custom designed and built using any machined, purchased or 3D printed materials and supplies or built based on kits, such as VEX (www.vexrobotics.com).

As part of the grant, the website, seaairland.psu.edu, was developed to provide universal access to the program content and to ensure consistency of the program delivery regardless of their coach's background in engineering. The website is accessible for all Regional Coordinators (RCs), educators, mentors and student participants. *Guidelines* for each of the Challenges - sea, air and land - are updated and available online. Training resources called *Survival Guides* were generated as references for the RCs and Challenge hosts, educators, mentors and judges. Other documents and posted information includes, but is not limited to:

- *Guidelines* for creating a Preliminary Design Review (PDR), piloting and volunteering
- *Rubrics* for scoring PDRs and judging Challenges

- *Sample Documents* for writing a PDR, Critical Design Review, funding request, thank you letter and permission form
- Description of the *Engineering Process*
- Information and links for resources, videos, media and sponsors
- Answers to *Frequently Asked Questions (FAQ)*
- How to *Get Involved* and *Find A Challenge*
- *DoD Careers*
- *Curriculum*

Figure 1 Challenge Day (CW from upper left): Sea Challenge Northern PA (Bradford HS), Air Challenge-South Central PA (Lancaster-Lebanon IU13), Land Challenge-Southwestern PA (Freeport HS), Land Challenge-Central PA (Bald Eagle Area HS), Air Challenge South Central PA (Lancaster-Lebanon IU13) and Sea Challenge-Southwestern PA (Freeport HS)

The exemplary semester-long high school STEM curriculum developed highlights the main subjects studied in engineering, as well as engineering methods, and uses the Sea Air and Land Challenge as the focal point for all of the topics presented. Several schools, which had started the Challenge as an after-school activity, have now added the program into their school course offerings. This is ideal for the program as well as for the students, providing roots for the program and offering students more opportunities in STEM education. Non-school based organizations, such as scouts or 4-H Clubs, have also benefitted from the program. As examples of the impact of this program on school curriculums, one school has added the program to all of their physics classes and is registered fourteen teams for the 2018 Challenge, and another school, which simply pulled together a few interested students their first year, has now formed an engineering class around the SeAL Challenge program and hosted the largest 2018 regional Challenge.

The student SeAL teams are linked with engineering or technical mentors from local industries or educational institutes. These mentors help familiarize students and their educators to the language and processes related to engineering disciplines and provide feedback and suggestions

to help solve problems encountered by the students. Mentors also check in with the students to ensure they are on schedule, and most importantly, act as engineering role models for the students. Students typically interact with the mentors for a total of two to ten hours during the semester.

In the first year of the program, there was one Challenge, held in southwestern Pennsylvania, which consisted of 71 student participants. By the spring and summer of 2018, there were eight regional Challenges held in Pennsylvania, Indiana, Ohio and Virginia with over 600 students participating on Challenge Day (see Figure 2/ Table 1). The eight regional Challenges involved a total of 46 schools plus a Penn State Summer Bridge program from Pennsylvania, Indiana, New York, Ohio and Virginia. From those schools, 111 teams of three to ten students competed in either the sea, air or land challenge.

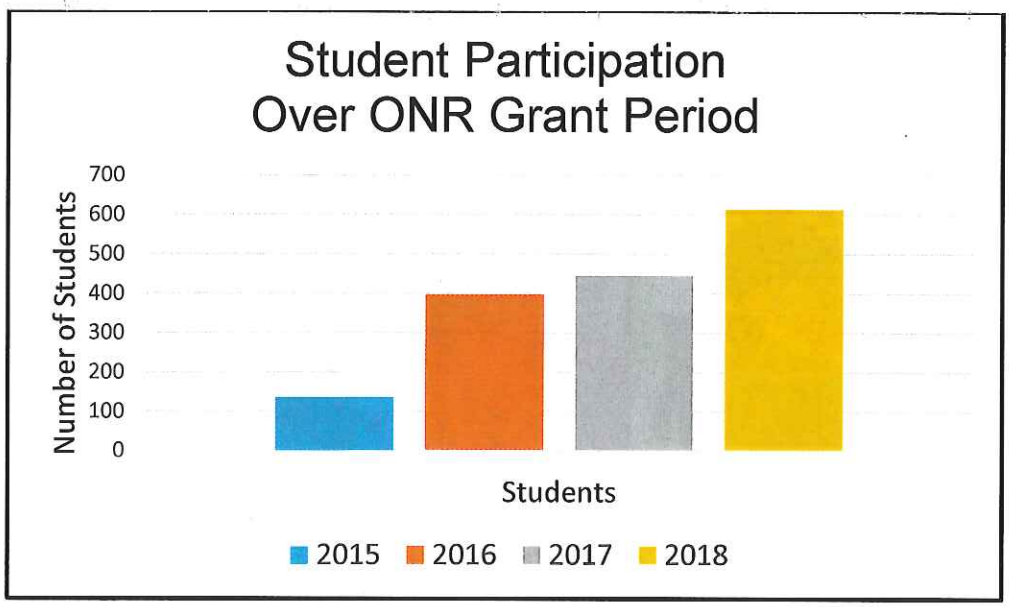

Figure 2. Student Participation over the ONR Grant Period

Spring	2015	2016	2017	2018
Students	136	396	444	613
Schools	8	28	35	47
Teams	22	51	82	111
Regions	1	3	5	8

Table 1. Participation Growth over the ONR Grant Period

Over 600 students from five states participated in the 2017-2018 school year, the final year of the ONR grant. As was typical of most seasons, participation was 75-80% male and 20-25% female. The response from the program has been great with 100% of the teachers and 94% of students stating that they would participate again if they had the opportunity.

Pre-Challenge surveys have administered as part of the student registration process. In 2018, 42% of the students reported that they did not have engineering influences in their home and another 13% were unsure about engineering influences. Even so, 72% of the students had an interest in a STEM career and 39% had interest in a career with the military.

After the Challenge, students were again surveyed, and 94% said that the SeAL Challenge program improved their understanding of the engineering process and 98% said that they would recommend this program to other students. Ninety-one percent of the students were now aware or were more aware of career opportunities with the Department of Defense than they were prior to the Challenge.

In surveying the teachers after the Challenge, 100% said they would recommend this Challenge to other teachers and that they would return to the program again the following year. Note that some of these teachers had never taught engineering or robotics previously. Roughly half of the teachers use the program as part of their curriculum and half as an after school activity with a group or club.

Observations and feedback from coordinating the Sea Air and Land Challenge include:

- The program provides positive exposure to engineering and programming and the opportunity for students to learn via a hands-on activity
- The SeAL Challenge distinguishes itself:
    - as an engineering competition, not just another robotics competition
    - affordable
    - fits with classroom curriculum
    - one day competition format
    - open-sourced design and build
    - flexible program structure benefits coordinators and participants
- Students learn more than engineering methods, they learn or improve soft-skills such as leadership, teamwork and time management, and they gain confidence.
- Judges enjoy the Challenge – both the format and interactions with the students. It is easy to recruit repeat judges.
- There is a lot of enthusiasm generated from students, teachers, regional coordinators and volunteers.

Publicity of regional Challenge Days has been generated via newspaper (print and online versions), news stations, school publications, social media such as Twitter and Facebook, websites such as ITEEA and National Robotics Week, and YouTube videos. Links to a representative sample of news articles, video and social media posts from the Challenges are cited in the Appendix.

The success of the initial program has led to a Phase II effort supported by ONR under grant number N00014-18-1-2696. The goals of the subsequent program to grow and sustain the SeAL Challenge are:

1. Mature Regional Seal Challenges: Mature the regional Challenges, which are planned for start-up or are already in place, so they largely continue on their own. These Challenges will maintain the three objectives of the original program.

2. Start New Regions: Grow the SeAL Challenge program and obtain a critical mass of regions by fostering regional coordinators and regional host venues in areas where there are no or relatively few STEM opportunities.
3. Streamline and Transition Central Resource Role: Streamline the Challenge's Central Resource support role at Penn State and transition it to business or non-profit based support so that it will be able to thrive on its own by the conclusion of the grant.

Appendix

A representative sample of news articles, video, social media and school district posts from the Challenges:

- Wheeling Channel 7 News Report by Brooke Chaplain on the first year Eastern Ohio Challenge, April 20, 2018: http://www.wtrf.com/news/education/sea-air-and-land-challenge-brings-dozens-to-the-valley/1131539838
- A pair of articles from the Suffolk (VA) News Herald. (There was also a television spot.) https://www.suffolknewsherald.com/2018/05/11/robots-take-to-sea-air-and-land/ https://www.suffolknewsherald.com/2018/05/12/seal-challenge-was-fun-coverage/
- Penn Manor High School Air Team in the South Central PA Challenge: https://www.pennmanor.net/blog/2018/04/26/penn-manor-hs-students-place-first-in-sea-air-land-challenge/
- Tribune Review article from the Southwestern PA Challenge, Thursday April 26, 2018: http://triblive.com/local/valleynewsdispatch/13516373-74/drone-competition-at-freeport-high-is-not-just-about-science!

- Crane, IN submersible testing at West Washington High School, April 14, 2017: https://www.facebook.com/WestWashingtonSchoolCorporation/videos/vb.285112861626545/866953770109115/?type=2&theater
- Interview of Kelly Montague, Navy Recruiter at Southwest PA Challenge, April 25, 2017: https://www.youtube.com/watch?v=kOFrNrhX-bM
- Altoona Mirror new article, May 14, 2017: http://www.altoonamirror.com/news/local-news/2017/05/altoona-students-win-awards-in-military-robotics-challenge/
- Twitter, May 9, 2017: https://twitter.com/lauren_beal26/media
- Facebook, May 11, 2017: https://www.facebook.com/pg/LancLebIU13/photos/?tab=album&album_id=1336810786404647