

ZERO-Robotics: a Student Competition Aboard the International Space Station

David W. Miller, Massachusetts Institute of Technology

As the International Space Station nears completion, it has gained importance by becoming a U.S. National Laboratory. ISS stands on the brink of having a substantial positive effect on the entire country through its new status, and education will play a major role in achieving the positive effect. The SPHERES program, led by MIT and Aurora Flight Sciences and supported by DoD DARPA/STP and NASA, has provided dozens of students unprecedented levels of access to microgravity for experimentation and analysis at the undergraduate and graduate levels. However, dozens is a very small number for a National Laboratory. "ZERO-Robotics" is envisioned as a robotics competition that will open the world-class research facilities on the International Space Station (ISS), specifically through SPHERES, to hundreds (potentially thousands) of students. By making the benefits and resources of the space program tangible to the students, it will inspire the future scientists and engineers, particularly to lead them back to working in the space program. In this way students, starting at the high school age group, will view working in space as "normal", and will grow up pushing the limits of space exploration, engineering, and development. Further, ZERO-Robotics also builds critical engineering skills for students, such as problem solving, design thought process, operations training, team work, and presentation skills.

The proposed program is aimed at high school, undergraduate, and graduate students, with age appropriate tasks. There are three main phases of ZERO-Robotics. Phase 1 is a software design competition that allows students to have their algorithms run in the microgravity environment on the SPHERES formation flight testbed aboard the ISS. Phase 2 is a hardware design competition that enables students the opportunity to design enhancements that use or add to the SPHERES satellites to accomplish complex tasks not possible with current hardware. By operating in the ISS, with SPHERES, the design of this hardware requires substantial engineering skills but is low risk. Phase 3 opens up the SPHERES program to by creating an open solicitation for unique ideas on an ongoing basis. All phases expose students to the challenges faced in the aerospace field, in a fun and safe learning environment.

Phase 1 - Software Design. This first phase is proposed to kick-start the ZERO-Robotics program by providing both high school and college students the opportunity to develop algorithms for SPHERES in the near future. Within a few months, the competition could have hundreds of students working on the design of software to accomplish complex tasks in space, such as docking, assembly, and formation flight. This first phase is low lead time because the SPHERES testbed is already operating successfully in the ISS. In the competition each team must complete a set of pre-determined tasks on which they are measured for performance. Tasks are age appropriate: high schools will have mission level tasks (determine the sequence of maneuvers), while college students' tasks may focus on controls and optimization. During all phases the students will be challenged not only

with programming, but also with the development of documentation and presentations to add to their engineering communications skills. In all cases, the students will have to learn and practice successful teamwork skills as there will be minimum team size requirements. Four steps are proposed for the competition in this Phase, including proposal submission, algorithm simulation, ground testing on the MIT flat floor facility, and, for top teams, flight testing.

In this final step, the selected teams modify their algorithms for implementation in space. Tests are integrated and packaged to be run on ISS. This step includes at least one ISS test session, with live feed of the crew executing the tests. Students will have the opportunity to view their tests run in real-time. Data and telemetry will be downlinked to them a few days after the event so that they can perform data analysis and submit a final report.

Phase 2: Hardware Design. The goal of the second phase is to immerse students, including high school teens, in the complexities of developing space hardware. The second phase is based strongly on the successful “FIRST Robotics” competition (see sidebar). The concept of Phase 2 is based on making a comprehensive kit of components available to the teams; it is to be previously approved to operate safely aboard the ISS as an expansion of the SPHERES facilities. Students will write procedures for crew to assemble their satellite on orbit.

Phase 3: Ongoing Collegiate Competition. Once the ZERO Robotics program infrastructure is well established, the next goal will be to create an ongoing “open solicitation” for ideas to investigate unique robotics problems aboard the International Space Station. This outreach would be primarily geared at undergraduate collegiate teams (but possible other levels too) who wish to demonstrate their own robotics research using SPHERES. On regular intervals (multiple times a year), the team will evaluate the submitted proposals and choose a winner to demonstrate their unique research aboard the ISS. This will create a constant outreach to students, utilizing the Station as a National resource for education and space-robotics research.

Summary. In summary, ZERO-Robotics looks forward to leverage on three existing highly successful programs: the International Space Station National Laboratory, SPHERES, and FIRST, to create a unique opportunity to expose students to space flight experience very early in their educational career. By exposing students early on to the challenges of the space program, these students are better trained to solve these problems as they enter the workforce. By making this a fun learning experience, these students are more likely to continue to pursue math, science, and engineering as a career. The first phase, software development, can be started in the near future.