

SPHERES

ZERO-Robotics

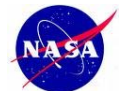
Massachusetts Space Grant
MIT Space Systems Laboratory

Prof. Jeffrey A. Hoffman

National Space Grant Directors' Meeting

Portland, Oregon

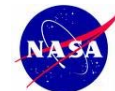
23 October, 2009





Agenda

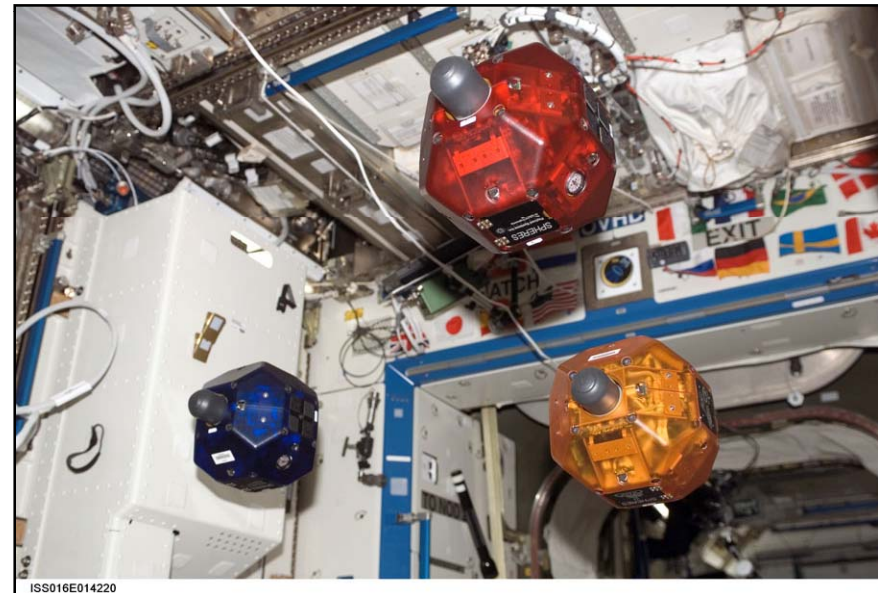
- Introduction to SPHERES
- ZERO-Robotics
 - Overview
 - Competition Description
 - Key Players
- Pilot Program
- How Space Grant can help





Introduction

- SPHERES is an internal testbed for the development and testing of estimation, control, and autonomy algorithms for distributed satellite systems
 - Test how to program satellites so that they do missions that need formation flight, docking, in-space assembly, etc, with minimal human intervention
 - Useful for future missions such as separated spacecraft telescopes, autonomous servicing missions, and in-space assembly of inter-planetary spacecraft
- ISS is like a research laboratory
 - Human-in-the-loop research
 - Crew can stop a test when it's obvious it is not working
 - We know instantly whether a test is good - can repeat
 - Consumables can be replenished
 - Iterative development
 - Use last session's results to develop next session





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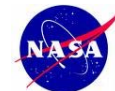
SPHERES Overview Movie





Overview of ZERO-Robotics

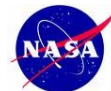
- **ZERO Robotics opens up the ISS for use by High School and Undergraduate students!**
 - ZR is modeled strongly on the “FIRST Robotics” competitions, starting with students programming the SPHERES satellites as part of a competition to design algorithms.
 - ZR can become an important STEM incentive in schools or areas which never thought their students would have access to the ISS.
 - The goal is for students, starting at the High School level, to learn that working in space is normal!
- Consists of three planned phases:
 - Phase 1 Software: geared directly to **High School** students, this phase consists of a **software design competition** where a **predetermined objective** is presented by the SPHERES team.
 - The objective will always involve competition between at least two SPHERES satellites, each programmed by a different team.
 - Teams will have multiple phases before the “best” teams test their algorithms onboard the ISS.
 - Phase 2 Hardware: geared towards **college level**, the hardware design competition will enable students the opportunity to **design enhancements** that use or add to the SPHERES satellites to **accomplish complex tasks** not possible with current hardware; new hardware would be designed approximately every four years.
 - Phase 3 Ongoing Collegiate Competition: after the HS software competition is well established, a third phase will open up regular interval “**open announcement**” style competitions to **college students** seeking to **design and test their own algorithms on SPHERES aboard the ISS.**





Phase 1 Software Competition

- **Current Phase of Zero Robotics under implementation (pilot program started)**
- Step 1: Proposals Preparation & Submission (May - Sep)
 - Students are asked to submit a proposal outlining their plans for the competition, specifically addressing algorithm development.
 - *Objective:* basics of writing a proposal and demonstrating software development
 - *Elimination:* none; all teams who submit a complete proposal are accepted
- Step 2: Algorithm development in simulation (Sep - Oct)
 - Code and test Game algorithm in MIT developed simulation (already under testing)
 - Send final algorithm files to MIT for review & scoring
 - *Objective:* initial competition to find determine schools with working algorithms
 - *Elimination:* only teams that have scored points go to “regionals”
- Step 3: Ground hardware testing “regionals”
 - Direct testing of algorithm files on SPHERES satellites at multiple NASA and/or industry facilities around the country that have **flat floors** (MIT, NASA MSFC, JSC, Lockheed Martin, etc.)
 - *Elimination:* determine regional winners, who will compete on ISS (approximately 8-12 teams)
- Step 4: ISS hardware testing
 - Update algorithms based on lessons learned from ground hardware testing to be operational on ISS SPHERES
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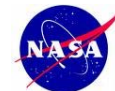
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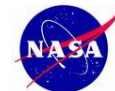
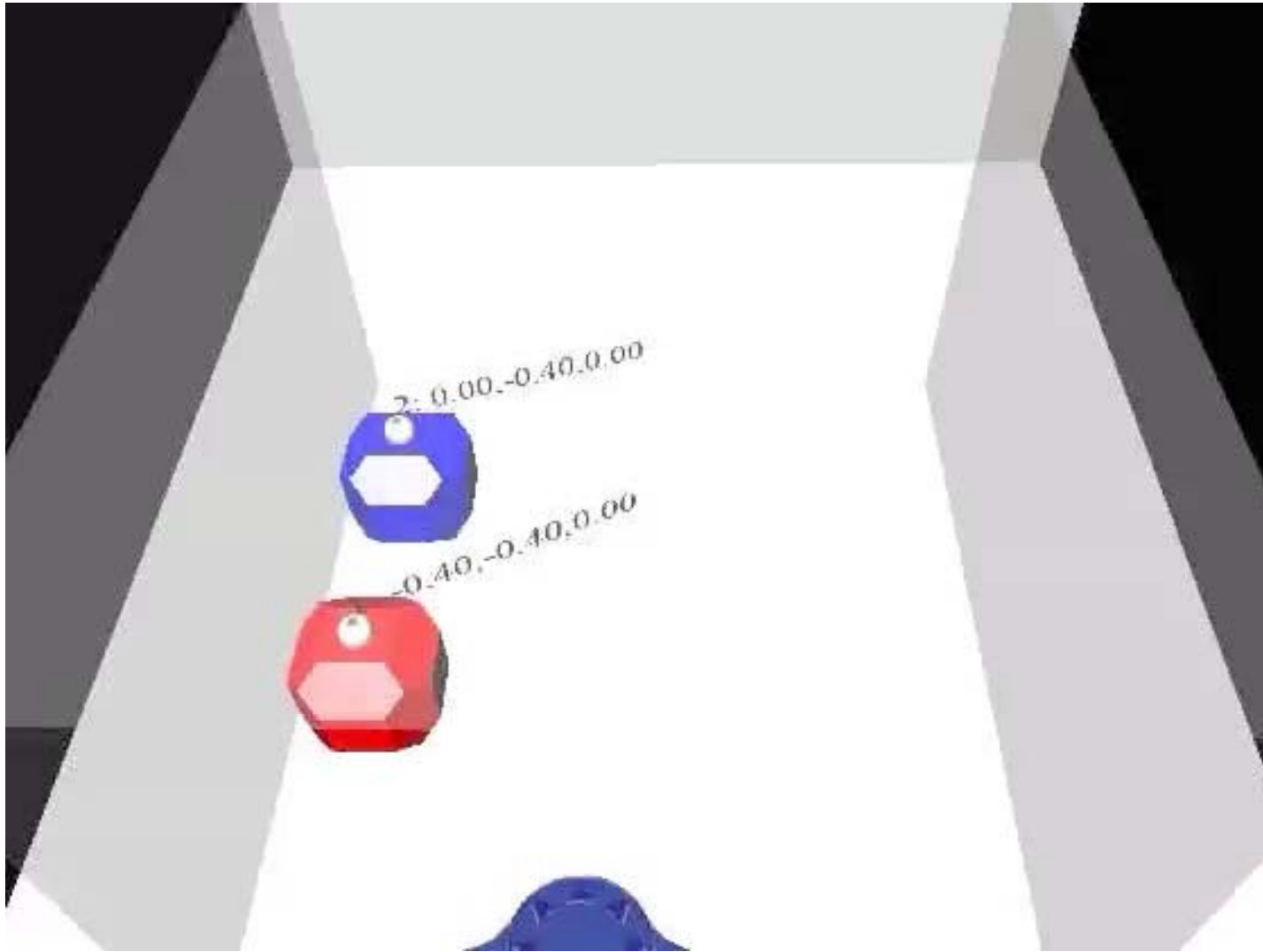
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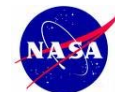
SPHERES Computer Simulation





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“Flat Floor” Testing

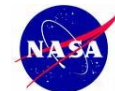
MIT SPHERES - NASA MSFC flat floor
Three-vehicle rotation (2x) 2004-06-09 (cam 1)





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Pilot Program

- 2 teams participating from Idaho (rural districts)
 - Team 1: Bonners Ferry High School
 - Team 2: Coeur d’Alene School District
- Kickoff in September, 2009
- Parts 2-4: simulation, ground hardware testing, ISS testing
 - No proposals were requested at this time
 - There will be “competitions” in simulation and ground testing, but neither team will be eliminated at any point
- Deliverables/Deadlines:

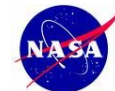
– Simulation files delivered to MIT	Mid Oct ‘09
– Hardware files delivered to MIT	Early Nov ‘09
– Files sent to NASA for ISS	Early Dec ‘09
– Log book of development process	Late Dec ‘09





Key Players

- **MIT SSL (Space Systems Laboratory)**
 - **David Miller, Alvar Saenz-Otero, Swati Mohan, Jacob Katz**
 - *Owners* of SPHERES, designed and maintain the simulation and all software support
 - Will determine scoring system for simulation tests
 - Packages software for and runs ISS test session
- **Aurora Flight Sciences (Cambridge, MA)**
 - **Javier de Luis, Joe Parish, John Merk**
 - *Second owners* of SPHERES, provide logistical support and consumables
- **NASA**
 - **Gregory Chamitoff, David Lavery (also “FIRST”), Bill Gerstenmeyer (SMOD)**
 - Will provide programmatic support from the Educational Outreach office
 - Schedule ISS Test Session specifically for ZERO Robotics
 - Make Flat Floor available
- **DARPA**
 - **Paul Eremenko, Owen Brown, Brook Sullivan**
 - Financial support for the program expected for 5 years
- **Private Supporters**
 - **Richard Garriott, Lorna Finman**
 - Lorna (Idaho resident) provided funding for the “pilot” program
 - Richard is establishing industry contacts for future support of ZERO Robotics (potential “micro gravity test aboard the ZERO-G reduced gravity airplane?”)
- **Space Grant...**





Space Grant Involvement

- How Space Grant Can help
 - Logistical Support
 - Receive proposals, help organize “regionals”, interface with industry contacts to gain access to Flat Floors
 - Networks with students
 - Help students establish ways to contact each other and the ZERO Robotics teams
 - Create events for “districts” or other smaller scope parts for teams to network
 - Publicity
 - Announce ZERO Robotics in general Space Grant publicity



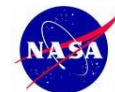


Contacts & References

- Program Lead Dr. Alvar Saenz-Otero alvarso@mit.edu
- Logistics Swati Mohan smohan@mit.edu

- Pilot Program Jacob Katz jgkatz@mit.edu

- References
 - ZeroRobotics: <http://ssl.mit.edu/spheres/zeroRobotics.html>
 - SPHERES: <http://ssl.mit.edu/spheres>
 - C coding: <http://www.cprogramming.com/tutorial.html#ctutorial>





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Let's get students using the ISS...

