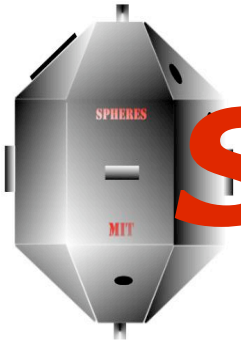


SPHERES

ZERO Robotics: A Student Competition Aboard the International Space Station

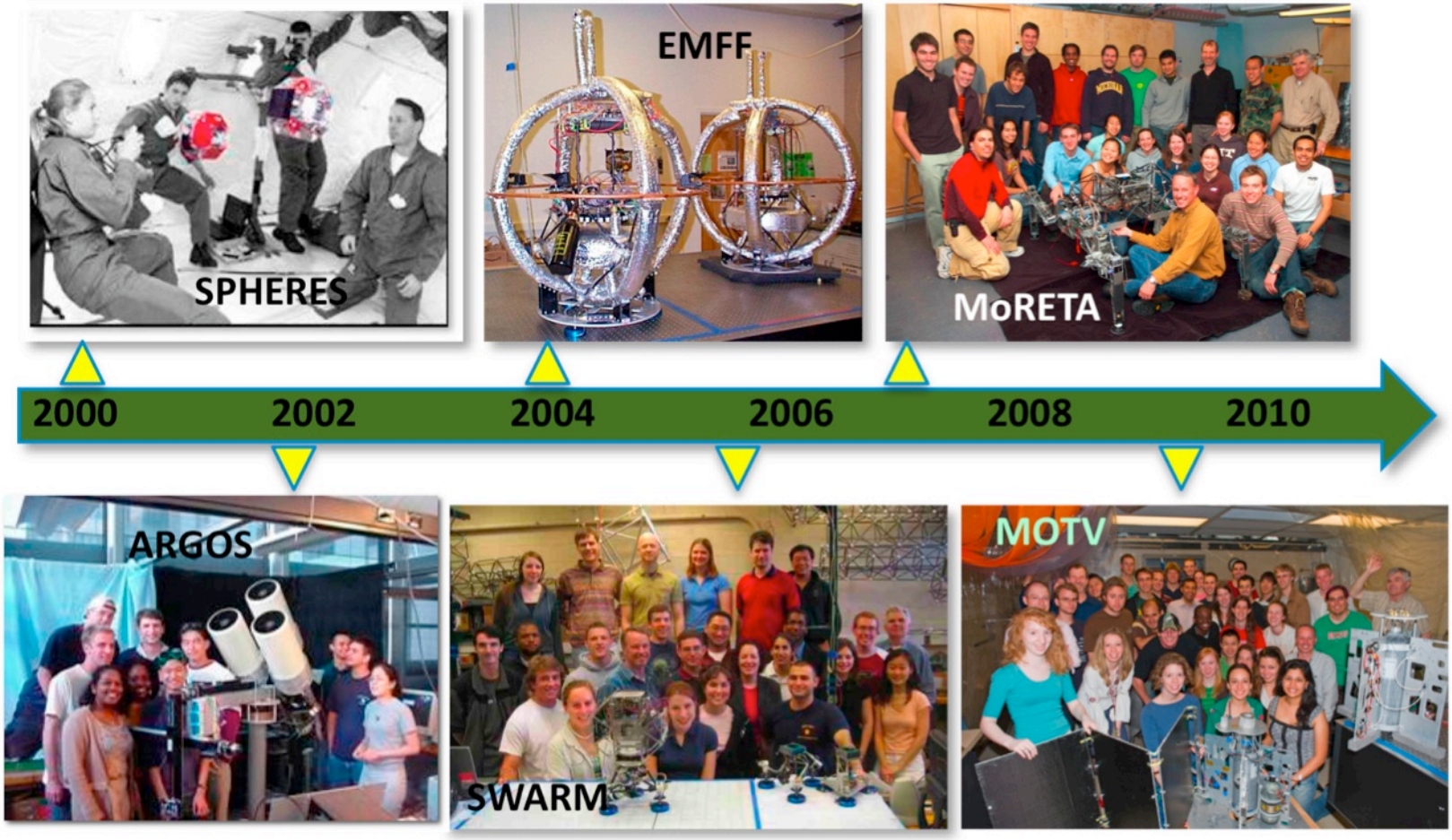
Next-Generation Suborbital Researchers Conference
Boulder, CO
February 19, 2010

Prof. David W. Miller and Jacob Katz
MIT Space Systems Laboratory

SPHERES Hands-On, Design-Build Education

Conceive, Design, Implement and Operate (CDIO)

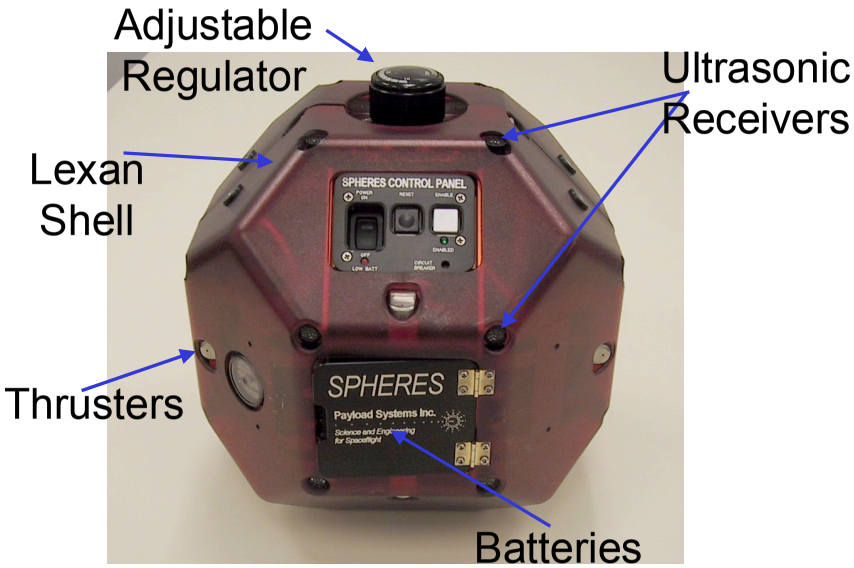
Mission Statement: To engage students in both the engineering science and engineering practice of developing an aerospace product from concept through to operation.



What is SPHERES?

SPHERES…

- Is a facility for the development of programs to control multiple spacecraft
- Consists of three self-contained volleyball-sized free-floating satellites
- Has test sessions on the ISS approximately once every 2-3 months
- Is an interactive testbed—crew members monitor the programmed maneuvers



ZERO Robotics Inspiration

- Inspired by astronaut and MIT alum Dr. Greg Chamitoff and private astronaut Richard Garriott
- Goals:
  - Encourage interest in space by providing a path to space research for young students
  - Leverage the SPHERES facility as an on-orbit, reprogrammable robot
  - Along the way, expose students to STEM skill sets
- Successful model from FIRST Robotics
  - Challenging engineering design
  - High profile, exciting competitions
  - Large participation

ISS017E015122

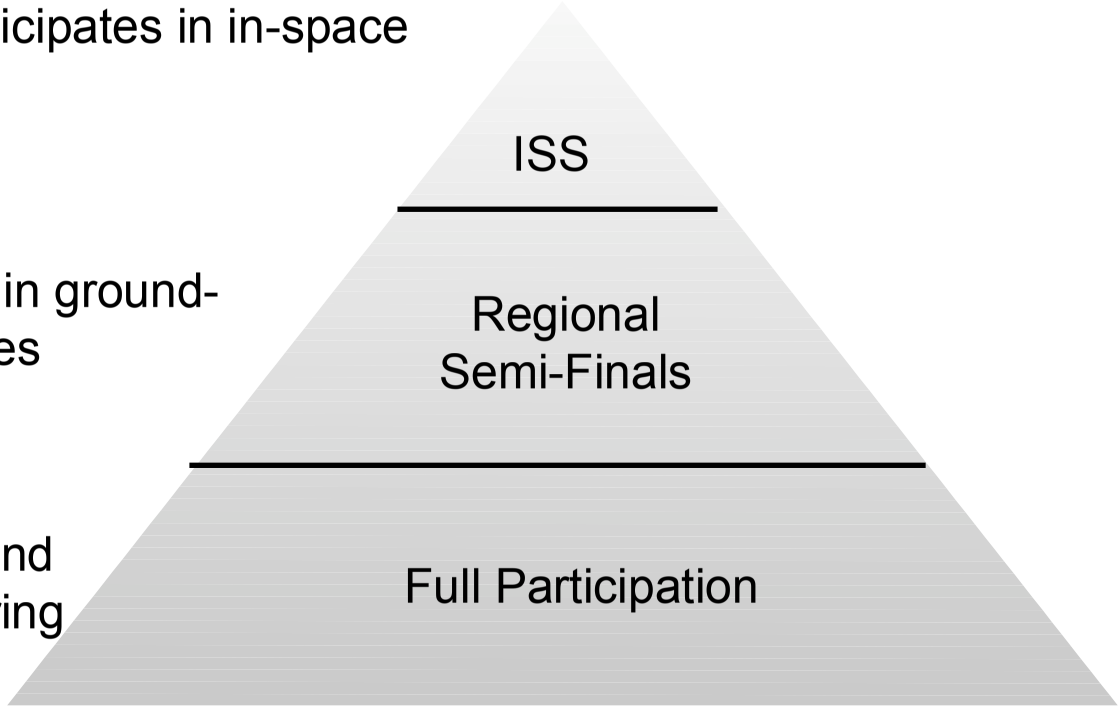
Achieving Broad Reach

Key question: how do we reach a broad set of students with a time constrained test environment?

Final group participates in in-space testing

Directly involve a subset in ground-based, hands-on activities (semi-finals)

Excite students about space and engage in solving an engineering problem

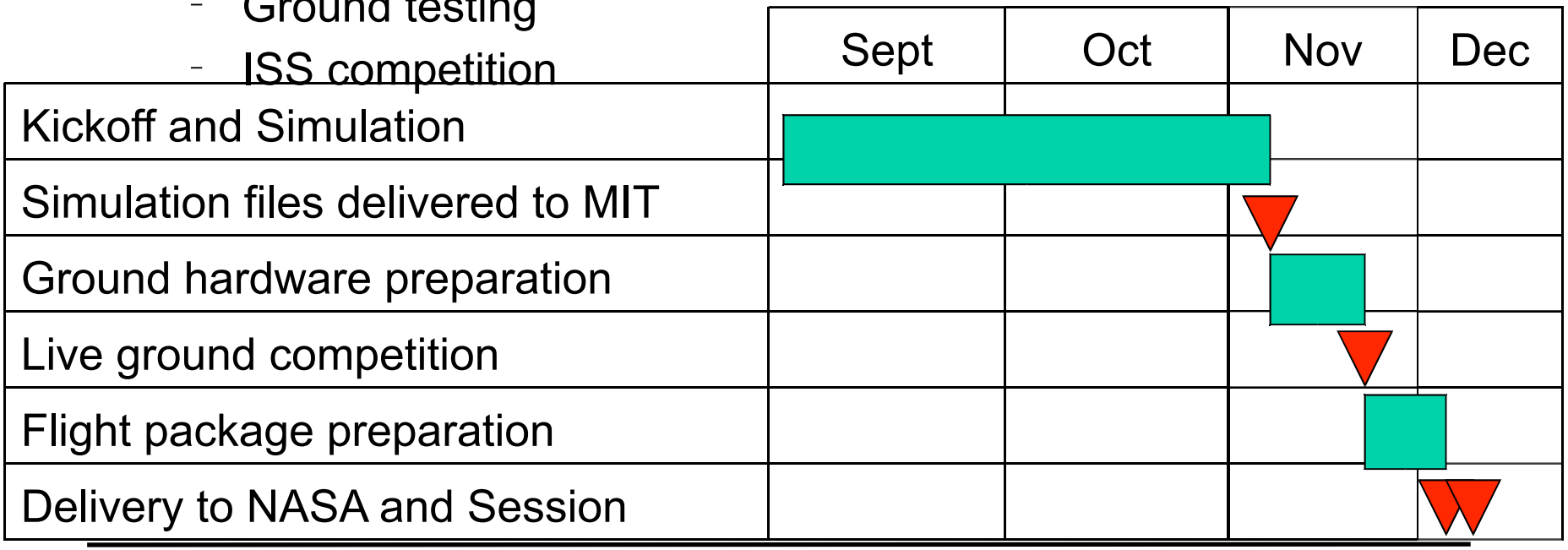


Competition Overview

- Step 1: Kickoff / Proposal / Tutorial phase
  - Unveil game
  - Encourage students to apply to the program to receive starting materials
- Step 2: Simulated Phase
  - Code and test in simulated environments
  - Down-select top performers to attend regionals
- Step 3: Ground hardware testing “regionals”
  - Direct testing of algorithm files on a hardware testbed
  - SPHERES satellites at multiple NASA and/or industry facilities that have flat floors around the country (MIT, NASA MSFC, JSC, Lockheed Martin, etc)
  - Determine regional winners, who will compete on ISS (approximately 8-12 teams)
- Step 4: ISS flight testing
  - Update algorithms based on lessons learned from ground hardware testing to be operational on ISS SPHERES
  - MIT will package, test, and send final files to NASA
  - Test Session with astronaut who will run the code in space (live video of session to winning teams, potentially invited to do it at MIT)

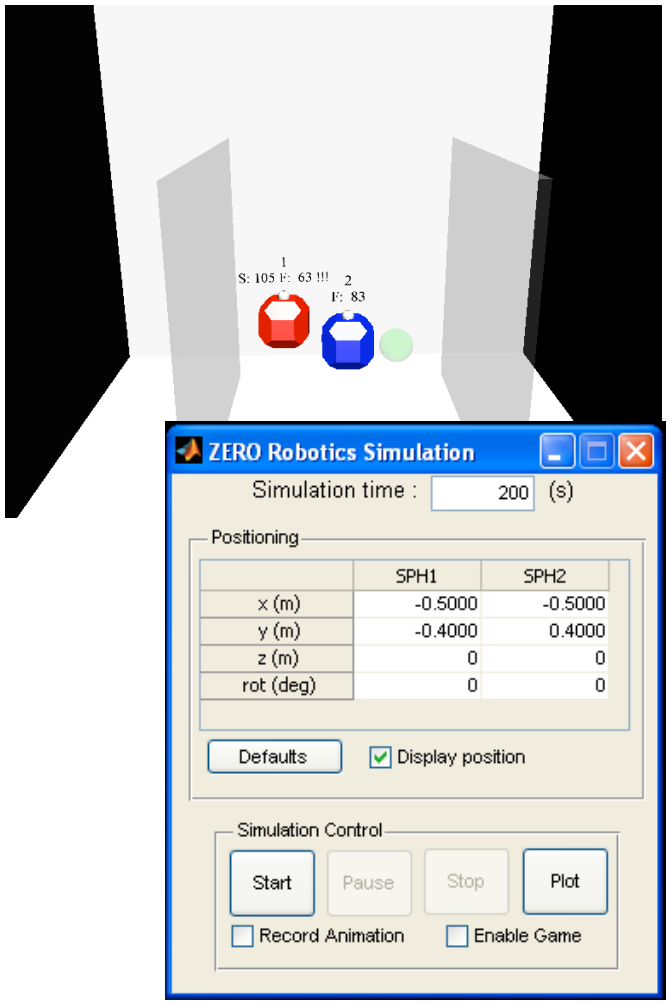
Pilot Program

- September to December 2009
- Two high school teams participated (10 students total)
- Tested components from competition structure
  - Kickoff and C coding tutorial
  - Simulation development
  - Ground testing
  - ISS competition

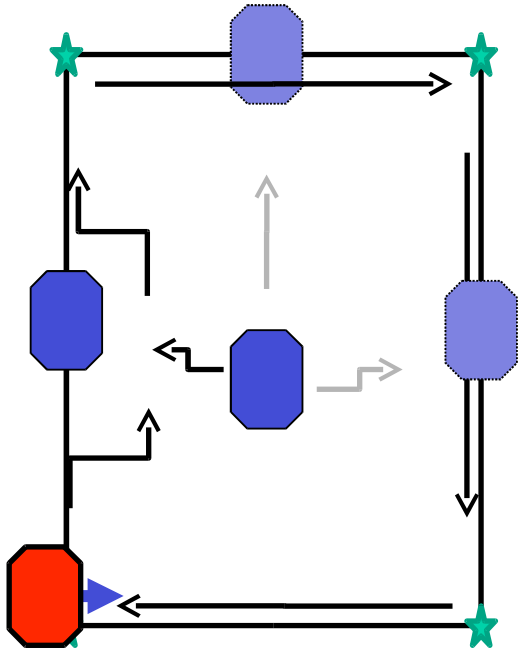


ZERO Robotics Simulation

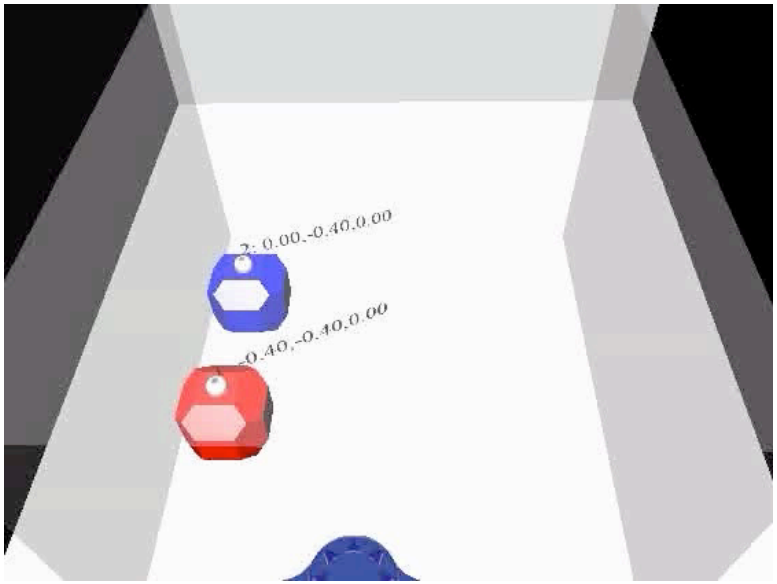
- Requirements:
  - High fidelity and directly applicable to hardware
  - Modest learning curve
  - Free or low cost
- Implementation:
  - Uses SSL's SPHERES MATLAB simulation packaged as an executable
  - All required software freely available
  - Same code used in simulation and hardware testing
  - Students interact with satellites by specifying position targets



Tutorial Phase



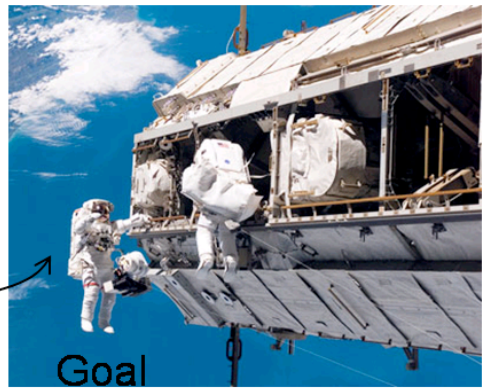
Game Schematic

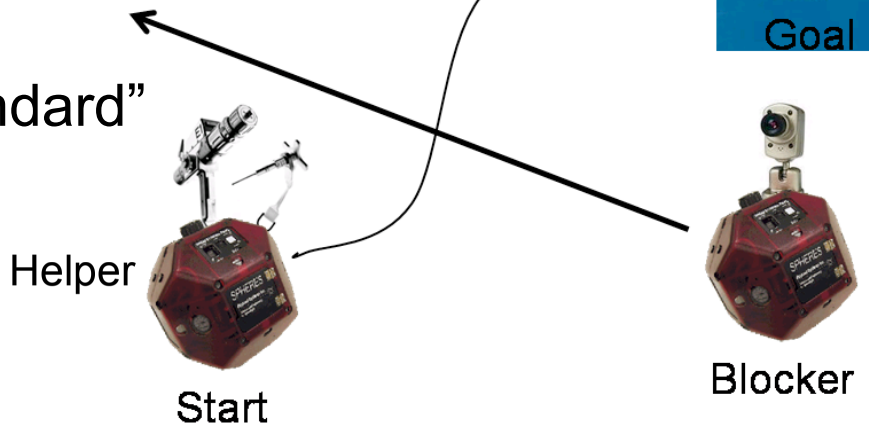


Student
Simulation

Competition Game

- Two roles based on satellite assistants
  - *Helper* satellite delivering a tool
  - *Blocker* gets in the way
- Fuel constraints
- Score based on time to reach goal and time blocked
- MIT provided “standard” player





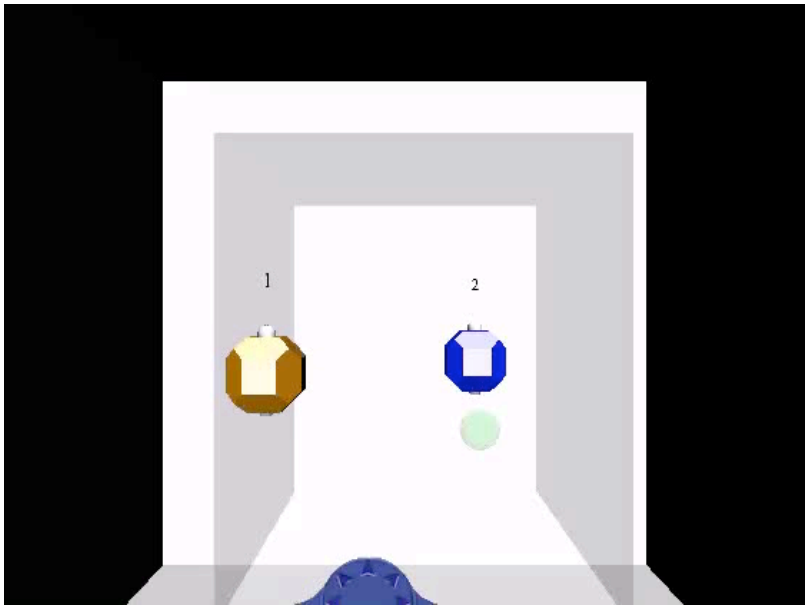
Flat Floor Testing

- Prototype for our “regional” competition
- Ran first round of student-developed code in a mock competition
- Live webcast session from SSL’s flat floor facility
- Mixed Results
  - From student feedback, it was difficult to discern the 3D behavior of their algorithms from 2D tests
  - Frequent interruptions due to consumable usage and disturbances (CO2, batteries, friction)
  - Prepared students for viewing a test session live

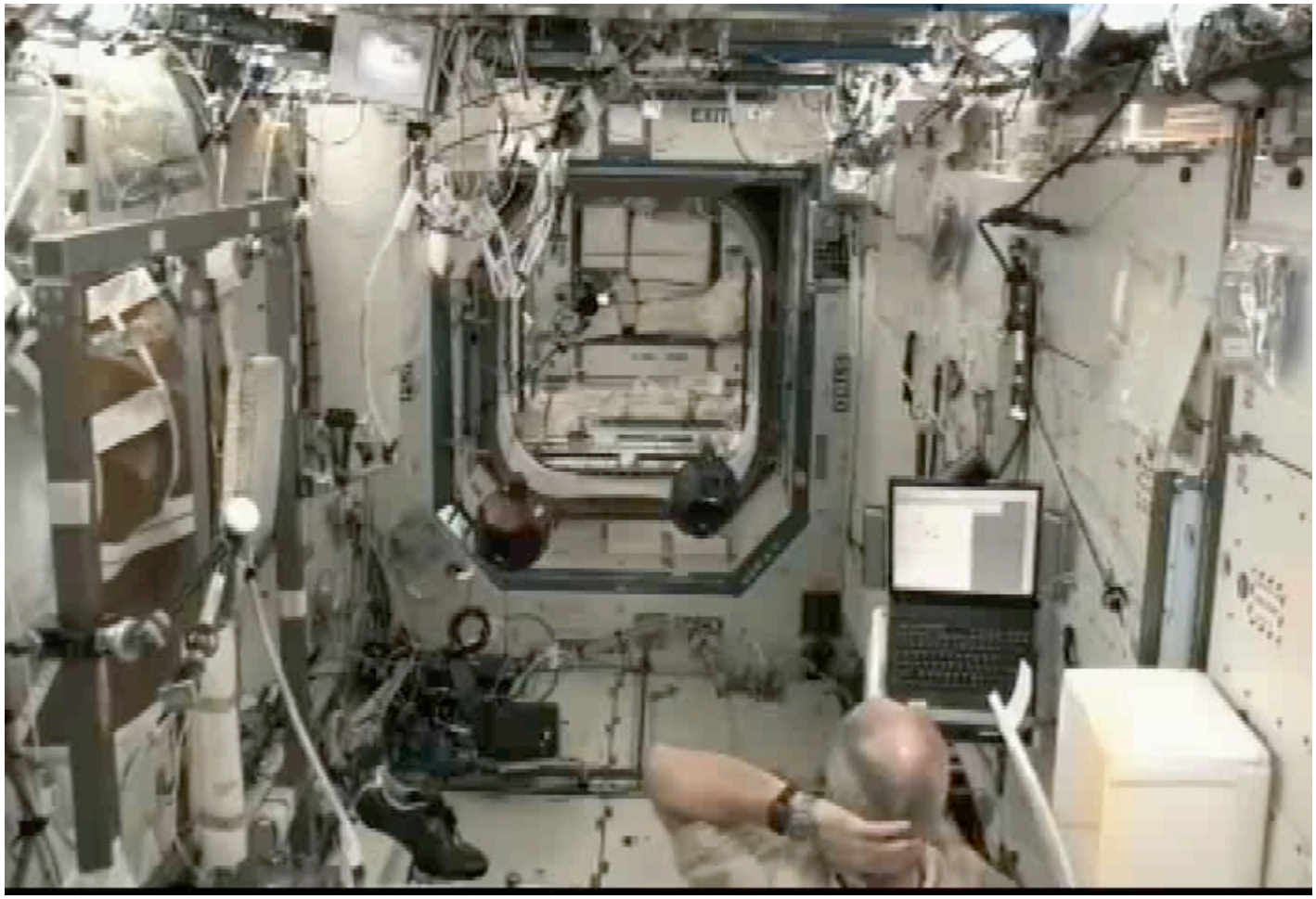
ISS Session

- December 9, 2009
- 2 hours of testing (at 3am!)
- Focus on high quality experience
  - Direct feed form ISS
  - Control center setup
  - Audio feeds on speakers
- A few hiccups
  - SPHERES estimation
  - Virtual fuel allocation

A Successful Helper



An Aggressive Blocker



Future Phases: Broadening the Pyramid

- Phase 1 Software: national level competition with simulated initial rounds
- Phase 2 Hardware:
  - geared towards college level
  - the hardware design competition to enable students the opportunity to design enhancements to enhance SPHERES
  - new hardware would be designed approximately every four years
- Phase 3 Ongoing Competition:
  - After HS software competition is well established
  - Regular interval “open announcement” style competitions to students seeking to design and test their own algorithms on SPHERES aboard the ISS

Conclusions

- ISS Competition
  - Still ironing out down-selection progress: appropriate blend of simulation and ground testing
  - Sufficient time for complicated mission and multiple permutations
  - Ability to rerun tests allowed successful demonstration of student code in both roles
- Thoughts for suborbital
  - Important to provide age-appropriate interfaces
  - Options for iteration: students can design *hardware* and fly it in space
  - High stakes, tests must be bulletproof
  - Find ways to involve many students at several levels of the design process