

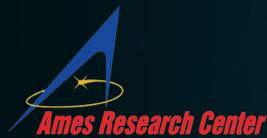
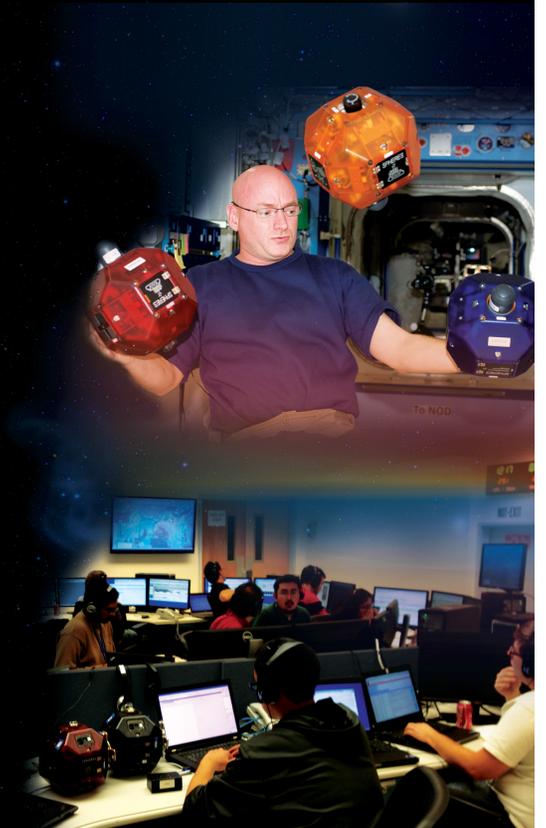
SPHERES

Synchronized, Position, Hold, Engage, Reorient,
Experimental Satellites



SPHERES National Lab Facility

Jose Benavides
NASA Ames Research Center
July 16, 2014





Synchronized Position Hold Engage Reorient Experimental Satellites - SPHERES

- A Facility of the ISS National Laboratory with three IVA nano-satellites designed and delivered by MIT to research estimation, control, and autonomy algorithms
- Installed on ISS in 2006
- Managed by ARC since Fall 2010
- By working aboard ISS under crew supervision, it provides a risk tolerant Testbed Environment for Distributed Satellite & Free-flying Control Algorithms
 - Formation flight,
 - Docking,
 - Close proximity operations
- If anything goes wrong, reset and try again!
- The satellites can be reused
 - ✓ Replenishable consumables
 - ✓ Multiple test sessions assigned per year



Scott Kelly working with SPHERES in the Kibo lab

SPHERES ISS National Lab Facility

- Program Executive: Jason Crusan (HQ)
- Program Manager: Andres Martinez (ARC / R)
- Chief Engineer: Jose Benavides (ARC / TI)
- Operations Lead: Aric Katterhagen (ARC / PX)

If you can't bring the space environment to the laboratory, take the laboratory to space!



SPHERES Platform Capabilities

Sensors

- Accelerometers, Gyroscopes, Ultrasonic ranging
- Smartphone Camera

Actuator

- CO₂ Propulsion, 0.2N of force possible

C&DH

- 115kbps downlink to laptop
- Real-time interface to laptop Matlab runtime
- 400kbps real-time downlink to Mission Operations Center

Expansion Port

- Provides an interface for integration with additional technologies
- Well documented ICD
- Currently used by several Payloads



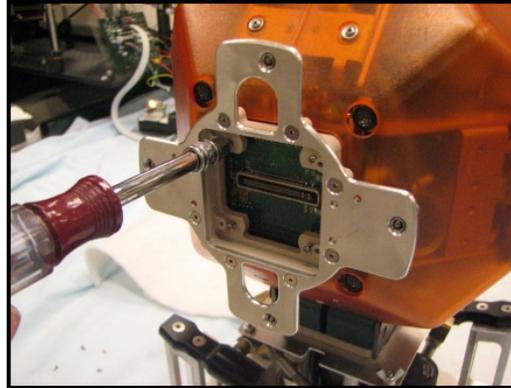
Diameter	8.3 in (0.2 m)
Mass	7.8 lb (3.5 kg)
Thrust (single thruster)	<1 oz (0.2 N)
CO ₂ Capacity	6 oz (170g)



SPHERES Nat Lab Facility



3 SPHERES



Expansion Port Enabled



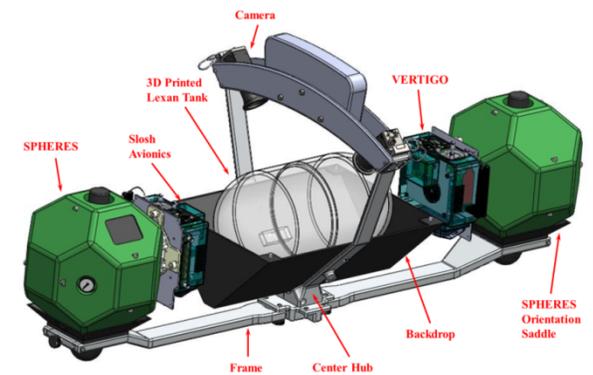
Smartphone



Vision Based Navigation



Electro-magnetic Actuation (RINGS)



Fluid SLOSH



SPHERES Facility Labs



Flight Lab



International Space Station



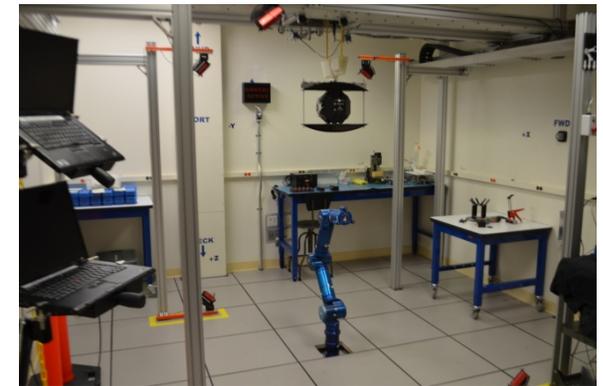
Engineering Evaluation Lab (EEL)



Granite Lab



Mission Operations Center

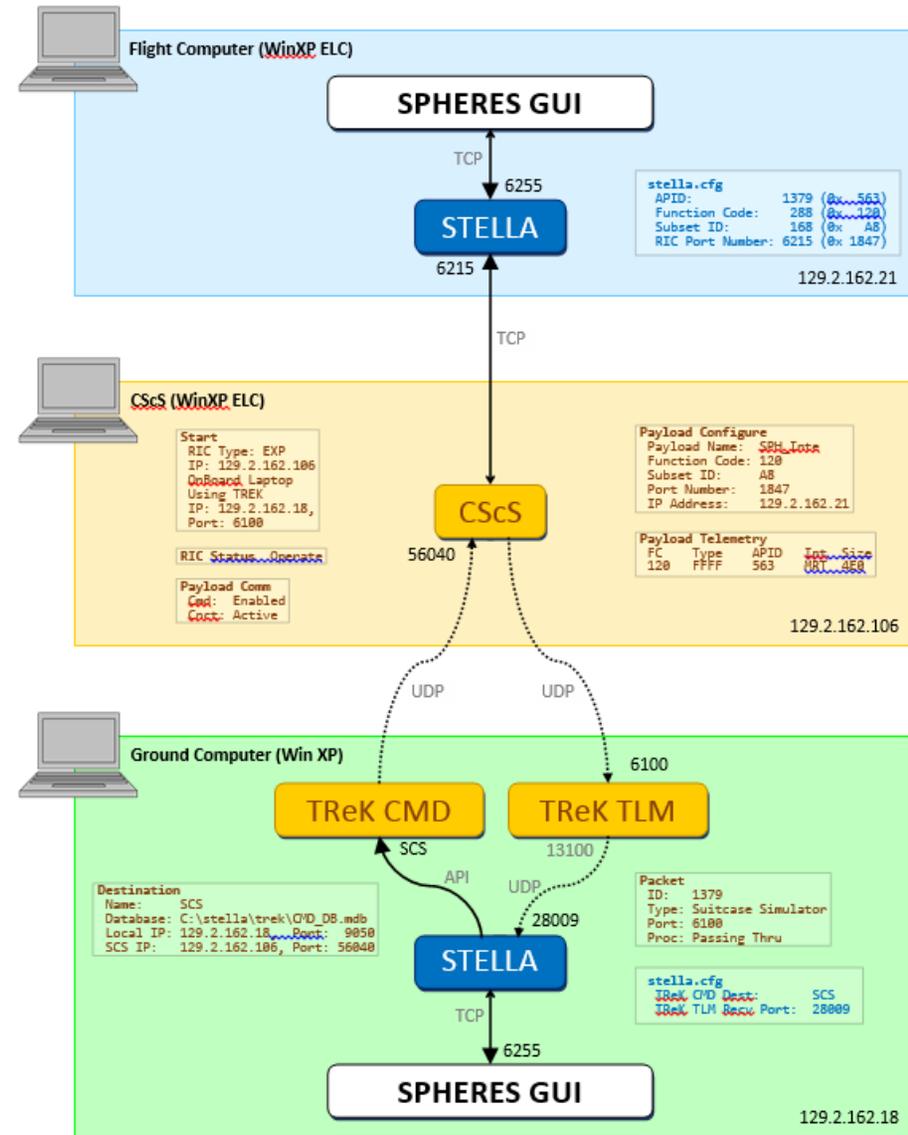


**Micro Gravity Test Facility (MGTF) Lab:
Cradle/Gimbal and Robotic ARM**



MGTF Lab Configured for SPHERES GUI C&DH

- ❑ Emulate space-to-ground end-to-end communication
- ❑ Collect real-time telemetry
- ❑ Send commands
- ❑ Matlab integration





Guest Scientist Program (GSP)

Technical Aspects

1. **Download GSP from Sourceforge, including simulator**
2. **Dev and Test your software on the simulator**
3. **Test in Ames SPHERES Lab**
4. **Deliver Software and planning products to SPHERES Operations**
5. **Conduct test session aboard ISS**

Operational Planning Aspects

1. **Deliver proposed investigation – one pager**
2. **SPHERES initiates request to schedule ISS Test Session**
3. **Generate all planning items required by ISS (e.g. Test Plan,)**



SPHERES Simulator Capabilities

Simulator Features

1. ISS-validated dynamics model
2. Matlab/Simulink & C programming environment
3. Full embedded architecture fidelity
 - a) Same C-code developed for Simulator can be re-compiled for SPHERES hardware un-modified
4. Integration with Simulink 3D Animation toolbox
5. Cross-platform compatibility (Windows/Mac OS X)
6. Publicly Available :
 - a) <http://sourceforge.net/projects/issospheres/>



Zero Robotics Overview



Zero Robotics is a competition designed to allow Middle & High School Students unprecedented access to the International Space Station.

Based on the FIRST Robotics model, teams of students work together to program the SPHERES Satellites to complete a set of tasks.

Once the programming phase is complete, the teams' code is put through several rounds before the final "best" teams are invited to MIT to upload their program to the International Space Station to be tested by the astronauts.





SPHERES Community

SPHERES Working Group (SWG) Quarterly meeting

- Membership includes MIT, UMD, FIT, Lockheed, AFS, DARPA, NRL, CASIS, NASA (HQ, KSC, JSC, MSFC, and ARC)
- Face-to-Face, twice a year, during September and March
- Next Face-to-Face will be scheduled in September 2014 at NASA HQs

Purpose:

- Information sharing across the SPHERES community
- Program office shares
 - National Lab Facility availability
 - Status of resources (batteries, CO2 tanks, etc.),
 - Overall Calendar (scheduled Test Sessions, upmass/return), and
 - Updates on “new” PD, Investigations, and ISS infrastructure.
- Provide the SPHERES community (PD, investigators, etc.) with up-to-date information to determine opportunities to use the NL Facility
- Discuss proposed changes/updates to SPHERES Nat Lab which may be required to support a specific activity or research.
- Discuss specific support requests made to the ISS Office



InSPIRE II Payloads - Coming soon!

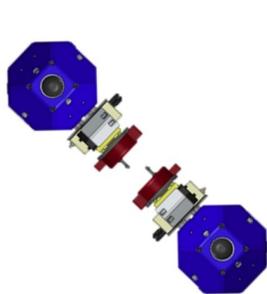
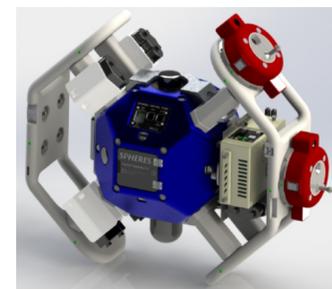
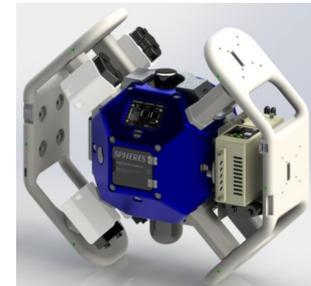
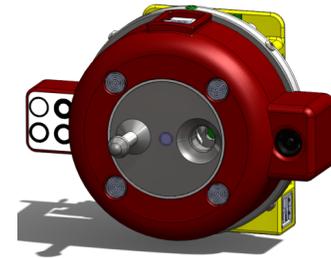
Develop a cost-effective facility for maturing adaptive GNC technology (guidance, navigation, and control) in support of on-orbit, robotic satellite assembly in a risk-tolerant, dynamically-authentic environment

SPHERES Docking Port

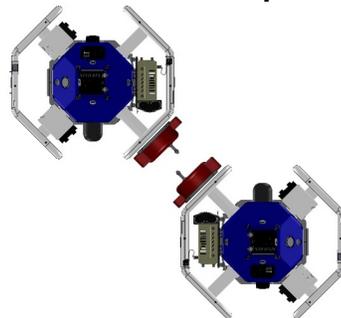
- Provides the ability to autonomously dock and undock in 6DOF changes the dynamics of the system and challenges the command and control of the assembly process

Halo

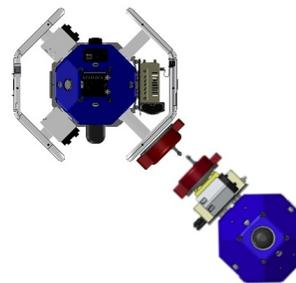
- Enables each satellite to **interface with six external objects simultaneously** through rigid mechanical and electrical interfaces called “Halo ports” (HPs)



Satellite to Satellite Docking



Halo to Halo Docking



Halo to Satellite Docking



Research & Benefits of SPHERES

- Demonstrated key close-proximity formation flight, rendezvous and docking maneuvers, fault diagnosis and recovery
- Supported human telerobotic operation and control investigations
- Conducted experimental evaluation of algorithms and sensing for autonomous docking, Satellite servicing, Re-supply, Upgrade of space systems
- Crew-based teleoperation and time-delayed ground control experiments for future crew-assistant robots.
- Evaluation of COTS technologies such as smartphones for rapid prototyping and deployment in space environments.
- Lessons learned on ISS have significant impact on ground robotics, mapping, localization, and sensing in 3D.
- Developed a platform to demonstrate and validate metrology, control, autonomy, and artificial intelligence algorithms for distributed satellite systems (DSS)

Over 80 Test Sessions (400+ hrs. of Facility Console activities involving crew), 62 Crew training sessions (Over 100 hrs.), and 11 presentations at the 1st ISS R&D Conference June 2012 and 7 this year!

One of the most used and popular ISS National Lab Facilities



Points of Contact

Andres Martinez, Program Manager
NASA Ames Research Center
(650) 604-0530
andres.martinez@nasa.gov

Jose Benavides, Chief Engineer
NASA Ames Research Center
(650) 604-4401
jose.v.benavides@nasa.gov

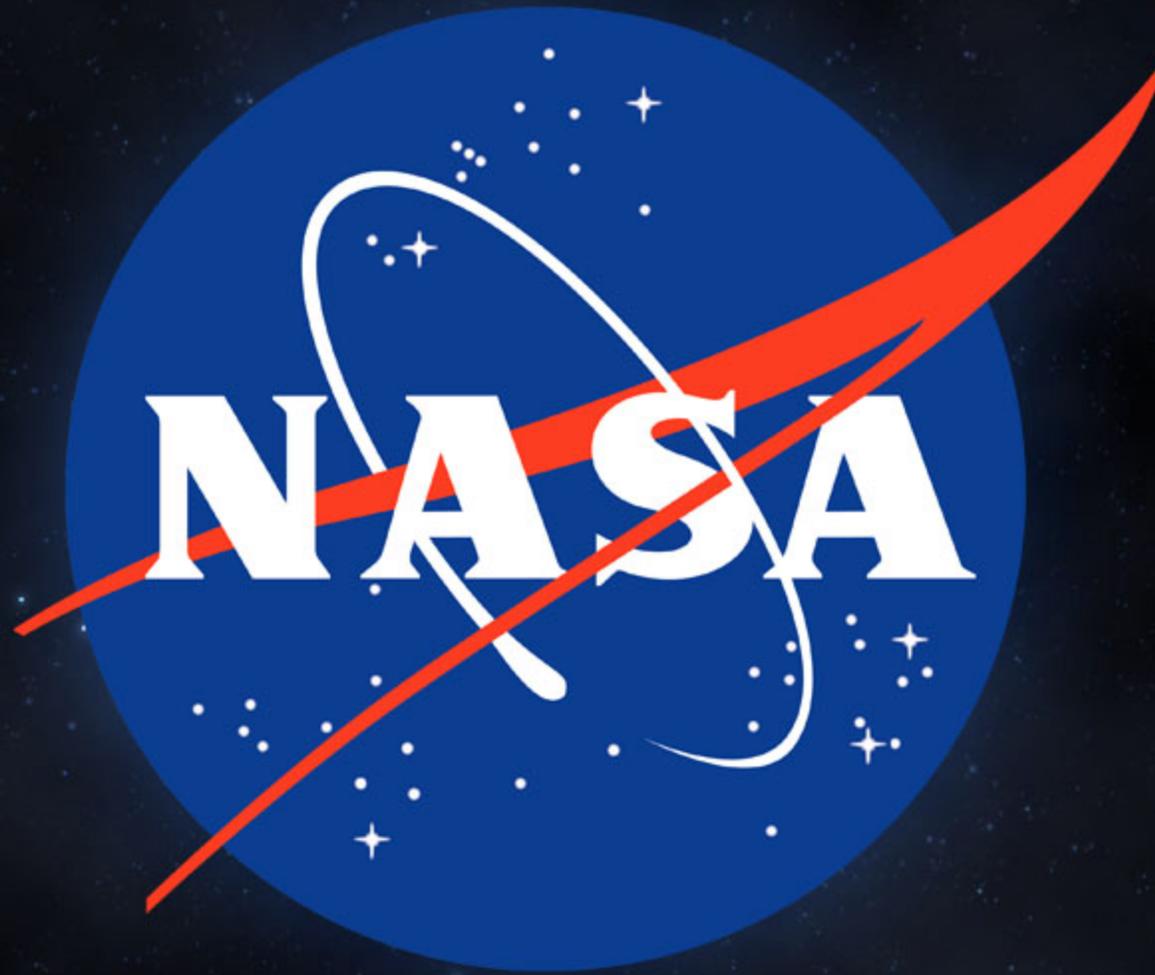
Aric Katterhagen, Operations Lead
NASA Ames Research Center
(650) 604-6689
aric.katterhagen@nasa.gov

<http://www.nasa.gov/spheres>



Questions?





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