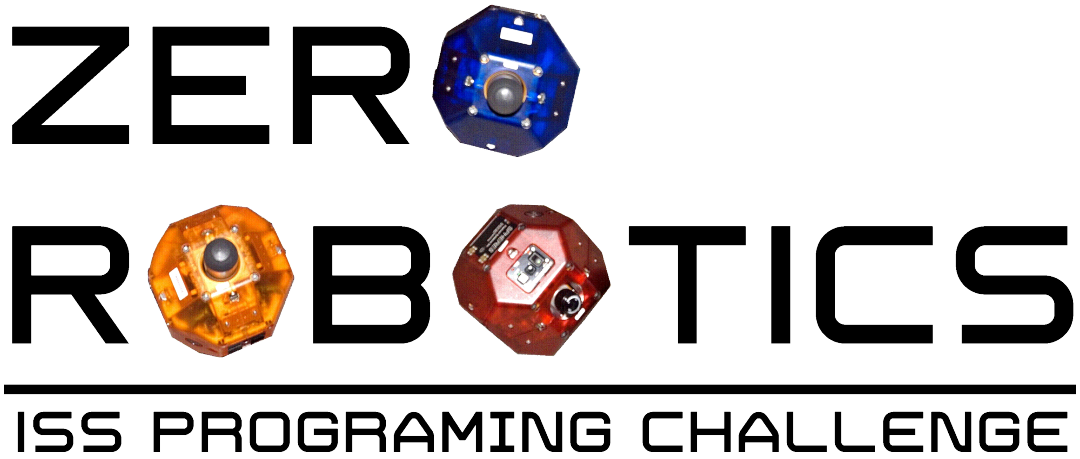


Getting to Know SPHERES

What Is in a Name?

"SPHERES" = Synchronized Position Hold, Engage, Reorient, Experimental Satellites

Let's see what that means . . .

ISS025E013444

Fun Facts

- SPHERES are the size of a bowling ball
- The SPHERES first reached the ISS in 2006
- There are currently three SPHERES aboard the ISS
- Each satellite is self-contained with power, propulsion, computers and navigation equipment
- The three satellites float freely in the ISS and perform flight formations much like the Blue Angels (check out this video)

What Are SPHERES?

Used as a testbed for computer programs—allow scientists to try out many versions of programs

Main purposes:

1. Test spacecraft docking
2. Test how spacecraft can fly in formation

Why SPHERES?

- Working in space is challenging:
  - —conditions are tough (i.e., no gravity, cold, huge distances),
  - —equipment used is very expensive,
  - —getting large pieces of equipment into space is expensive and/or impractical, and
  - —results of failure can be disastrous
- Spacecraft and satellite maneuvers are preprogrammed (humans cannot guide remotely using real-time visual feedback)

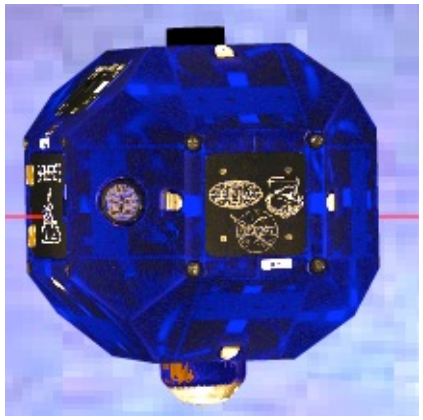
How Can SPHERES Help?

- Testing spacecraft docking:
  - Make it easier and cheaper to assemble new large spacecraft, like a new Space Station or a transport to Mars
  - Help to recover old spacecraft and reuse them or dispose of them safely (instead of them floating forever around Earth)
- Testing fly in formation:
  - Share features, such as computers and antennas, among satellites
  - Create future space telescopes (the grandson of Hubble, 15–20 years from now)

Watch tests aboard the ISS to see SPHERES at work

ZERO ROBOTICS
ISS PROGRAMING CHALLENGE

View of a SPHERES from all sides



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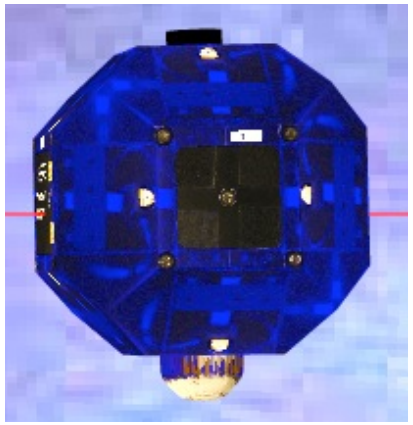

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(known as the Velcro face because it has Velcro on it!)

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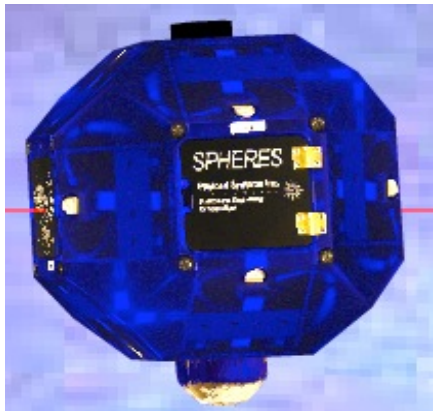

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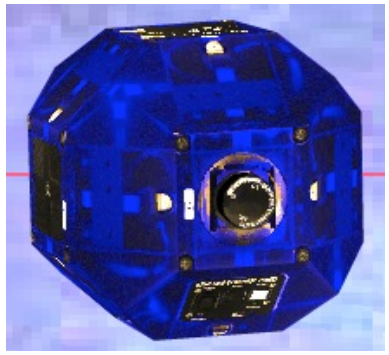

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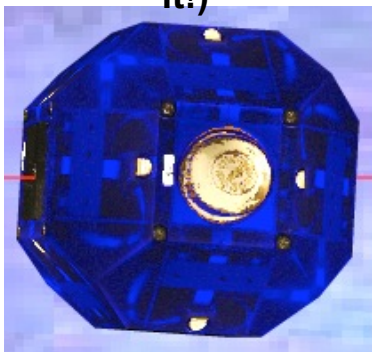

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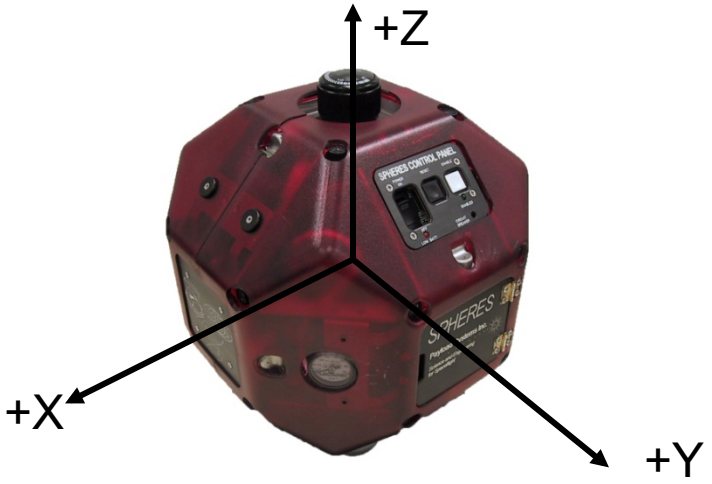
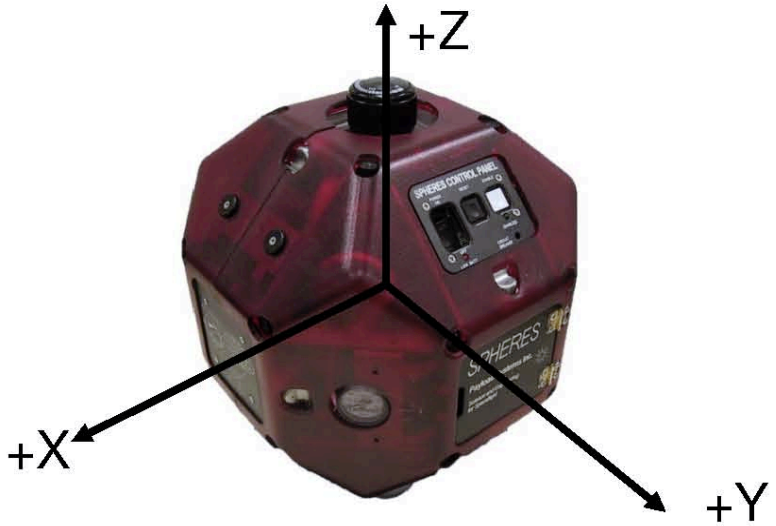
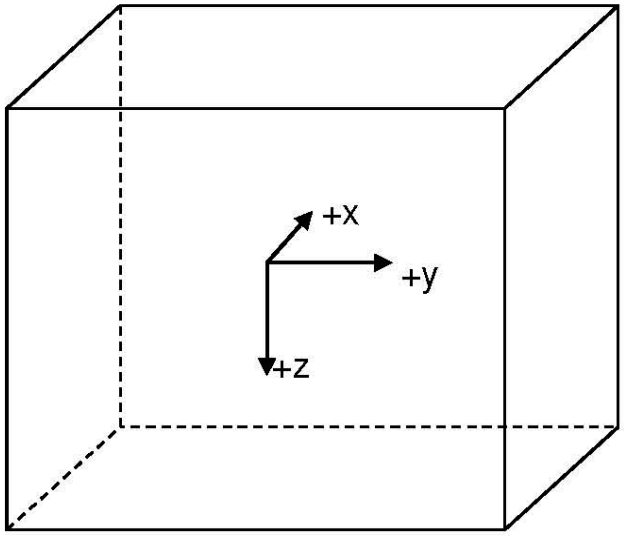


Local vs. Global Coordinate Systems

- Two separate systems for movement
- **Global system:** space that SPHERES move around in (in simulation or on the ISS)
- **Local system:** orientation of satellite itself



Local system



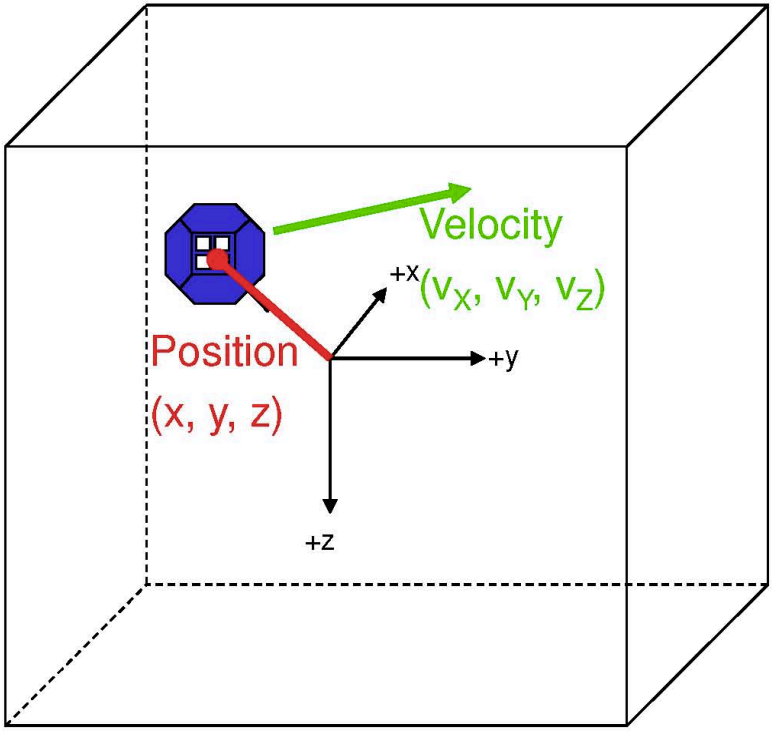
Global system

You will learn more about coordinate systems later in Week 1

What State?

State describes how local coordinate system relates to global coordinate system

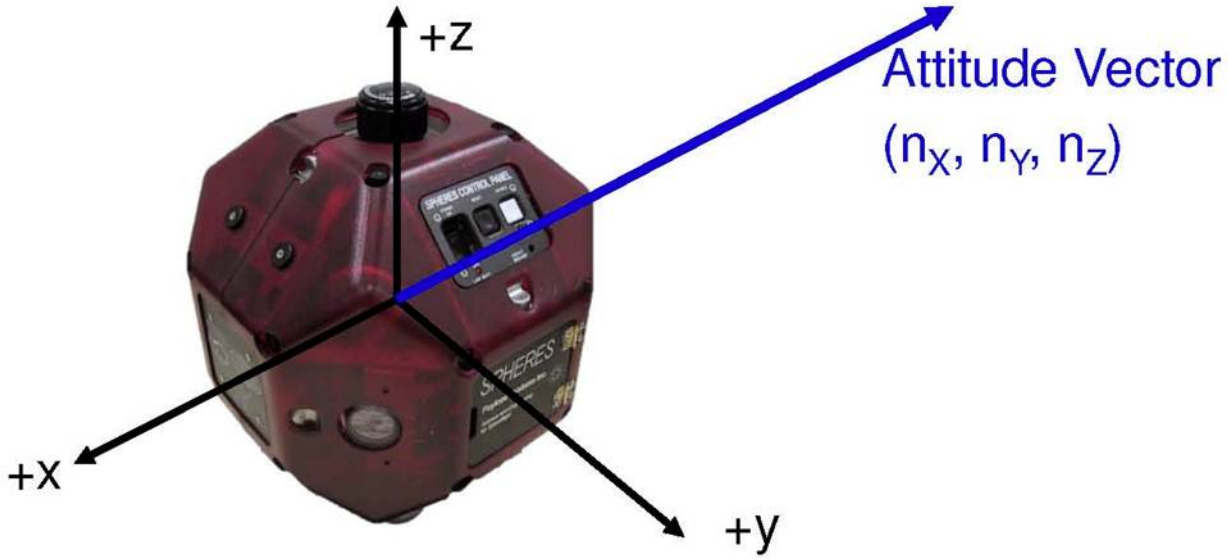
- **Position** (x, y, z) describes where center of the satellite is in global frame
- **Velocity** describes how fast and in what direction satellite is moving in global frame
- **Attitude** describes where satellite is pointing (i.e., describes how local coordinate frame is rotated within global frame)



You will learn more about "state" in Week 3

Attitude—Which Way Is It Turned?

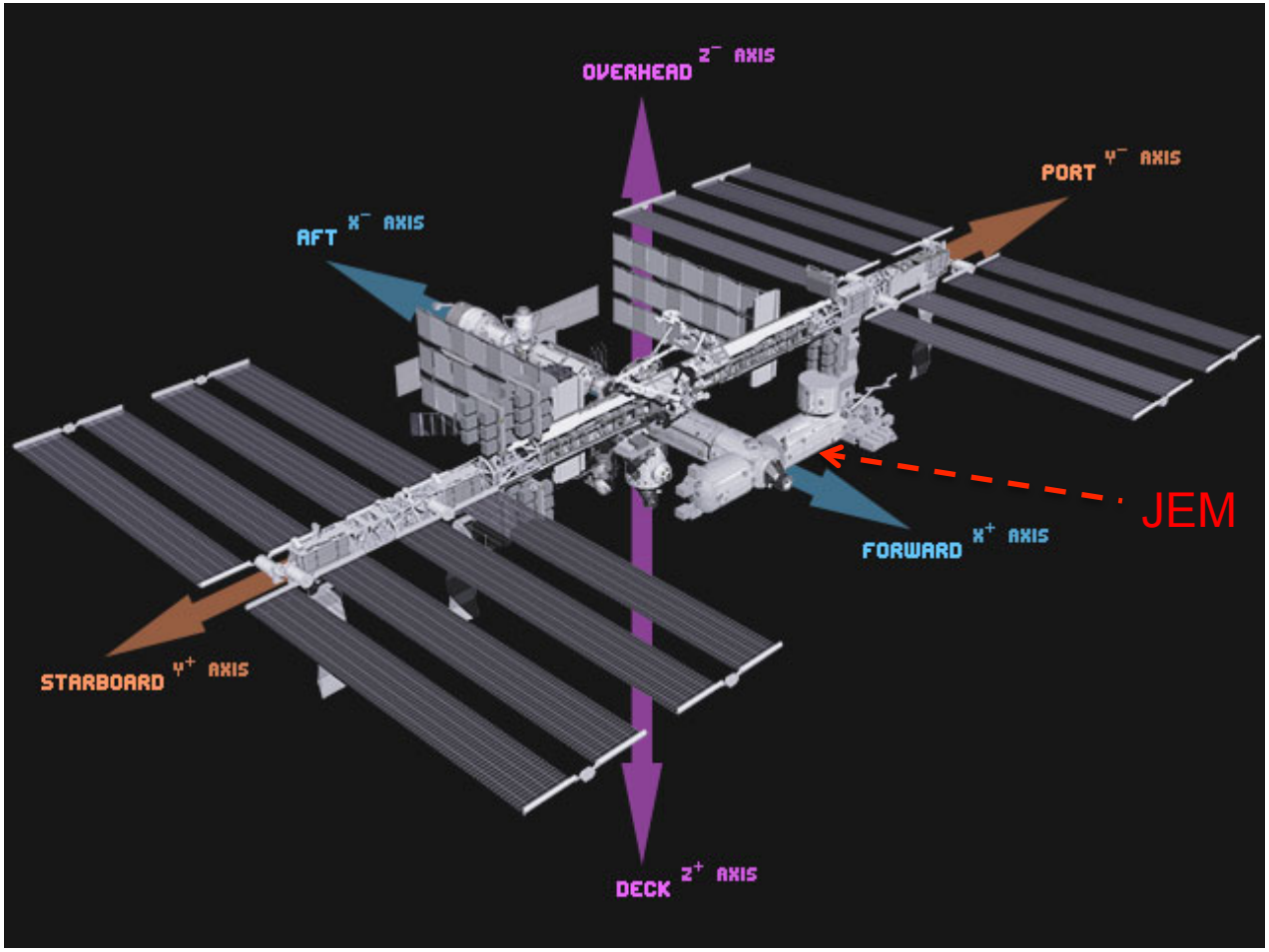
Attitude vector is a set of coordinates that indicate the direction of the –X (Velcro) face of satellite in global frame



You will learn more about Attitude at the end of Week 1

ISS Global Coordinate System

- The ISS Global Coordinate System for the US
  - Positive Z axis points toward the center of the Earth
  - Positive X axis points in the direction of travel
- Note the location of the JEM
  - Japanese Experiment Module



Japanese Experiment Module (JEM)

- SPHERES operate in the JEM Module as shown here
- Ship terminology is used to describe directions on the ISS:
  - Starboard (right)
  - Port (left)
  - Forward
  - Aft
  - Deck
  - Overhead

View from STARBOARD to PORT (towards airlock)
(looking along y axis, toward -y)