ZERO ROBOTICS

SPHERES ISS CHALLENGE

Spinning: Torque

DARPA NASA CASIS [TOPCODER] MAP Aurora SSL MIT

Rotational Motion

- At this point, you are pretty well versed in translational motion. It's now time to get into rotational motion.
- We'll start our focus on rotational motion by learning how to spin. You already know how to rotate to face a direction, but you don't know how to continuously change your attitude yet. To do this, we can use the function **setTorques**.
- In this tutorial you will:
  - learn the basics of rotational motion and torque
  - practice using body frame controls
  - control direction of spin with cross products and the right hand rule

setTorques

- **Torque** is the rotational equivalent of force. It causes rotational motion and **angular acceleration**.
- Like setForces, setTorques is an open loop control function. setTorques doesn't use a target value; it sets the rotational impulses to be applied to the satellite every time the thrusters fire.
- Also like setForces, setTorques can be used with closed loop control functions, but be very careful.

ZERO ROBOTICS SPHERES ISS CHALLENGE

Axis of Rotation

- All of the functions we have covered so far operate on the **global frame**, meaning that the x-, y-, and z-components refer to the axes of the coordinate plane.
- setTorques operates on the **body frame**, meaning that the x-, y-, and z-components refer to the axes of the satellite.

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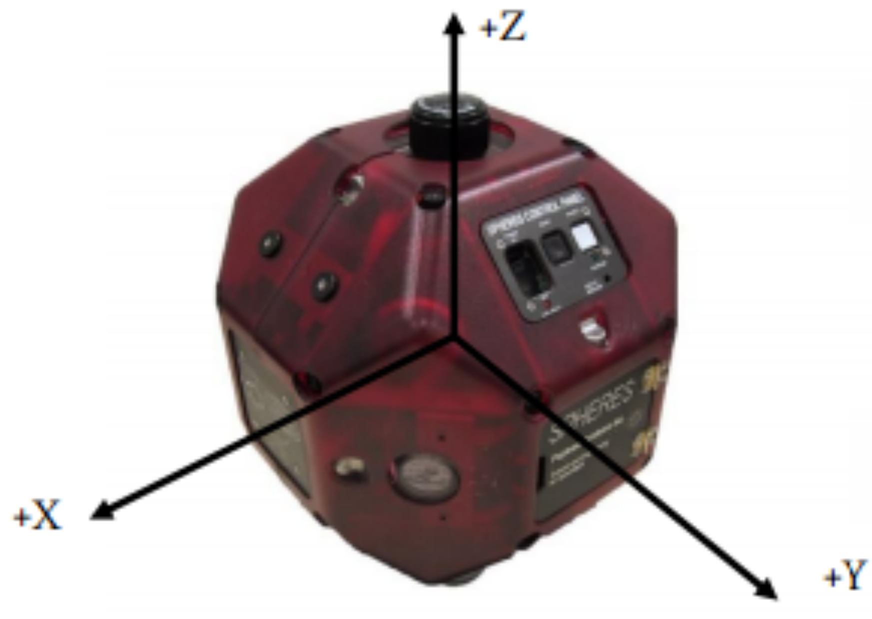
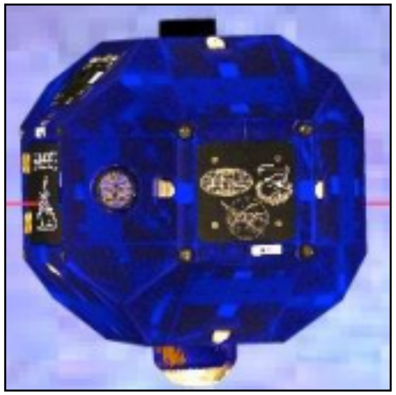
SPHERES Dimensions



SPHERES Faces



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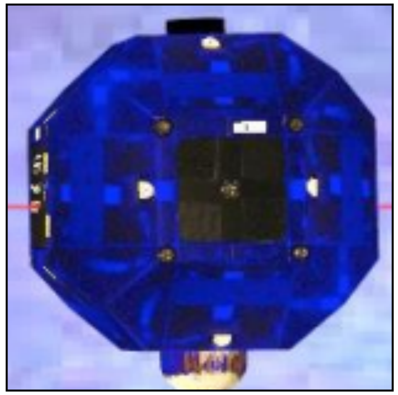

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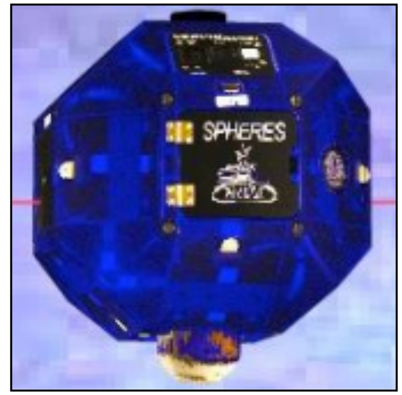

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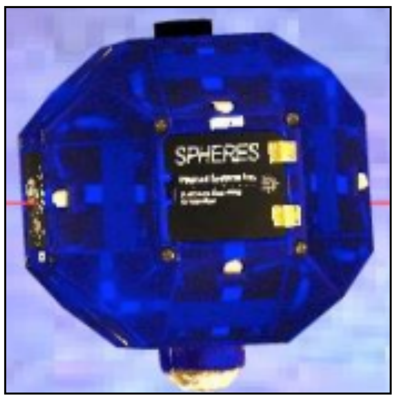
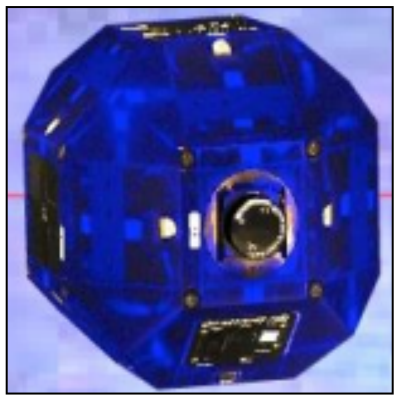
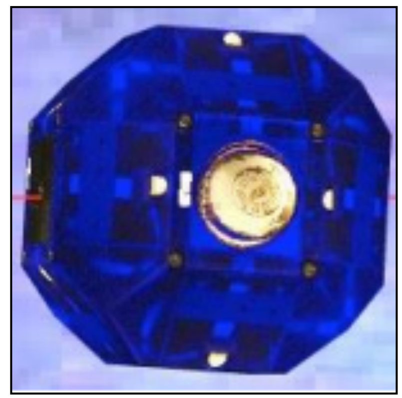


-Y



+Z



-Z

Cross Product

- Torque (**τ**) is equal to the **cross product** of force and radius.

$$\boldsymbol{\tau} = \mathbf{F} \times \mathbf{r}$$

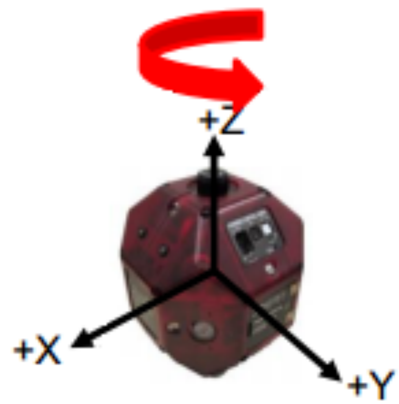
- The cross product of two vectors is a resultant vector that is perpendicular to *both* original vectors. We will revisit cross product later.
- For now, just know that torque is always parallel to the axis of rotation.

Axis of Rotation

- You will need to know how to control the direction of spin. As we've mentioned before, setTorques operates on the body frame.
- Associate a **positive** value with **counter-clockwise** rotation.
- Associate a **negative** value with **clockwise** rotation.
- See the next slide for an example.

Axis of Rotation

- For example, if we set a positive value for the z-component of torque, the satellite will rotate counter-clockwise on its z-axis like this:



- We'll show you a few tips later to help you better understand direction of spin. But first, let's code!

Try It

- Create a new project called Project16. Create an array called **torques** and initialize it with a very small value for the z component.

```
float torques[3];

void init(){
  torques[0]=0.00;
  torques[1]=0.00;
  torques[2]=0.01;
}
```

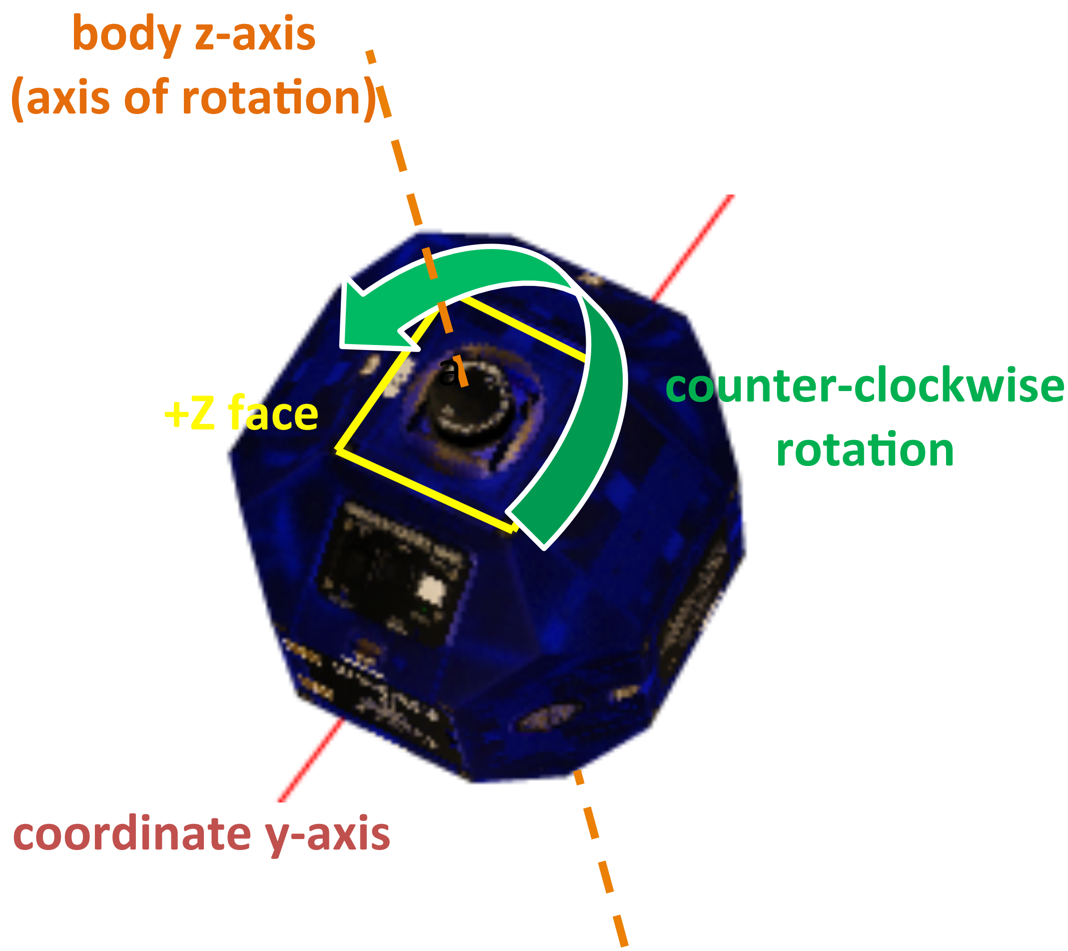
- setTorques to torques and run the simulation.

```
void loop(){
  api.setTorques(torques);
}
```

Results

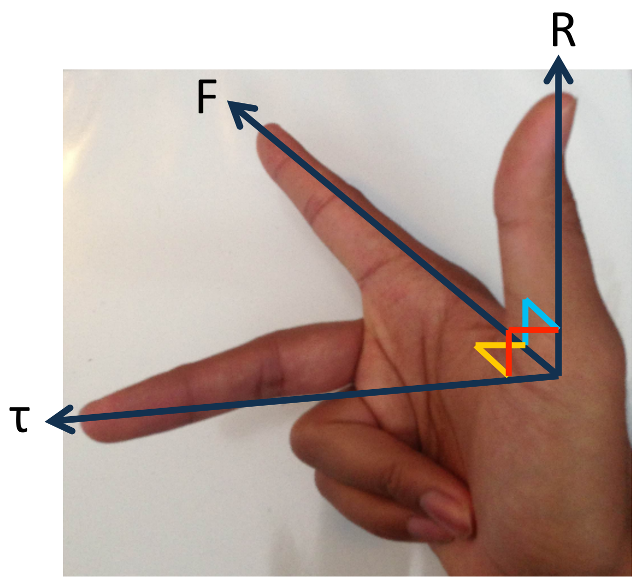
- We expect the satellite to rotate counter-clockwise on its z-axis because we set a positive z-component value.
- One way to test this is to rotate the coordinate plane so that the +Z face of the SPHERE is facing you (see Slide 6). It might help to zoom in.
- The satellite is clearly rotating counter-clockwise, so our code passes.

Results


body z-axis
(axis of rotation)
+Z face
counter-clockwise
rotation
coordinate y-axis

Right Hand Rule

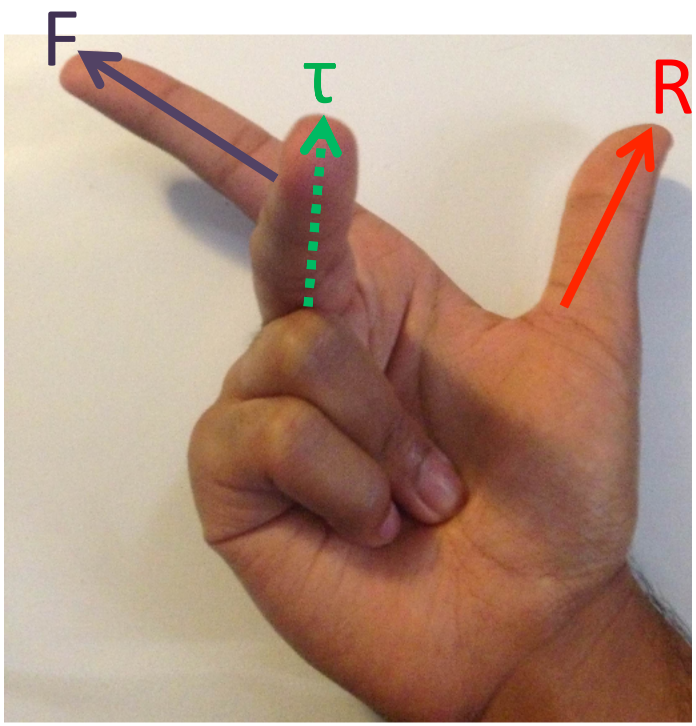
- Another way to test if your satellite is spinning the right way is to use the **right hand rule**. To understand the right hand rule, we will need to revisit cross products.
- Torque is the cross product of force and radius. The right hand rule lets us visualize this with our fingers.

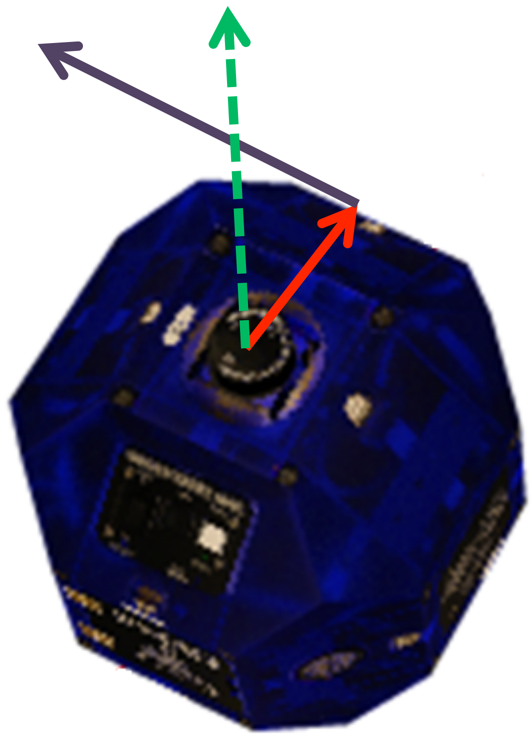


Right Hand Rule

- Your thumb represents the radius of the SPHERE.
- Your index finger represents the direction the SPHERE is turning.
- Your middle finger represents torque.
- Let's try this for our simulation. Before you see the diagram on the next page, try it yourself.
- Rotate your hand so it lines up with the satellite. The rotational force spins the satellite counter-clockwise, so torque should point out of the +Z face.

Right Hand Rule





Stabilization

- As you may have noticed, rotation using setTorques is unstable. The wobble is distinctly noticeable around 15 seconds, and the spin becomes increasingly shaky as time progresses.
- Before you start thinking about ways to stabilize your spin algorithm, go on to the next tutorial on angular velocity. Good job for making it this far!