# Intermediate Axis Theorem with Shifting Weights

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## Goal

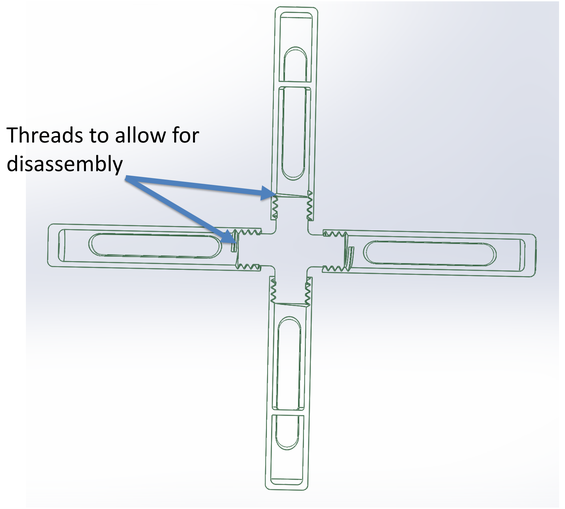
The *Intermediate Axis Theorem* is one of the more surprising things to learn within Newtonian mechanics. This theorem is difficult to explain conceptually and is not intuitive. Because of this, we wanted to create a way to demonstrate the effect of the Intermediate Axis Theorem on a system that contains moving weights.

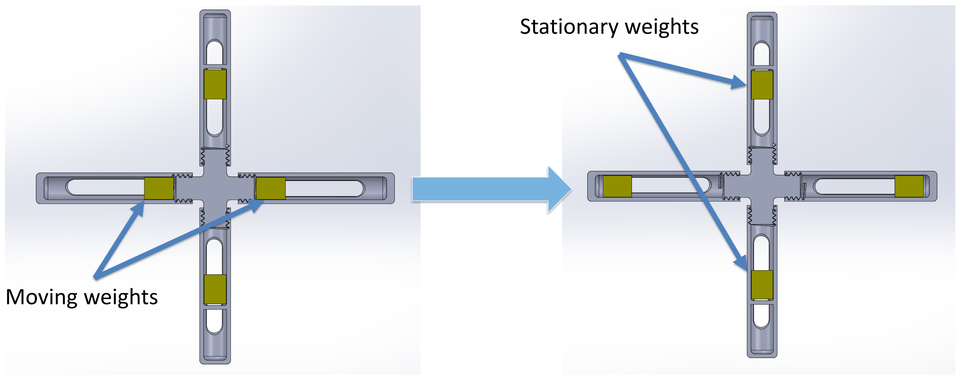
One of the most popular videos to demonstrate the Intermediate Axis Theorem is of a T-handle being spun on the ISS. As it spins you can see the T-bar flipping orientations.

Our design will show this effect, but with the additional component of weights which move as a result of the chaotic rotations. We hope to create a video of the object rotating either in microgravity or simulated microgravity through freefall.

## Design

Demonstration Experiment for the International Space Station




## Design Process

Many important factors had to be considered in order to make this design effective at demonstrating the effect of shifting weights with the Intermediate Axis Theorem while also making this design safe for potential experimentation on board the ISS. Some factors were:

- Material off-gassing
- Heat production (from motors)

The first problem was how to allow the weights to move during a chaotic spin without the use of motors. We solved this problem by taking advantage of the inertial centrifugal force, which 'pulls' the weights to the outer portion of the tubes as they spin.

The design was also created to be collapsible in order to allow for easy transportation to the ISS. The 4 tubes can unscrew from the center joint for compact storage

## Initial Findings

Through simple tests of spinning the apparatus while in freefall to simulate zero gravity, we were able to make some preliminary observations of what occurs as this object spins in freefall.

When spun about its unstable axis with the shifting weights in their starting position, the object undergoes 1-2 initial rotations before the chaotic flip occurs. This results in the shifting weights being moved towards the outer ends of the apparatus, changing which axis is the intermediate axis.

Additionally, this change in moments of inertia causes the apparatus to stop its spin about the previously unstable axis and to now instead spin about the new unstable axis.

As a result, the apparatus continues to flip chaotically.

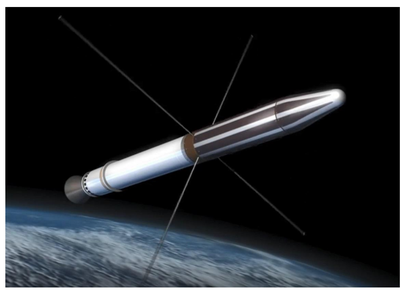
Having consulted astronauts and physicists, we also suspect that after an extended period of time, the apparatus will undergo a flat spin as it is the lowest energy state.

## Applications

- Satellite Stabilization and Orientation:

  This experiment demonstrates concerns that impact the design of satellites because if a satellite uses angular momentum to stay stable, chaotic rotations could be catastrophic for the satellite. Additionally, with motors implemented in this design, it could be possible to use the chaotic rotations in order to reorientate the satellite in a controlled manner without the need for propulsion systems.

  Some satellites have failed as a result of chaotic spins. One example of this is Explorer-1, which used extending wires in order to reduce its angular rotation, but this resulted in a non-rigid body which dissipated kinetic energy and fell into a flat spin.



Explorer 1 Artist Rendition - NASA