

Flux-Pinned Interfaces for the Assembly, Manipulation, and Reconfiguration of Modular Space Systems

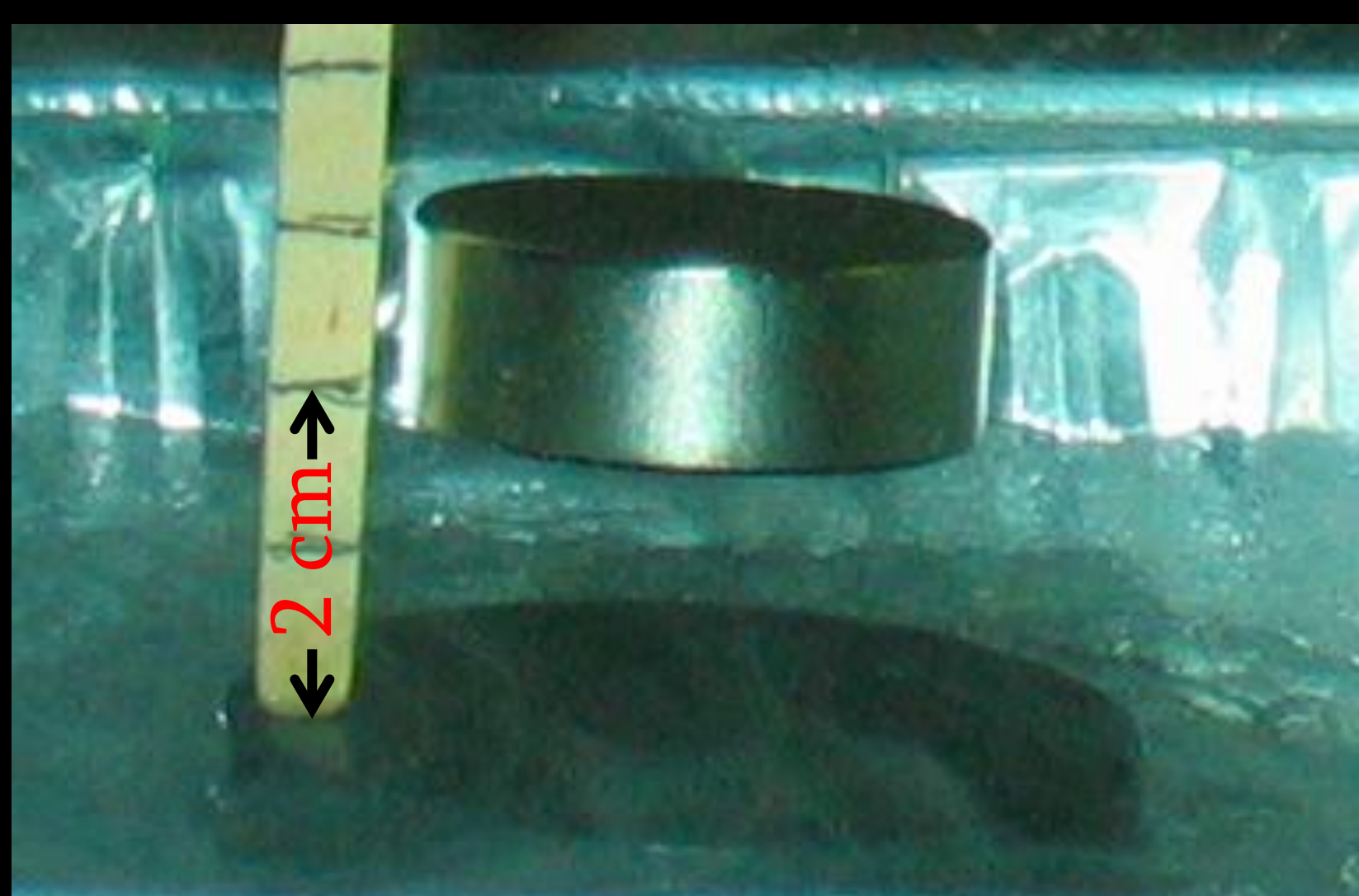
Joseph Shoer

jps87@cornell.edu

Mason Peck, Ph.D., advisor

mp336@cornell.edu

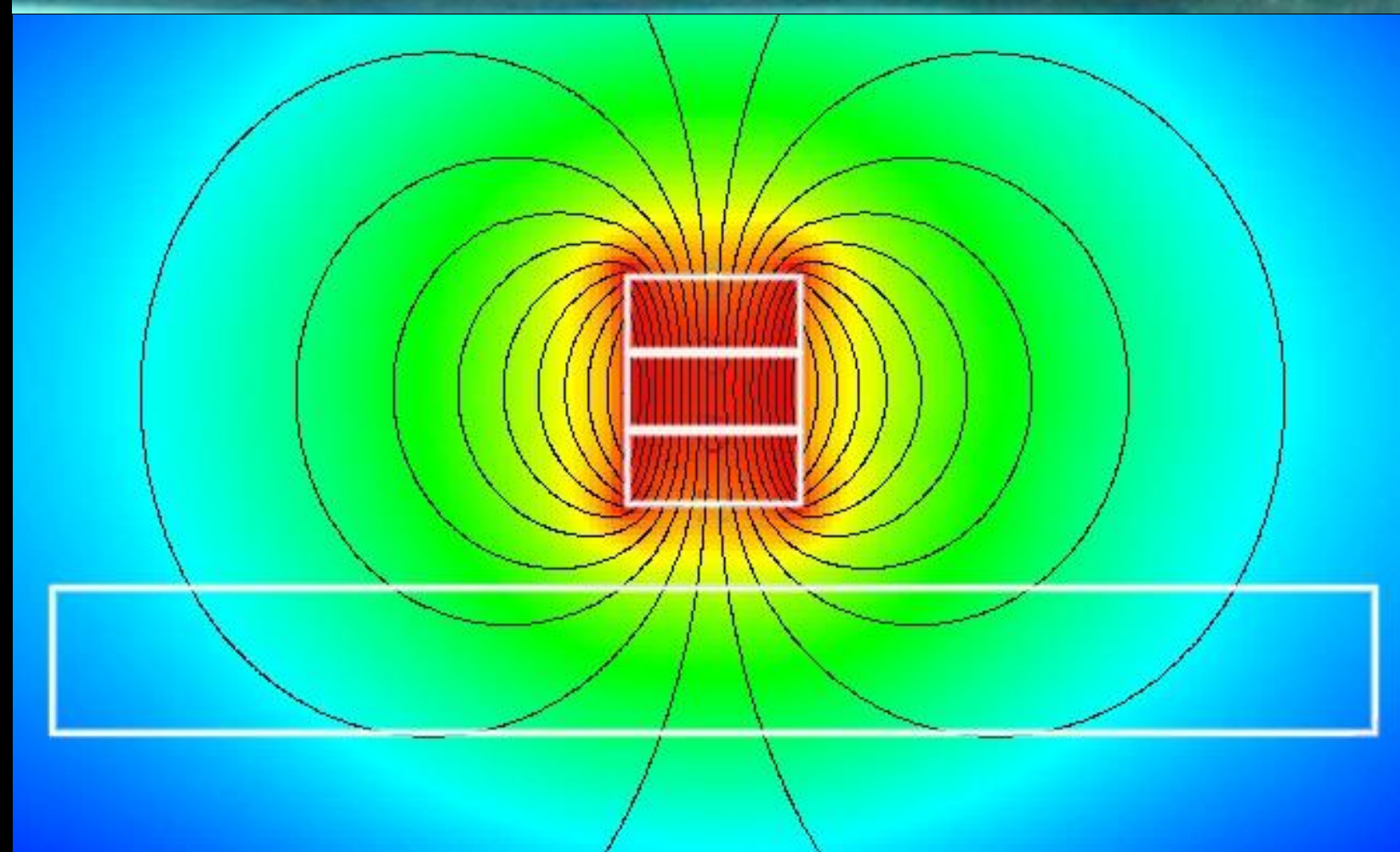
Magnetic Flux Pinning: Surprising Physics



Magnetic flux lines penetrate a type-II superconductor and become trapped or "pinned."

This unusual **action-at-a-distance** phenomenon is very attractive for modular spacecraft applications:

- The temperature dependence of the superconductor is suitable for the space environment
- Flux pinning defines a **stable, many-DOF equilibrium**
- Pinning provides **high stiffness** for small motions
- It provides very **high damping**



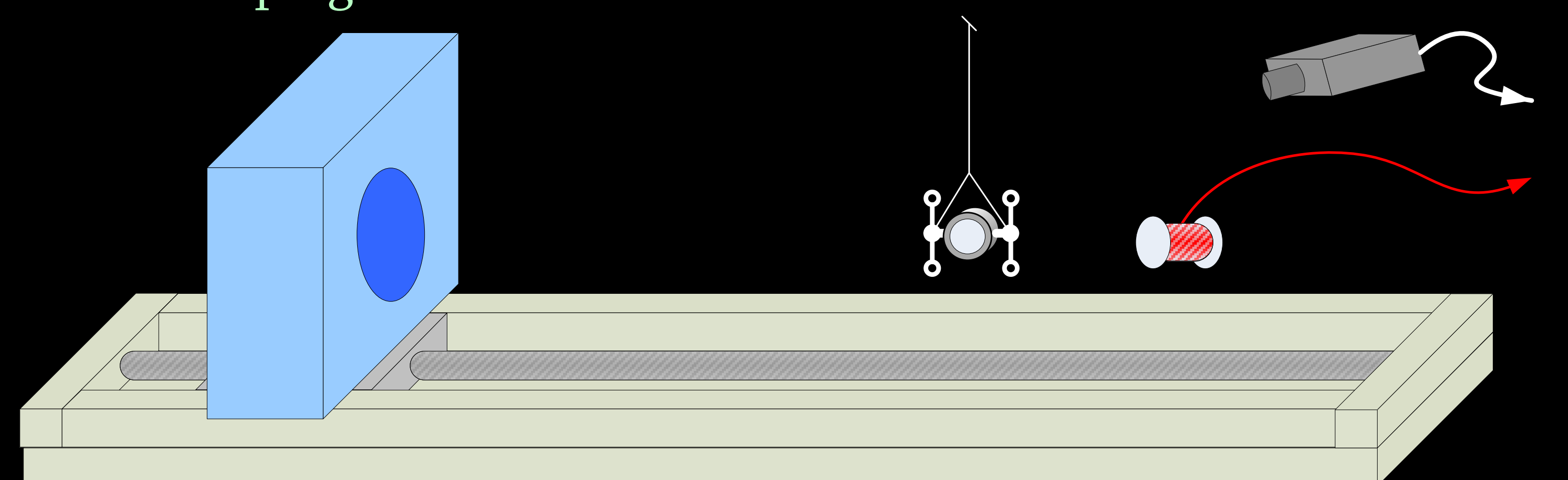
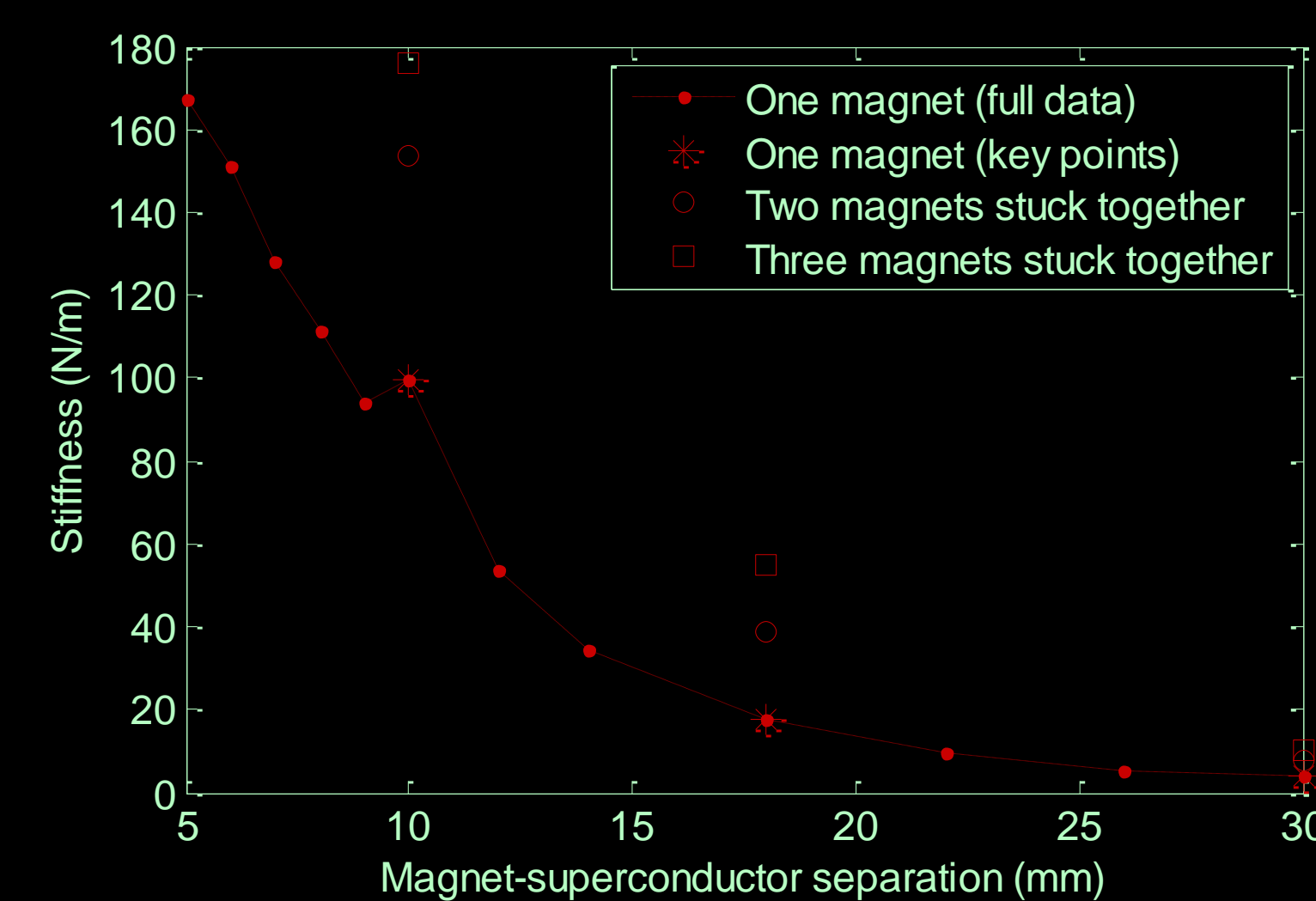
Quantifying Flux Pinning

2007: Quasistatic measurements of stiffness over distance

Stiffness: $\sim 5 \rightarrow >200 \text{ N/m}$

2008: Dynamic measurements of stiffness, damping, and new actuation methods

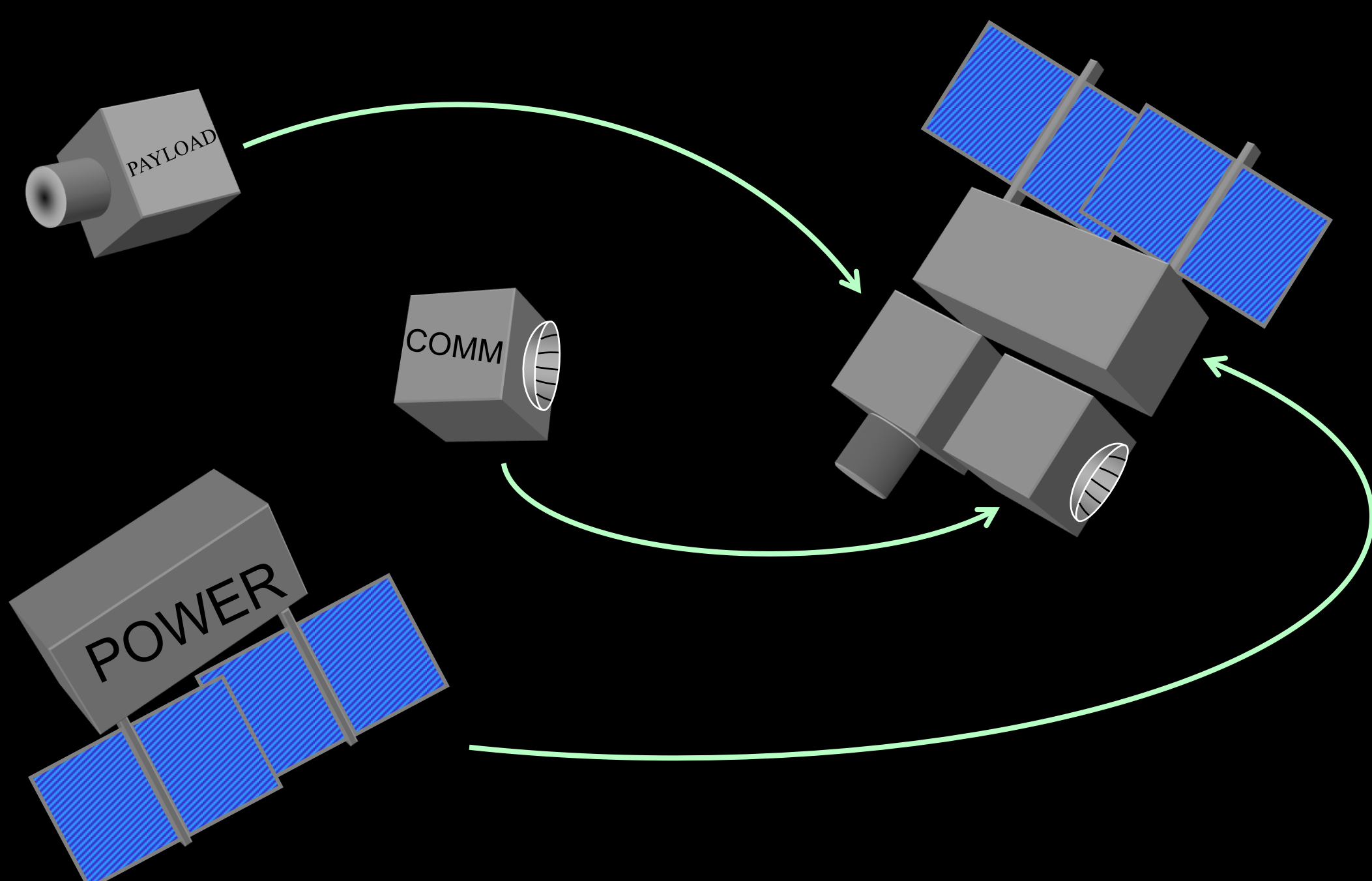
Damping: $\sim 1 - 10\%$ of critical



Dynamic experiment: magnetic pendulum, tracking camera, perturbing coil

Spacecraft Applications

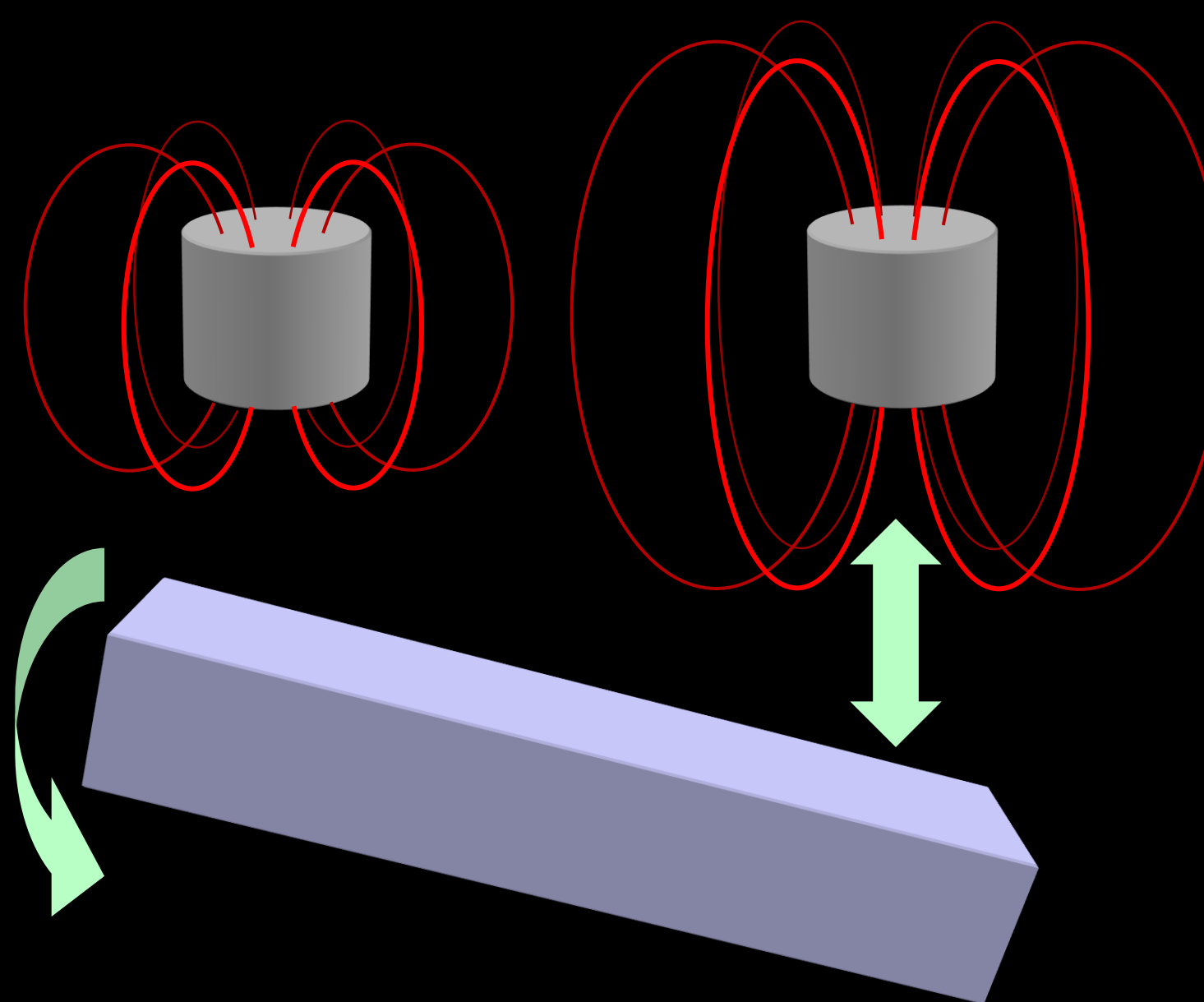
Assembly



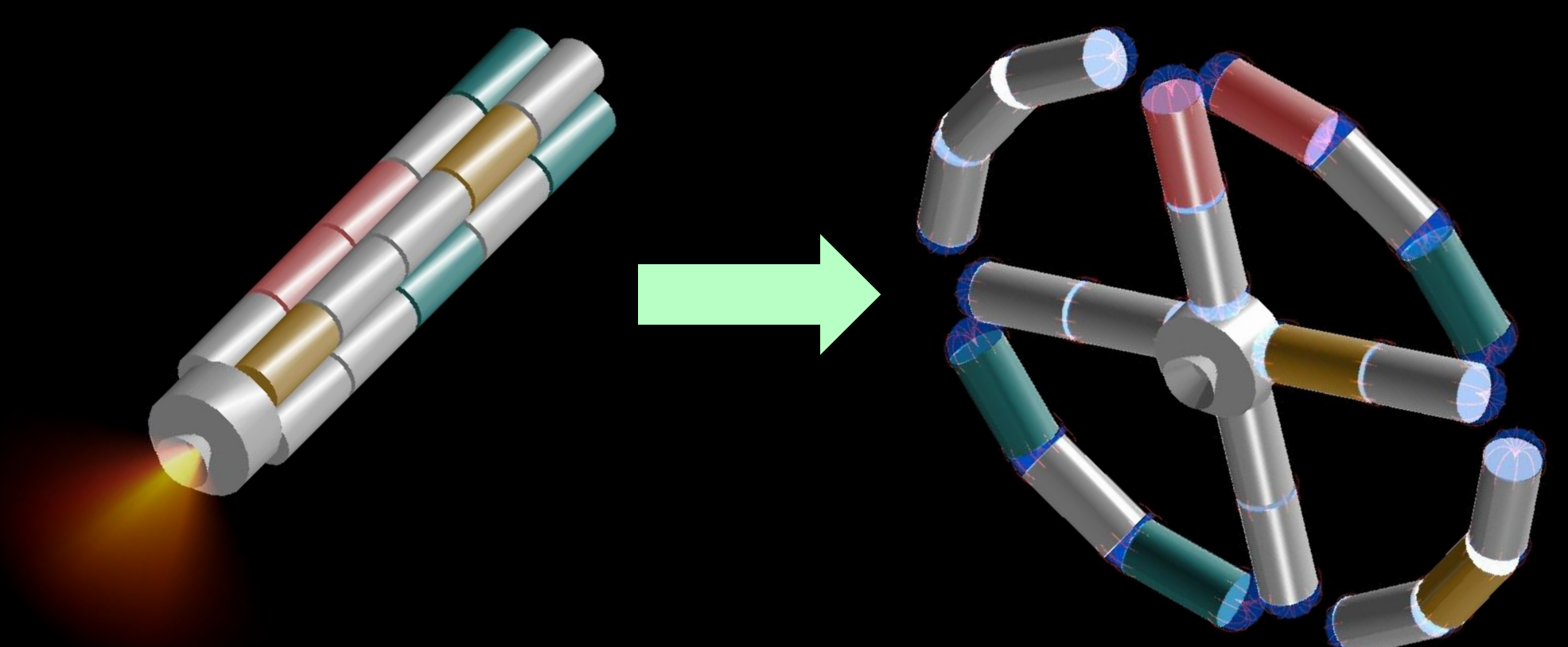
- **Passive:** utilize a large basin of attraction
- **Low power:** sunshades keep superconductors cold and toggle pinning interfaces
- **Robust:** avoid risks from physical contact

Manipulation

- **Actuate** with magnetic fields
- **Deploy** systems without contact
- **Capture** other spacecraft
- **Exchange momentum** between components

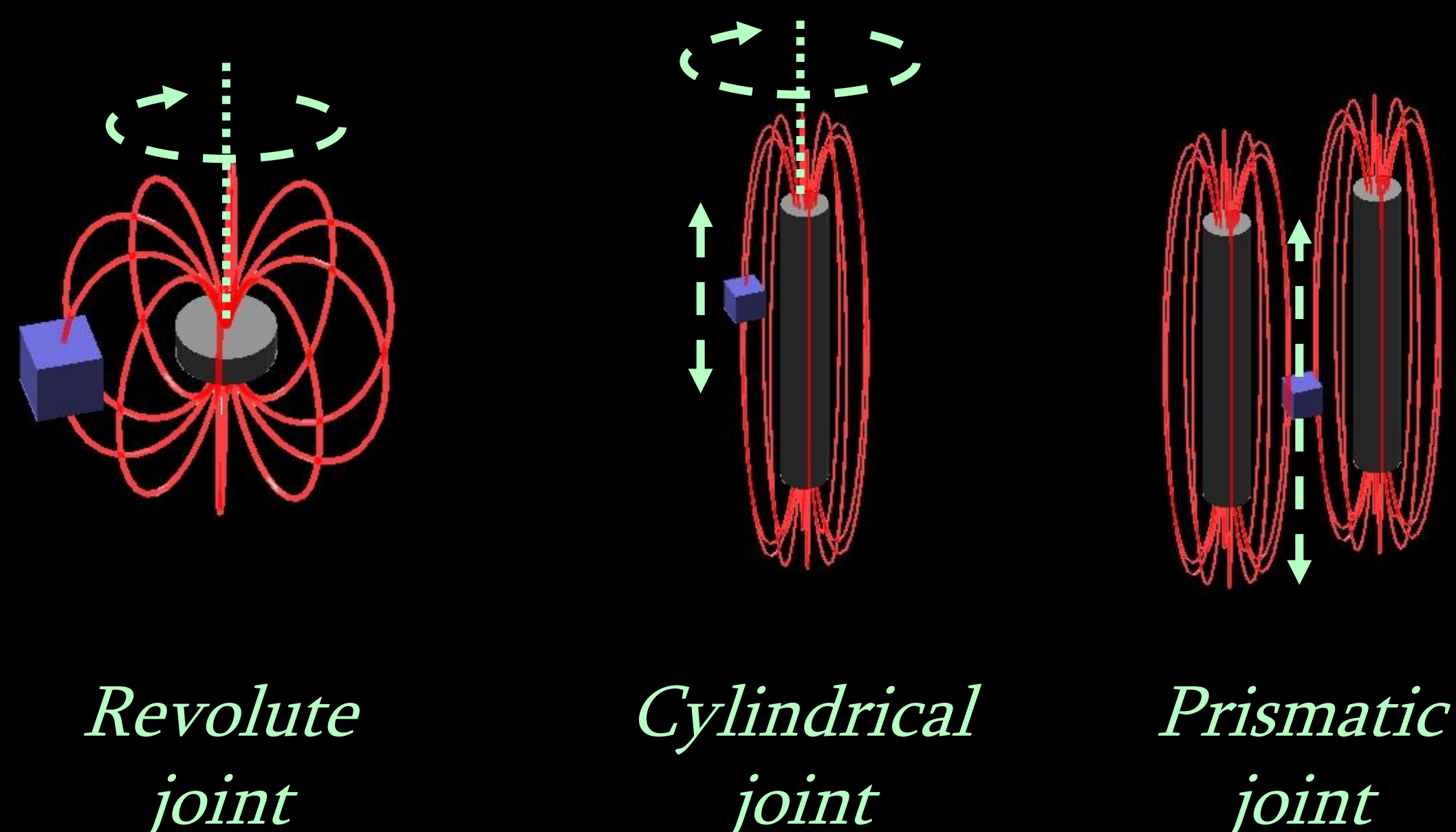


Reconfiguration



- **Scalability:** Add more functionality to the spacecraft at any time
- **Self-repair:** reject and replace broken or obsolete modules
- **Adaptability:** respond to new mission objectives or changing mission requirements

Flux-Pinned Kinematic Mechanisms for Reconfiguration



Flux pinning **constrains** motion in the direction of a magnetic **field gradient**. Other motions remain free.

This principle allows flux pinned **hinges** and **joints**, and therefore the creation of **kinematic mechanisms**.

Modular spacecraft can form a mechanism to **reconfigure deterministically** rather than relying on active control.

