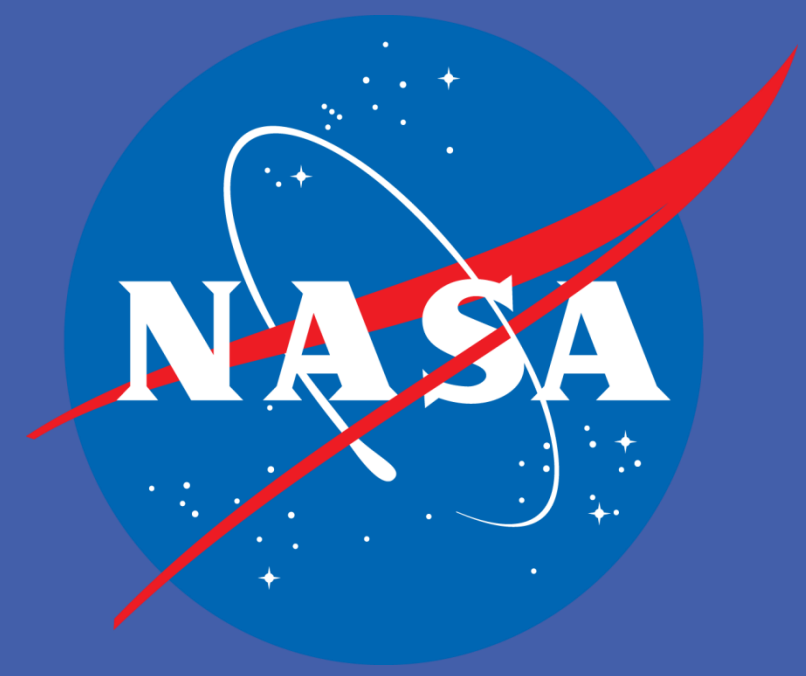


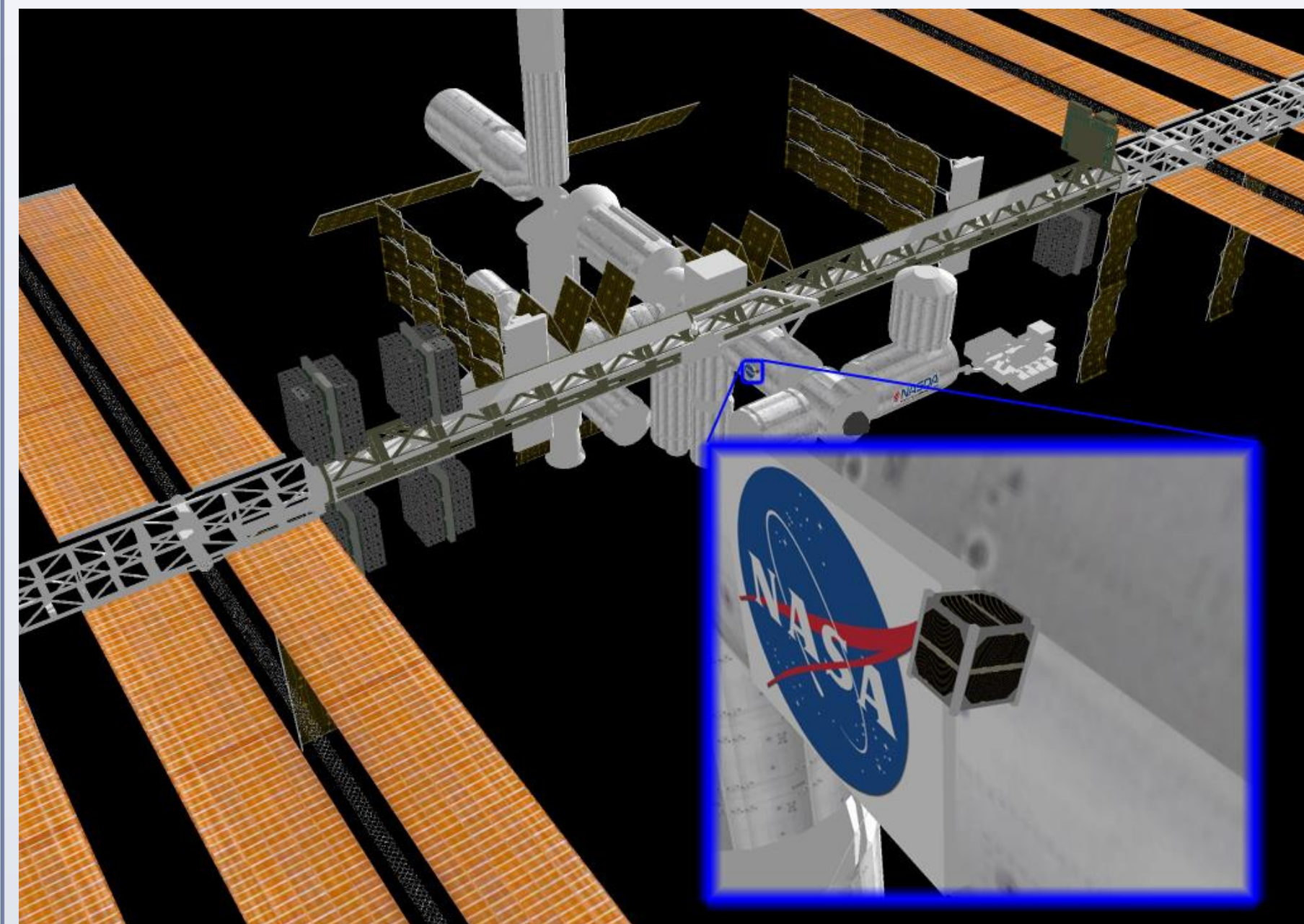
A New Actuator of On-Orbit Inspection

Benjamin Reinhardt and Mason Peck

Cornell University



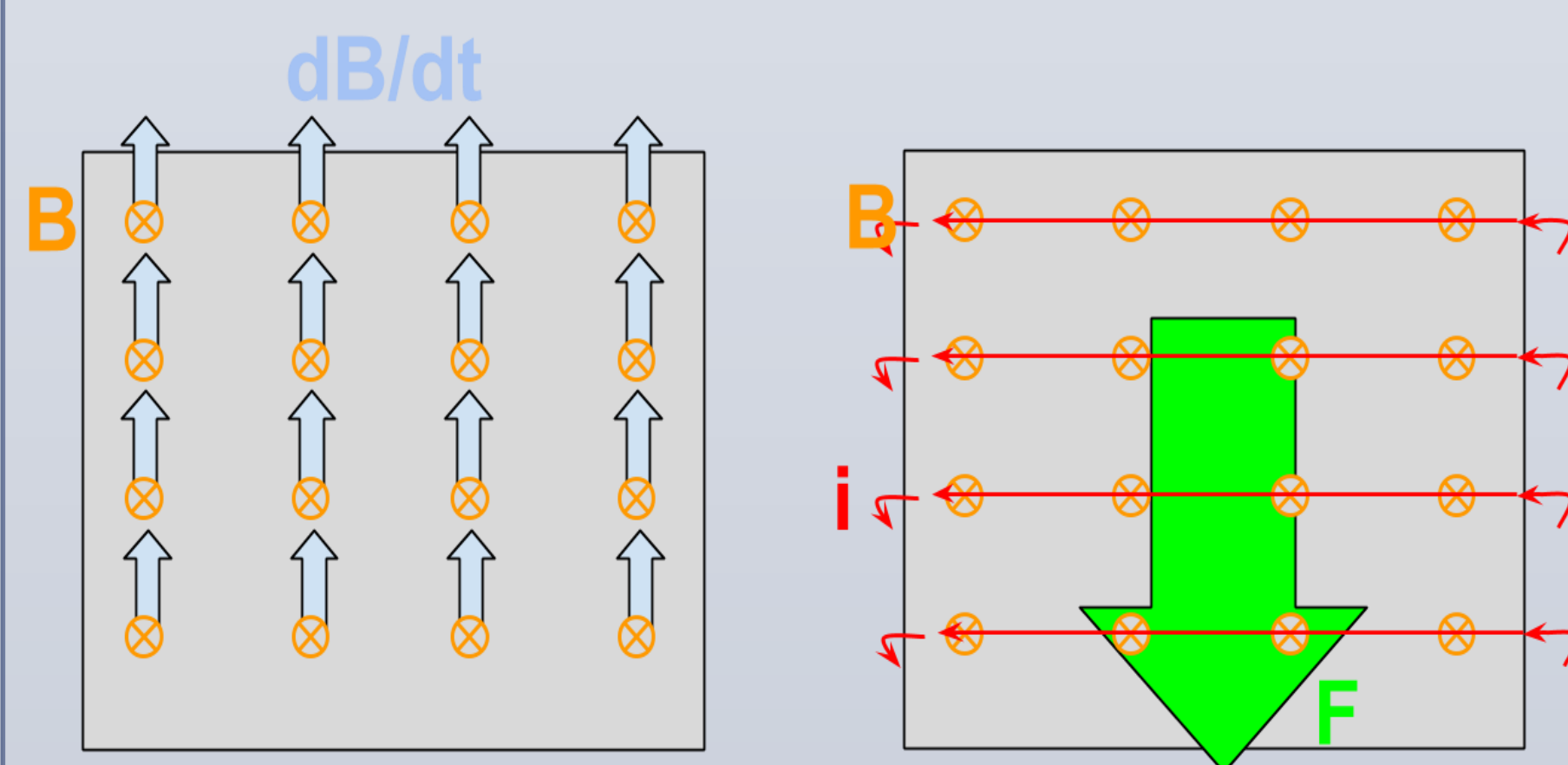
On-Orbit Servicing



Why On-Orbit Servicing?

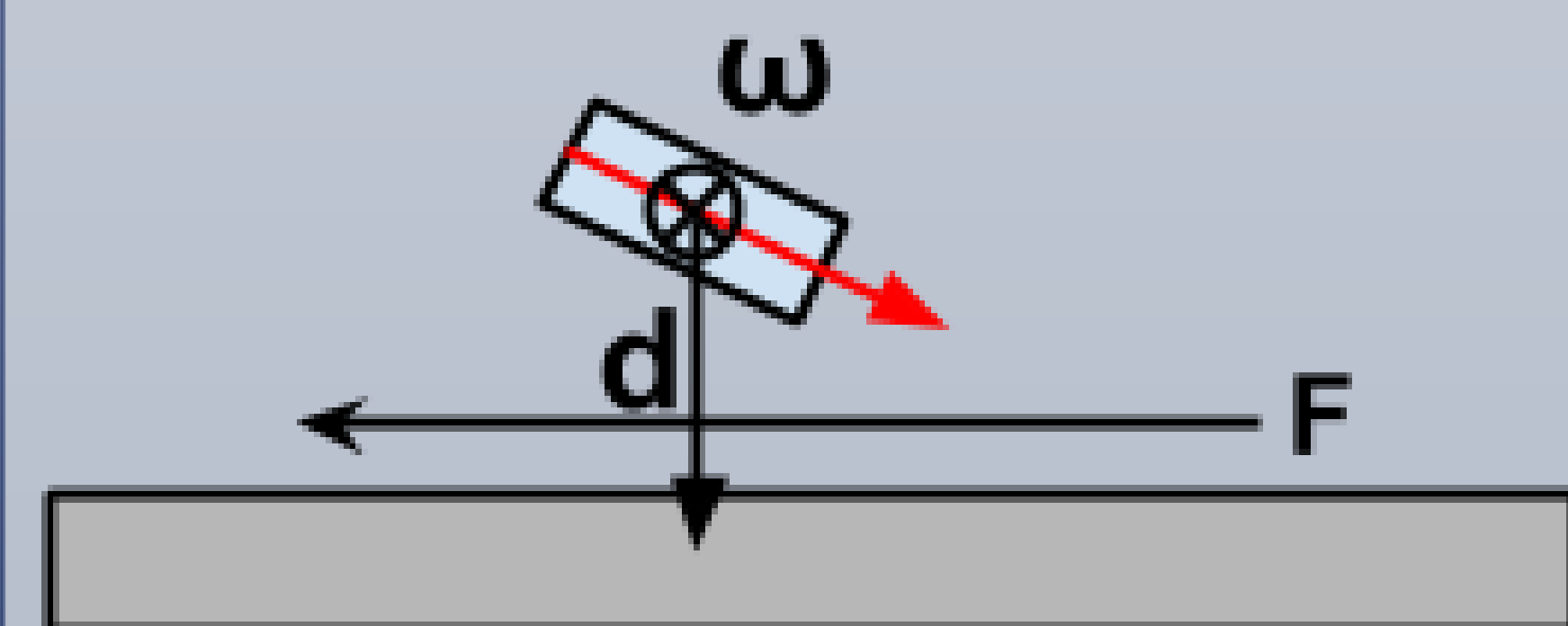
- Autonomous inspection
- Repair, refuel, and repurpose satellites
- Lowers the cost of space operations

Eddy Currents

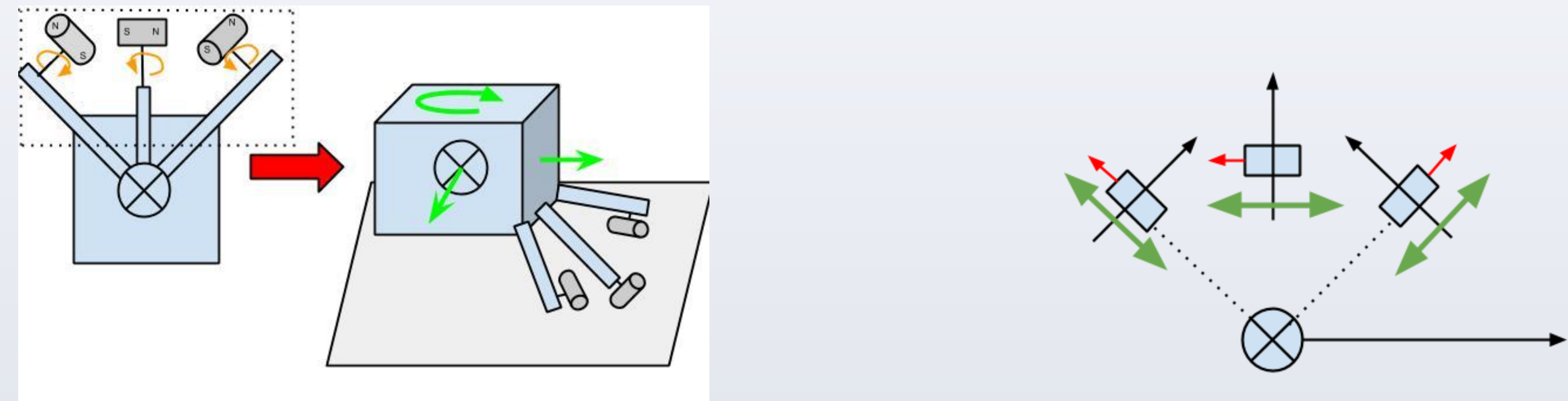


Why Eddy Currents?

- 6 Degree-of-Freedom Actuation
- No dangerous grappling
- Purely electric power – no propellant
- Built-in collision avoidance



Design and Control of An Inspection Spacecraft



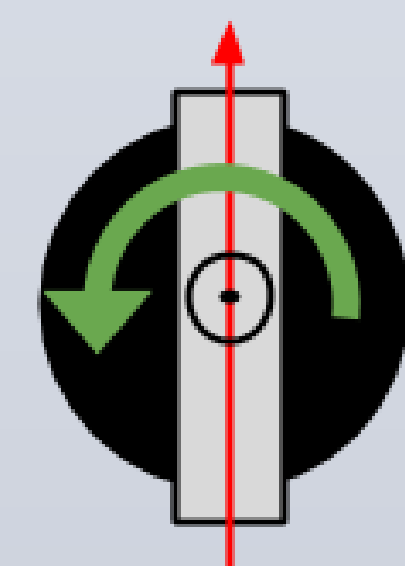
Above: Example design of a planar inspection vehicle and its induction coupler layout.

- Three arrays of spinning magnets provide 3 degree-of-freedom control.

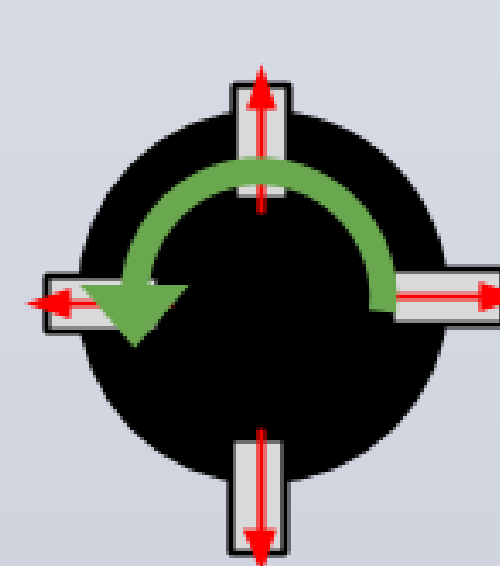
Below: Rotating permanent magnets comprise an induction coupler array.

- The angular velocity of the arrays control the forces and torque on the inspector.
- The Jacobian mapping between array speeds and actuation forces depends on the system geometry.

One Magnet Array



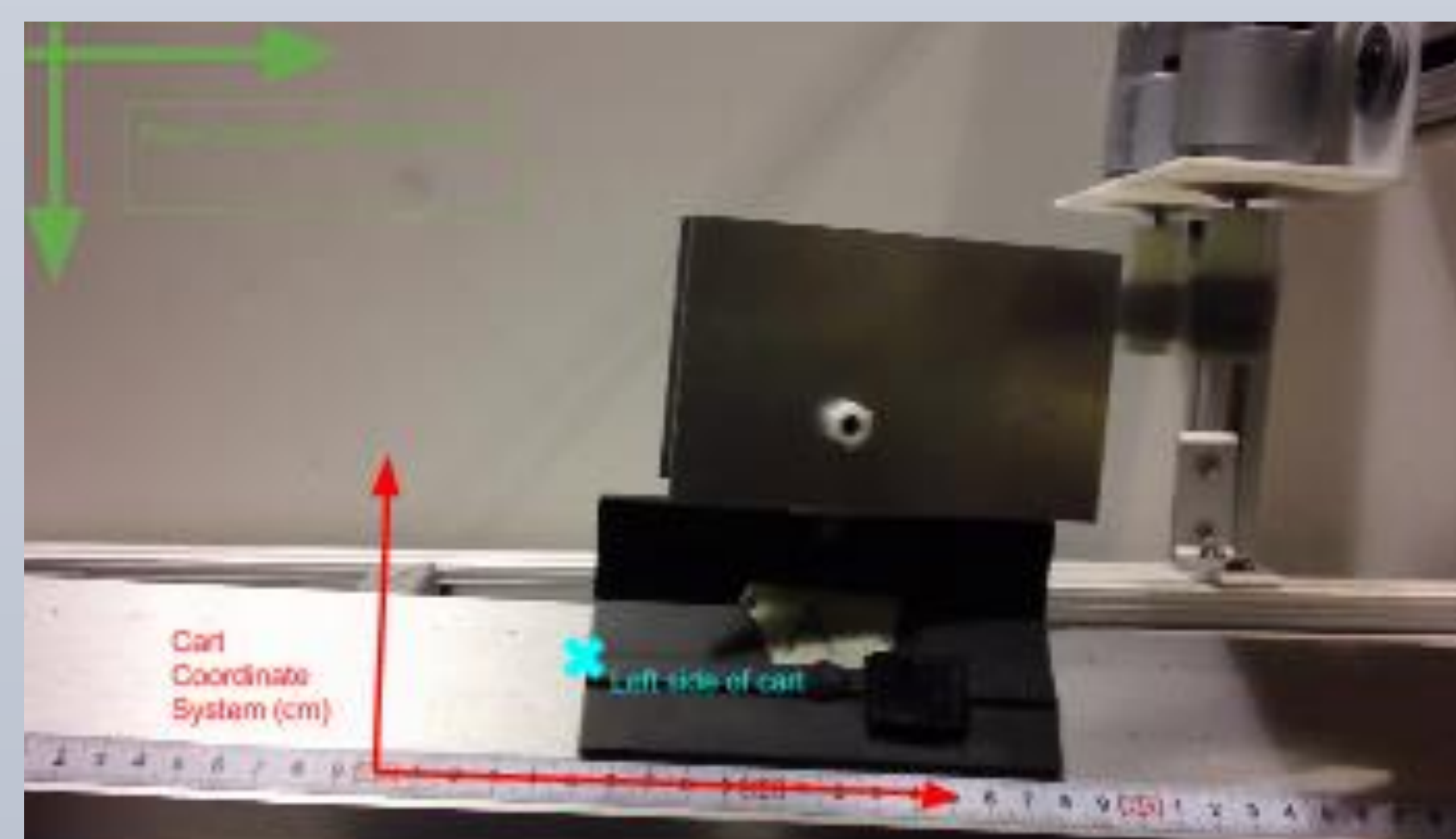
Four Magnet Array



$$\begin{bmatrix} F_x \\ F_y \\ \tau \end{bmatrix} = C \begin{bmatrix} \cos(\phi_1 - \pi/2) & \cos(\phi_2 - \pi/2) & \dots & \cos(\phi_N - \pi/2) \\ \sin(\phi_1 - \pi/2) & \sin(\phi_2 - \pi/2) & \dots & \sin(\phi_N - \pi/2) \\ r_1 \cdot \hat{a}_1 & r_2 \cdot \hat{a}_2 & \dots & r_N \cdot \hat{a}_N \end{bmatrix} \begin{bmatrix} \omega_1 \\ \omega_2 \\ \dots \\ \omega_N \end{bmatrix}$$

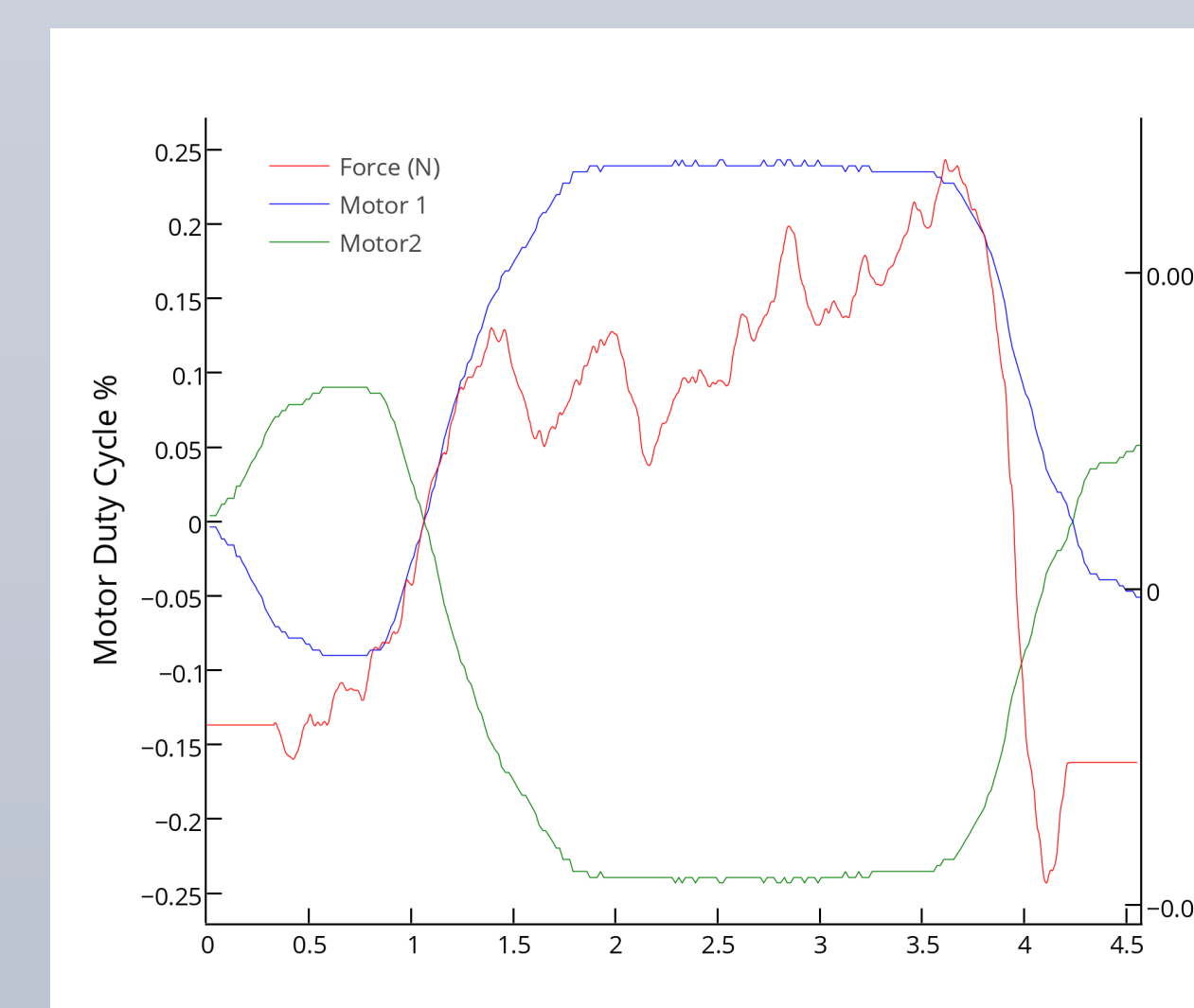
$$J = \begin{bmatrix} \cos(\phi_1 - \pi/2) & \cos(\phi_2 - \pi/2) & \dots & \cos(\phi_N - \pi/2) \\ \sin(\phi_1 - \pi/2) & \sin(\phi_2 - \pi/2) & \dots & \sin(\phi_N - \pi/2) \\ r_1 \cdot \hat{a}_1 & r_2 \cdot \hat{a}_2 & \dots & r_N \cdot \hat{a}_N \end{bmatrix}$$

Empirical Measurements

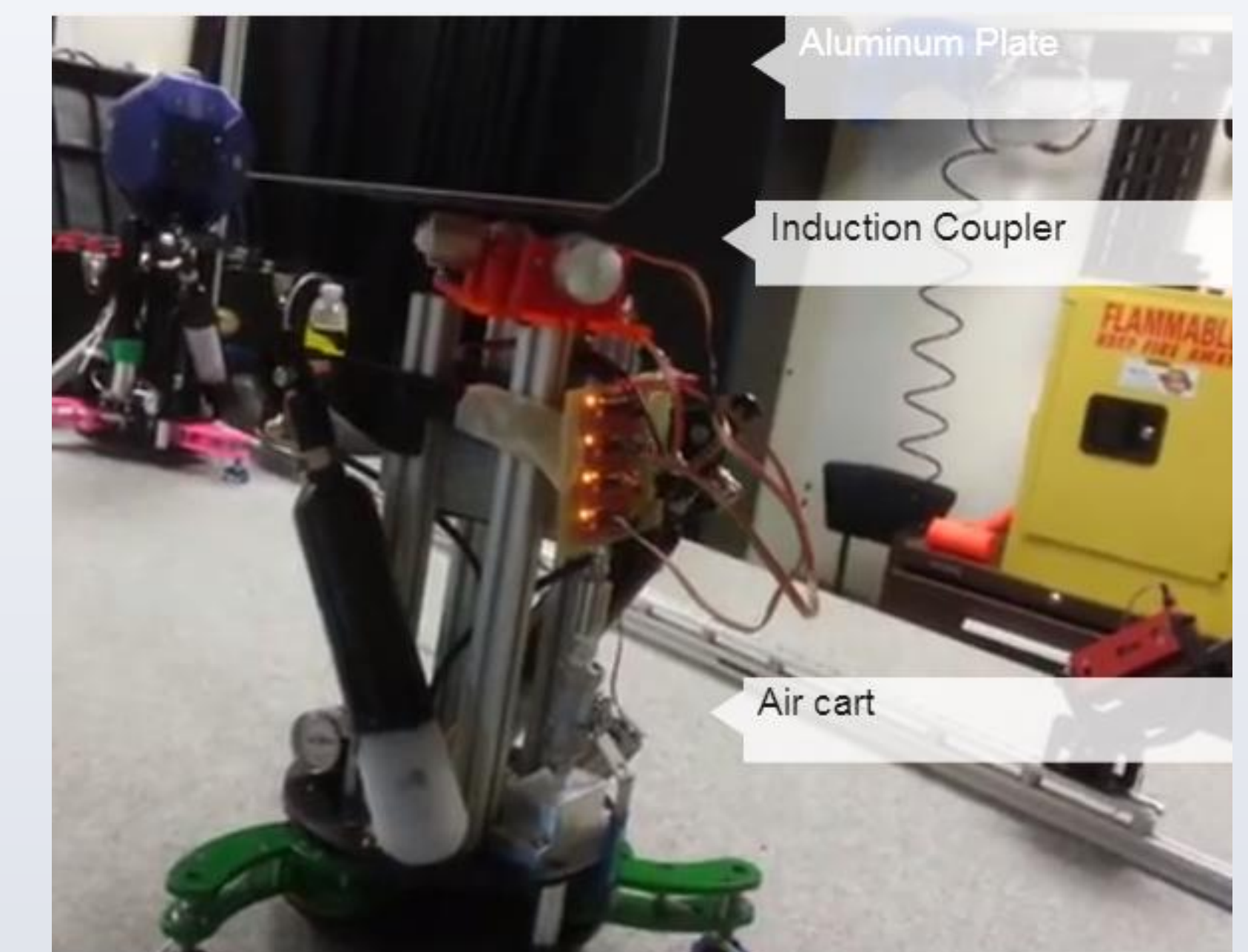


Implementing an Induction Coupler on an air track

- 12v off-the-shelf motors
- 50 mN at a range of 2 cm for < 10 W

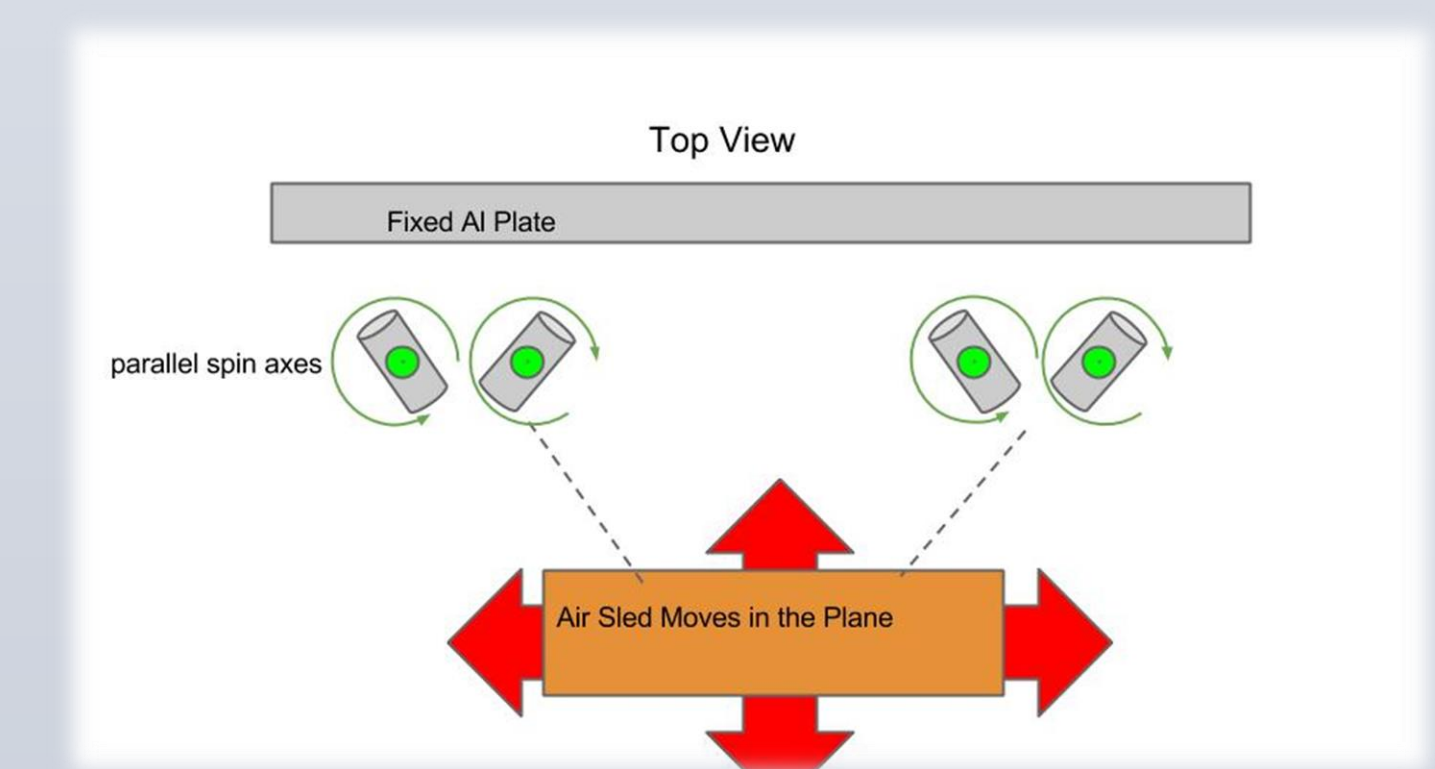


What's Next?



Three degree of freedom testing

- Design of a 3-DoF Induction Coupler
- More accurate force and power measurements
- System demonstration



Questions to Answer

- Can two magnet arrays fully control distance to a flat plate?
- How much control does the induction coupler enable?
- How well does an induction coupler work with an inspection vehicle mass-analog?

For More Information

Visit:
www.spacecraftresearch.com
[Youtube.com/scengr](https://www.youtube.com/scengr)
[Youtube.com/SeigeEngineer](https://www.youtube.com/SeigeEngineer)

