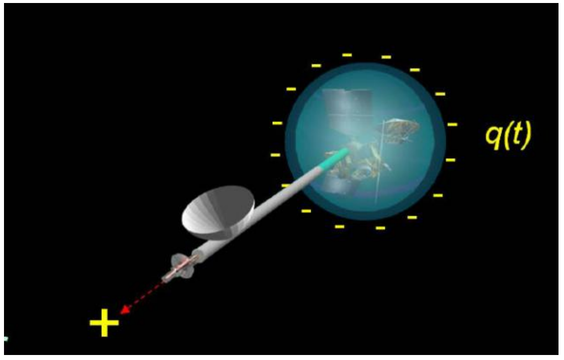
Lorentz Charged Propulsion Feasibility Study

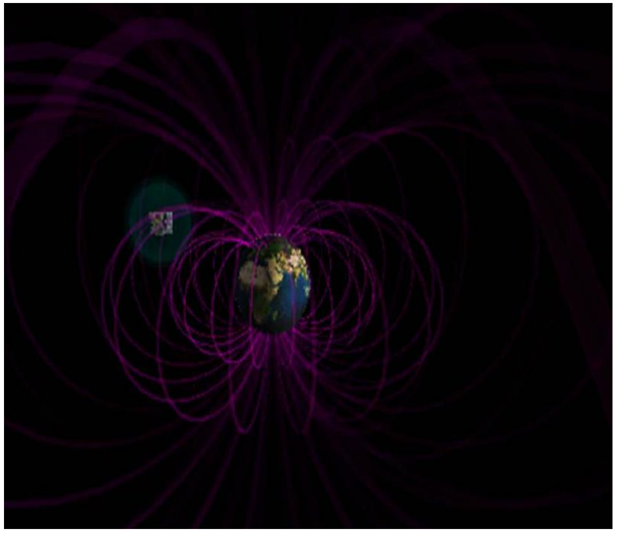
Andrew Heaton
11/27/2012

Lorentz Force from Charging

The “Lorentz Force” of interest is a static charge on a spacecraft…



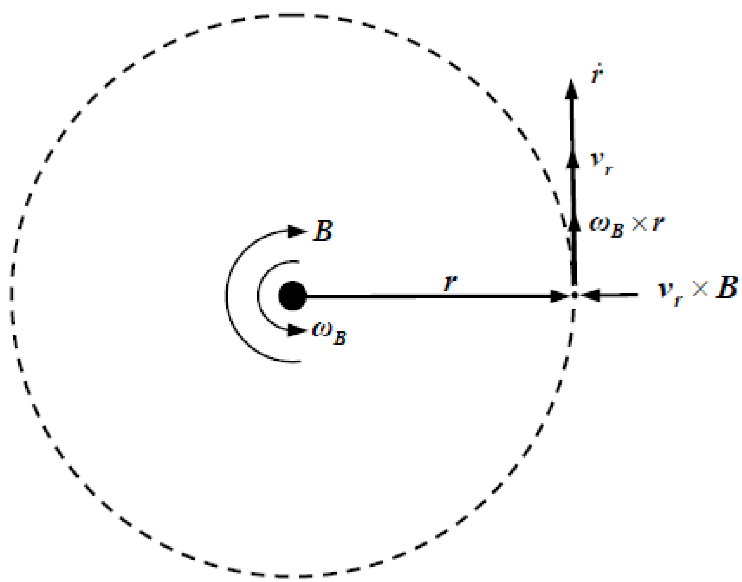
That interacts with a magnetic field….



Which generates a force…

$$F = q\,\boldsymbol{V} \times \mathbf{B}$$

Propulsive Capability



Cross section of Equatorial Orbit

Mag field out of page

Velocity is wrt to rotating central body

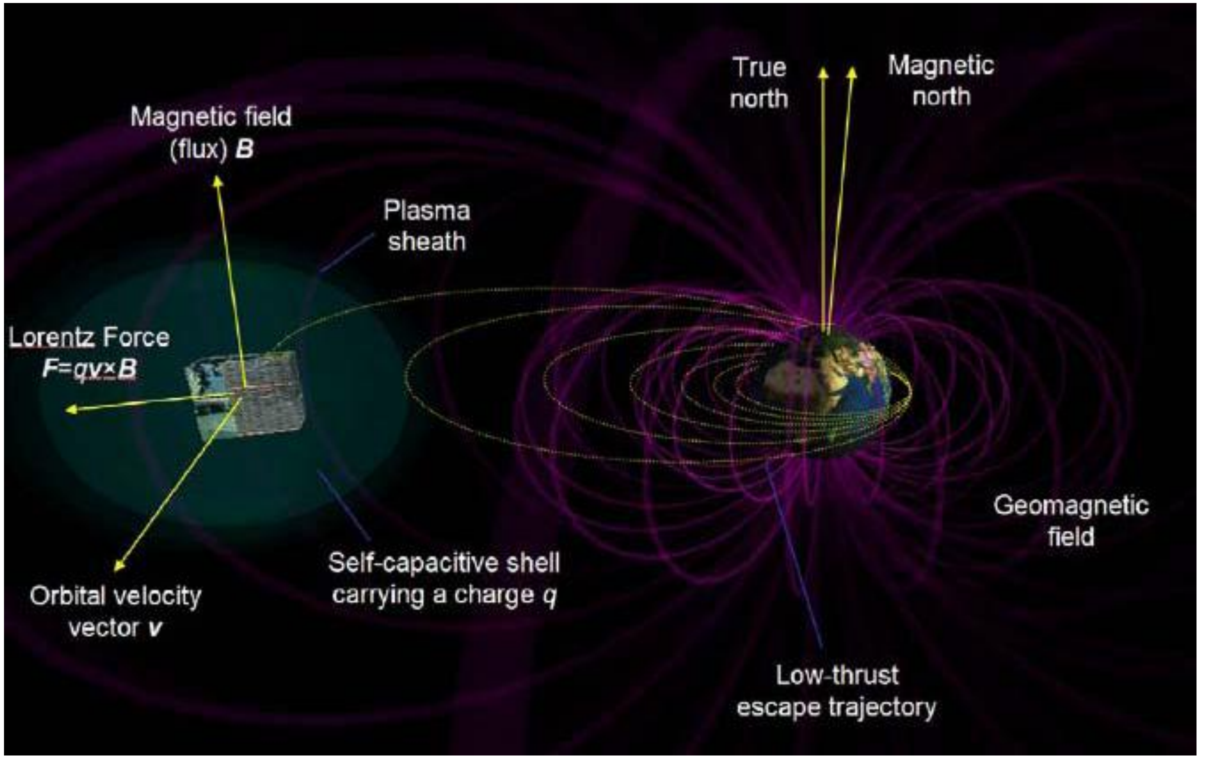
Resultant force in direction of radius

$$\mathbf{a} = {}^{q}/_{m}\ \boldsymbol{V} \times \mathbf{B}$$

More conveniently expressed as an acceleration

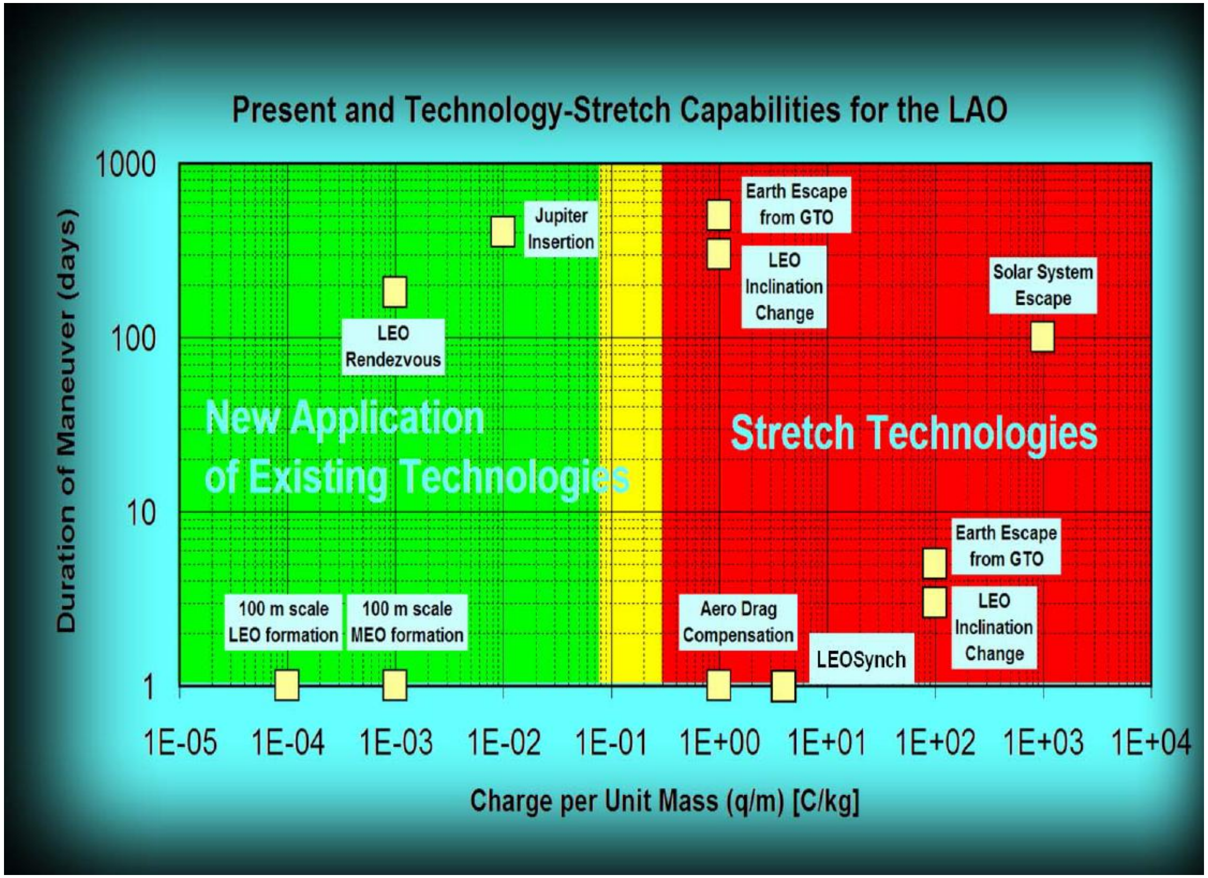
Previous Work

This idea was first explored by Mason Peck of Cornell University
In a 2006 NASA Institute for Advanced Concepts (NIAC) study



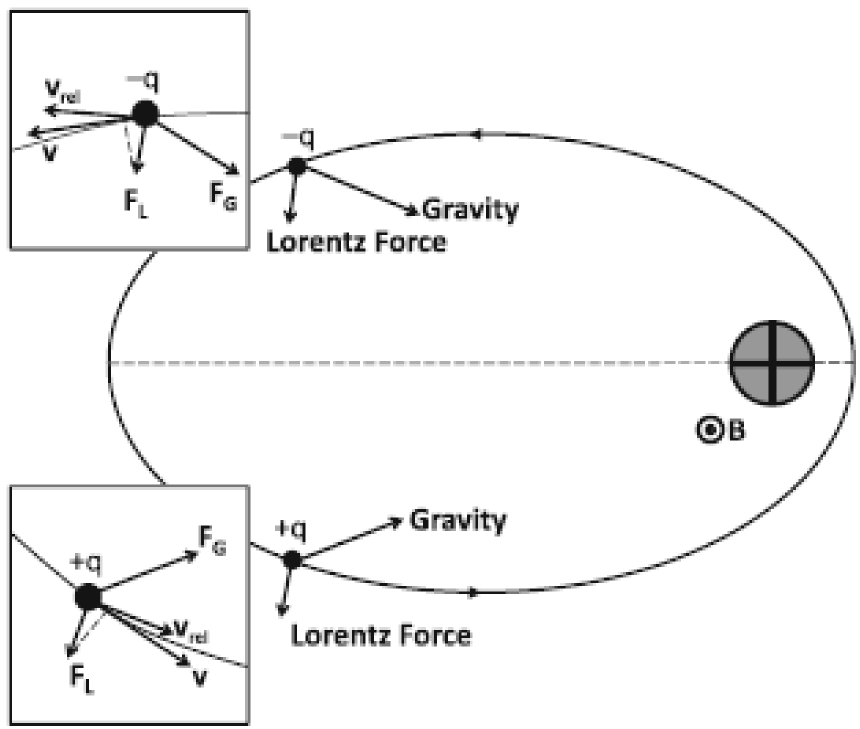
Suggested Mission Applications

From the NIAC study…..



Control Method

From a paper by Gangestad et al….



Challenges

- When to apply force to usefully modify orbit?
  - Is there anything we can do with it?

- How much charge is possible for a given power?
  - Is it too costly?

- How to hold charge in plasma?
  - Can the charge be maintained?

Research at MSFC

Team

Principal Investigator: EV42/Andy Heaton – Mission Analysis and Systems Integration
Co-Investigator: EV44 Joe Minow – Space Environments and Spacecraft Charging
Co-Investigator: EV44/Linda Parker (Jacobs) – Spacecraft Charging and NASCAP
Co-Investigator: EM50/Jason Vaughn – Space Environments Test Facility
Co-Investigator: Purdue/Michael Mueterthies – PhD student working on 6-DOF mag sc

Approach

Demonstrate that this form of propulsion can be useful

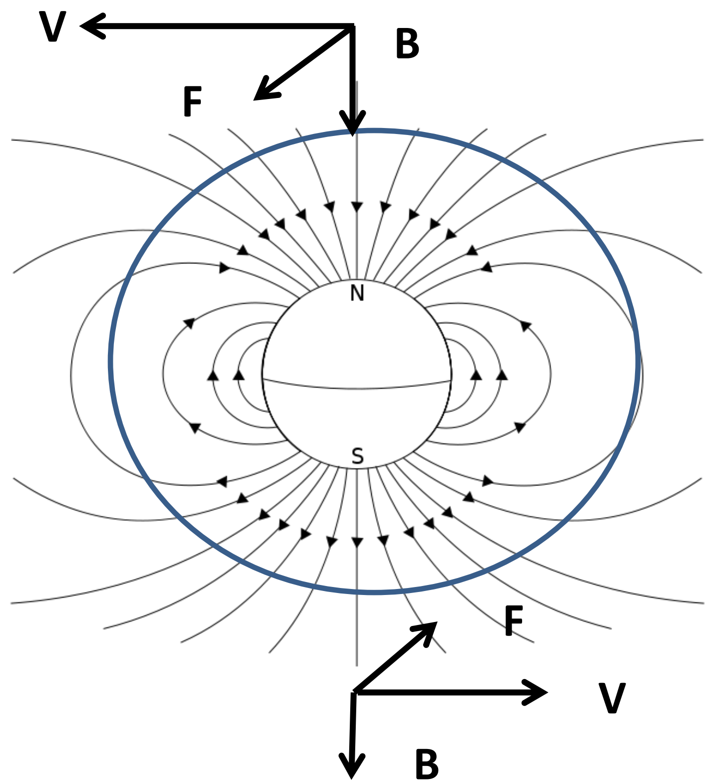
Demonstrate that a charge can be achieved on a test article in a space-like environment

Demonstrate that the charge can be maintained via a Faraday cage in a space-like plasma

A Specific Mission Example

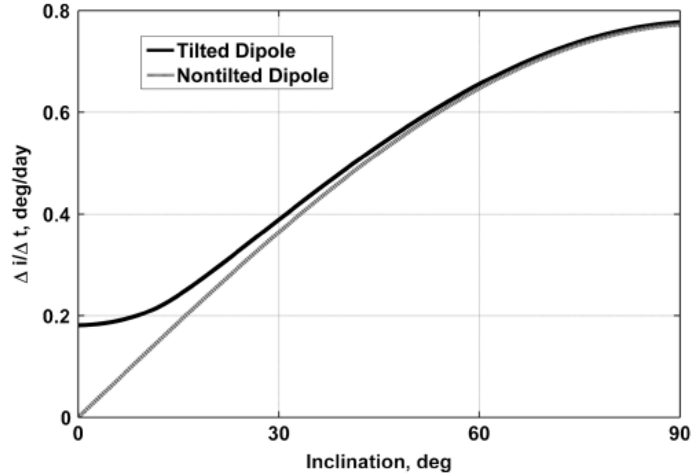
From a paper by Gangestad et al at Purdue….

Inclination change for a polar orbit



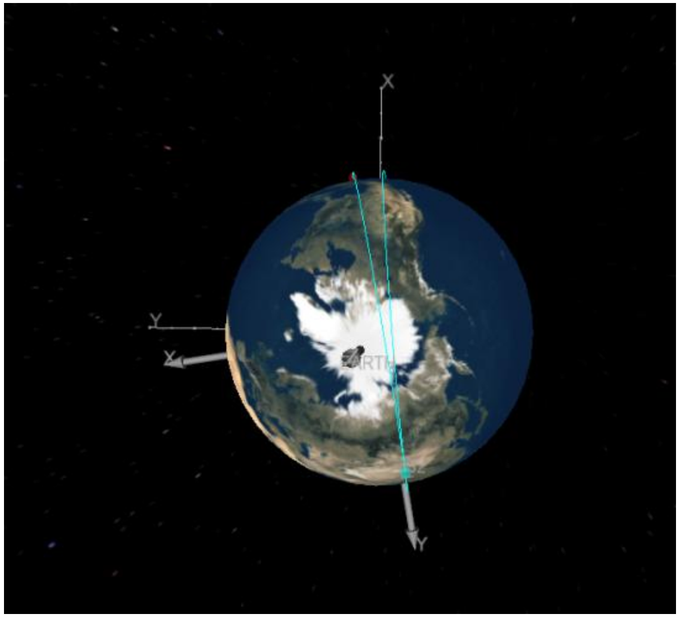
$$F = q\,\boldsymbol{V} \times \mathbf{B}$$

Results of Mission Study

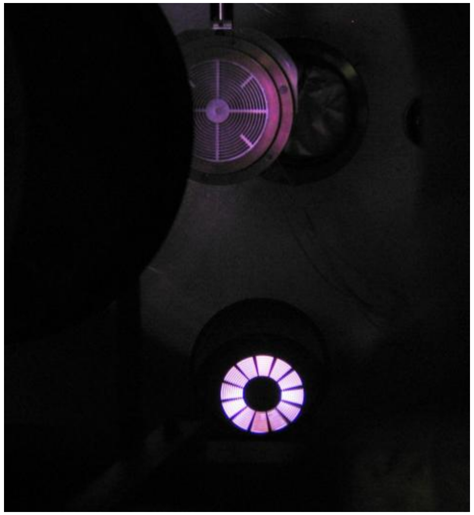


We confirmed this result

The ability to change inclination in LEO was identified as the most promising

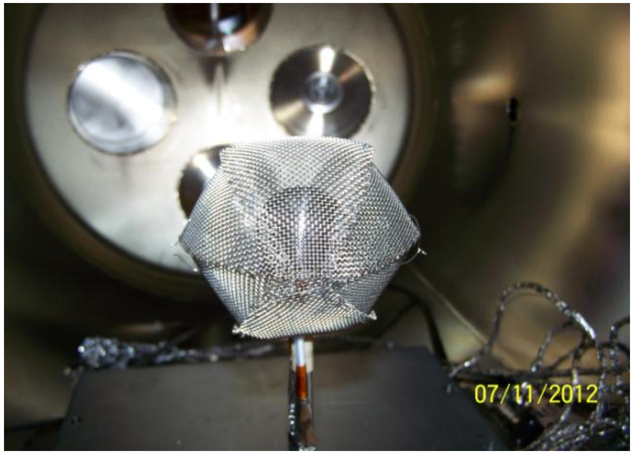


Testing



We tested in the world class Space Environments Lab at MSFC

A spherical test article was tested in vacuum and simulated space plasma



The article was tested with a Faraday cage

Test Results

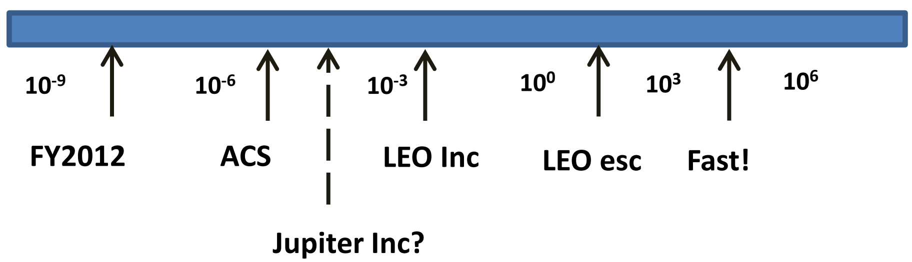
- The test article was charged in a space-like environment (vacuum and plasma)
- The test article was shielded successfully at a modest cost in power
- These results provided “proof of concept”
- Raised TRL from 1 to 3
  - (Technology Readiness Level)

Next Step

We did not achieve a very large charge on the article

Time and resources did not allow us to pursue max charge possible in lab

Charge Level in Coulombs



$Q = CV$

Increase Capacitance

Increase Voltage

Accomplishments

Review of physics in space environment by experts in the field.

The test of a charged Lorentz Force device in a realistic space vacuum environment including simulated plasma.

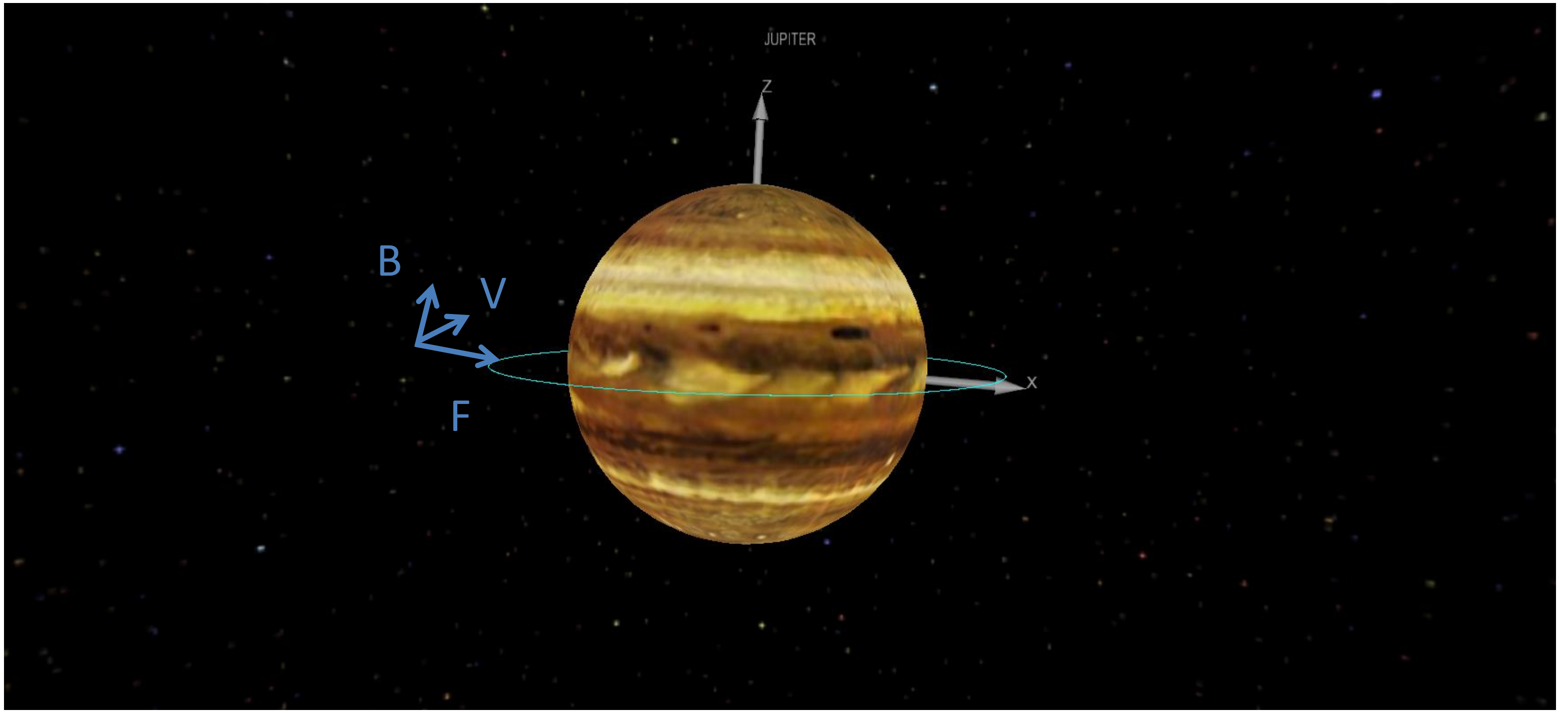
The shielding of a charged device in space-like plasma via a Faraday cage.

The concept of using a charge on a spacecraft subsystem for attitude control.

Achieved a Technology Readiness Level (TRL) of 3.

Jovian Light Speed Mission

If in a circular, equatorial orbit at Jupiter



The force will be inward….in the same direction as gravity.

Derivation

Circular Velocity in Orbit:

$$VC = \sqrt{GM/RC}$$

Square and divide by Rc (centripetal acceleration):

$$VC^2 = GM/RC$$

Add velocity to circular velocity:

$$VEC^2 = GM/Rc$$

Balance with Lorentz Acceleration:

$$VEC^2 = \frac{GM}{Rc} + QVECB \qquad (Q = \frac{q}{m})$$

Some Numbers