High Fidelity Surface Charging and Magnetic Noise Analysis of the Juno Magnetometer

James Chinn, Boyan Kartolov, Wousik Kim, Ira Katz

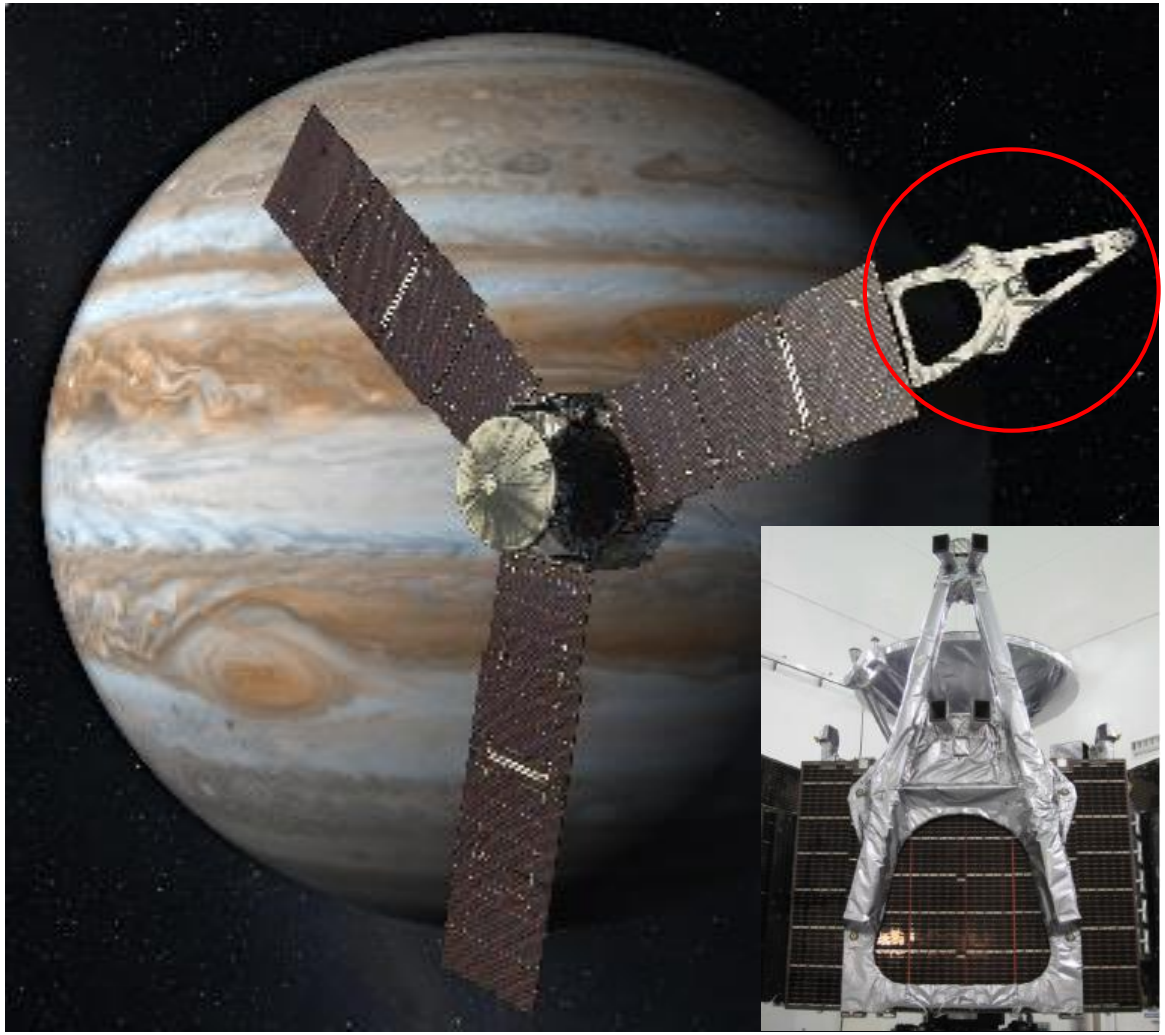
14th Annual Spacecraft Charging Technology Conference
April 4-8, 2016

Jet Propulsion Laboratory
California Institute of Technology

Contents

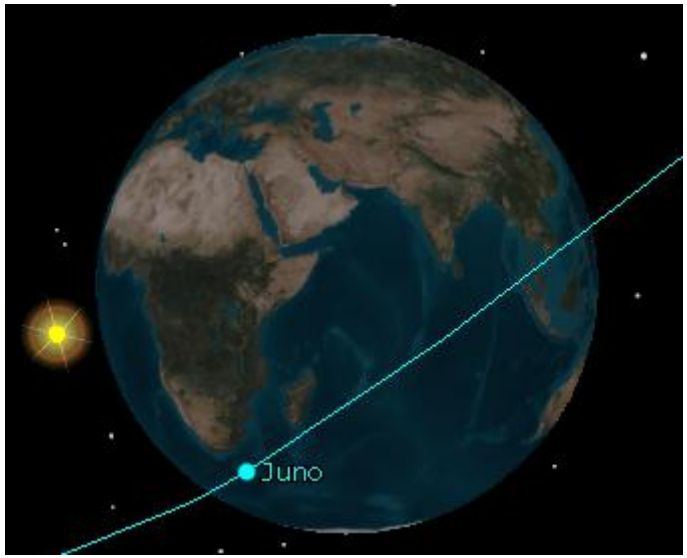
1. Introduction to the Juno Mission
2. Surprising Noise in Magnetometer Data
3. Source of Noise as Surface Charging and vxB Effect
4. Developing a High Fidelity Model in NASCAP2k
5. Interfacing NASCAP2k with ANSYS FEA
6. ANSYS Results: Comparing Simulated Noise with Measured Noise
7. Extending the Model to Jupiter
8. Results at Jupiter and Comparison to Earth's
9. Conclusion; No Risk to Magnetometer Science!

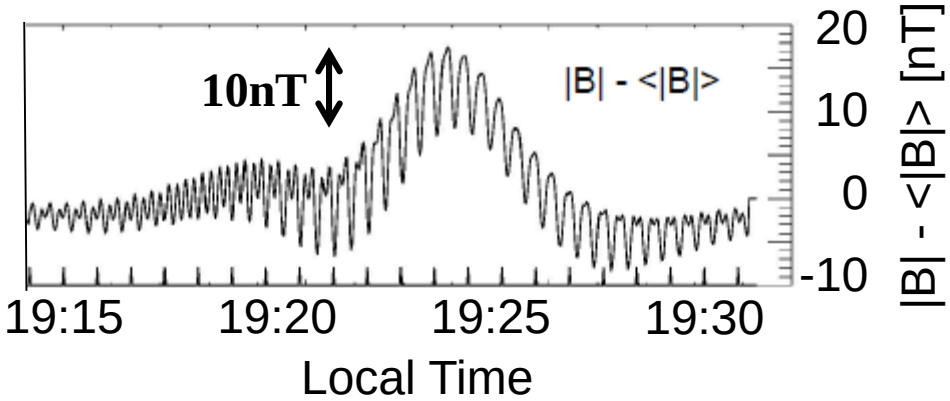
The Juno Mission



- “Juno will improve our understanding of the solar system's beginnings by revealing the origin and evolution of Jupiter.”
- Juno will study Jupiter’s atmosphere, gravity field, and **magnetic field**.

Surprise in Magnetometer Data during Earth Flyby

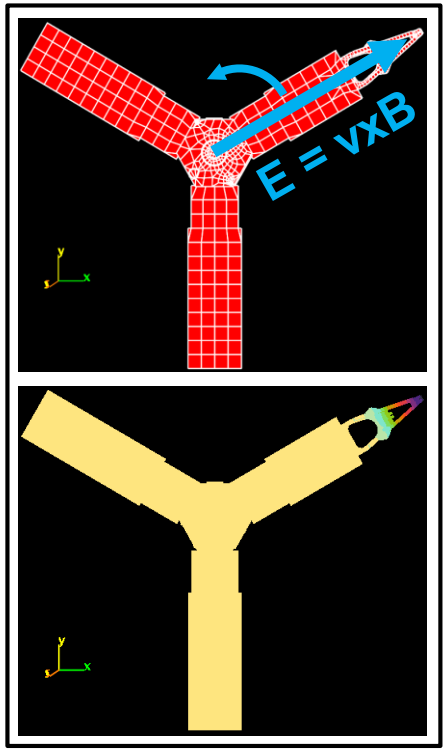




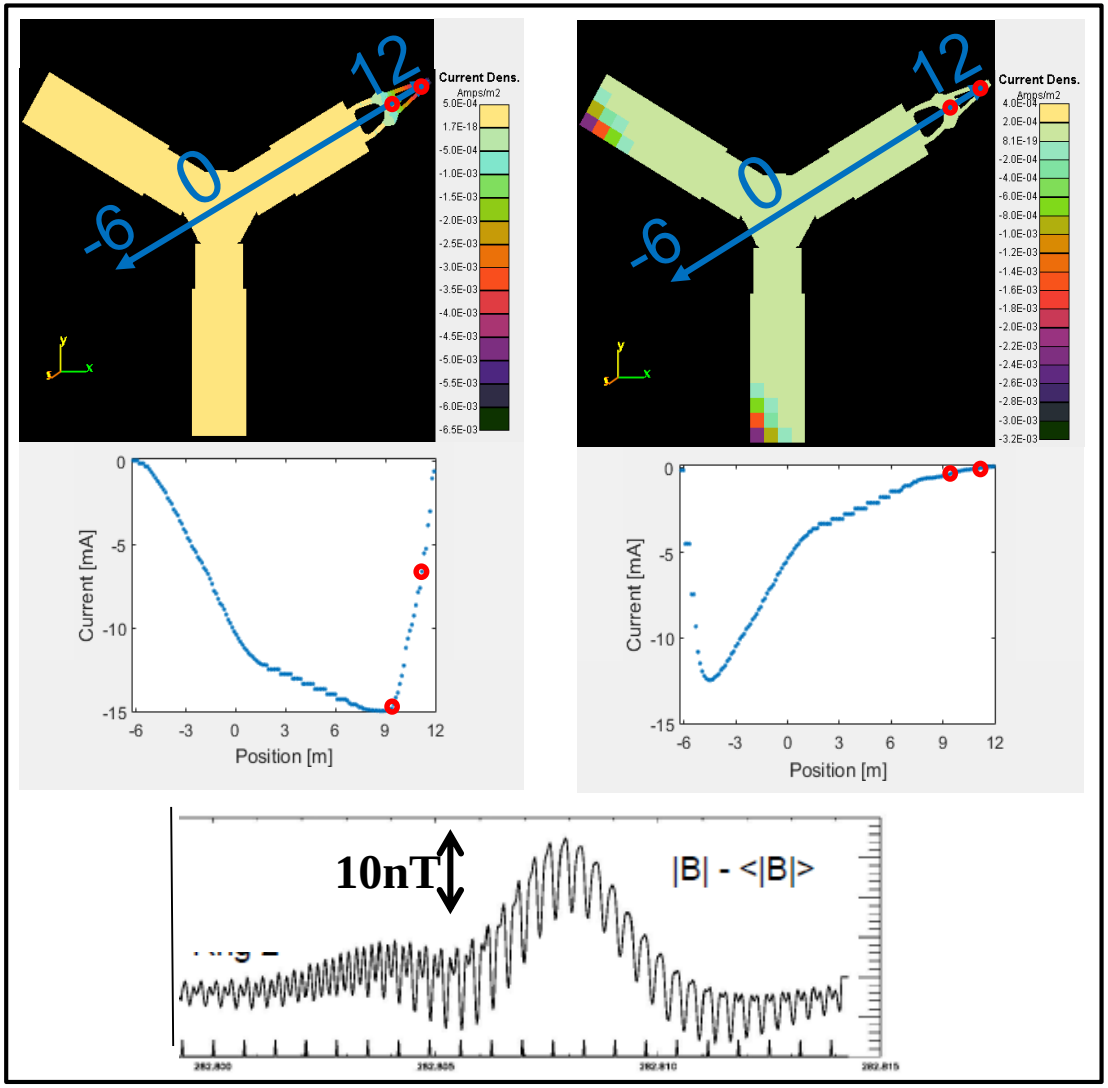
Observed noise an order of magnitude higher than expected

Time (UTC):	10/9/2013 19:21
Latitude:	-34.23°
W Longitude:	34.05°
Altitude:	561.10 km
Electron Density:	8.14E+10 m^-3
Plasma Temperature:	0.12 eV
Juno Velocity: |v|	14.6 km/s
Magnetic field: |B|	24.3 µT
v X B: |vxB|	29 V/m

Structure Currents on Spacecraft



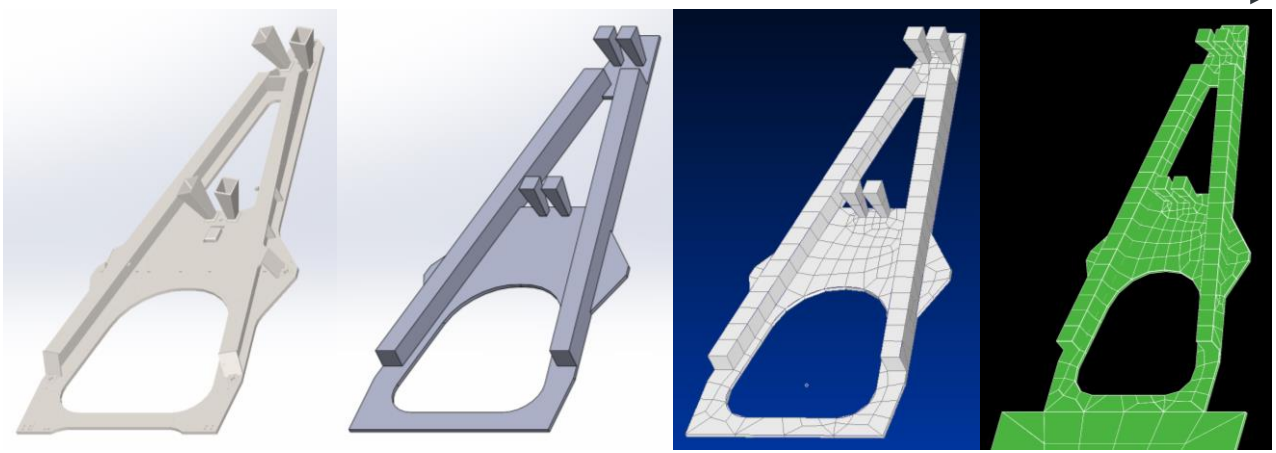
vxB Effect Periodically Drives Current Past the Magnetometer

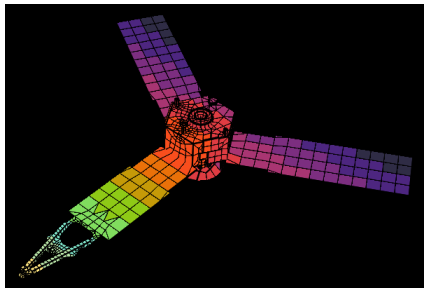


Developing High Fidelity NASCAP2k Model

Increase Fidelity in Geometry, Plasma, Velocity, Magnetic Field

CAD from Juno → Simplified → Meshed → NASCAP2k





CAD

Time
Position
Geomagnetic Indices

IRI model

Electron Density
Plasma Temperature
Ion Species

Velocity Vector
IGRF (Magnetic Field Vector)
Sun Intensity

NASCAP 2k

Interface NASCAP2k with ANSYS Maxwell FEA

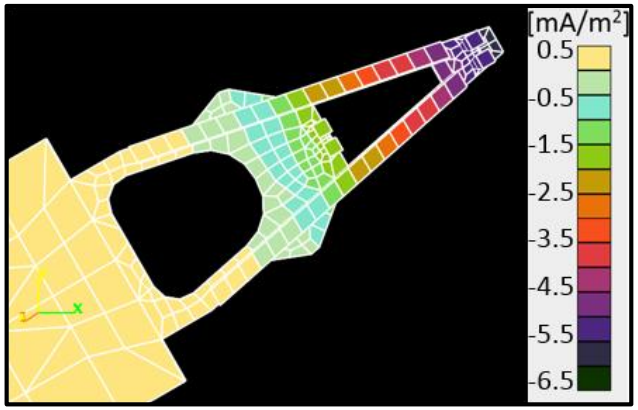
NASCAP2k
Surface Charging Current

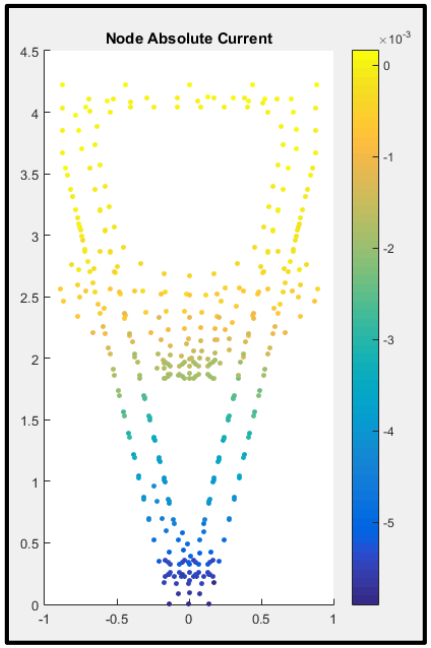
→

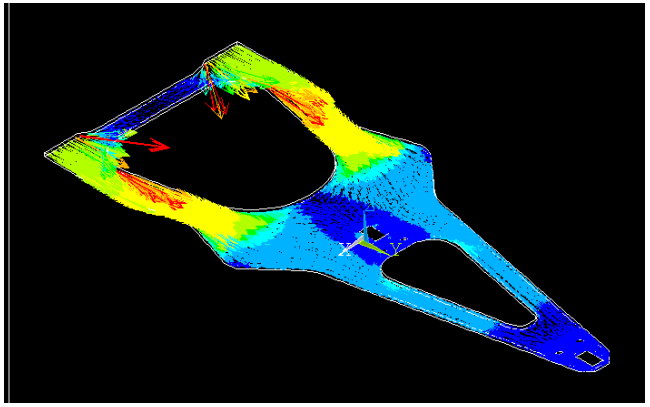
Matlab

→

ANSYS
Boundary Current Source



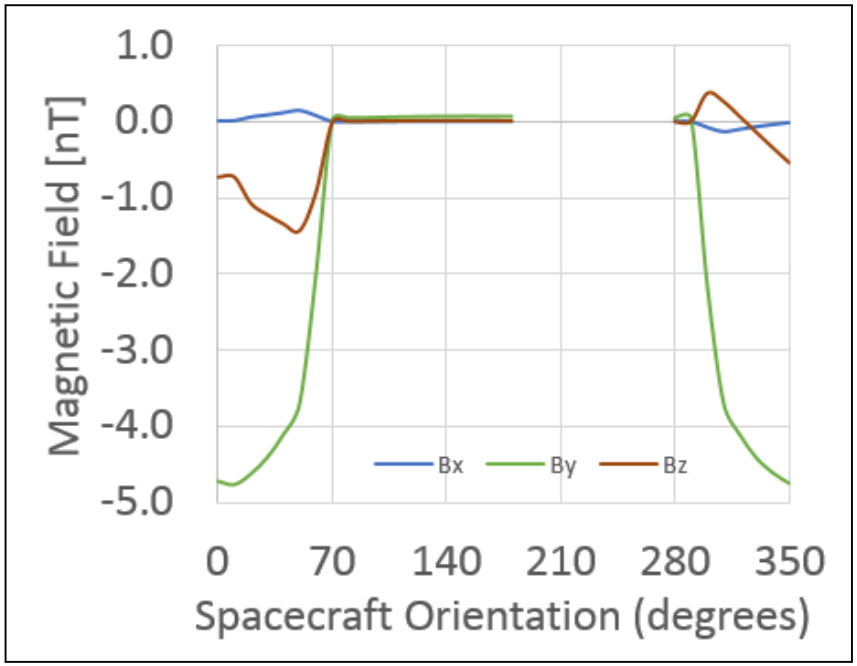


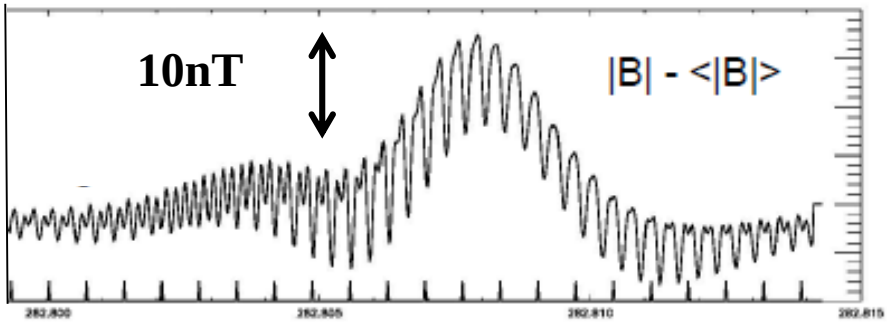


Select Data, Reformat, Change Coordinate System

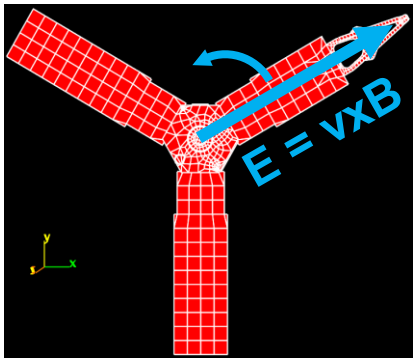
Results of ANSYS Simulation

Simulation agrees with measurement to a factor of 2





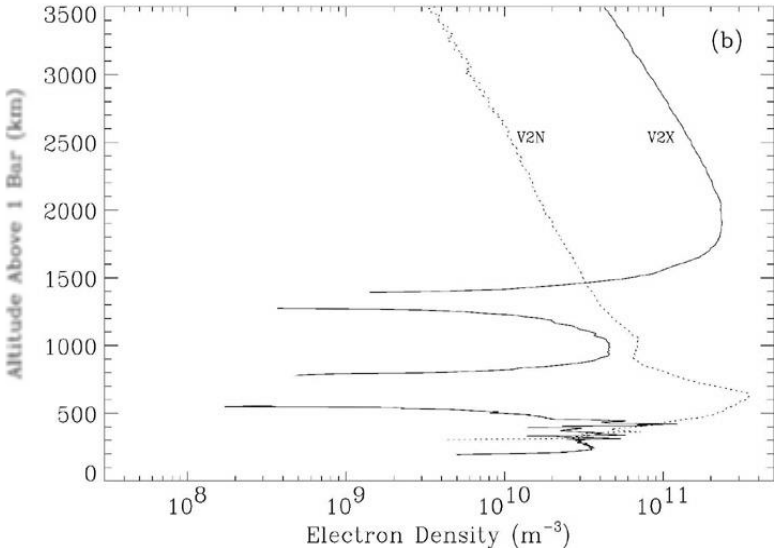
- Simulated Magnetic Field Magnitude of 5nT Agrees with Measured Field of 10nT to a Factor of 2
- The somewhat jagged shape of the measured waveform corresponds well with the variation of the simulated fields over a 360 degree cycle



Extending the Model to Jupiter

- Using the same model but with different plasma environment, velocity, magnetic field, and sun conditions. Worst case plasma density from Voyager data in Yelle and Miller 2004 [1] and Ion number densities from Divine and Garrett 1983 [2].
- Plasma temperature calculated theoretically by Hunter Waite of SWRI.

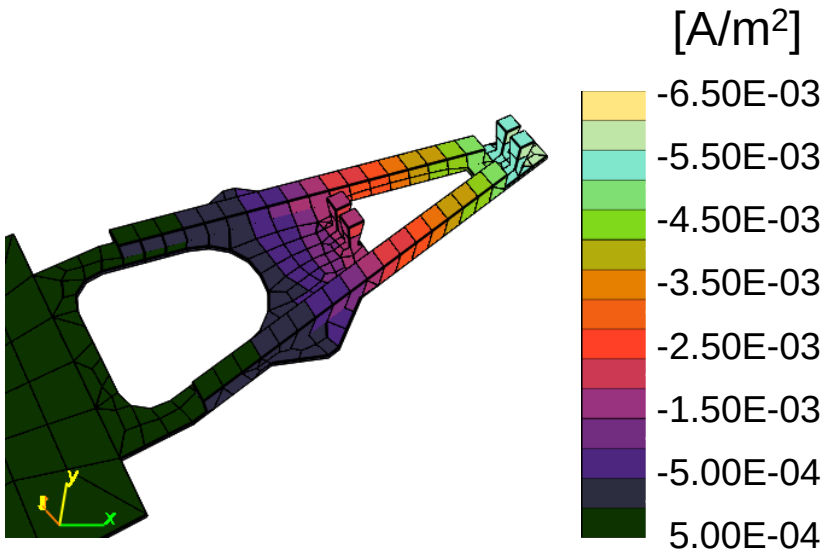
Parameter	Units	Earth	Jupiter Worst Case
Electron Density	[m^-3]	8.14E+10	3.00E+10
Plasma Temperature	[eV]	0.12	0.86
Debye Length	[cm]	1	4
Dominant Ion Species	-	O+(.98), H+(.02)	S+(.7), O+(.2), S++(.02), O++(.03)
Sun Intensity (rel to Earth)	-	0	0.04
Juno Velocity: |v|	[km/s]	14.6	57
Magnetic field: |B|	[µT]	24.3	540
v X B: |vxB|	[V/m]	0.35	29
Collected Current	[mA]	16	29
Induced Magnetic Field: |B|	[nT]	5	17



Jupiter vs. Earth: Surface Charging Current

- Plasma density at Jupiter closest approach is lower but spacecraft velocity relative to plasma is higher and so is the magnetic field. Net result is a much stronger vxB effect (80x) and 2x more current collected.

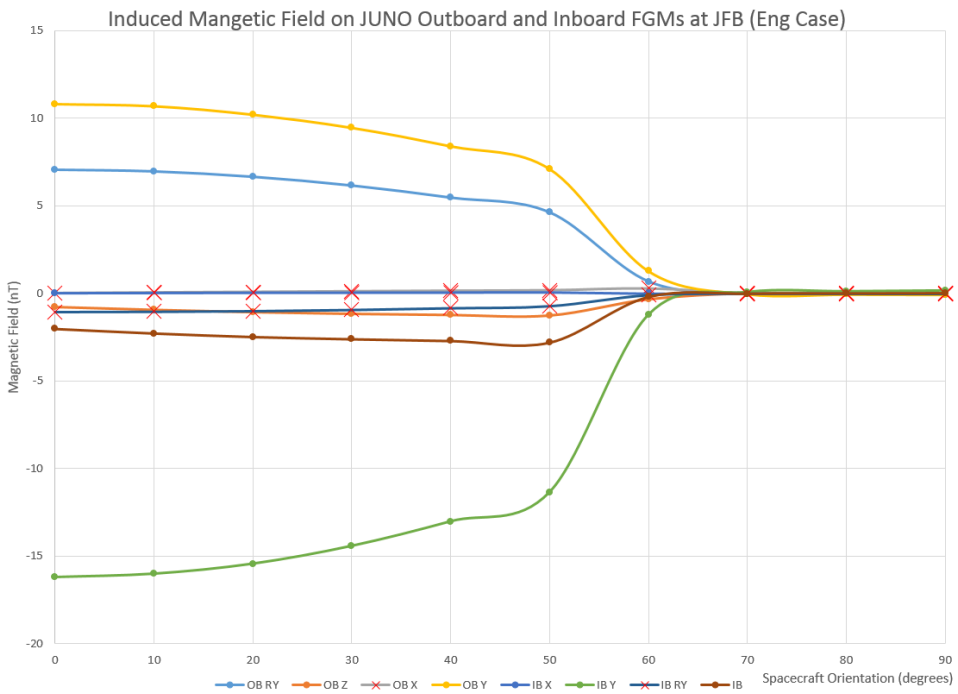
Earth Case: 15mA

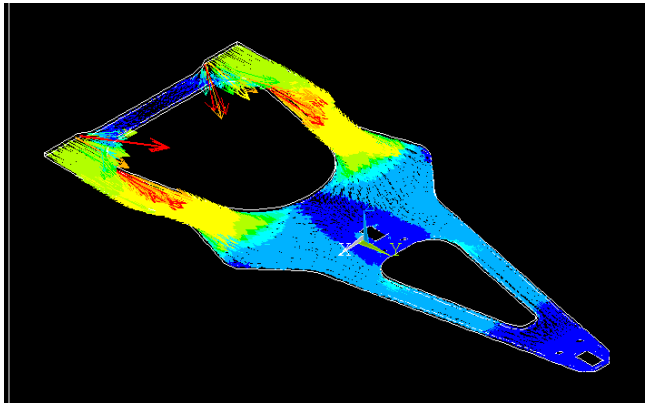


Jupiter Case: 29mA

Jupiter Results and Conclusions

- Induced field is 3x higher than at Earth but the measured field is 20x higher, resulting in a better signal-to-noise ratio at Jupiter
- Magnitude of Induced Current At Jupiter is 16nT, Signal-to-Noise ratio is 17,000:1





Signal-to-Noise Ratio of 17,000:1 poses no risk to Magnetometer Science

Summary/Conclusion

- Initial low-fidelity approximation of the problem predicted noise that deviated from measurements by about an order of magnitude
- Risk to magnetometer science prompted a high-fidelity analysis
- Combining CAD and FEA tools with NASCAP2k, measurements were replicated to a factor of 2 – within the uncertainty of the environment
- Extending the now validated model to Jupiter, the worst expected signal-to-noise ratio from this effect is 17,000:1, which is acceptable to magnetometer science

References

- [1] Yelle, R. V., and S. Miller, "Jupiter's Thermosphere and Ionosphere", Chapter 9, pp. 185-218, in *Jupiter, The Planet, Satellites and Magnetosphere*, edited by F. Bagenal, T. Dowling and W. McKinnon, Cambridge Press, Cambridge, UK, 2004.
- [2] Divine, Neil & Garrett, H.B. (1983). Charged Particle Distributions in Jupiter’s Magnetosphere, Journal of Geophysical Research, Vol. 88, No. A9, Pages 6889-6903.

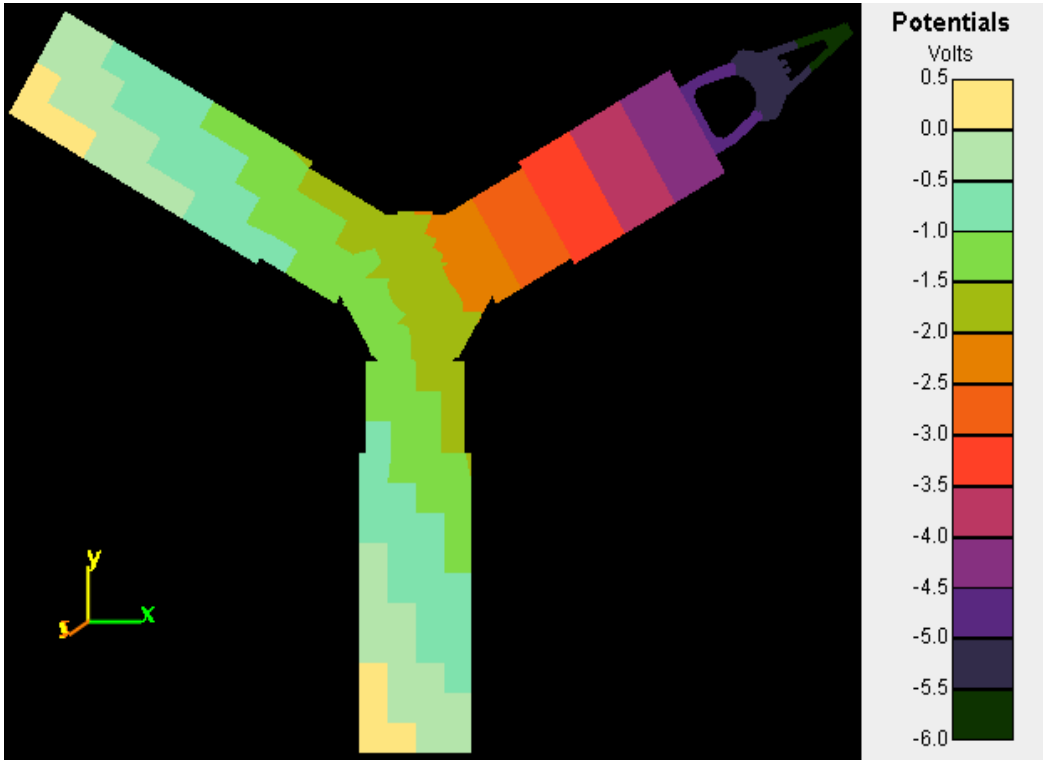
Thanks to Boyan Kartolov, Wousik Kim, and Ira Katz for their help and insight

Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov

Backup

[V]
1
0
-1
-2
-3
-4
-5
-6
y
x


Potentials
Volts
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
-5.5
-6.0
y
x