

# ROBERT A. MARSHALL

Assistant Professor  
Department of Aerospace Engineering Sciences  
University of Colorado Boulder  
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## RESEARCH INTERESTS

My research focuses on improving our understanding of the **geospace environment**, defined as the region of the near-Earth space environment influenced by gravity and the Earth's magnetic field. My research topics have a common theme of **electromagnetic wave interactions with naturally-occurring plasmas** in geospace. I study the physics of lightning and thunderstorms, and their effects on the geospace environment, through ionospheric heating, precipitation of radiation belt electrons, and energy transport through gravity and acoustic waves. I study meteors, the plasma surrounding a meteoroid as it enters the Earth's atmosphere, using radar and optical techniques to understand the meteoroid environment around Earth. I study the propagation of Very-Low-Frequency radio waves in the waveguide formed by the Earth and the lower ionosphere, through the ionosphere, and throughout the magnetosphere, together with the interaction between these waves and radiation belt particles.

I approach these and other research topics through a combination of **instrument development and data collection, data analysis, and modeling**. I develop optical, radio, and particle instruments for ground-based and space-based measurements. I analyze the data from these and other space-based instruments using advanced analytical tools, including machine learning and Kalman filtering. I utilize a range of numerical modeling techniques, including Finite Difference, Finite Element, and Monte Carlo techniques.

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## PROFESSIONAL EXPERIENCE

- Aug 2015 – present: **Assistant Professor**, Aerospace Engineering Sciences, CU Boulder
- May 2015 – Aug 2015: **Visiting Assistant Professor**, Aerospace Engineering Sciences, CU Boulder
- May 2013 – July 2015: **Research Associate**, Aeronautics and Astronautics, Stanford University
- May 2011 – Apr 2013: **Research Associate**, Electrical Engineering, Stanford University
- Oct 2009 – May 2011: **Research Scientist**, Center for Space Physics, Boston University
- June 2009 – Oct 2009: **Postdoctoral Scholar**, Electrical Engineering, Stanford University
- Jan 2003 – May 2009: **Research Assistant**, Electrical Engineering, Stanford University

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## EDUCATION

- **Ph.D., Electrical Engineering**, Stanford University, June 2009  
Dissertation Advisor: Umran S. Inan  
Dissertation Title: VLF Radio Signatures of Transient Luminous Events Above Thunderstorms
- **M.S., Electrical Engineering**, Stanford University, 2004
- **B.S., Electrical Engineering**, University of Southern California, 2002, *Summa Cum Laude*

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## AWARDS AND HONORS

- 2017 JGR-Space Physics Editor's Citation for Excellence in Refereeing
- 2011 International Radio Science Union (URSI) Young Scientist Award

- 2011 Winner, Andor Insight Awards, Scientific Imaging Competition (Physical Sciences)
- 2010 National Science Foundation CEDAR/GEM Postdoctoral Fellowship
- 2008 American Geophysical Union (AGU) Outstanding Student Paper Award
- 2007 Gerald J. Lieberman Fellowship, awarded at Stanford for “demonstrated potential for leadership roles in the academic community”
- First Place, URSI Student Paper Competition; Ottawa, ON, Canada
- 2004 AGU Outstanding Student Paper Award
- 2002–2005 Texas Instruments Stanford Graduate Fellowship

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## PROFESSIONAL SERVICE ACTIVITIES

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- Meeting Organizer: 2015 Stanford Meteor Environment and Effects (SMEE) Workshop, Stanford, CA, July 14-16, 2015
- Meeting Session Organizer for 2015, 2016, and 2017 CEDAR Workshops
- CEDAR student poster judge: 2013 – 2016 Annual Workshops
- Meeting Session Organizer for 2009 and 2016 – 2019 URSI National Radio Science Meeting
- AGU student poster judge: 2012 – 2016 Fall Meetings, Atmospheric and Space Electricity Focus Group
- NASA Review Panelist, 2014, 2015, and 2016
- NSF Review Panelist, 2016
- Numerous proposal reviews for NSF, NASA and international agencies
- Journal reviews: Journal of Geophysical Research (Atmospheres and Space Physics); Geophysical Research Letters; Journal of Physics D; Journal of Atmospheric and Solar Terrestrial Physics; Earth Moon and Planets; Icarus; Annales Geophysicae.

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## UNIVERSITY SERVICE ACTIVITIES

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- AES Department, Undergraduate Curriculum Committee, Fall 2018 – Spring 2019
- AES Department, Strategic Vision Committee, Fall 2017 – Spring 2019
- AES Department, Graduate Committee, Fall 2016 – Spring 2018
- AES Department, Focus Area Lead, Remote Sensing, Earth and Space Sciences (RSESS), Fall 2016 – Spring 2018

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## TEACHING

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- ASEN 4519, *Space: Environment and Effects*, Fall 2018
- ASEN 5018/6028, *Graduate Projects I & II*, project advisor, AY 2017–2018 and 2018–2019
- ASEN 5440, *Mission Design and Development for Space Sciences*, Fall 2017
- ASEN 3300, *Aerospace Electronics and Communications*, Spring 2017 & 2018
- ASEN 4018/4028, *Senior Design Projects I & II*, team advisor, AY 2015–2016 and 2016–2017
- ASEN 5519, *Space Mission Concept Development*, Fall 2015
- EE 256, *Numerical Electromagnetics* (Stanford University), Summer 2008
- Teaching assistant, *Numerical Electromagnetics*, Prof. Umran Inan (Stanford University); 2005, 2007

- Teaching assistant, *Analog Circuits*, Prof. John Choma and Dr. Edward Maby (University of Southern California); 2001, 2002.

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## PUBLICATIONS AND PRESENTATIONS

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Publication statistics from [Google Scholar citations index](#), as of December 1, 2018:

Peer-reviewed Publications	55
Total Citations	1309
h-index	20
i10-index	31

h-index is the largest number  $h$  such that  $h$  publications have at least  $h$  citations.

i10-index is the number of publications with at least 10 citations.

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## BOOKS & BOOK CHAPTERS

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1. U. S. Inan and R. A. Marshall (2011), *Numerical Electromagnetics: The FDTD Method*, Cambridge University Press: <http://www.cambridge.org/gb/knowledge/isbn/item5760378/>
2. Marshall. R. A. and C. Cully (2018), Atmospheric effects and signatures of high energy electron precipitation. In *The Dynamic Loss of Earth's Radiation Belts: From Loss in the Magnetosphere to Particle Precipitation in the Atmosphere*, Elsevier; in press.
3. Kaeppler, S. R., E. Sanchez, R. H. Varney, R. Irvin, R. A. Marshall, J. Bortnik, A. S. Reimer, and P. Reyes (2018), Incoherent Scatter Radar Observations of 10-100 keV Precipitation: Review and Outlook. In *The Dynamic Loss of Earth's Radiation Belts: From Loss in the Magnetosphere to Particle Precipitation in the Atmosphere*, Elsevier; in press.

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## PEER-REVIEWED JOURNAL ARTICLES\*

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\* Papers first-authored by graduate students, for whom Dr. Marshall serves or served as the student's primary research supervisor, are highlighted **in bold**.

55. Cohen, M. B., N. C. Gross, M. A. Higginson-Rollins, R. A. Marshall, M. Golkowski, W. Liles, et al. (2018), The lower ionospheric VLF/LF response to the 2017 Great American Solar Eclipse observed across the continent, *Geophysical Research Letters*, 45, 3348–3355, doi:10.1002/2018GL077351.
54. Xu, W., R. A. Marshall, X. Fang, E. Turunen, and A. Kero (2018), On the effects of bremsstrahlung radiation during energetic electron precipitation, *Geophysical Research Letters*, 45, 1167–1176, doi:10.1002/2017GL076510.
53. Marshall, R. A., and J. Bortnik (2018), Pitch angle dependence of energetic electron precipitation: Energy deposition, backscatter, and the bounce loss cone, *Journal of Geophysical Research: Space Physics*, 123, 2412–2423, doi:10.1002/2017JA024873.
52. **Jackson, S. W.** and R. A. Marshall (2017), Conceptual Design of an Air-Breathing Electric Thruster for CubeSat Applications, *J. Spacecraft and Rockets*, doi:10.2514/1.A33993.
51. Xu, W., R. A. Marshall, S. Celestin, and V. P. Pasko (2017), Modeling of X-ray Images and Energy Spectra Produced by Stepping Lightning Leaders, *J. Geophys. Res. Atmos.*, 122 (21).
50. Marshall, R. A., T. Wallace, and M. Turbe (2017), Finite-Difference Modeling of Very-Low-Frequency Propagation in the Earth-Ionosphere Waveguide, *IEEE Trans. Ant. Prop.*, 65 (12), 7185–7197.
49. Janches, D., N. Swarnalingam, J. D. Carrillo-Sanchez, J. C. Gomez-Martin, R. Marshall, J. Plane, W. Feng, and P. Pokorný (2017), Radar detectability studies of slow and small Zodiacal Dust Cloud Particles: III. The role of sodium and the Head Echo size on the probability of detection, *The Astrophysical Journal*, 843 (1), 1.

48. Kabirzadeh, R., R. A. Marshall, and U. S. Inan (2017), Early/fast VLF events produced by the quiescent heating of the lower ionosphere by thunderstorms, *J. Geophys. Res. Atmos.*, 122, doi:10.1002/2017JD026528.
47. Marshall, R. A., P. Brown, and S. Close (2017), Plasma distributions in meteor head echoes and implications for radar cross section interpretation, *Planet. Space Sci.*, 143, pp. 203–208, doi:10.1016/j.pss.2016.12.011.
46. Thomas, E., J. Simolka, M. DeLuca, M. Horanyi, D. Janches, R. A. Marshall, and Z. Sternovsky (2017), Experimental setup for the laboratory investigation of micrometeoroid ablation using a dust accelerator, *Rev. Sci. Instr.*, 88(3), 034501.
45. Xu, W., S. Celestin, V. P. Pasko, and R. A. Marshall (2017), A novel type of transient luminous event produced by terrestrial gamma-ray flashes, *Geophys. Res. Lett.*, 44(5), 2571–2578.
44. Goenka, C., J. Semeter, J. Noto, J. Baumgardner, J. Riccobono, M. Migliozzi, H. Dahlgren, R. Marshall, S. Kapali, M. Hirsch, D. Hampton, and H. Akbari (2016), Multichannel tunable imager architecture for hyperspectral imaging in relevant spectral domains, *Applied Optics*, 55, pp. 3149–3157.
43. **Blaes, P. R.**, R. A. Marshall, and U. S. Inan (2016), Global Occurrence Rate of Elves and Ionospheric Heating due to Cloud-to-Ground Lightning, *J. Geophys. Res. Space Physics*, 120, doi:10.1002/2015JA021916.
42. Marshall, R. A., J. Yue, and W. A. Lyons (2015), Numerical simulation of an elve modulated by a gravity wave, *Geophys. Res. Lett.*, 42, 6120–6127, doi:10.1002/2015GL064913.
41. Marshall, R. A., C. L. da Silva, and V. P. Pasko (2015), Elve doublets and compact intracloud discharges, *Geophys. Res. Lett.*, 42, 6112–6119, doi:10.1002/2015GL064862.
40. Marshall, R. A., and S. Close (2015), An FDTD model of scattering from meteor head plasma, *J. Geophys. Res. Space Physics*, 120, 5931–5942, doi:10.1002/2015JA021238.
39. Goenka, C., J. Semeter, J. Noto, J. Baumgardner, J. Riccobono, M. Migliozzi, H. Dahlgren, R. Marshall, S. Kapali, M. Hirsch, D. Hampton, and H. Akbari (2015), LiCHI – Liquid Crystal Hyperspectral Imager for simultaneous multispectral imaging in aeronomy, *Opt. Express* 23, 17772–17782, doi: 10.1364/OE.23.017772
38. Douglas, E.S., J. Martel, Z. Li, G. Howe, K. Hewawasam, R. A. Marshall, C. L. Schaaf, T. A. Cook, G. J. Newnham, A. Strahler, S. Chakrabarti (2015), Finding Leaves in the Forest: The Dual-Wavelength Echidna Lidar, *IEEE Geoscience and Remote Sensing Letters*, vol.12, no.4, pp.776–780, doi: 10.1109/LGRS.2014.2361812.
37. Marshall, R. A., M. Nicolls, E. Sanchez, N. G. Lehtinen, and J. Neilson (2014), Diagnostics of an artificial relativistic electron beam interacting with the atmosphere, *J. Geophys. Res. Space Physics*, 119, doi:10.1002/2014JA020427.
36. Marshall, R. A. (2014), Effect of self-absorption on attenuation of lightning and transmitter signals in the lower ionosphere, *J. Geophys. Res. Space Physics*, 119, doi:10.1002/2014JA019921.
35. Marshall, R. A., and J. B. Snively (2014), Very low frequency subionospheric remote sensing of thunderstorm-driven acoustic waves in the lower ionosphere, *J. Geophys. Res. Atmos.*, 119, doi:10.1002/2014JD021594.
34. Marshall, R. A., T. Adachi, R.-R. Hsu, and A. B. Chen (2014), Rare examples of early VLF events observed in association with ISUAL-detected Gigantic Jets, *Radio Sci.*, 49, 36–43, doi:10.1002/2013RS005288.
33. **Blaes, P. R.**, R. A. Marshall, and U. S. Inan (2014), Return stroke speed of cloud-to-ground lightning estimated from elve hole radii, *Geophys. Res. Lett.*, 41, 9182–9187, doi:10.1002/2014GL062392.
32. Liang, C., B. Carlson, H. Lehtinen, M. Cohen, R. A. Marshall, and U. Inan (2014), Differing current and optical return stroke speeds in lightning, *Geophys. Res. Lett.*, 41, doi:10.1002/2014GL059703.
31. Goenka, C., J. L. Semeter, J. Noto, H. Dahlgren, R. Marshall, J. Baumgardner, J. Riccobono, and M. Migliozzi (2013), Tunable filters for multispectral imaging of aeronomical features, *Adv. Space Res.*, 52, 1366–1377, doi:10.1016/j.asr.2013.06.014.

30. Dahlgren, H., J. L. Semeter, R. A. Marshall, and M. Zettergren (2013), The optical manifestation of dispersive field-aligned bursts in auroral breakup arcs, *J. Geophys. Res. Space Physics*, 118, 4572-4582, doi:10.1002/jgra.50415.
29. Graf, K. L., N. G. Lehtinen, M. Spasojevic, M. B. Cohen, R. A. Marshall, and U. S. Inan (2013), Analysis of experimentally validated trans-ionospheric attenuation estimates of VLF signals, *J. Geophys. Res. Space Physics*, 118, 2708-2720, doi:10.1002/jgra.50228.
28. Graf, K. L., M. Spasojevic, R. A. Marshall, N. G. Lehtinen, F. R. Foust, and U. S. Inan (2013), Extended lateral heating of the nighttime ionosphere by ground-based VLF transmitters, *J. Geophys. Res. Space Physics*, 118, doi:10.1002/2013JA019337.
27. Marshall, R. A. (2012), An Improved Model of the Lightning Electromagnetic Field Interaction with the D-region Ionosphere, *J. Geophys. Res.*, 117, A03316, doi:10.1029/2011JA017408.
26. Douglas, E. S., A. Strahler, J. Martel, T. Cook, C. Mendillo, R. Marshall, S. Chakrabarti, C. Schaaf, C. Woodcock, Z. Li, X. Yang, D. Culvenor, D. Jupp, G. Newnham, and J. Lovell (2012), DWEL: A Dual-wavelength Echidna LIDAR for Ground-based Forest Scanning, *Proceedings of the Geoscience and Remote Sensing Symposium (IGARSS)*, July 2012, pp. 4998-5001.
25. Cohen, M. B., and R. A. Marshall (2012), ELF/VLF recordings during the 11 March 2011 Japanese Tohoku earthquake, *Geophys. Res. Lett.*, 39, L11804, doi:10.1029/2012GL052123.
24. Marshall, R. A., S. M. Smith, J. Baumgardner, and S. Chakrabarti (2011), Continuous Ground-based Multi-wavelength Airglow Measurements, *J. Geophys. Res.*, 116, A11304, doi:10.1029/2011JA016901.
23. Marshall, R. A., J. Bortnik, N. Lehtinen, and S. Chakrabarti (2011), Optical signatures of lightning-induced electron precipitation, *J. Geophys. Res.*, 116, A08214, doi:10.1029/2011JA016728.
22. Marshall, R. A., R. T. Newsome, N. G. Lehtinen, N. Lavassar, and U. S. Inan (2010), Optical signatures of radiation-belt electron precipitation induced by ground-based VLF transmitters, *J. Geophys. Res.*, 115, A08206, doi:10.1029/2010JA015394.
21. Marshall, R. A., and U. S. Inan (2010), Two-dimensional frequency domain modeling of lightning EMP-induced perturbations to VLF transmitter signals, *J. Geophys. Res.*, 115, A00E29, doi:10.1029/2009JA014761.
20. Marshall, R. A., U. S. Inan, and V. Glukhov (2010), Elves and Associated Electron Density Changes due to Vertical and Horizontal Lightning Channels, *J. Geophys. Res.*, 115, A00E17, doi:10.1029/2009JA014469.
19. Kendall, E., R. Marshall, R. T. Parris, A. Bhatt, A. Coster, T. Pedersen, P. Bernhardt, and C. Selcher (2010), Decameter structure in heater-induced airglow at the High frequency Active Auroral Research Program facility, *J. Geophys. Res.*, 115, A08306, doi:10.1029/2009JA015043.
18. Inan, U. S., S. A. Cummer, and R. A. Marshall (2010), A survey of ELF and VLF research on lightning-ionosphere interactions and causative discharges, *J. Geophys. Res.*, 115, A00E36, doi:10.1029/2009JA014775.
17. Lehtinen, N., R. A. Marshall, and U. S. Inan (2010), Full-wave modeling of "early" VLF perturbations caused by lightning EMP, *J. Geophys. Res.*, 115, A00E40, doi:10.1029/2009JA014776.
16. Lefeuvre, F., R. Marshall, J.-L. Pincon, U. Inan, D. Lagoutte, M. Parrot, and J.-J. Berthelier (2009), On remote sensing of transient luminous events' parent lightning discharges by ELF/VLF wave measurements on board a satellite, *J. Geophys. Res.*, 114, A09303, doi:10.1029/2009JA014154.
15. Marshall, R. A., R. T. Newsome, and U. S. Inan (2008), Fast Photometric Imaging Using Orthogonal Linear Arrays, *IEEE Transactions on Geoscience and Remote Sensing*, vol.46, no.11, pp.3885-3893, doi:10.1109/TGRS.2008.2000824.
14. Marshall, R. A., U. S. Inan, and T. W. Chevalier (2008), Early VLF perturbations caused by lightning EMP-driven dissociative attachment, *Geophys. Res. Lett.*, 35, L21807, doi:10.1029/2008GL035358.
13. Pedersen, T. R., R. J. Esposito, E. A. Kendall, D. Sentman, M. J. Kosch, E. V. Mishin, and R. A. Marshall (2008), Observations of artificial and natural optical emissions at the HAARP facility, *Ann. Geophys.*, 26, 1089-1099, doi:10.5194/angeo-26-1089-2008.

12. Marshall R. A., U. S. Inan, W. A. Lyons (2007), Very low frequency sferic bursts, sprites, and their association with lightning activity, *J. Geophys. Res.*, 112, D22105, doi:10.1029/2007JD008857.
11. Marshall, R. A., and U. S. Inan (2007), Possible direct cloud-to-ionosphere current evidenced by sprite-initiated secondary TLEs, *Geophys. Res. Lett.*, 34, L05806, doi:10.1029/2006GL028511.
10. Marshall R. A., U. S. Inan, W. A. Lyons (2006), On the association of early/fast very low frequency perturbations with sprites and rare examples of VLF backscatter, *J. Geophys. Res.*, 111, D19108, doi:10.1029/2006JD007219.
9. Marshall R. A., U. S. Inan (2006), High-speed measurements of small-scale features in sprites: Sizes and lifetimes, *Radio Sci.*, 41, RS6S43, doi:10.1029/2005RS003353.
8. Mika, A., C. Haldoupis, T. Neubert, H. T. Su, R. R. Hsu, R. J. Steiner, and R. A. Marshall (2006), Early VLF perturbations observed in association with elves, *Ann. Geophys.*, 24, 2179-2189, doi:10.5194/angeo-24-2179-2006.
7. Haldoupis, C., R. J. Steiner, A. Mika, S. Shalimov, R. A. Marshall, U. S. Inan, T. Bosinger, T. Neubert (2006), "Early/slow" events: A new category of VLF perturbations observed in relation with sprites, *J. Geophys. Res.*, 111, A11321, doi:10.1029/2006JA011960.
6. Marshall, R. A., U. S. Inan, T. Neubert, A. Hughes, G. Satori, J. Bor, A. Collier, and T. H. Allin (2005), Optical observations geomagnetically conjugate to sprite-producing lightning discharges, *Ann. Geophys.*, 23(6), 2231, doi:10.5194/angeo-23-2231-2005.
5. Marshall, R. A., and U. S. Inan (2005), High-speed telescopic imaging of sprites, *Geophys. Res. Lett.*, 32, L05804, doi:10.1029/2004GL021988.
4. M. J. Kosch, T. Pedersen, J. Hughes, R. Marshall, E. Gerken, A. Senior, D. Sentman, M. McCarrick, and F. T. Djuth (2005), Artificial optical emissions at HAARP for pump frequencies near the third and second electron gyro-harmonic, *Ann. Geophys.*, 23, 1585-1592, doi:10.5194/angeo-23-1585-2005.
3. Neubert, T., T. H. Allin, E. Blanc, T. Farges, C. Haldoupis, A. Mika, S. Soula, L. Knutsson, O. van der Velde, R. A. Marshall, U. Inan, G. Satori, J. Bor, A. Hughes, A. Collier, S. Laursen, and I. Lundgaard Rasmussen (2005), Co-ordinated observations of transient luminous events during the EuroSprite2003 campaign, *J. Atm. Solar Terr. Phys.*, 67, 807-820, doi:10.1016/j.jastp.2005.02.004.
2. Mika, A., C. Haldoupis, R. A. Marshall, T. Neubert, and U. S. Inan (2005), Subionospheric VLF signatures and characteristics in association with sprites observed during EuroSprite-2003, *J. Atm. Solar Terr. Phys.*, 67, 1580-1597, doi:10.1016/j.jastp.2005.08.011.
1. Haldoupis, C., T. Neubert, U. Inan, A. Mika, T. H. Allin, and R. A. Marshall (2004), Sub-ionospheric early VLF signal perturbations observed in one-to-one association with sprites, *J. Geophys. Res.*, 109, (A10), A10303, doi:10.1029/2004JA010651.

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#### CONFERENCE PRESENTATIONS

Presentations given by Dr. Marshall are listed. Numerous talks for which Dr. Marshall is listed as a co-author are not included.

43. Marshall, R. A., F. Gasdia, and W. Xu (2018), Estimating Energetic Electron Precipitation Fluxes from Subionospheric Very-Low-Frequency Transmitter Signals, *7th International HEPPA-Solaris Workshop*, Roanoke, VA, June 11, 2018.
42. Marshall, R. A., W. Xu, F. Gasdia, D. Drob, A. Kero, and E. Turunen (2018), The D-region response to the 2017 Total Solar Eclipse: Observations and Modeling, *URSI Atlantic Radio Science Conference*, Gran Canaria, Spain, May 30, 2018.
41. Marshall, R. A., P. Brown, J. Kero, G. Stober, and C. Schult (2018), Meteor radar masses derived from dual-frequency head-echo observations and model inversion, *URSI Atlantic Radio Science Conference*, Gran Canaria, Spain, May 30, 2018, **Invited**.

40. Marshall, R. A., W. Xu, F. Gasdia, and A. Sousa (2018), Atmospheric Signatures of Radiation Belt Precipitation and their Relationship to Precipitating Flux and Spectra, *AGU Chapman Conference on Radiation Belt Dynamics*, Cascais, Portugal, March 8, 2018.
39. Marshall, R. A., W. Xu, A. Sousa, and A. Kero (2018), Secondary Effects of Lightning-induced Electron Precipitation: Chemical Effects, Optical Emissions, and X-rays, *URSI National Radio Science Meeting*, Boulder, CO, January 6, 2018, HEG1-5.
38. Marshall, R. A., E. Sanchez, A. Kero, E. Turunen, and D. Marsh (2017), Atmospheric Signatures and Effects of Space-based Relativistic Electron Beam Injection, *AGU Fall Meeting*, New Orleans, LA, December 11, 2017.
37. Marshall, R. A. (2017), Diagnostics of Relativistic Electron Beam Injection in the Upper Atmosphere, *Active Experiments in Space: Past, Present, and Future*, Santa Fe, NM, September 11, 2017.
36. Marshall, R. A., W. Xu, A. Kero, and E. Turunen (2017), Atmospheric Signatures and Diagnostics of Energetic Particle Precipitation, *URSI General Assembly*, Montreal, Canada, August 23, 2017.
35. Marshall, R. A. (2017), Meteor Head Echoes: Theory, Modeling, Observation, and Experiment, *CEDAR Annual Workshop*, Keystone, CO, June 22, 2017.
34. Marshall, R. A. (2017), Studying the D-region ionosphere response to the total solar eclipse through data and modeling, *CEDAR Annual Workshop*, Keystone, CO, June 23, 2017.
33. Marshall, R. A., T. Wallace, and M. Turbe (2017), Modeling VLF Transmitter Amplitude and Phase Variations in the Earth-Ionosphere Waveguide, *URSI National Meeting*, Boulder, CO, January 5, 2017.
32. Marshall, R. A., T. Wallace, and M. Turbe (2016), Finite Difference modeling of VLF Propagation in the Earth-Ionosphere Waveguide, *AGU Fall Meeting*, San Francisco, CA, December 15, 2016.
31. Marshall, R. A., S. Close, P. Brown, and Y. Dimant (2016), Characteristics of meteor plasma distributions from radar head echoes, *CEDAR Annual Workshop*, Santa Fe, NM, June 22, 2016.
30. Marshall, R. A. (2016), Atmospheric Response to Energetic Electron Precipitation: Ionization, optical emissions, x-rays, and backscatter, *6th International HEPPA-SOLARIS Workshop*, Helsinki, Finland, June 13, 2016.
29. Marshall, R. A., S. Close, P. Brown, and Y. Dimant (2016), Characteristics of meteor plasma distributions from radar head echoes, *Meteoroids 2016 Conference*, Noordwijk, Netherlands, June 8, 2016.
28. Marshall, R. A., S. Close, P. Brown, and Y. Dimant (2016), Effects of meteor head plasma distribution on head echo radar cross sections, *International Meteor Conference*, Egmond Aan Zee, Netherlands, June 4, 2016.
27. Marshall, R. A., P. R. Blaes, and U. S. Inan (2015), Global occurrence of Elves and lightning-induced heating of the ionosphere from ground-based observations, *AGU Fall Meeting*, San Francisco, CA, December 15, 2015.
26. Marshall, R. A. and S. Close (2015), Numerical modeling of radio wave scattering from meteor head plasma, *Radio Science Meeting (Joint with AP-S Symposium)*, 2015 USNC-URSI, 19-24 July 2015; doi:10.1109/USNC-URSI.2015.7303538
25. Marshall, R. A., M. J. Nicolls, E. Sanchez, N. Lehtinen, and J. Nielson (2015), Effects of a Relativistic Electron Beam Interaction with the Upper Atmosphere: Ionization, X-Rays, and Optical Emissions, *AGU Fall Meeting*, San Francisco, CA, December 2014.
24. Marshall, R. A. and J. B. Snively (2013), Very-Low-Frequency Subionospheric Remote Sensing of Thunderstorm-driven Acoustic and Gravity Waves in the D-region, *AGU Fall Meeting*, San Francisco, CA, Dec 9-13, 2013, SA53A-06.
23. Marshall, R. A. (2013), Time-domain modeling of lightning, VLF transmitters, and their effects on the lower ionosphere, *CEDAR Annual Workshop*, Boulder, CO, June 22-28, 2013.
22. Marshall, R. A. (2012), Effects of Lightning Return Stroke Parameters on Radiated Fields, on the Ground and in the Ionosphere, *AGU Fall Meeting*, San Francisco, CA, Dec 6-10, 2012, AE43A-0241.

21. Marshall, R. A. (2012), High-speed Observations and Modeling of Elves and Associated Ionospheric Effects, *TEA-IS Workshop*, Málaga, Spain, June 17-22, 2012, **Invited**.
20. Marshall, R. A., S. Close, and U. S. Inan (2012), Subionospheric VLF Remote Sensing of Convective Gravity Waves and Acoustic Waves in the Lower Ionosphere, *CEDAR Workshop*, Santa Fe, NM, June 20-24, 2012.
19. Marshall, R. A. (2011), Lightning Interaction with the Lower Ionosphere: Elve Doublets and Ring Sprites, *AGU Fall Meeting*, San Francisco, CA, Dec 5-9, 2011, AE21A-0221.
18. Marshall, R. A. and U. S. Inan (2011), Model Estimates of Optical Emissions due to Lightning-Induced Electron Precipitation, *URSI General Assembly*, Istanbul, Turkey, August 15-19, 2011, GP2.40.
17. Marshall, R. A., J. Bortnik, and N. Lehtinen (2010), Optical Signatures of Lightning-Induced Electron Precipitation, *AGU Fall Meeting*, San Francisco, CA, Dec 13-17, 2010; AE13B-01, **Invited**.
16. Marshall, R. A. and U. S. Inan (2009), Ionospheric Effects of Cloud-to-ground and In-cloud Lightning Discharges, *AGU Chapman Conference on Effects of Thunderstorms and Lightning in the Upper Atmosphere*, State College, PA, May 10-14, 2009.
15. Marshall, R. A. and U. S. Inan (2008), Elves and Associated Ionospheric Density Perturbations due to Horizontal In-cloud Lightning EMP, *AGU Fall Meeting*, San Francisco, CA, Dec 10-14, 2008, Abstract AE13A-0300; *Outstanding Student Paper Award*.
14. Marshall, R. A. and U. S. Inan (2008), Early VLF Perturbations Driven by Lightning-EMP Generated Density Perturbations in the Ionosphere: Model Results, *URSI General Assembly*, Chicago, IL, USA, August 10-15, 2008; EGH-4.
13. Marshall, R. A. and U. S. Inan (2008), Dissociative Attachment as a Possible Cause of Early VLF Perturbations, *URSI National Radio Science Meeting*, Boulder, CO, USA, January 3-6, 2008; GH5-10.
12. Marshall, R. A. (2007), Observations and Statistics of Small-scale Streamer and Bead Features in Sprites; *Streamers, sprites, leaders, lightning: from micro- to macroscales*, Leiden, The Netherlands, Oct 8-12, 2007.
11. Marshall, R. A. and U. S. Inan (2007), The Association of Very-Low-Frequency Sferic Bursts with Sprites and Intra-cloud Lightning Activity, *URSI Joint National Radio Science Meeting*, Ottawa, ON, Canada, July 23-26, 2007; *First Place, Student Paper Competition*.
10. Marshall, R. A. and U. S. Inan (2006), Observations of Burst-like VLF Sferic Activity in Association with Sprites, *AGU Fall Meeting*, San Francisco, CA, Dec 11-15, 2006; AE51A-0263.
9. Marshall, R. A. and U. S. Inan (2006), Evidence for Direct Cloud-to-Ionosphere Electrical Connection through Sprite and Jet Processes, *CEDAR Workshop*, Santa Fe, NM, June 19-23, 2006; SPRT-06.
8. Marshall, R. A. and U. S. Inan (2006), Early/Fast VLF Perturbations caused by Scattering from Transient Luminous Events, *URSI National Radio Science Meeting*, Boulder, CO, January 4-7, 2006; H/G3-1, **Invited**.
7. Marshall, R. A. and U. S. Inan (2005), Measurements of Small-scale Features in Sprites: Sizes, Lifetimes and Propagation, *URSI General Assembly*, New Delhi, India, October 23-29, 2005; HGEP.8(0465), **Invited**.
6. Marshall, R. A. and U. S. Inan (2005), High-speed Measurements of Evolution and Propagation of Fine Structure in Sprites, *CAL Mid-Term Review and Science Meeting*, Elounda, Crete, Greece, June 20-24, 2005, talk D1-02.
5. Marshall, R. A. and U. S. Inan (2005), High-speed Measurements of Small-scale Features in Sprites: Sizes, Lifetimes and Propagation, *Ionospheric Effects Symposium*, Alexandria, VA, May 3-5, 2005; 1B-6 (A057).
4. Marshall, R. A. and U. S. Inan (2005), High-speed Telescopic Imaging of Sprites, *URSI National Radio Science Meeting*, Boulder, CO, January 5-8, 2005, oral presentation H/G7-7, **Invited**.
3. Marshall, R. A. and U. S. Inan (2004), Sprite observations from Langmuir Laboratory, New Mexico, *NATO Advanced Study Institute on Sprites, Elves, and Intense Lightning Discharges*, Corte, Corsica, France, July 21-25, 2004.



2. Marshall, R. A. and U. S. Inan (2004), High Time Resolution Telescopic Imaging of Fine Structure in Sprites, *AGU Fall Meeting*, San Francisco, CA, Dec 8-12, 2004, Abstract AE51A-09; *Outstanding Student Paper Award*.
1. Marshall, R. A., U. S. Inan, T. Neubert, A. Hughes, A. Collier, and T. H. Allin (2004), Optical Observations of Conjugate Sprites as Evidence for Geomagnetically Trapped Relativistic Electron Beams, *URSI National Radio Science Meeting*, Boulder CO, January 4-8, 2004, talk G/H1-3.

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#### INVITED SEMINARS AND SYMPOSIA

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17. Marshall, R. A. (2018), Thunderstorm Electrification, Lightning Flash Rates, and the RELAMPAGO Field Campaign, *Colorado School of Mines, Physics Department*, Golden, CO, October 2018.
16. Marshall, R. A. (2018), Atmospheric Signatures and Diagnostics of Radiation Belt Electron Precipitation, *LASP Friends of the Magnetosphere (FOM)*, Boulder, CO, February 2018.
15. Marshall, R. A. (2017), Lightning Effects in the Upper Atmosphere, Ionosphere, and Magnetosphere, *Presented at University of Alabama in Huntsville, Department of Atmospheric Sciences*, Huntsville, AL, October 2017.
14. Marshall, R. A. (2017), Very-Low-Frequency Subionospheric Remote Sensing as a Diagnostic of D-region Ionosphere Variations, *Presented at Utah State University, Department of Physics*, Logan, UT, April 2017.
13. Marshall, R. A. (2016), The Earth's Atmosphere as a Natural Source of X-ray Radiation, *Presented at the University of Western Ontario, Department of Physics and Astronomy*, London, ON, Canada, October 2016.
12. Marshall, R. A. (2016), Atmospheric Signatures of Energetic Particle Precipitation in the Upper Atmosphere, *Presented at the National Center for Atmospheric Research (NCAR), High Altitude Observatory (HAO)*, Boulder, CO, September 2016.
11. Marshall, R. A. (2016), The Earth's Atmosphere as a Natural Source of X-ray Radiation, *Presented at Dartmouth College, Plasma Seminar Series*, Hanover, NH, May 2016.
10. Marshall, R. A. (2015), Lightning Effects in Space, *presented at CU Boulder, Department of Aerospace Engineering Sciences*, Boulder, CO, February 2015.
9. Marshall, R. A. (2014), The Artificial Relativistic Electron Beam, *presented at CU Boulder and the Laboratory of Atmospheric and Space Physics (LASP)*, Boulder, CO, April 2014.
8. Marshall, R. A. (2014), Numerical modeling of the lightning EMP and its interaction with the lower ionosphere, *presented at Lawrence Livermore National Laboratory (LLNL)*, Livermore, CA, January 2014.
7. Marshall, R. A. (2011), Interactions between Lightning and the Lower Ionosphere, *presented for SESS Group, Stanford University*, Stanford, CA, November 29, 2011.
6. Marshall, R. A. (2011), High-speed Imaging of Auroral and High-energy Particle Precipitation, *presented at KLA-Tencor*, Milpitas, CA, November 4, 2011.
5. Marshall, R. A. (2010), Optical Signatures of Transmitter- and Lightning-induced Electron Precipitation, *presented for SESS Group, Stanford University*, Stanford, CA, September 22, 2010.
4. Marshall, R. A. (2009), An Introduction to Near-Earth Space Physics, *presented at Bermuda College*, Bermuda, September 30, 2009.
3. Marshall, R. A. (2009), Ionospheric Effects of Intense Lightning Discharges, *presented at Center for Space Physics, Boston University*, Boston, MA, September 9, 2009.
2. Marshall, R. A. (2009), Ionospheric Effects of Intense Lightning Discharges, *presented at Geospace Studies Institute, SRI International*, Menlo Park, CA, March 12, 2009.
1. Marshall, R. A. (2009), Ionospheric Effects of Intense Lightning Discharges, *presented at Institute for Geophysics and Planetary Physics, UCLA*, Los Angeles, CA, Feb 19, 2009.

## THESES SUPERVISED

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Ph.D, Engineer, and Master's theses by students for whom Dr. Marshall is or was the student's primary research supervisor.

11. Grant Berland, Aerospace Engineering Sciences, CU Boulder, Ph.D expected 2023
10. Liane Tarnecki, Aerospace Engineering Sciences, CU Boulder, Ph.D expected 2023
9. Carolina Peña, Aerospace Engineering Sciences, CU Boulder, Ph.D expected 2022
8. Alexandra Wold, Aerospace Engineering Sciences, CU Boulder, Ph.D expected 2022
7. Forrest Gasdia, Aerospace Engineering Sciences, CU Boulder, Ph.D expected 2020
6. André Antunes de Sá, Aerospace Engineering Sciences, CU Boulder, Ph.D expected 2020
5. Austin Sousa, Ph.D, Aeronautics and Astronautics, Stanford University, June 2018
4. Jennifer Kampmeier, M.S., Aerospace Engineering Sciences, CU Boulder, May 2018
3. Stephen Jackson, M.S., Aerospace Engineering Sciences, CU Boulder, May 2017
2. Patrick Blaes, Ph.D, Electrical Engineering, Stanford University, May 2015
1. Steven Ingram, Engineer Degree, Electrical Engineering, Stanford University, January 2015

## DOCTORAL THESIS COMMITTEE MEMBER

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15. Andrew Dahir, Aerospace Engineering Sciences, CU Boulder, Ph.D expected Fall 2020
14. Michael DeLuca, Aerospace Engineering Sciences, CU Boulder, Ph.D expected Fall 2020
13. Kun Zhang, Aerospace Engineering Sciences, CU Boulder, Ph.D expected Fall 2019
12. Rory Barton-Grimley, Aerospace Engineering Sciences, CU Boulder, Ph.D expected Summer 2019
11. Yining Shi, Aerospace Engineering Sciences, CU Boulder, Ph.D expected Spring 2019
10. Kevin-Druis Merenda, Physics, Colorado School of Mines, Ph.D expected Spring 2019
9. Robinson Wallace, Atmospheric and Ocean Sciences, CU Boulder, Ph.D expected Spring 2019
8. Alex Barrie, Ph.D, Aerospace Engineering Sciences, CU Boulder, September 2018
7. Saurabh Sanghai, Ph.D, Electrical Engineering, CU Boulder, May 2018
6. Dilini Subasinghe, Ph.D, Physics and Astronomy, University of Western Ontario, December 2017.
5. Derek Houtz, Ph.D, Aerospace Engineering Sciences, CU Boulder, May 2017
4. Evan Thomas, Ph.D, Physics, CU Boulder, May 2017
3. Greg Lucas, Ph.D, Aerospace Engineering Sciences, CU Boulder, May 2017
2. David Garrido López, Ph.D, Electrical Engineering, CU Boulder, December 2016
1. Thomas Rogers, Ph.D, Astrophysics and Planetary Sciences, CU Boulder, July 2016

## UNDERGRADUATE RESEARCH ADVISEES

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\* Discovery Learning Apprenticeship (DLA)

- Connor Myers\*, Aerospace Engineering Sciences, Summer 2018 – present
- Elliott Davis, Aerospace Engineering Sciences, Fall 2018 – present
- Matthew Funk\*, Aerospace Engineering Sciences, Fall 2017 – Spring 2018
- Catherine Witt\*, Electrical and Computer Engineering, Fall 2017 – Spring 2018
- Alec Viets, Aerospace Engineering Sciences, Summer 2017 – Summer 2018

- Leina Hutchinson, Aerospace Engineering Sciences, Summer 2017
- Noah Holland-Moritz\*, Engineering Physics, Fall 2016 – Spring 2017
- Joshua (Luke) Tafur, Aerospace Engineering Sciences, Spring 2016

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POSTDOCTORAL FELLOWS AND RESEARCH ASSOCIATES

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2. Austin Sousa (Ph.D 2018, Stanford University), October 2017 – present
1. Wei Xu (Ph.D 2015, Pennsylvania State University), January 2016 – present

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EXTERNALLY FUNDED RESEARCH PROJECTS AT CU BOULDER

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12. Next Generation Space Environment Technologies (NSET)  
 Prime Sponsor: Air Force Research Laboratory; Subaward Sponsor: Atmospheric and Environmental Research, Inc.  
 Period of Performance: 01/01/2019 – 12/31/2021  
 CU Budget: \$318,000
11. Meteor Plasma Formation and Dynamics with Implication for Radar Measurements  
 PI: Robert Marshall  
 Prime Sponsor: NSF, Aeronomy  
 Period of Performance: 11/01/2018 – 10/31/2021  
 Budget: \$197,607
10. Improved Meteoroid Characterization through Laboratory Experiments, Modeling, and Ground-based Observations  
 Prime Sponsor: NSF, Aeronomy  
 Period of Performance: September 01, 2018 – August 31, 2022  
 Award Amount: \$645,134
9. VIPER – VLF Trans-Ionospheric Propagation Experiment Rocket  
 Prime Sponsor: NASA Heliophysics Division; Subaward Sponsor: University of California Berkeley  
 Period of Performance: July 01, 2018 – June 30, 2021  
 Award Amount: \$194,833
8. Very Low Frequency Wave and Particle Precipitation Mapper (VPM)  
 Prime Sponsor: Air Force Research Laboratory  
 Period of Performance: November 09, 2017 – December 31, 2018  
 Award Amount: \$103,326
7. Collaborative Research: Energetic Particle Precipitation Mechanisms in the Inner Magnetosphere: Van Allen Probes and Incoherent Scatter Radar Coordinated Measurements  
 Prime Sponsor: NSF, Magnetospheric Physics  
 Period of Performance: September 1, 2017 – August 31, 2020  
 Award Amount: \$120,791
6. Prevalence of Distinct Energetic Intra-Cloud Lightning Events and Their Connection to Terrestrial Gamma Ray Flashes  
 Prime Sponsor: NASA, Earth and Space Science Fellowships (André Antunes de Sá)  
 Period of Performance: September 1, 2017 – August 31, 2020  
 Award Amount: \$135,000
5. Collaborative Research: Investigation of kinematic, microphysical and electrical processes leading to extreme lightning flash rates over Argentina using RELAMPAGO observations  
 Prime Sponsor: NSF, Physical and Dynamic Meteorology  
 Period of Performance: September 1, 2017 – August 31, 2021  
 Award Amount: \$550,643

4. Quantifying the Contributions of Ionization Sources on the Formation of the D-region Ionosphere During the 2017 Solar Eclipse  
Prime Sponsor: NASA, Living With a Star  
Period of Performance: April 1, 2017 – March 31, 2018  
Award Amount: \$49,824
3. Spatial, Temporal, and Orientation Information in Contested Environments (STOIC)  
Prime Sponsor: DARPA; Subaward Sponsor: Leidos Inc.  
Period of Performance: October 1, 2015 – January 31, 2019  
Award Amount: \$402,645
2. Thunderstorm Coupling to the Lower Ionosphere through Electromagnetic, Acoustic, and Gravity Waves  
Prime Sponsor: NSF; Subaward Sponsor: Stanford University  
Period of Performance: September 1, 2015 – July 31, 2017  
Award Amount: \$131,529
1. Concept Development for Active Magnetospheric, Radiation Belt, and Ionospheric Experiments using In Situ Relativistic Electron Beam Injection  
Prime Sponsor: NSF; Subaward Sponsor: SRI International  
Period of Performance: September 1, 2015 – August 31, 2017  
Award Amount: \$47,290

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#### INTERNALLY FUNDED RESEARCH PROJECTS AT CU BOULDER

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3. Magnetic CubeSat Constellation for Advanced Navigational Models  
Sponsor: CU Boulder Grand Challenge  
Period of Performance: September 1, 2017 – August 31, 2021  
Award Amount: \$745,520
2. *ASEN 4519: Space Environment and Effects* (course development)  
Sponsor: CU Boulder Space Minor  
Start Date: September 1, 2017  
Award Amount: \$10,000
1. Integrated Remote and In-Situ Sensing (IRISS): Project Lightning  
Sponsor: Research and Innovation Office, CU Boulder  
Period of Performance: January 1 – December 31, 2016  
Award Amount: \$69,446

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#### EXTERNAL PROPOSALS PENDING

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4. CubeSat: Climatology of Anthropogenic and Natural VLF wave Activity in Space (CANVAS)  
PI: Robert Marshall  
Submitted to NSF, CubeSat Program  
Period of performance (proposed): 02/01/2019 – 01/31/2023  
Budget: \$1,196,654 (4-year total)
3. SolarCube: An Imaging Spectro-Polarimeter CubeSat Mission for the Chromosphere and Transition Region  
PI: Phil Oakley (UCAR)  
Submitted to NASA, HTIDES CubeSat Program  
Period of Performance (proposed): 04/21/2019 – 10/20/2022  
CU Budget: \$304,122 (4-year total)
2. Atmospheric Effects of Precipitation through Energetic X-rays (AEPEX) CubeSat Mission  
PI: Robert Marshall

Submitted to NASA, HTIDES CubeSat Program  
Period of Performance (proposed): 11/01/2018 – 10/31/2022  
Budget: \$4,477,621 (4-year total)

1. Quantifying Radiation Belt Precipitation through D-region Ionosphere Imaging  
PI: Robert Marshall  
Submitted to NASA, Heliophysics Early Career Investigator Program  
Period of Performance (proposed): 04/01/2019 – 03/31/2024  
Budget: \$757,158