

ROBERT A. MARSHALL

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RESEARCH OVERVIEW

My research focuses on improving our understanding of the **geospace environment**, the region of the near-Earth space environment influenced by the Earth's magnetic field. My research topics have a common theme of **electromagnetic wave interactions with plasmas** in geospace. My research group studies the physics of lightning and its impact on the geospace environment. We 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. We study the propagation of very low frequency (VLF) 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 electrons.

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

PROFESSIONAL EXPERIENCE

- July 2023 – present: **Associate Chair for Graduate Studies**, AES¹, CU Boulder
- May 2022 – present: **Associate Professor**, AES, CU Boulder
- Jan – July 2023: **Visiting Researcher**, Le Studium Institute for Advanced Studies, Orléans, France
- Aug 2015 – May 2022: **Assistant Professor**, AES, CU Boulder
- May – Aug 2015: **Visiting Assistant Professor**, AES, 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 – Oct 2009: **Postdoctoral Scholar**, Electrical Engineering, Stanford University
- Jan 2003 – May 2009: **Research Assistant**, Electrical Engineering, Stanford University

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*

¹AES = Ann & H. J. Smead Aerospace Engineering Sciences Department

AWARDS AND HONORS

- 2022 Outstanding Research Award, Aerospace Engineering Sciences, CU Boulder
- 2021 Provost's Faculty Achievement Award, CU Boulder
- 2021 NSF CAREER Award
- 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 & 2004 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"
- 2007 First Place, URSI Student Paper Competition; Ottawa, ON, Canada
- 2002-2005 Texas Instruments Stanford Graduate Fellowship

PROFESSIONAL SERVICE ACTIVITIES

- URSI Vice Chair for Commission H, 2023 – present
- AIAA Small Satellite Technical Committee, 2022 – present
- Meeting Session Organizer: 2021, 2023 URSI General Assembly
- Meeting Session Organizer: 2022, 2023 AGU Fall Meeting
- Meeting Session Organizer: 2015, 2016, 2017 CEDAR Workshops
- Meeting Session Organizer: 2009, 2016 – 2019 URSI National Radio Science Meeting
- Meeting Organizer: 2015 Stanford Meteor Environment and Effects (SMEE) Workshop, Stanford, CA, July 14-16, 2015
- CEDAR and GEM student poster judge at numerous Annual Workshops
- AGU student poster judge at numerous Fall Meetings, Atmospheric and Space Electricity Focus Group
- NASA Review Panelist every year since 2014
- NSF Review Panelist most years since 2016
- Numerous proposal reviews for NSF, NASA and international agencies (3-4 reviews per year)
- Journal reviews: Active reviewer for 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 (~9-10 reviews per year)

UNIVERSITY SERVICE ACTIVITIES

- AES Department, Associate Chair for Graduate Studies, July 2023 – present
- College of Engineering and Applied Science, Graduate Education Committee, July 2023 – present
- CU Boulder Campus, Provost Faculty Achievement Award Committee, 2022 – 2023
- AES Department, Faculty Search Committee, Fall 2022 – Spring 2023
- AES Department, Undergraduate Operations Committee, Fall 2021 – Spring 2022
- AES Department, Undergraduate Curriculum Committee, Fall 2019 – Spring 2021

- AES Department, Avionics and Instrumentation Curriculum Group Lead, Fall 2019 – Spring 2021
- 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

COURSES TAUGHT

† Denotes courses created or co-created

‡ Denotes courses significantly revised

- ASEN 5519[†], *Space Mission Concept Development*, Fall 2015
- ASEN 5440, *Mission Design and Development for Space Sciences*, Fall 2017 & 2019
- ASEN 5335[‡], *Aerospace Environment*, Spring 2021 & 2022, Fall 2023
- ASEN 5018/6028, *Graduate Projects I & II*, project advisor, AY 2017–2022
- ASEN 4519[†], *Space: Environment and Effects*, Fall 2018
- ASEN 4018/4028, *Senior Design Projects I & II*, team advisor, AY 15–16, 16–17, 23–24
- ASEN 3300, *Aerospace Electronics and Communications*, Spring 2017 & 2018, Fall 2020 & 2021
- 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.

PUBLICATIONS AND PRESENTATIONS

Publication statistics from [Google Scholar citations index](#), as of December 2023:

Peer-reviewed Publications	93
Total Citations	2860
h-index	29
i10-index	64

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.

BOOKS & BOOK CHAPTERS

1. Marshall, R. A. and C. Cully (2020), 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.
2. Kaeppler, S. R., E. Sanchez, R. H. Varney, R. Irvin, R. A. Marshall, J. Bortnik, A. S. Reimer, and P. Reyes (2020), 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.
3. U. S. Inan and R. A. Marshall (2011), *Numerical Electromagnetics: The FDTD Method*, Cambridge University Press: <http://www.cambridge.org/gb/knowledge/isbn/item5760378/>

* Graduate student authors, for whom Dr. Marshall serves or served as the student's primary research supervisor, are highlighted in **bold**; postdoctoral scholars highlighted with underline.

93. **Berland, G. D.**, Marshall, R. A., Capannolo, L., McCarthy, M. P., & Zheng, L. (2023), Kinetic modeling of radiation belt electrons with Geant4 to study energetic particle precipitation in Earth's atmosphere. *Earth and Space Science*, 10, e2023EA002987, doi.org/10.1029/2023EA002987
92. Shane, A. D., Marshall, R. A., Claudepierre, S. G., & Pettit, J. M. (2023), Electron lifetimes measured at LEO: Comparison with RBSP estimates and pitch angle resolved lifetimes. *Journal of Geophysical Research: Space Physics*, 128, e2023JA031679, doi.org/10.1029/2023JA031679.
91. **Juarez Madera, D.**, Marshall, R. A., Elschot, S., Kaeppler, S., Reyes, P., Varney, R. H., and Crew, A. B. (2023), Time-dependent inversion of energetic electron precipitation spectra from ground-based Incoherent Scatter Radar measurements. *Journal of Geophysical Research: Space Physics*, 128, e2022JA031000, doi.org/10.1029/2022JA031000.
90. **Tarnecki, L. K.**, Marshall, R. A., Fontanese, J., Sternovsky, Z., and Munsat, T. (2023), Experimentally derived luminous efficiencies for aluminum and iron at meteoric speeds. *Geophysical Research Letters*, 50, e2023GL103016, doi:10.1029/2023GL103016.
89. **Berland, G. D.**, R. A. Marshall, **C. Martin, J. Buescher**, R. A. Kohnert, S. Boyajian, C. M. Cully, M. P. McCarthy, and W. Xu (2023), The atmospheric X-ray imaging spectrometer (AXIS) instrument: Quantifying energetic particle precipitation through bremsstrahlung X-ray imaging. *Review of Scientific Instruments*, 94, 023103, doi:10.1063/5.0127272.
88. **Gasdia, F.**, and Marshall, R. A. (2023), A method for imaging energetic particle precipitation with subionospheric VLF signals. *Earth and Space Science*, 10, e2022EA002460, doi:10.1029/2022EA002460
87. Kaeppler, S. R., R. Marshall, E. R. Sanchez, **D. H. Juarez Madera**, R. Troyer, and A. N. Jaynes (2022), pyGPI5: A python D- and E-region chemistry and ionization model. *Frontiers in Astronomy and Space Science*, 9:1028042, doi:10.3389/fspas.2022.1028042.
86. Ma, Q., Xu, W., Sanchez, E. R., Marshall, R. A., Bortnik, J., Reyes, P. M., et al. (2022), Analysis of electron precipitation and ionospheric density enhancements due to hiss using incoherent scatter radar and Arase observations. *Journal of Geophysical Research: Space Physics*, 127, e2022JA030545, doi:10.1029/2022JA030545.
85. Sanchez, E. R., Ma, Q., Xu, W., Marshall, R. A., Bortnik, J., Reyes, P., et al. (2022), A test of energetic particle precipitation models using simultaneous incoherent scatter radar and Van Allen Probes observations. *Journal of Geophysical Research: Space Physics*, 127, e2021JA030179, doi:10.1029/2021JA030179
84. **Reid, R. A.**, Marshall, R. A., Starks, M. J., Usanova, M. E., Wilson, G. R., Johnston, W. R., et al. (2022), Active VLF transmission experiments between the DSX and VPM spacecraft. *Journal of Geophysical Research: Space Physics*, 127, e2021JA030087, doi:10.1029/2021JA030087.
83. Usanova, M. E., **Reid, R. A.**, Xu, W., Marshall, R. A., Starks, M. J., & Wilson, G. R. (2022), Using VLF transmitter signals at LEO for plasmasphere model validation. *Journal of Geophysical Research: Space Physics*, 127, e2022JA030345, doi:10.1029/2022JA030345.
82. Berge, N., Celestin, S., Garnung, M. B., Xu, W., Marshall, R. A., & Cummer, S. A. (2022), Modeling low-frequency radio emissions from Terrestrial Gamma ray Flash sources. *Journal of Geophysical Research: Atmospheres*, 127, e2021JD036040, doi:10.1029/2021JD036040.
81. Marshall, R. A., Sousa, A., **Reid, R.**, Wilson, G., Starks, M., Ramos, D., et al. (2021), The micro-Broadband Receiver (uBBR) on the Very-Low-Frequency Propagation Mapper (VPM) CubeSat, *Earth and Space Science*, 8, e2021EA001951.
80. **Antunes de Sá, A. L.**, Marshall, R., and Deierling, W. (2021), Energetic intracloud lightning in the RELAMPAGO field campaign, *Earth and Space Science*, 8, e2021EA001856, doi:10.1029/2021EA001856.
79. Xu, W., Marshall, R. A., Kero, A., and Sousa, A. (2021), Chemical response of the upper atmosphere due to lightning-induced electron precipitation, *Journal of Geophysical Research: Atmospheres*, 126, e2021JD034914, doi:10.1029/2021JD034914.

78. **Antunes de Sá, A.**, Marshall, R., and Deierling, W. (2021), Lightning Geolocation and Flash Rates from LF Radio Observations During the RELAMPAGO Field Campaign, *Earth and Space Science*, 8, e2021EA001813, doi:10.1029/2021EA001813.
77. Xu, W., Marshall, R. A., and Tobiska, W. K. (2021), A Method for Calculating Atmospheric Radiation Produced by Relativistic Electron Precipitation, *Space Weather*, 19, e2021SW002735, doi:10.1029/2021SW002735.
76. **Tarnecki, L. K.**, Marshall, R. A., Stober, G., and Kero, J. (2021), Meteoroid mass estimation based on single-frequency radar cross section measurements, *Journal of Geophysical Research: Space Physics*, 126, e2021JA029525, doi:10.1029/2021JA029525
75. **Gasdia, F.**, and Marshall, R. A. (2021), A New Longwave Mode Propagator for the Earth-Ionosphere Waveguide, *IEEE Transactions on Antennas and Propagation*, doi: 10.1109/TAP.2021.3083753.
74. Sugar, G., Marshall, R., Oppenheim, M. M., Dimant, Y. S., and Close, S. (2021), Simulation-derived radar cross sections of a new meteor head plasma distribution model, *Journal of Geophysical Research: Space Physics*, 126, e2021JA029171, doi:10.1029/2021JA029171.
73. Xu, W., Marshall, R. A., Bortnik, J., and Bonnell, J. W. (2021), An electron density model of the D- and E-region ionosphere for transionospheric VLF propagation, *Journal of Geophysical Research: Space Physics*, 126, e2021JA029288, doi:10.1029/2021JA029288.
72. Burns, S., **F. Gasdia**, J. J. Simpson, and R. A. Marshall (2021), 3-D FDTD Modeling of Long-Distance VLF Propagation in the Earth-Ionosphere Waveguide, *IEEE Transactions on Antennas and Propagation*, doi:10.1109/TAP.2021.3070621.
71. Nesbitt, S. W., P. V. Salio, E. Avila, P. Bitzer, L. Carey, V. Chandrasekar, W. Deierling, F. Dominguez, M. E. Dillon, C. M. Garcia, D. Gochis, S. Goodman, D. A. Hence, K. A. Kosiba, M. R. Kumjian, T. Lang, L. M. Luna, J. Marquis, R. Marshall, L. A. McMurdie, E. L. Nascimento, K. L. Rasmussen, R. Roberts, A. K. Rowe, J. J. Ruiz, E. F. M. T. São Sabbas, A. C. Saulo, R. S. Schumacher, Y. G. Skabar, L. A. Toledo Machado, R. J. Trapp, A. Varble, J. Wilson, J. Wurman, E. J. Zipser, I. Arias, H. Bechis, and M. A. Grover (2021), A storm safari in Subtropical South America: proyecto RELAMPAGO, *Bulletin of the American Meteorological Society*, doi:10.1175/BAMS-D-20-0029.1.
70. Borovsky, J. E., G. L. Delzanno, E. E. Dors, M. F. Thomsen, E. R. Sanchez, M. G. Henderson, R. A. Marshall, B. E. Gilchrist, G. Miars, B. E. Carlsten, S. A. Storms, M. A. Holloway, and D. Nguyen (2020), Solving the auroral-arc-generator question by using an electron beam to unambiguously connect critical magnetospheric measurements to auroral images, *Journal of Atmospheric and Solar-Terrestrial Physics*, Vol. 206, 105310, doi:10.1016/j.jastp.2020.105310.
69. Xu, W., Marshall, R. A., Tyssøy, H. N., and Fang, X. (2020), A generalized method for calculating atmospheric ionization by energetic electron precipitation, *Journal of Geophysical Research: Space Physics*, 125, e2020JA028482, doi:10.1029/2020JA028482.
68. **Antunes de Sá, A.**, R. A. Marshall, A. P. Sousa, **A. Viets**, and Deierling, W. (2020), An array of low-cost, high-speed, autonomous electric field mills for thunderstorm research, *Earth and Space Science*, 7, e2020EA001309, doi:10.1029/2020EA001309.
67. Marshall, R. A., W. Xu, T. Woods, C. Cully, A. Jaynes, C. Randall, D. Baker, M. McCarthy, H. E. Spence, **G. Berland**, **A. Wold**, and **E. Davis** (2020), The AEPEX Mission: Imaging Energetic Particle Precipitation in the Atmosphere through its Bremsstrahlung X-ray Signatures, *Advances in Space Research*, Vol. 66, Issue 1, pp. 66–82, doi:10.1016/j.asr.2020.03.003.
66. Sung, C. Y., P. Brown, and R. Marshall (2020), A two year survey for VLF emission from fireballs, *Planetary and Space Science*, 184, 104872.
65. **Antunes de Sá, A.**, and R. A. Marshall (2020), Lightning Distance Estimation Using LF Lightning Radio Signals Via Machine-Learned Models, *IEEE Transactions on Geoscience and Remote Sensing*, doi:10.1109/TGRS.2020.2972153.
64. Limonta, L., S. Close, and R. A. Marshall (2020), A technique for inferring lower thermospheric neutral density from meteoroid ablation, *Planetary and Space Science*, 180, doi:10.1016/j.pss.2019.104735.

63. Marshall, R. A., W. Xu, A. Sousa, M. McCarthy, and R. Millan (2019), X-ray signatures of lightning-induced electron precipitation, *Journal of Geophysical Research: Space Physics*, 124, doi:10.1029/2019JA027044.
62. **Gasdia, F.** and R. A. Marshall (2019), Assimilating VLF Transmitter Observations with an LETKF for Spatial Estimates of the D-region Ionosphere, *IEEE Transactions on Geoscience and Remote Sensing*, doi:10.1109/TGRS.2019.2957716.
61. Sanchez, E. R., A. T. Powis, I. D. Kaganovich, R. Marshall, P. Porazik, J. Johnson, M. Greklek-Mckeon, K. S. Amin, D. Shaw, and M. Nicolls (2019), Relativistic Particle Beams as a Resource to Solve Outstanding Problems in Space Physics, *Front. Astron. Space Sci.*, 6, 71, doi: 10.3389/fspas.2019.00071.
60. Ramos, D., G. Wilson, A. Sousa, R. Marshall, K. Brunetto, J. Ballenthin, R. Kay, J. Patton, S. Quigley, J. Fennelly, M. Starks, T. Willet-Gies, S. Tullino, I. Linscott, and U. Inan (2019), A CubeSat receiver for the study of VLF-waves at LEO, *Proc. SPIE 11131, CubeSats and SmallSats for Remote Sensing III*, 111310P (30 August 2019), doi:10.1117/12.2530479.
59. Xu, W., R. A. Marshall, A. Kero, E. Turunen, D. Drob, J. Sojka, and D. Rice (2019), VLF Measurements and Modeling of the D-region Response to the 2017 Total Solar Eclipse, *IEEE Transactions on Geoscience and Remote Sensing*, 57, 10, doi:10.1109/TGRS.2019.2914920.
58. Xu, W., S. Celestin, V. P. Pasko, and R. A. Marshall (2019), Compton Scattering Effects on the Spectral and Temporal Properties of Terrestrial Gammaray Flashes, *Journal of Geophysical Research: Space Physics*, doi: 10.1029/2019JA026941.
57. Marshall, R. A., W. Xu, A. Kero, R. Kabirzadeh, and E. Sanchez (2019), Atmospheric Effects of a Relativistic Electron Beam Injected From Above: Chemistry, Electrodynamics, and Radio Scattering. *Front. Astron. Space Sci.* 6:6. doi: 10.3389/fspas.2019.00006.
56. Xu, W., and R. A. Marshall (2019), Characteristics of energetic electron precipitation estimated from simulated bremsstrahlung Xray distributions. *Journal of Geophysical Research: Space Physics*, 124, doi:10.1029/2018JA026273.
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.
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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. Migliozi, 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. Migliozi, 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. Migliozi (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.
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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.
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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.

PEER-REVIEWED CONFERENCE PAPERS

5. Marshall, R. A., **G. D. Berland**, J. Buescher, S. Regmi, R. A. Kohnert, A. Chandran, S. Boyajian, T. Woods, H. E. Spence, S. Smith, M. P. McCarthy, and C. M. Cully (2023), The AEPEX Mission: Imaging Energetic Particle Precipitation into Earth's Upper Atmosphere, 37th Annual AIAA/USU Conference on Small Satellites, paper SSC23-WIV-01.
4. Marshall, R. A., **R. A. Reid**, **J. M. Cannon**, S. Wankmueller, **P. Vankawala**, S. Palo, D. M. Malaspina, T. Dudok de Wit, and G. Jannet (2022), The CANVAS Mission: Quantifying the Very-Low-Frequency Radio Energy Input from the Ground into the Earth's Magnetosphere, 36th Annual AIAA/USU Conference on Small Satellites, paper SSC22-WKVIII-06.
3. **Berland, G. D.**, R. A. Marshall, **C. Martin**, **D. Mhadgut**, **J. Buescher**, R. A. Kohnert, S. Boyajian, C. M. Cully, and M. P. McCarthy (2021), The AEPEX CubeSat Mission: Quantifying Energetic Particle Precipitation through Bremsstrahlung X-Ray Imaging, 35th Annual AIAA/USU Conference on Small Satellites, paper SSC21-XIII-01.
2. **Reid, R. A.**, R. A. Marshall, S. E. Palo, and D. M. Malaspina (2021), A Compact Five-Channel VLF Wave Receiver for CubeSat Missions, 35th Annual AIAA/USU Conference on Small Satellites, paper SSC21-VI-09.

1. Aboaf, A. P., E. S. Harrod, M. Zola, A. Prakash, S. E. Palo, R. Marshall, M. D. Pilinski, N. Rainville, A. Dahir, V. Nataraja, B. Schwab, A. Gardell, and L. Warshaw (2020), A Methodology for Successful University Graduate CubeSat Programs, 34th Annual AIAA/USU Conference on Small Satellites, paper SSC20-WKV-06.

CONFERENCE PRESENTATIONS

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

60. Marshall, R. A., D. M. Malaspina, T. Dudok de Wit, G. Jannet, J. M. Cannon, M. Stratton, and S. Wankmueller (2023), Design and Performance of the Compact Five-channel VLF Wave Receiver on the CANVAS CubeSat Mission, URSI General Assembly, Sapporo, Japan, August 24, 2023.
59. Marshall, R. A., J. M. Cannon, and F. Gasdia (2023), Mesoscale D-region ionospheric imaging with an array of VLF receivers, URSI General Assembly, Sapporo, Japan, August 22, 2023.
58. Marshall, R. A., et al (2023), The AEPEX Mission: Imaging Energetic Particle Precipitation Into Earths Upper Atmosphere, 37th Annual AIAA/USU Conference on Small Satellites, Logan, Utah, August 5, 2023.
57. Marshall, R. A., D. M. Malaspina, S. E. Palo, T. Dudok de Wit, G. Jannet, R. A. Reid, J. M. Cannon, S. Wankmueller, P. Vankawala, and A. Aguilar-Nidalini (2022), The CANVAS Mission: Quantifying the VLF Radio Energy Input from the Ground into the Earths Magnetosphere, 10th VERSIM workshop, Sodankyla, Finland, November 9, 2022.
56. Marshall, R. A., F. Gasdia, and J. M. Cannon (2022), Imaging the D-region ionosphere over large scales using an array of VLF receivers, 10th VERSIM workshop, Sodankyla, Finland, November 8, 2022.
55. Marshall, R. A., R. A. Reid, J. M. Cannon, S. Wankmueller, P. Vankawala, S. Palo, D. M. Malaspina, T. Dudok de Wit, and G. Jannet (2022), The CANVAS Mission: Quantifying the Very-Low-Frequency Radio Energy Input from the Ground into the Earth's Magnetosphere, 36th Annual AIAA/USU Conference on Small Satellites, Logan, Utah, August 6, 2022.
54. Marshall, R. A. (2022), Imaging Energetic Particle Precipitation from Above: The AEPEX CubeSat Mission, 8th International HEPPA-SOLARIS Meeting, Bergen, Norway, June 15, 2022.
53. Marshall, R. A., D. M. Malaspina, R. Reid, P. Vankawala, S. Wankmueller, J. Cannon, B. Nez, Z. Witte, T. Dudok de Wit, and G. Jannet (2022), Design and performance of the compact five-channel VLF receiver for the CANVAS CubeSat mission, 3rd URSI AT-AP-RASC Conference, Gran Canaria, Spain, May 30, 2022.
52. Marshall, R. A., P. Vankawala, D. Vida, and P. Brown (2021), Do meteors radiate very-low-frequency radio emissions?, *URSI General Assembly*, Rome Italy (and virtual), August 30, 2021, **Invited**.
51. Marshall, R. A., R. Reid, M. Usanova, M. Starks, and G. Wilson (2021), First observations and results from the very-low-frequency propagation mapper (VPM) cubesat mission, *USNC-URSI Radio Science Meeting*, Honolulu, HI, August 9, 2021, **Invited**.
Three talks (two of which were invited) in calendar year 2020 were cancelled due to the COVID-19 pandemic causing conference cancellations.
50. Marshall, R. A. and A. Wold (2019), Space Environment and Effects: an Undergraduate Course for both Potential Space Scientists and Casual Space Enthusiasts, *AGU Fall Meeting*, San Francisco, CA, December 12, 2019.
49. Marshall, R. A., W. Xu, A. P. Sousa, M. P. McCarthy, and R. M. Millan (2019), Modeling bremsstrahlung X-ray signatures of Lightning-induced electron precipitation in the upper atmosphere, *AGU Fall Meeting*, San Francisco, CA, December 9, 2019.

48. Marshall, R. A., W. Xu, G. Berland, A. Antunes de Sa, E. Davis, T. Woods, R. Kohnert, C. Randall, D. Baker, H. Spence, M. McCarthy, C. Cully, and A. Jaynes (2019), The Atmospheric Effects of Precipitation through Energetic X-rays (AEPEX) CubeSat mission, *4th COSPAR Symposium on Small Satellites*, Herzliya, Israel, November 4, 2019.
47. Marshall, R. A., A. Sousa, S. Palo, and D. Malaspina (2019), The Climatology of Anthropogenic and Natural VLF wave Activity in Space (CANVAS) CubeSat mission, *4th COSPAR Symposium on Small Satellites*, Herzliya, Israel, November 4, 2019.
46. Marshall, R. A., W. Xu, and G. Berland (2019), Towards Space-based Imaging of Radiation Belt Precipitation using Backscattered X-rays, *IUGG General Assembly*, Montréal, Canada, July 14, 2019.
45. Marshall, R. A., L. K. Tarnecki, Z. Sternovsky, T. Munsat, and M. DeLuca (2019), Improved Characterization of Meteor Luminous Efficiency through Laboratory Experiments *10th International Meteoroids Conference*, Bratislava, Slovakia, June 18, 2019.
44. Marshall, R. A., A. Antunes de Sa, A. Viets, A. Sousa, and W. Deierling (2019), Design of a Low-Cost, High-Speed Electric Field Mill for Continuous Electric Field Monitoring, *99th American Meteorological Society Annual Meeting*, Phoenix, AZ, January 7, 2019.
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.

INVITED SEMINARS AND SYMPOSIA

31. The Array for VLF Imaging of the D-region Ionosphere (AVID), *Hakai Institute*, Calvert Island, BC, Canada, August 10, 2023.
30. Imaging Energetic Particle Precipitation into Earth's Upper Atmosphere through Backscattered Hard X-rays, *University of Bergen*, Bergen, Norway, March 20, 2023.
29. Lightning-induced Electron Precipitation and its indirect effects on the upper atmosphere, *LPC2E Seminar series*, Orléans, France, March 7, 2023.
28. CubeSats for Heliophysics, *Le Studium seminar series*, Orléans, France, March 2, 2023.
27. Remote Sensing with Hard X-rays: The AEPEX CubeSat Mission, *CU Aerospace Remote Sensing seminar series*, Boulder, CO, December 5, 2022.
26. Energetic electron precipitation from the magnetosphere into the atmosphere: how to measure the effects in the ignorsphere, *Magnetosphere Online Seminar Series*, Virtual, August 29, 2022.
25. CubeSats for Space Science, *Taiwan Space Union*, Virtual, August 11, 2021.
24. A multi-pronged approach to measuring and understanding the D-region ionosphere, *Laboratory for Atmospheric and Space Physics Seminar*, Virtual, May 27, 2021.

23. Radiation Belt Precipitation into the Upper Atmosphere: Mesoscale Observations from Above and Below *NASA Goddard Heliophysics Seminar Series*, Virtual, May 12, 2021.
22. X-ray Imaging of Energetic Particle Precipitation from the Radiation Belts: The AEPEX CubeSat Mission, *NCAR High Altitude Observatory Colloquium*, Boulder, CO, November 4, 2020.
21. Characterization of Radiation Belt Electron Precipitation using Space-based X-ray Observations, *University of Minnesota, department of Physics and Astronomy*, Minneapolis, MN, February 18, 2020.
20. The AEPEX Mission: Imaging Radiation Belt Precipitation using Bremsstrahlung X-rays, “*Friends of the Magnetosphere*” seminar at the *Laboratory for Atmospheric and Space Physics*, Boulder, CO, January 28, 2020.
19. Climatology of Anthropogenic and Natural VLF wave Activity in Space (CANVAS), *Centre Nationale de la Recherche Scientifique*, Orléans, France, June 11, 2019.
18. Effects of the Lightning Electromagnetic Pulse in the Ionosphere and Magnetosphere, *SAINTE International Workshop*, Leiden, Netherlands, January 30, 2019.
17. Thunderstorm Electrification, Lightning Flash Rates, and the RELAMPAGO Field Campaign, *Colorado School of Mines, Physics Department*, Golden, CO, October 2018.
16. Atmospheric Signatures and Diagnostics of Radiation Belt Electron Precipitation, *LASP Friends of the Magnetosphere (FOM)*, Boulder, CO, February 2018.
15. 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. 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. 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. 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. The Earth’s Atmosphere as a Natural Source of X-ray Radiation, *Presented at Dartmouth College, Plasma Seminar Series*, Hanover, NH, May 2016.
10. Lightning Effects in Space, *presented at CU Boulder, Department of Aerospace Engineering Sciences*, Boulder, CO, February 2015.
9. The Artificial Relativistic Electron Beam, *presented at CU Boulder and the Laboratory of Atmospheric and Space Physics (LASP)*, Boulder, CO, April 2014.
8. 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. Interactions between Lightning and the Lower Ionosphere, *presented for SESS Group, Stanford University*, Stanford, CA, November 29, 2011.
6. High-speed Imaging of Auroral and High-energy Particle Precipitation, *presented at KLA-Tencor*, Milpitas, CA, November 4, 2011.
5. Optical Signatures of Transmitter- and Lightning-induced Electron Precipitation, *presented for SESS Group, Stanford University*, Stanford, CA, September 22, 2010.
4. An Introduction to Near-Earth Space Physics, *presented at Bermuda College*, Bermuda, September 30, 2009.
3. Ionospheric Effects of Intense Lightning Discharges, *presented at Center for Space Physics, Boston University*, Boston, MA, September 9, 2009.
2. Ionospheric Effects of Intense Lightning Discharges, *presented at Geospace Studies Institute, SRI International*, Menlo Park, CA, March 12, 2009.

1. Ionospheric Effects of Intense Lightning Discharges, *presented at Institute for Geophysics and Planetary Physics, UCLA, Los Angeles, CA, Feb 19, 2009.*

PH.D THESES SUPERVISED

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

13. Julia Claxton, Aerospace Engineering Sciences, CU Boulder, Ph.D expected 2028
12. Wyatt Spies, Aerospace Engineering Sciences, CU Boulder, Ph.D expected 2028
11. Paraksh Vankawala, Aerospace Engineering Sciences, CU Boulder, Ph.D expected 2026
10. James Cannon, Aerospace Engineering Sciences, CU Boulder, Ph.D expected 2026
9. Riley Reid, Aerospace Engineering Sciences, CU Boulder, Ph.D expected 2024
8. Carolina (Peña) Chism, Aerospace Engineering Sciences, CU Boulder, Ph.D expected 2024
7. Alexandra Wold, Aerospace Engineering Sciences, CU Boulder, Ph.D expected 2024
6. Grant Berland, Aerospace Engineering Sciences, CU Boulder, **Ph.D completed** August 2023
5. Liane Tarnecki, Aerospace Engineering Sciences, CU Boulder, **Ph.D completed** August 2023
4. Forrest Gasdia, Aerospace Engineering Sciences, CU Boulder, **Ph.D completed** December 2021
3. André Antunes de Sá, Aerospace Engineering Sciences, CU Boulder, **Ph.D completed** May 2021
2. Diana Juarez Madera, Aeronautics & Astronautics, Stanford University, **Ph.D completed** May 2020
1. Austin Sousa, Electrical Engineering, Stanford University, **Ph.D completed** June 2018

M.S. THESES SUPERVISED

Master's theses by students for whom Dr. Marshall is or was the student's primary research supervisor.

4. Maria Callas, Aerospace Engineering Sciences, CU Boulder, M.S. **completed** August 2023
3. Erin McMurchie, Aerospace Engineering Sciences, CU Boulder, M.S. **completed** December 2022
2. Jennifer Kampmeier, M.S., Aerospace Engineering Sciences, CU Boulder, **completed** May 2018
1. Stephen Jackson, M.S., Aerospace Engineering Sciences, CU Boulder, **completed** May 2017

DOCTORAL THESIS COMMITTEE MEMBER

30. Daniel da Silva, Aerospace Engineering Sciences, CU Boulder, comprehensive exam Sept. 29, 2023.
29. John Marino, Aerospace Engineering Sciences, CU Boulder, comprehensive exam March 15, 2023.
28. Ben Hogan, Aerospace Engineering Sciences, CU Boulder, comprehensive exam November 15, 2022.
27. Arika Egan, Astrophysical and Planetary Sciences, CU Boulder, comprehensive exam August 27, 2022.
26. Vicki Herde, Aerospace Engineering Sciences, CU Boulder, comprehensive exam September 16, 2022.
25. Bill Goode, Aerospace Engineering Sciences, CU Boulder, comprehensive exam November 2, 2021.
24. Bennet Schwab, Ph.D, Aerospace Engineering Sciences, CU Boulder, June 2022
23. Leng Ying Khoo, Ph.D, Aerospace Engineering Sciences, CU Boulder, January 2022
22. Mitchell Shen, Ph.D, Aerospace Engineering Sciences, CU Boulder, July 2021
21. Kieran Wilson, Ph.D, Aerospace Engineering Sciences, CU Boulder, May 2021
20. Miles Bengtson, Ph.D, Aerospace Engineering Sciences, CU Boulder, November 2020
19. JoAnna Fulton, Ph.D, Aerospace Engineering Sciences, CU Boulder, July 2020
18. Andrew Dahir, Ph.D, Aerospace Engineering Sciences, CU Boulder, December 2020
17. Michael DeLuca, Ph.D, Aerospace Engineering Sciences, CU Boulder, April 2020
16. Kun Zhang, Ph.D, Aerospace Engineering Sciences, CU Boulder, December 2020

15. Kevin-Druis Merenda, Ph.D, Physics, Colorado School of Mines, July 2020
14. Diana Juarez Madera, Ph.D, Aeronautics and Astronautics, Stanford University, June 2020
13. Robinson Wallace, Ph.D, Atmospheric and Ocean Sciences, CU Boulder, July 2020
12. Yining Shi, Ph.D, Aerospace Engineering Sciences, CU Boulder, December 2019
11. Rory Barton-Grimley, Ph.D, Aerospace Engineering Sciences, CU Boulder, May 2019
10. Alex Barrie, Ph.D, Aerospace Engineering Sciences, CU Boulder, September 2018
9. Austin Sousa, Ph.D, Aeronautics and Astronautics, Stanford University, June 2018
8. Saurabh Sanghai, Ph.D, Electrical, Computer, & Energy Engineering, CU Boulder, May 2018
7. Dilini Subasinghe, Ph.D, Physics and Astronomy, University of Western Ontario, December 2017
6. Derek Houtz, Ph.D, Aerospace Engineering Sciences, CU Boulder, May 2017
5. Evan Thomas, Ph.D, Physics, CU Boulder, May 2017
4. Greg Lucas, Ph.D, Aerospace Engineering Sciences, CU Boulder, May 2017
3. David Garrido López, Ph.D, Electrical, Computer, & Energy Engineering, CU Boulder, December 2016
2. Thomas Rogers, Ph.D, Astrophysics and Planetary Sciences, CU Boulder, July 2016
1. Patrick Blaes, Ph.D, Electrical Engineering, Stanford University, May 2015

UNDERGRADUATE RESEARCH ADVISEES

† CU Summer Program for Undergraduate Research (SPUR)

‡ Research Experience for Undergraduates (REU)

* Discovery Learning Apprenticeship (DLA)

35. Thomas Collier*, Aerospace Engineering Sciences, Fall 2023 – Spring 2024
34. Courtney Hogan*, Aerospace Engineering Sciences, Fall 2023 – Spring 2024
33. Tsuening Lee*, Aerospace Engineering Sciences, Fall 2023 – Spring 2024
32. Andrew Miller*, Aerospace Engineering Sciences, Fall 2023 – Spring 2024
31. Hayden Gebhardt†, Aerospace Engineering Sciences, Summer 2023
30. Matayay Karuna†, Computer Science, Summer 2023
29. Micah Bergeron†, Aerospace Engineering Sciences, Summer 2023
28. Bennett Frangomeni†, Software Engineering, Summer 2022 – Fall 2023
27. Sophia Orlandella†, Aerospace Engineering Sciences, Summer – Fall 2022
26. Kevin Pipich†, Aerospace Engineering Sciences, Summer – Fall 2022
25. Catherine Xiao†, Computer Science, Summer – Fall 2022
24. Max Feinland‡, Aerospace Engineering Sciences, Summer – Fall 2022
23. Ryan Dick‡, Astrophysics & Engineering Physics, Summer 2022 – Fall 2023
22. Maria Callas*, Aerospace Engineering Sciences, Fall 2021 – Spring 2022
21. Shawn Stone*, Aerospace Engineering Sciences, Fall 2021 – Spring 2022
20. Keith Poletti*, Aerospace Engineering Sciences, Summer 2020 – Spring 2021
19. Jett Moore*, Aerospace Engineering Sciences, Summer 2020 – Spring 2021
18. Logan Vangyia*, Aerospace Engineering Sciences, Fall 2020 – Spring 2021
17. Jash Bhalavat, Aerospace Engineering Sciences, Fall 2020 – Spring 2022
16. Conner Martin*, Aerospace Engineering Sciences, Spring 2020 – Spring 2021
15. Joseph Buescher*, Aerospace Engineering Sciences, Spring 2020 – Spring 2021

14. Dean Curtis, Engineering Physics, Fall 2019 – Spring 2020
13. Bruce Barnstable*, Aerospace Engineering Sciences, Fall 2019 – Spring 2020
12. Jaykob Velasquez*, Aerospace Engineering Sciences, Summer 2019 – Spring 2020
11. Brandon King[†], Aerospace Engineering Sciences, Summer 2019
10. Haley Drexel[†], Aerospace Engineering Sciences, Summer 2019
9. Elliott Davis, Aerospace Engineering Sciences, Fall 2018 – Spring 2020
8. Mark Zakhem, Electrical, Computer, & Energy Engineering, Fall 2018 – Spring 2019
7. Connor Myers*, Aerospace Engineering Sciences, Summer 2018 – Spring 2020
6. Matthew Funk*, Aerospace Engineering Sciences, Fall 2017 – Spring 2018
5. Catherine Witt*, Electrical and Computer Engineering, Fall 2017 – Spring 2018
4. Alec Viets, Aerospace Engineering Sciences, Summer 2017 – Summer 2018
3. Leina Hutchinson, Aerospace Engineering Sciences, Summer 2017
2. Noah Holland-Moritz*, Engineering Physics, Fall 2016 – Spring 2017
1. Joshua (Luke) Tafur, Aerospace Engineering Sciences, Spring 2016

POSTDOCTORAL FELLOWS AND RESEARCH ASSOCIATES

5. Grant Berland (Ph.D 2023, CU Boulder), August 2023 – present
4. Alexander Shane (Ph.D 2022, University of Michigan), March 2022 – present
3. Edwin Bernardoni (Ph.D 2022, University of Colorado Boulder), February 2022 – August 2023
2. Austin Sousa (Ph.D 2018, Stanford University), October 2017 – July 2020
1. Wei Xu (Ph.D 2015, Pennsylvania State University), January 2016 – July 2021

EXTERNALLY FUNDED RESEARCH PROJECTS AT CU BOULDER

21. JUpiters Global maGnetic Environment and RadiationN ObservaTory (JUGGERNOT)
 PI: George Clark (JHU APL); co-PI: Robert Marshall
 Prime Sponsor: NASA Heliophysics Mission Concept Studies
 Period of Performance: 09/01/2021 – 10/31/2022
 Total Award Amount: \$368,146
 Marshall Award Amount: \$20,000
20. Design of a novel imaging relativistic electron instrument for future radiation belt missions
 PI: Robert Marshall
 Prime Sponsor: NASA, FINESST (FI: Riley Anne Reid)
 Period of Performance: 09/01/2021 – 08/31/2024
 Total / Marshall Award Amount: \$135,000
19. CAREER: Quantifying Radiation Belt Precipitation and Atmospheric Impacts through D-region Ionosphere Imaging
 PI: Robert Marshall
 Sponsor: NSF, Aeronomy
 Period of Performance: 02/01/2021 – 01/31/2026
 Total / Marshall Award Amount: \$605,354
 REU Supplement awarded May 2022: \$90,600

18. Quantifying the Contributions of Radiation Belt Precipitation to the Effective Radiation Dose at Spacecraft and Aviation Altitudes
 PI: Robert Marshall
 Sponsor: NASA, Space Weather Operations-to-Research (SWO2R)
 Period of Performance: 09/01/2020 – 08/31/2022
 Total Award Amount: \$499,995
 Marshall Award Amount: \$309,920
17. Lightning-induced Whistler waves in the Inner Magnetosphere and their effect on Radiation Belt Electrons
 PI: Robert Marshall
 Sponsor: NASA Heliophysics Division
 Period of Performance: 04/01/2020 – 03/31/2023
 Total Award Amount: \$520,540
 Marshall Award Amount: \$443,423
16. Ground-based VLF and HF measurements in support of the VIPER sounding rocket experiment
 PI: Robert Marshall
 Sponsor: NSF, Aeronomy
 Period of Performance: 03/15/2020 – 02/28/2022
 Total / Marshall Award Amount: \$82,931
15. VLF emission characteristics of meteors and lightning
 PI: Robert Marshall
 Sponsor: Northrop Grumman Corporation
 Period of Performance: 12/26/2019 – 9/30/2021
 Total / Marshall Award Amount: \$135,000
14. Atmospheric Effects of Precipitation through Energetic X-rays (AEPEX) CubeSat Mission
 PI: Robert Marshall
 Sponsor: NASA Heliophysics Division
 Period of Performance: 12/12/2019 – 12/11/2023
 Total Award Amount: \$4,122,490
 Marshall Award Amount: \$1,502,592
13. Next Generation Space Environment Technologies (NSET)
 PI: Rick Quinn (AER); co-I: Robert Marshall
 Prime Sponsor: Air Force Research Laboratory; Subaward Sponsor: Atmospheric and Environmental Research, Inc.
 Period of Performance: 07/01/2019 – 08/31/2021
 Total / Marshall Award Amount: \$218,538
12. Climatology of Anthropogenic and Natural VLF wave Activity in Space (CANVAS) CubeSat Mission
 PI: Robert Marshall
 Sponsor: NSF, Atmospheric and Geospace Sciences
 Period of Performance: 02/01/2019 – 01/31/2023
 Total Award Amount: \$1,196,654
 Marshall Award Amount: \$808,977
11. Meteor Plasma Formation and Dynamics with Implication for Radar Measurements
 PI: Robert Marshall
 Prime Sponsor: NSF, CEDAR
 Period of Performance: 11/01/2018 – 10/31/2021
 Total / Marshall Award Amount: \$197,607
10. Improved Meteoroid Characterization through Laboratory Experiments, Modeling, and Ground-based Observations
 PI: Robert Marshall
 Prime Sponsor: NSF, Aeronomy
 Period of Performance: 09/01/2018 – 08/31/2022

- Total Award Amount: \$645,134
 Marshall Award Amount: \$597,818
9. VIPER – VLF Trans-Ionospheric Propagation Experiment Rocket
 PI: John Bonnell (Berkeley); co-I: Robert Marshall
 Prime Sponsor: NASA Heliophysics Division; Subaward Sponsor: University of California Berkeley
 Period of Performance: 07/01/2018 – 06/30/2021
 Total Award Amount: \$2,098,428
 Marshall Award Amount: \$194,833
 8. Very Low Frequency Wave and Particle Precipitation Mapper (VPM)
 PI: Robert Marshall
 Prime Sponsor: Air Force Research Laboratory
 Period of Performance: 11/09/2017 – 12/31/2018
 Total / Marshall Award Amount: \$102,501
 7. Collaborative Research: Energetic Particle Precipitation Mechanisms in the Inner Magnetosphere: Van Allen Probes and Incoherent Scatter Radar Coordinated Measurements
 co-PIs: Robert Marshall, Jacob Bortnik (UCLA), Ennio Sanchez (SRI)
 Prime Sponsor: NSF, Magnetospheric Physics
 Period of Performance: 09/01/2017 – 08/31/2021
 Total / Marshall Award Amount: \$120,791
 6. Prevalence of Distinct Energetic Intra-Cloud Lightning Events and Their Connection to Terrestrial Gamma Ray Flashes
 PI: Robert Marshall
 Prime Sponsor: NASA, Earth and Space Science Fellowships (André Antunes de Sá)
 Period of Performance: 09/01/2017 – 08/31/2020
 Total / Marshall 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
 co-PI: Robert Marshall, Wiebke Deierling (NCAR), Phil Bitzer (UAH), Larry Carey (UAH)
 Prime Sponsor: NSF, Physical and Dynamic Meteorology
 Period of Performance: 09/01/2017 – 08/31/2021
 Total Award Amount: \$550,643
 Marshall Award Amount: \$297,204
 4. Quantifying the Contributions of Ionization Sources on the Formation of the D-region Ionosphere During the 2017 Solar Eclipse
 PI: Robert Marshall
 Prime Sponsor: NASA, Living With a Star
 Period of Performance: 04/01/2017 – 03/31/2018
 Total / Marshall Award Amount: \$49,824
 3. Spatial, Temporal, and Orientation Information in Contested Environments (STOIC)
 PI: Michael Turbe (Leidos); co-I: Robert Marshall
 Prime Sponsor: DARPA; Subaward Sponsor: Leidos Inc.
 Period of Performance: 10/01/2015 – 01/31/2019
 Total / Marshall Award Amount: \$404,439
 2. Thunderstorm Coupling to the Lower Ionosphere through Electromagnetic, Acoustic, and Gravity Waves
 PI: Sigrid Close (Stanford); co-I: Robert Marshall
 Prime Sponsor: NSF, CEDAR; Subaward Sponsor: Stanford University
 Period of Performance: 09/01/2015 – 07/31/2017
 Total / Marshall Award Amount: \$116,357
 1. Concept Development for Active Magnetospheric, Radiation Belt, and Ionospheric Experiments using In Situ Relativistic Electron Beam Injection

PI: Ennio Sanchez (SRI); co-I: Robert Marshall
Prime Sponsor: NSF, INSPIRE; Subaward Sponsor: SRI International
Period of Performance: 09/01/2015 – 08/31/2017
Total / Marshall Award Amount: \$47,290

CHALLENGE OR OTHER PRIZE AWARDS

5. MagQuest Competition, Phase 4B
Funding Source: National Geospatial Intelligence Agency (NGA)
Date: September 1, 2023
Marshall Award Amount: \$1,136,818
4. MagQuest Competition, Phase 4A
Funding Source: National Geospatial Intelligence Agency (NGA)
Date: September 17, 2021
Marshall Award Amount: \$3,423,000
3. MagQuest Competition, Phase 3
Funding Source: National Geospatial Intelligence Agency (NGA)
Date: October 13, 2021
Marshall Award Amount: \$225,000
2. MagQuest Competition, Phase 2
Funding Source: National Geospatial Intelligence Agency (NGA)
Date: September 23, 2019
Marshall Award Amount: \$200,000
1. MagQuest Competition, Phase 1
Funding Source: National Geospatial Intelligence Agency (NGA)
Date: June 6, 2019
Marshall Award Amount: \$20,000

INTERNALLY FUNDED RESEARCH PROJECTS AT CU BOULDER

3. Magnetic CubeSat Constellation for Advanced Navigational Models
Sponsor: CU Boulder Grand Challenge
Period of Performance: 09/01/2017 – 08/31/2021
Marshall Award Amount: \$745,520
2. *ASEN 4519: Space Environment and Effects* (course development)
Sponsor: CU Boulder Space Minor
Start Date: 09/01/2017
Marshall Award Amount: \$10,000
1. Integrated Remote and In-Situ Sensing (IRISS): Project Lightning
Sponsor: Research and Innovation Office, CU Boulder
Period of Performance: 01/01/2016 – 12/31/2016
Marshall Award Amount: \$69,446