PENINA AXELRAD
University of Colorado Distinguished Professor
Joseph T. Negler Professor of Aerospace Engineering Sciences
Colorado Center for Astrodynamics Research
Ann and H.J. Smead Aerospace Engineering Sciences
3775 Discovery Drive, Boulder, CO 80303-0429
Office: AERO 417, Phone: (303) 492-6872
email : Penina.Axelrad@Colorado.EDU
https://orcid.org/0000-0002-9749-7740

Research Interests

Global Positioning System (GPS) and Global Navigation Satellite System (GNSS) technology and applications for position, navigation and timing (PNT); satellite orbit determination; satellite timing systems and space-based time and frequency transfer; space applications of quantum technology; GNSS-based remote sensing; GNSS multipath characterization and mitigation.

Education

Ph.D. in Aeronautics and Astronautics, 1991, Stanford University, Stanford, CA
Dissertation: "A Closed-Loop GPS-Based Orbit Trim System for Gravity Probe B."

S.M. in Aeronautics and Astronautics, 1986, Massachusetts Institute of Technology, Cambridge, MA, Master's thesis: "Near-Earth Orbit Determination and Rendezvous Navigation Using GPS."

S.B. in Aeronautics and Astronautics (Avionics Option), 1985, Massachusetts Institute of Technology, Cambridge, MA.

Professional Experience

2024	Interim Associate Dean of Faculty Advancement, College of Engineering and Applied Science, University of Colorado Boulder.
2020-present	University of Colorado Distinguished Professor, Ann and H.J. Smead Aerospace Engineering Sciences, Colorado Center for Astrodynamics Research, University of Colorado Boulder.
2017-2018	NRC Senior Research Associate, AFRL/RVEP Space Experiments and Programs, Albuquerque, NM.
2012-2017	Chair, Ann and H.J. Smead Dept. of Aerospace Engineering Sciences, University of Colorado Boulder.
2008-2009	Visiting Scientist COSMIC Program Office, University Corporation for Atmospheric Research (UCAR).
2007-2008	Acting Chair, Department of Aerospace Engineering Sciences, University of Colorado Boulder.
2005-2007	Associate Chair, Department of Aerospace Engineering Sciences, University of Colorado Boulder.
2005-2020	Professor, Ann and H.J. Smead Aerospace Engineering Sciences, University of Colorado Boulder.
1999-2005	Associate Professor, University of Colorado Boulder.
1992-1999	Assistant Professor, University of Colorado Boulder.
1991-2011	Instructor, Navtech Seminars, Inc., Arlington, VA.
1991-1992	Lecturer, Department of Aeronautics and Astronautics, Stanford University.
1990-1992	Member of the Technical Staff and Program Manager, GPS Systems Organization, Stanford Telecommunications Inc., Santa Clara, CA.
1986-1990	Graduate Research Assistant, Gravity Probe B, Stanford University.
1985-1986	Systems Engineer, Space and Communications Group, Hughes Aircraft Co., El Segundo, CA.

Honors and Awards

Smead Aerospace Outstanding Faculty Award Outstanding Graduate Teaching and Mentoring (2023)
University of Colorado Distinguished Professor (2020)
Smead Aerospace Outstanding Faculty Award for Research (2020)
Member of the National Academy of Engineering (2019)

Joseph T. Negler Professor of Aerospace Engineering Sciences (2018-Present)
University of Colorado Excellence in Leadership Award (2017)
National Research Council (NRC) Senior Research Associate, Air Force Research Laboratory (AY2017-2018)
Women in Aerospace Educator Award (2015)
Institute of Navigation Samuel Burka Award (2011)
American Institute of Aeronautics and Astronautics Summerfield Book Award (2011)
University of Colorado, College of Engineering and Applied Science, Max S. Peters Faculty Service Award (2009)
Institute of Navigation Johannes Kepler Award (2009)
Fellow, American Institute of Aeronautics and Astronautics (2008)
Institute of Navigation Outstanding Service Award (2005)
Fellow, Institute of Navigation (2004)
University of Colorado, Subaru Educator Spotlight (2004)
Senior Member, Institute of Electrical and Electronics Engineers (2003)
Institute of Navigation Tycho Brahe Award (2003)
AIAA Lawrence Sperry Award (1996)
AAS/AIAA Space Flight Mechanics Meeting Best Paper Award (1996)
Naval Research Laboratory Alan Berman Annual Research Publications Award (1995, 2000)
AIAA Rocky Mountain Section, Young Engineer of the Year (1995)
AIAA Guidance, Navigation and Control Conference Best Paper Award (1993)
Stanford University Graduate Fellowship (1986)
Hughes Aircraft Company Graduate Fellowship (1986)
James Means Award for Leadership in Aerospace Design (1985)
Member Sigma Xi and Tau Beta Pi

Research Funding – Award Total: $17.2M (Axelrad share $13.4M), Award Total as PI: $12.9M

Professional Activities

Current External Service and Committee Memberships

2024-	National Academy of Engineering, Aerospace Section Nominating Committee
2020-Present	National Research Council Space Technology Industry-Government-University Roundtable (STIGUR)
1993-Present	Associate Editor, Navigation

Past External Service and Committee Memberships

2023	University of Washington Aeronautics & Astronautics External Review Committee
2013-2023	National Space-Based Positioning, Navigation and Timing (PNT) Advisory Board
2023	Stanford University Aeronautics & Astronautics Visiting Committee, May 24-26, 2023
2022-2023	Assessment of Weapons Sciences at the Army Research Laboratory (ARL) Panel Member, National Academies of Sciences, Engineering, and Medicine
2022	CU-MIT-Stanford Rising Stars in Aerospace Symposium Co-Organizer, May 12-13, 2022
2022	U.S. Naval Academy Aerospace Engineering Program Visiting Committee, March 7-9, 2022
2013, 2019-2022	AIAA Fellow Peer Reviewer
1994-2021	Member of the Draper Corporation
2016-2019	NASA Advisory Council Member at Large
2019	Panel Member Purdue University Amelia Earhart Summit, September 2019
2019	Panel Member MIT-Stanford-CU Women in Aerospace Symposium, May 2019
2017	CU-MIT-Stanford Women in Aerospace Symposium Organizer and Host, May 30- Jun 1 https://www.colorado.edu/aerospace/wias

2016	International Committee on Global Navigation Satellite Systems (ICG-10) Organizing Committee Member
2014-2018	AIAA Publications Ethics Subcommittee
2013-2015	Institute of Navigation (ION) Awards Chair
2013-2014	Astrodynamics Collaboration Environment Working Group (AFRL)
2012-2016	Member of the Board of eSpace: The Center for Space Entrepreneurship
2009	Keck Institute for Space Studies External Advisory Committee
2007-2010	Program Co-Chair, ION/IEEE PLANS
2005-2006	NASA ST9 Precision Formation Flying Technology Review Board
2004-2005	Institute of Navigation (ION) President
2003-2004	Institute of Navigation (ION) Executive Vice President
2002-2012	Massachusetts Institute of Technology, Department of Aeronautics and Astronautics Visiting Committee
2000-2002	Institute of Navigation (ION) Chair, Satellite Division
1998-2000	Institute of Navigation (ION) Vice-Chair, Satellite Division
1997	General Chair, ION GPS-97
1996	Program Chair, ION GPS-96
1995	General Chair, ION National Technical Meeting
1994-1995	Member, National Research Council Committee on the Future of the Global Positioning System
1994-1996	Institute of Navigation (ION) Secretary, Satellite Division
1994-1995	Institute of Navigation (ION) Vice President, Western Region
1994	Technical Program Chair, ION National Technical Meeting
1993-1996	Faculty Advisor, University of Colorado Student Chapter Institute of Navigation (ION)
1993-1994	Institute of Navigation (ION) Chair, Student Awards Committee
1992-1994	Institute of Navigation (ION) Council Space Representative
1993	Institute of Navigation (ION) Technical Chair, ION GPS-93
1993	Institute of Navigation (ION) Chair, Rocky Mountain Section
1991-1992	Institute of Navigation (ION) Western Region Council Member at Large
1988-1989	Institute of Navigation (ION) Chair, Annual Satellite Division Student session

University of Colorado (CU) Service Activities

2021-present	Smead Aerospace Awards Committee Chair
2023	LEAP Orientation Panelist
2022-2023	Smead Aerospace Primary Unit Evaluation Committee Chair
2021-2022	CU Teaching Quality Framework Committee
2022	College of Engineering Professional Rights and Responsibilities Investigation (Ad hoc)
2020-2022	Smead Aerospace Performance Evaluation Committee
2019-2021	Smead Aerospace Graduate Committee, Astrodynamics and Satellite Navigation Focus Lead
2018-2021	College of Engineering and Applied Science First Level Review Committee
2018-2021	Smead Aerospace Executive Committee
2005-2019	Faculty Teaching Excellence Faculty Associate and Advisory Board Member
2016-2017	Aerospace Building Design Committee
2012-2017	Chair CU AeroSpace Ventures Executive Committee
2016-2017	Provost's Chairs Committee (Ad hoc)
2016	College of Engineering and Applied Science Dean's Search Committee
2014-2015	CU Grand Challenge Steering Committee
2014-2015	Internal Review Committee – Continuing Education
2014-2015	CU Libraries Dean's Review Committee
2011-2012	Internal Review Committee - Geography
2006-2007	University of Colorado Emerging Leaders Program Fellow

2005-2007 College of Engineering First Level Review Committee
2005-2007 Aerospace Engineering Sciences Coop Program Faculty Advisor
2004-2006 CRCW Committee
2003-2005 LEAP Program Coach
2002-03, 04-05 Aerospace Engineering Sciences Department, Search Committee Chair
1999-2008 Faculty Teaching Excellence Program Advisory Board
1998-2002 CU, College of Engineering Summer Success Institute
1994-2002 Lab Demonstrations for Women in Engineering Program High School Career Day

Journal Publications
Names of Dr. Axelrad's students are underlined.

1. Parkinson, B.W. and P. Axelrad, "Autonomous GPS Integrity Monitoring Using the Pseudorange Residual," *NAVIGATION,* Vol. 35, No. 2, p. 255-274, 1988.
2. Axelrad, P. and B.W. Parkinson, "Closed Loop Navigation and Guidance for Gravity Probe B Orbit Insertion," *NAVIGATION*, Vol. 36, No. 1, p. 45-61, 1989.
3. Green, G.B. and P. Axelrad, "Space Applications of GPS," *NAVIGATION*, Vol. 36, No. 3, p. 239-251, 1989.
4. Kee, C., B.W. Parkinson, P. Axelrad, "Wide Area Differential GPS," *NAVIGATION*, Vol. 38, No. 2, p. 123-146, 1991.
5. Born, G.H., M.E. Parke, P. Axelrad, K.L. Gold, J. Johnson, K.W. Key, D.G. Kubitschek, E.J. Christensen, "Calibration of the TOPEX altimeter using a GPS buoy," *Journal of Geophysical Research*, Vol. 99, No. C12, p. 24,517-24,526, 1994.
6. Adams, L.J., P. Axelrad, et al., The Global Positioning System - A Shared National Asset, A Report by the Committee on the Future of the Global Positioning System, National Academy Press, 264 pages, 1995.
7. Axelrad, P., C.J. Comp, P.F. MacDoran, "SNR Based Multipath Error Correction for GPS Differential Phase," *IEEE Transactions on Aerospace & Electronic Systems*, Vol. 32, No. 2, p. 650-660, April 1996.
8. Axelrad, P. and L.M. Ward, "Spacecraft Attitude Estimation Using the Global Positioning System: Methodology and Results for RADCAL," *Journal of Guidance, Control and Dynamics*, Vol. 19, No. 6, p. 1201-1209, November-December 1996.
9. Melvin, P.J., L.M. Ward, P. Axelrad, "The Analysis of GPS Attitude Data From a Slowly Rotating, Symmetrical Gravity Gradient Satellite," *Journal of the Astronautical Sciences*, Vol. 44, p. 515-539, October-December 1996.
10. Axelrad, P. and C.P. Behre, "Attitude Estimation Algorithms for Spinning Satellites Using GPS Phase Data," *Journal of Guidance, Control and Dynamics*, Vol. 20, No. 1, p. 164-169, January-February 1997.
11. Ward, L.M. and P. Axelrad, "A Combined Filter for GPS-Based Attitude and Baseline Estimation, " *NAVIGATION*, Vol. 44, No. 2, p. 195-213, 1997.
12. Comp, C.J. and P. Axelrad, "Adaptive SNR-Based Carrier Phase Multipath Mitigation Technique", *IEEE Transactions on Aerospace & Electronic Systems*, Vol. 34, No. 1, p. 264-276, January 1998.
13. Irish, K., K. Gold, G. Born, A. Reichert, P. Axelrad, "Precision Orbit Determination for the Geosat Follow-On Satellites," *Journal of Spacecraft and Rockets*, Vol. 35, No. 3, p. 336-341, May-June 1998.
14. Garrison, J.L., P. Axelrad, N.J. Kasdin, "Ill-Conditioned Covariance Matrices in the First-Order Two-Step Estimator," *Journal of Guidance, Control and Dynamics*, Vol. 21, No. 5, p. 754-760, September-October 1998.
15. Axelrad, P., and C.P. Behre, "Satellite Attitude Determination Based on GPS Signal-to-Noise Ratio," (Invited Paper) *Proceedings of the IEEE*, Vol. 87, No. 1, p. 133-144, January 1999.
16. Komjathy, A., V.U. Zavorotny, P. Axelrad, G.H. Born, J.L. Garrison, "GPS Signal Scattering from Sea Surface: Wind Speed Retrieval Using Experimental Data and Theoretical Model," *Journal of Remote Sensing of Environment*, Vol. 73, p. 162-174, August 2000.
17. Moreau, M., P. Axelrad, J.L. Garrison, A. Long, "GPS Receiver Architecture and Expected Performance for Autonomous Navigation in High Earth Orbits," *NAVIGATION*, Vol. 47, No. 3, p. 191-204, 2000.
18. Bauer, F.H., P. Axelrad, et al., "Enabling Spacecraft Formation Flying in Any Earth Orbit Through Spaceborne GPS and Enhanced Autonomy Technologies," *Space Technology*, Vol. 20, No. 4, p. 175-185, 2001.
19. Reichert, A.K. and P. Axelrad "Carrier-Phase Multipath Corrections for GPS-Based Satellite Attitude Determination," *NAVIGATION*, Vol 48. No.2, p. 77-88, 2001.
20. Goldstein, D., G. Born, P. Axelrad "Real-time, Autonomous, Precise Orbit Determination Using GPS," *NAVIGATION*, Vol. 48, No. 3, p. 155-168, 2001.

21. Thompson, B., M.C. Meek, K.L. Gold, P. Axelrad, G.H. Born, D.G. Kubitschek, "Orbit Determination for the QuikSCAT Spacecraft," *Journal of Spacecraft and Rockets*, Vol. 39, No. 6, p. 852-858, November-December 2002.
22. Madhani, P.H., P. Axelrad, K. Krumvieda, J. Thomas, "Application of Successive Interference Cancellation to the GPS Pseudolite Near-Far Problem," *IEEE Transactions on Aerospace and Electronic Systems*, Vol. 39, No.2, p. 481-489, April 2003.
23. Komjathy, A., M. Armatys, D. Masters, P. Axelrad, V.U. Zavorotny, S.J. Katzberg, "Retrieval of Ocean Surface Wind Speed and Wind Direction Using Reflected GPS Signals," *Journal of Atmospheric and Oceanic Technology*, Vol.21, No.3, p. 515-526, March 2004.
24. Mickler, D., G.H. Born, P. Axelrad "Using GPS Reflections for Satellite Remote Sensing," *Acta Astronautica*, Vol. 55:1, p. 39-49, 2004.
25. Masters, D., P. Axelrad, S. Katzberg, "Initial Results of Land-Reflected GPS Bistatic Radar Soil Moisture Measurements in SMEX02," *Remote Sensing of Environment*, Vol. 92:4 p. 507-520, 2004.
26. Choi, K., A. Bilich, K.M. Larson, P. Axelrad, "Modified Sidereal Filtering: Implications for High-Rate GPS Positioning," *Geophys. Res. Lett*., Vol. 31, No. 22, 2004.
27. Weiss, J.P., S. Anderson, P. Axelrad, "Development of Multipath Error Budgets for JPALS Ground Station Receivers," *NAVIGATION*, Vol. 52, No. 3, p. 145-154, 2005.
28. Lane, C. and P. Axelrad, "Formation Design in Eccentric Orbits Using Linearized Equations of Relative Motion," *Journal of Guidance, Control, and Dynamics*, Vol. 29, No. 1, p. 146-160, 2006.
29. Meek, M.C., G.H Born, P. Axelrad, "Automated Operational Orbit Determination for the Ice Cloud and Land Elevation Satellite Mission," *Journal of Spacecraft and Rockets,* Vol. 43, No. 5, p. 1048-1053, Sept-Oct 2006.
30. Belmonte-Rivas, M., J. Maslanik, J. Sonntag, P. Axelrad, "Sea Ice Roughness from Airborne Lidar Profiles," *IEEE Transactions on Geoscience and Remote Sensing*, Volume 44, Issue 11, p. 3032 – 3037, 2006.
31. Lane, C. and P. Axelrad, "Analysis of Relative Navigation in High Earth Orbits," *Journal of the Astronautical Sciences*, Vol. 55, No 1, Jan-Mar 2007, p. 23-52.
32. Larson, K., A. Bilich, P. Axelrad, "Improving the precision of high-rate GPS," *Journal of Geophysical Research*, *112*, B05422, DOI:10.1029/2006JB004367, 2007.
33. Lane, C. and P. Axelrad, "Relative Semimajor Axis Uncertainty in High Earth Orbits," *Journal of Guidance, Control, and Dynamics,* Vol. 30, No. 6, p. 1827-1830, 2007.
34. Weiss, Jan P., P. Axelrad, S. Anderson, "A GNSS Code Multipath Model for Semi-Urban, Aircraft, and Ship Environments," *NAVIGATION*, Vol. 54, No.4, p. 294-307, 2007.
35. Larson, K. M., E. E. Small, E. Gutmann, A. Bilich, P. Axelrad, J. Braun, "Using GPS multipath to measure soil moisture fluctuations: initial results," *GPS Solutions*, Vol 12 (3), p. 173-177, DOI:10.1007/s10291-007-0076-6, July 2008.
36. Bilich, A., K. M. Larson, P. Axelrad, "Modeling GPS Phase Multipath with SNR: Case study from Salar de Uyuni, Bolivia," *Journal of Geophysical Research*, 113, B04401, DOI:10.1029/2007JB005194, 2008.
37. Jah, M.K., M.E. Lisano, G.H. Born, P. Axelrad, "Mars Aerobraking Spacecraft State Estimation by Processing Inertial Measurement Unit Data," *Journal of Guidance, Control, and Dynamics,* Vol. 31, No. 6, p. 1802-1813, 2008.
38. Belmonte Rivas, M., J. Maslanik, P. Axelrad, "Bistatic scattering of GPS signals off Arctic Sea Ice," *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 48, No. 3, p. 1548-1553, doi: 10.1109/TGRS.2009.2029342, 2010.
39. Vinande, E., P. Axelrad, D. Akos, "Mounting Angle Estimation for Personal Navigation Devices," *IEEE Transactions on Vehicular Technology*, Vol.59, No. 3, p. 1129-1138, March 2010.
40. Tombasco, J., P. Axelrad, M. Jah, "Analysis of Specialized Coordinate Representation for Dynamic Modeling and Orbit Estimation in the Geosynchronous Regime," *Journal of Guidance, Control, and Dynamics*, Vol. 33, No. 6, p. 1824-1836, 2010.

41. Axelrad, P., "Global Navigation Satellite Systems," in *Encyclopedia of Aerospace Engineering,* R. Blockley and W. Shyy (eds). John Wiley & Sons Ltd., Chichester, UK, p. 3167-3178, 2010.
42. Tombasco, J.M. and P. Axelrad, "A Study of the Achievable Geosynchronous Angles-Only Orbit Estimation Accuracy," *Journal of Astronautical Sciences*, Vol. 58, No. 2, April-June 2011, pp. 275-290.
43. Axelrad, P., B.K. Bradley, J. Donna, M. Mitchell, S. Mohiuddin, "Collective Detection and Direct Positioning Using Multiple GNSS Satellites," *NAVIGATION*, Vol. 58, No. 4, p. 305-321, 2011.
44. L.B. Cornman, R.K. Goodrich, P. Axelrad, E. Barlow, "Progress in turbulence detection via GNSS occultation data," *Atmospheric Measurement Techniques*, 5, 789-808, DOI:10.5194/amt-5-789-2012, 2012.
45. Tombasco, J.M. and P. Axelrad, "Along-Track Separation Uncertainty Modeling Given Space-Based Angles-Only Tracking," *Journal of Guidance, Control, and Dynamics*, Vol. 35, No. 3, p. 732-739, DOI: 10.2514/1.56240, 2012.
46. Tombasco, J.M. and P. Axelrad, "Observability of Relative Hybrid Elements Given Space-Based Angles-Only Observations," *Journal of Guidance, Control, and Dynamics*, Vol. 35, No. 5, p. 1681-1686, DOI: 10.2514/1.54981, 2012.
47. Pratt, J., P. Axelrad, K.M. Larson, B. Lesage, R. Gerren, N. DiOrio, "Satellite clock bias estimation for iGPS," *GPS Solutions*, 17(3): 381-389, doi: 10.1007/s10291-012-0286-4, 2013.
48. Bradley, B.K., B.A. Jones, G. Beylkin, K. Sandberg, P. Axelrad, "Bandlimited Implicit Runge-Kutta Integration for Astrodynamics," *Celestial Mechanics and Dynamical Astronomy*, 119:143–168, doi: 10.1007/s10569-014-9551-x, 2014.
49. Bradley, B.K., A. Sibois, P. Axelrad, "Influence of ITRF/GCRF Implementation for Astrodynamics: Coordinate Transformations" *Advances in Space Research*, Vol. 57, Issue 3, p. 850-866, doi: 10.1016/j.asr.2015.11.006, 2016.
50. Mashburn, J., P. Axelrad, S. T. Lowe, K. M. Larson, "An Assessment of the Precision and Accuracy of Altimetry Retrievals for a Monterey Bay GNSS-R Experiment," *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 9, no. 10, pp. 4660-4668, doi: 10.1109/JSTARS.2016.2537698, 2016.
51. Gehly, S., B. Jones, P. Axelrad, "Sensor Allocation for Tracking Geosynchronous Space Objects," *AIAA Journal of Guidance, Control, and Dynamics,* Vol. 41, No. 1, pp. 149-163, doi 10.2514/1.G000421, 2018.
52. Strandjord, K.L. and P. Axelrad, "Improved Prediction of GPS Satellite Clock Sub-Daily Variations Based on Daily Repeat," *GPS Solutions*, 22:58, doi: 10.1007/s10291-018-0723-0, 2018.
53. Mashburn, J., P. Axelrad, S. Lowe, K.M. Larson, "Global Ocean Altimetry with GPS Reflections from TechDemoSat-1," *IEEE Trans. on Geoscience and Remote Sensing*, 56(7) doi: 10.1109/TGRS.2018.2823316, 2018.
54. Gehly, S., B. Jones, P. Axelrad "Search-Detect-Track Sensor Allocation for Geosynchronous Space Objects" *IEEE Trans. on Aerospace and Electronic Systems,* Vol. 54, No. 6, pp. 2788-2808, doi: 10.1109/TAES.2018.2830578, 2018.
55. Schumacher, P.W, J. Gaebler, C. Roscoe, M. Wilkins, P. Axelrad, "Parallel Initial Orbit Determination Using Angles-Only Observation Pairs," *Celestial Mech and Dynamical Astronomy*, 130(60), doi: 10.1007/s10569-018-9852-6, 2018.
56. Klein, V, P. Axelrad, "Advanced multipath modeling and validation for GPS onboard the International Space Station," *NAVIGATION*, Vol. 66, pp. 559– 575, doi.org/10.1002/navi.327, 2019.
57. Mutschler, S., P. Axelrad, T. Matsuo, "A Partially Orthogonal EnKF approach to atmospheric density estimation using orbital debris," *Advances in Space Research*, 65(8), pp. 1965-1980, https://doi.org/10.1016/j.asr.2020.01.021, 2020.
58. Mashburn, J., P. Axelrad, C. Zuffada, E. Loria, A. O'Brien, B. Haines, "Improved GNSS-R Ocean Surface Altimetry with CYGNSS in the Seas of Indonesia," in *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 58, No. 9, pp. 6071-6087, doi: 10.1109/TGRS.2020.2973079, Sept. 2020.
59. Strandjord, K.L., P. Axelrad, S. Mohiuddin, "Improved Urban Navigation with Collaborative Shadow Matching and Specular Matching in Formation," *NAVIGATION*, 67:547-565, https://doi.org/10.1002/navi.378, 2020.
60. Gaebler, J., P. Axelrad, P. Schumacher, "CubeSat Cluster Deployment Track Initiation via a Radar Admissible Region Birth Model," *Journal of Guidance, Control, and Dynamics*, Vol. 43, No. 10, p. 1927-1934, doi.org/10.2514/1.G005139, October 2020.

61. Gaebler, J. and P. Axelrad, "Identity Management of Clustered Satellites with a Generalized Labeled Multi-Bernoulli Filter," *AIAA Journal of Guidance, Control, and Dynamics,* Vol. 43, No. 11, p. 2046-2057, doi.org/10.2514/1.G004725, November 2020.
62. Rybak, M. P. Axelrad, J. Seubert, T. Ely, "Chip Scale Atomic Clock–Driven One-Way Radiometric Tracking for Low-Earth-Orbit CubeSat Navigation," *AIAA Journal of Spacecraft and Rockets*, Vol. 58, No. 1, p. 200-2019, doi.org/10.2514/1.A34684, 2021.
63. VanBuren, D., P. Axelrad, S. Palo, "A Low Complexity Smoothing Algorithm for Improved GPS Point Solutions Onboard LEO Spacecraft," *NAVIGATION*, 68:185-198, doi: 10.1002/navi.410, 2021.
64. VanBuren, D., P. Axelrad, S. Palo, "Design of a high-stability heterogeneous clock system for small satellites in LEO," *GPS Solutions,* 25:105, doi.org/10.1007/s10291-021-01134-x, 2021.
65. Nicotra, M.M., J. Shao, J. Combes, A.C. Theurkauf, P. Axelrad, L.Y. Chih, M. Holland, A. Zozula, C.K. LeDesma, K. Mehling, D.Z. Anderson, "Modeling and Control of Ultracold Atoms Trapped in an Optical Lattice: An Example-driven Tutorial on Quantum Control," in *IEEE Control Systems Magazine*, vol. 43, no. 1, pp. 28-43, doi: 10.1109/MCS.2022.3216652, 2023.
66. Mutschler, S.M., P. Axelrad, E.K. Sutton, D.Masters, D. "Physics-based approach to thermospheric density estimation using CubeSat GPS data," *Space Weather*, 21, e2021SW002997. https://doi.org/10.1029/2021SW002997, 2023.
67. Rybak, M., P. Axelrad, C. LeDesma, D. Anderson, T. Ely, "Application of Shaken Lattice Interferometry Based Sensors to Space Navigation," *Advances in Space Research*, 71:4288-430, doi.org/10.1016/j.asr.2022.12.050, 2023.
68. Conrad, A., P. Axelrad, B. Haines, C. Zuffada, A. OBrien, E. Loria, "Improved Single-frequency Orbit Determination for the CYGNSS Spacecraft in GipsyX," *NAVIGATION*, 70 (1), https://navi.ion.org/content/70/1/navi.565, 2023.
69. Conrad, A., S. Desai, B. Haines, P. Axelrad, "Extending the GPS Block III antenna calibration for precise orbit determination of low Earth orbit satellites," *J. of Geodesy* 97:35, https://doi.org/10.1007/s00190-023-01718-0, 2023.
70. Flood, C., P. Axelrad, J. Hinks, "The Formation of a Chip Scale Atomic Clock Ensemble using Software Defined Radios," *IEEE Open Journal of Ultrasonics, Ferroelectrics, & Freq Control*, 3:77-87, doi:10.1109/OJUFFC.2023.3285204, 2023.
71. Dobbin, M. and P. Axelrad, "A Flexible Ephemeris Representation for GNSS and Alternative PNT Signal Sources Using B-splines," *Navigation*, 70(4), https://doi.org/10.33012/navi.610, 2023.
72. Gill E., J. Morton, P. Axelrad, D.M. Akos, M. Centrella, S. Speretta, "Overview of Space-Capable Global Navigation Satellite Systems Receivers: Heritage, Status and the Trend towards Miniaturization," *Sensors*, 23(17):7648 https://doi.org/10.3390/s23177648, 2023.

Manuscripts in Progress or in Review

73. Rybak, M., P. Axelrad, J. Seubert, T. Ely, "Chip Scale Atomic Clock One-Way Radiometric Tracking for Lunar CubeSats," in preparation for submission to *Navigation*, December 2022.
74. Wallace, B., S. Palo, P. Axelrad, J. Marino, N. Rainville, R. Kingsbury, J. Ditomas, M. Shihabi, D. Ogbe, "Development of a Lunar Surface Navigation Pseudolite Testbed," submitted to *Navigation*, December 2023.
75. Conrad, A., P. Axelrad, S. Desai, B. Haines, "Sentinel-6 Michael Freilich precise orbit determination using PODRIX and TriG receiver measurements," submitted to J. of Geodesy, January 2024.

Books and Book Chapters

1. Axelrad, P. and R.G. Brown, "GPS Navigation Algorithms," in *Global Positioning System*: *Theory and Applications,* Ed. by B.W. Parkinson, J.J. Spilker, Assoc. Ed. P. Axelrad and P. Enge, Progress in Astronautics and Aeronautics, Vol. 163 , Chapt 9, American Institute of Aeronautics and Astronautics, 409-433, 1996.

2. *Global Positioning System*: *Theory and Applications,* Ed. by B.W. Parkinson, J.J. Spilker, Assoc. Ed. P. Axelrad and P. Enge, Progress in Astronautics and Aeronautics, Volumes 163 and 164, American Institute of Aeronautics and Astronautics, 1394 pages, 1996.

Conference Proceedings
NOTE: ION conference papers are selected for presentation and inclusion in the proceedings based on an abstract. AIAA/AAS Papers are selected for presentation and inclusion in the proceedings based on a draft of the paper.
All items listed here include actual papers as well as presentation material.

1. Axelrad, P. and J.F. Kelley, "Near Earth Orbit Determination and Rendezvous Navigation Using GPS," *IEEE PLANS*, p. 184-191, Las Vegas, NV, November 1986.
2. Parkinson, B.W. and P. Axelrad, "Simplified GPS Integrity Checking with Multiple Satellites," *ION National Technical Meeting*, Dayton, OH, p. 78-83, January 1987.
3. Parkinson, B.W. and P. Axelrad, "A Basis for the Development of Operational Algorithms for Simplified GPS Integrity Checking," *ION Satellite Division Meeting*, Colorado Springs, CO, p. 269-276, September 1987.
4. Parkinson, B.W. and P. Axelrad, "A Practical Algorithm for Autonomous Integrity Verification Using the Pseudo Range Residual," *ION National Technical Meeting*, Santa Barbara, CA, p. 254-260, January 1988.
5. Parkinson, B.W. and P. Axelrad, "Closed Loop Orbit Trim Using GPS," *40th International Astronautical Congress*, Malaga, Spain, IAF-89-393, 14 pages, October 1989.
6. Kee, C., B.W. Parkinson, P. Axelrad, "Wide Area Differential GPS," *ION- GPS 90*, Colorado Springs, CO, p. 587-598, September 1990.
7. Axelrad, P., R.H. Vassar, B.W. Parkinson, "Gravity Probe B Orbit Modeling and Injection Requirements," *AAS/AIAA Spaceflight Mechanics Meeting*, Houston, TX, AAS 91-164, February 1991.
8. Hanson, P., P. Axelrad, T. Hayashi, T. Ishizaki, "A Real-Time GPS Kinematic Survey System (GKSS)," *ION- GPS 92*, Albuquerque, NM, p. 1005-1013, September 1992.
9. Axelrad, P. and B.C. Chesley, "Performance Testing of a GPS Based Attitude Determination System.," *AIAA Guidance, Navigation, and Control Conference*, Monterey, CA, p. 809-819, August 1993. (Received award for best paper presented at the conference.)
10. Axelrad, P. and L.M. Ward, "On-Orbit GPS Based Attitude and Antenna Baseline Estimation," *ION National Technical Meeting*, San Diego, CA, p. 441-450, January 1994.
11. Chesley, B.C. and P. Axelrad, "An Integrated GPS Attitude Determination System for JAWSAT," *ION-GPS 94*, Salt Lake City, UT, p. 1251-1261, September 1994.
12. Axelrad, P., C.J. Comp, P.F. MacDoran, "Use of Signal-to-Noise Ratio for Multipath Error Correction in GPS Differential Phase Measurements," *ION-GPS 94*, Salt Lake City, UT, p. 655-666, September 1994. (Received award for best paper out of eight in the session.)
13. Park, M., G. Born, P. Axelrad, K. Gold, K. Key, D. Kubitshek, T. Kelecy, J. LaMance, C. Rocken, J, Johnson, "The Use of GPS Buoys to Calibrate Altimetric Satellites," *ION-GPS 94*, Salt Lake City, UT, p. 221-230, September 1994.
14. Lawrence, D.A., T.E. Holden, F. Padieu, P. Axelrad, M. Malone, "Disturbance Learning Control for Small Satellites," *American Control Conference*, Baltimore, MD, p. 2882-2886, 1994.
15. Ward, L.M. and P. Axelrad, "Spacecraft Attitude Estimation Using GPS: Methodology and Results for RADCAL," *ION National Technical Meeting*, Anaheim, CA, p. 813-825, January 1995.
16. Chesley, B.C. and P. Axelrad, "Mitigating Measurement Errors in a Low Cost Satellite Attitude Determination System," *ION National Technical Meeting*, Anaheim, CA, p. 763-774, January 1995.
17. Gold, K., G.H. Born, K. Irish, A. Reichert, R. Markin, B. Binning, P. Axelrad, S. Mitchell, W. Frazier, W. Bertiger, G. Hajj, "Precision Orbit Determination in the Geosat Orbit," *ION National Technical Meeting*, Anaheim, CA, p. 579-591, January 1995.

18. Melvin, P.J., L.M. Ward, P. Axelrad, "The Analysis of GPS Attitude Data From a Slowly Rotating, Symmetrical Gravity Gradient Satellite," *Spaceflight Mechanics 1995, Advances in the Astronautical Sciences,* Vol. 89, Part 1, p. 539-558, 1995. (Received a 1995 Alan Berman Research Publications Award from the Naval Research Laboratory)
19. Garrison, J.L., T.G. Gardner, P. Axelrad, "Relative Motion in Highly Elliptical Orbits," *Spaceflight Mechanics 1995, Advances in the Astronautical Sciences,* Vol. 89, Part 2, p. 1359-1376, 1995.
20. Axelrad, P. and C.P. Behre, "A Comparison of GPS-Based Attitude Estimation Techniques for Spinning Satellites," *ION GPS-95*, Palm Springs, CA, p. 1785-1796, September 1995.
21. Garrison, J.L., and P. Axelrad, "Application of the Extended Kalman Filter for Relative Navigation in an Elliptical Orbit," *Spaceflight Mechanics 1996*, *Advances in the Astronautical Sciences*, Vol. 93, Part 1, 693-712, 1996. (Received award for best paper presented at the conference.)
22. Irish, K.J., K. Gold, G. Born, R. Markin, A. Reichert, P. Binning, P. Axelrad, C. Behre, "Precision Orbit Determination for GFO and GFO-2," *Spaceflight Mechanics 1996*, *Advances in the Astronautical Sciences*, Vol. 93, Part 2, 1331-1342, 1996. (Received award for best paper in session.)
23. Solomon, S.C., C.A. Barth, P. Axelrad, et al., "The Student Nitric Oxide Explorer," *Space Sciencecraft Control and Tracking in the New Millenium*, SPIE Proceedings Series Vol 2810, p. 121-132, August 1996.
24. Comp, C.J. and P. Axelrad, "An Adaptive SNR-Based Carrier Phase Multipath Mitigation Technique", *ION GPS-96*, Kansas City, MO, p. 683-697, September 1996.
25. Ward, L.M. and P. Axelrad, "A Combined Filter for GPS-Based Attitude and Baseline Estimation", *ION GPS-96*, Kansas City, MO, p. 1047-1061, September 1996. (Received award for best paper in session.)
26. Garrison, J.L., P. Axelrad, N.J. Kasdin, "On the Possibility of Ill-Conditioned Covariance Matrices in the First-Order Two-Step Estimator," *Spaceflight Mechanics 1997, Advances in the Astronautical Sciences*, Vol. 95, Part 2, 1087-1102, 1997.
27. Reichert, A., P. Axelrad, S.C. Wu, W. Bertiger, J. Srinivasan, "Initial Demonstration of a Point Solution Algorithm for Orbit Determination Using the microGPS Receiver," *ION National Technical Meeting*, Santa Monica, p. 377-387, January 1997.
28. Behre, C.P. and P. Axelrad, "Coarse Single-Axis Attitude Estimation Using GPS Signal-to-Noise Ratio," *KIS'97 Conference*, Banff, Canada, p. 417-427, June 2-6, 1997.
29. Axelrad, P. and D.E. Highsmith, "Post-Processed Attitude and Baseline Estimation for the GPS Attitude and Navigation Experiment (GANE)," *ION Annual Meeting*, Albuquerque, NM, p. 353-363, June 1997.
30. Davis, G.W., K.L. Gold, P. Axelrad, G.H. Born, T.V. Martin, "A Low Cost, High Accuracy Automated GPS-Based Orbit Determination System for Low Earth Satellites," *ION GPS-97*, Kansas City, MO, p. 723-733, September 1997.
31. Nelson, L.M., P. Axelrad, D.M. Etter, "Adaptive Detection of Code Delay and Multipath in a Simplified GPS Signal Model," *ION GPS-97*, Kansas City, MO, p. 569-581, September 1997.
32. Garrison, J.L. and P. Axelrad, "Relative Navigation in Highly Elliptical Orbits Using an Iterative Nonlinear Filter," *ION GPS-97*, Kansas City, MO, p. 745-754, September 1997.
33. Highsmith, D. and P. Axelrad, "A Batch Filter for Baseline Estimation Using On-Orbit GPS and Gyro Data," *ION Annual Meeting*, Denver, CO, p. 133-143, June 1998.
34. Komjathy, A., V. Zavorotny, P. Axelrad, G. Born, J. Garrison, "GPS Signal Scattering from Sea Surface: Comparison Between Experimental Data and Theoretical Model," *Fifth International Conference on Remote Sensing for Marine and Coastal Environments*, San Diego, CA, p. 530-539, October 1998.
35. Moreau, M., P. Axelrad, J.L. Garrison, D. Kelbel, A. Long, "GPS Receiver Architecture and Expected Performance for Autonomous GPS Navigation in Highly Eccentric Orbits," *ION Annual Meeting*, Boston, MA, p. 653-665, June 1999.
36. Kubitschek, D.G., K. Gold, M. Ondrey, P. Axelrad, G.H. Born, "ICESat Attitude Algorithm for Maintained Reference Groundtrack Pointing," *Astrodynamics 1999, Advances in the Astronautical Sciences*, Vol. 103, Part 2, p. 1115-1130, August 1999.

37. Mickler, D., P. Axelrad, G.H. Born, "Reducing Selective Availability Effects on Post-Processed Orbits for Satellites with Limited GPS Telemetry," *Spaceflight Mechanics 1999, Advances in the Astronautical Sciences*, Vol. 102, Part 2, 1477-1489, 1999.
38. Axelrad, P., K. Gold, P. Madhani, A. Reichert, "Analysis of Orbit Errors Induced by Multipath for the ICESat Observatory," *ION GPS-99*, Nashville, TN, p. 875-883, September 1999.
39. Highsmith, D. and P. Axelrad, "Relative State Estimation Using GPS Flight Data from Co-Orbiting Spacecraft," *ION GPS-99*, Nashville, TN, p. 401-409, September 1999.
40. Reichert, A. and P. Axelrad, "GPS Carrier Phase Multipath Reduction Using SNR Measurements to Characterize an Effective Reflector," *ION GPS-99*, Nashville, TN, p. 1951-1960, September 1999.
41. Armatys, M., D. Masters, A. Komjathy, P. Axelrad, J.L. Garrison, "Exploiting GPS as a New Oceanographic Remote Sensing Tool," *ION National Technical Meeting*, Anaheim, CA, p. 339-347, January 2000.
42. Komjathy, A., J.A. Maslanik, V.U. Zavorotny, P. Axelrad, S.J. Katzberg, "Towards GPS Surface Reflection Remote Sensing of Sea Ice Conditions," *Sixth International Conference on Remote Sensing for Marine and Coastal Environments*, Charleston, SC, Vol. II, p. 447-456, 1-3 May 2000.
43. Armatys, M., A. Komjathy, P. Axelrad, S.J. Katzberg, "A Comparison of GPS and Scatterometer Sensing of Ocean Wind Speed and Direction," *IEEE Geoscience and Remote Sensing Symposium IGARSS 2000,* Vol. 7 , p. 2861 –2863, 2000.
44. Emery, W.J., P. Axelrad, D. Masters, S. Solomon, M. McGrath, "Ocean Wind and Land Surface Student Satellite (OWLS)," *IEEE Geoscience and Remote Sensing Symposium IGARSS 2000*, Vol. 7 , p. 3084 -3086, 2000.
45. Komjathy, A., J. Maslanik, V.U. Zavorotny, P. Axelrad, S.J. Katzberg, "Sea ice remote sensing using surface reflected GPS signals," *IEEE Geoscience and Remote Sensing Symposium IGARSS 2000*, Vol. 7 , p. 2855 –2857, 2000.
46. Highsmith, D.E., P.W. Binning, P. Axelrad, "Design and Test of an Algorithm for Satellite-to-Satellite Time Transfer," *ION GPS-2000*, Salt Lake City, UT, p. 1582-1594, September 2000 (Received 2000 Alan Berman Research Publications Award from the Naval Research Laboratory).
47. Komjathy, A., M. Armatys, D. Masters, P. Axelrad, V.U. Zavorotny, S.J. Katzberg, "Developments in Using GPS for Oceanographic Remote Sensing: Retrieval of Ocean Surface Wind Speed and Wind Direction," *ION National Technical Meeting*, Long Beach, CA, pp. 753-761, January 2001.
48. Goldstein, D.B., G.H. Born, P. Axelrad, "Real-time Autonomous, Precise Orbit Determination Using GPS," *ION 57th Annual Meeting*, Albuquerque, NM, p. 149-158, June 2001.
49. Garrison, J.L., M. Moreau, P. Axelrad, "Tracking Loop Optimization for On-Board Orbit Navigation in HEO/GEO Missions," *ION 57th Annual Meeting*, Albuquerque, NM, p. 168-175, June 2001.
50. Thompson, B., P. Axelrad, G.H. Born, "Orbit Determination for the QuikSCAT Spacecraft," *2001 Flight Mechanics Symposium*, NASA GSFC, Greenbelt, MD, June 2001.
51. Armatys, M., P. Axelrad, D. Masters, "GPS-Based Remote Sensing of Ocean-Surface Wind Speed from Space," *IEEE Geoscience and Remote Sensing Systems (IGARSS) 2001*, Sydney, Australia, p. 2522-2524, 2001.
52. Emery, W.J., P. Axelrad, R.S. Nerem, D. Masters, M. Armatys, A. Komjathy, "Student Reflected GPS Experiment (SuRGE)," *IEEE Geoscience and Remote Sensing Systems (IGARSS) 2001*, Sydney, Australia, p. 1518-1520, 2001.
53. Nerem, R. S., J. C. Ries, P. Bender, B. Thompson, P. Axelrad, J. Labrecque, M. Gabor, "Applications of Drag-Free Technology to Precision Satellite Navigation," *Astrodynamics 2001, AAS/AIAA Astrodynamics Specialist Conference,* p. 1757-1768, 2001.
54. Masters, D., P. Axelrad, V. Zavorotny, S.J. Katzberg, F. Lalezari, "A Passive GPS Bistatic Radar Altimeter for Aircraft Navigation," *ION GPS-2001*, Salt Lake City, OR, p. 2435-2445, September 2001 (Received award for best paper in session.).

55. Madhani, P.H., P. Axelrad, K. Krumvieda, J. Thomas, "Mitigation of the Near-Far Problem by Successive Interference Cancellation," *ION GPS-2001*, Salt Lake City, UT, p. 148-154, September 2001 (Received award for best paper in session.).
56. Krumvieda, K., C. Cloman, E. Olson, J. Thomas, W. Kober, P.H. Madhani, P. Axelrad, "A Complete IF Software GPS Receiver: A Tutorial About the Details," *ION GPS-2001*, Salt Lake City, UT, p. 789-829, September 2001.
57. Moreau, M., P. Axelrad, J.L. Garrison, M. Wennersten, A. Long, "Test Results of the PiVoT Receiver in High Earth Orbits Using a GSS GPS Simulator," *ION GPS-2001*, Salt Lake City, UT, p. 2316-2326, September 2001.
58. Moreau, M., E.P. Davis, J.R. Carpenter, D. Kelbel, G.W. Davis, P. Axelrad, "Results from the GPS Flight Experiment on the High Earth Orbit AMSAT OSCAR-40 Spacecraft," *ION GPS-2002*, Portland, OR, p. 122-133, September 2002.
59. Meek, M., K. Gold, Y. Hwang, P. Axelrad, G. Born, "Orbit Determination for the Quickbird Spacecraft," *Proceedings of the 2002 Core Technologies for Space Systems Conference*, Colorado Springs, CO, November 19-21, 2002.
60. Meek, M., G.H. Born, K.S. Morris, P. Axelrad, "Automated Operational Orbit Determination for the ICESat Mission," *John L. Junkins Astrodynamics Symposium AAS/AIAA Space Flight Mechanics Meeting*, College Station, TX, May 23-24, 2003.
61. Masters, D., Katzberg, S., Axelrad, P., "Airborne GPS Bistatic Radar Soil Moisture Measurements During SMEX02," *Proceedings of IEEE International Geoscience and Remote Sensing Symposium* (IGARSS), 2003.
62. Zavorotny, V., Masters, D.; Gasiewski, A.; Bartram, B.; Katzberg, S.; Axelrad, P.; Zamora, R., "Seasonal Polarimetric Measurements of Soil Moisture Using Tower-Based GPS Bistatic Radar," *Proceedings of IEEE International Geoscience and Remote Sensing Symposium (IGARSS),* v 2, p 781-783, 2003.
63. Sturtevant, P., D. Masters, P. Axelrad, S.J. Katzberg, "GPS-based Bistatic Radar for Terrain Awareness – Methods and Preliminary Results," *ION GPS/GNSS-2003*, Portland, OR, p. 2358-2370, September 2003 (Received award for best paper in session.).
64. Weiss, J.P., S. Anderson, P. Axelrad, R.L. Brinkley, R.P. Pennline, "Multipath Modeling and Test Results for JPALS Ground Station Receivers," *ION GPS/GNSS-2003*, Portland, OR, p. 1801-1811, September 2003.
65. Zarske, M.S., P. Axelrad, J. Yowell, J. Sullivan, "Navigation Modules for Middle School Students", *ION GPS/GNSS-2003*, Portland, OR, p. 418-424, September 2003.
66. Bilich, A., K.M. Larson, P. Axelrad, "Observations of Signal-to-Noise Ratios (SNR) at Geodetic GPS Site CASA: Implications for Phase Multipath," *Proceedings of The State of GPS Vertical Positioning Precision: Separation of Earth Processes by Space Geodesy*, Luxembourg, April 2-4, 2003.
67. Axelrad, P., D. Akos, K. Larson, G. Born, S. Nerem, S. Palo, "GPS Research and Education at the University of Colorado, Boulder,"*, ION 60th Annual Meeting*, Dayton, OH, p. 223-229, June 7-9, 2004.
68. Weiss, J.P., S. Anderson, P. Axelrad, R. L. Brinkley, R. P. Pennline, "Analysis of P(Y) Code Multipath for JPALS LDGPS Ground Station and Airborne Receivers," *ION GNSS-2004*, Long Beach, CA, p. 2728-2741, Sept. 21-24, 2004.
69. Anderson, S., J.P. Weiss, P. Axelrad, R.P. Pennline, "A GPS Multipath Simulator with Beam-Steering Antenna Modeling for JPALS LDGPS," *ION GNSS-2004*, Long Beach, CA, p. 2271-2282, September 21-24, 2004.
70. Lane, C., P. Axelrad, "Analysis of Formation Flying in Eccentric Orbits Using Linearized Equations of Relative Motion," *Proceedings of the 2nd International Symposium on Formation Flying Missions & Technologies*, Washington, DC**,** September 14-16, 2004.
71. Belmonte-Rivas, M., P. Axelrad, J. Maslanik, "Remote Sensing of the Cryosphere Using GPS Reflections," *Proceedings of the 2nd ESA Workshop on Satellite Navigation User Equipment Technologies*, Noordwijk, The Netherlands, 9 pages, December 8-10, 2004.
72. Vinande, E., D. Akos, D. Masters, P. Axelrad, S. Esterhuizen, "GPS Bistatic Radar Measurements of Aircraft Altitude and Ground Objects with a Software Receiver," *ION 61st Annual Meeting*, Cambridge, MA, p. 528-534, June 27-29, 2005.

73. Weiss, J., S. Anderson, C. Fenwick, L. Song, P. Axelrad, R.L. Brinkley, "Development and Validation of an Aircraft Multipath Model for Land-Based JPALS," *ION 61st Annual Meeting*, Cambridge, MA, p. 818-829, June 27-29, 2005.
74. Anderson, S., L.S. Stowe, C. Fenwick, J.P. Weiss, P. Axelrad, J. Stevens, R. L. Brinkley S. M. Calhoun, "Analysis of P(Y) Code and Carrier Multipath for JPALS Ship and Airborne Receivers," *ION GNSS-2005*, Long Beach, CA, p. 2195-2206, September 13-16, 2005
75. Axelrad, P., K. Larson, B. Jones, "Use of the Correct Satellite Repeat Period to Characterize and Reduce Site Specific Multipath Errors," *ION GNSS-2005*, Long Beach, CA, p. 2638- 2648, September 13-16, 2005.
76. Weiss, J., S. Anderson, C. Fenwick, L. Stowe, P. Axelrad, S.M. Calhoun, R.P. Pennline, "Aircraft Carrier Multipath Modeling for Sea-Based JPALS," *ION GNSS-2005*, Long Beach, CA, p. 2697-2706, September 13-16, 2005 (Received award for best paper in session).
77. Lane, C. and P. Axelrad, "Analysis of Relative Navigation in Highly Eccentric Orbits," *AAS Guidance, Navigation, and Control Conference*, Breckenridge, CO, February 2006, AAS 06-147.
78. Lindgren, T., E. Vinande, D. Akos, D. Masters, P. Axelrad, "Measurement of Backscattered GPS Signals," *2006 IEEE/ION Position, Location, and Navigation Symposium*, San Diego, CA p. 664-669, Apr 25-27 2006.
79. Weiss, Jan P., S. Anderson, P. Axelrad, "Improved Multipath Model Validation in Semi-Urban, Aircraft, and Shipboard Environments," *International Global Navigation Satellite Systems Society Symposium 2006*, Surfers Paradise, Queensland, Australia, Paper No. 98, July 17-21, 2006
80. Junered, M., S. Esterhuizen, D. Akos, P. Axelrad, "A Modular GPS Remote Sensing Software Receiver for Small Platforms, *ION GNSS-2006*, Fort Worth, TX, p. 634-643, September 26-29, 2006.
81. Weiss, J.P., P. Axelrad, S. Anderson, "Assessment of Digital Terrain Models for Multipath Prediction at Geodetic GNSS Installations," *ION GNSS-2006*, Fort Worth, TX, p. 2815-2823, September 26-29, 2006.
82. Lane, C. and P. Axelrad, "Effects of Orbital Perturbations on the Performance of a Relative Navigation Filter for High Earth Orbits," *AAS/AIAA Space Flight Mechanics Meeting, Sedona, AZ*, *January 28-February 1, 2007,* AAS 07-155.
83. Weiss, Jan P., P. Axelrad, A. G. Dempster, C. Rizos, S. Lim, "Estimation of Simplified Reflection Coefficients for Improved Modeling of Urban Multipath," *Proc. ION 63rd Annual Meeting*, p. 635-643, Cambridge, MA, April 23-25, 2007.
84. Bilich, A., P. Axelrad, K.M. Larson, "Scientific Utility of the Signal-to-Noise Ratio (SNR) Reported by Geodetic GPS Receivers," *ION GNSS-2007*, Fort Worth, TX, p. 1999-2010, September 25-28, 2007.
85. Weiss, J.P. and P. Axelrad, "Multipath Signal Simulation in a Dynamic Aircraft Landing Environment," *ION GNSS-2007*, Fort Worth, TX, p. 2687-2695, September 25-28, 2007. (Received award for best presentation in session.)
86. Tombasco, J. and P. Axelrad, "Linearized Relative State Estimation and Data Association for Orbit Determination of Clustered Geosynchronous Satellites," *AIAA/AAS Astrodynamics Specialist Conference and Exhibit*, Honolulu, HI, 22 pages, AIAA 2008-6605, August 18-21, 2008.
87. Axelrad, P., J. Donna, M. Mitchell, "Enhancing GNSS Acquisition by Combining Signals from Multiple Channels and Satellites," *ION GNSS-2009*, Savannah, GA, p. 2617 - 2628, September 22-25, 2009.
88. Tombasco, J., P. Axelrad, M. Jah, "Analysis of Specialized Coordinate Representation for Dynamic Modeling and Orbit Estimation in the Geosynchronous Regime," *20th AAS/AIAA Space Flight Mechanics Meeting*, February 14-17, 2010, San Diego, CA.
89. Bradley, B.K., P. Axelrad, J. Donna, S. Mohiuddin, "Performance Analysis of Collective Detection of Weak GPS Signals," *ION GNSS-2010*, Portland, OR, p. 3041-3053, September 21-24, 2010. (Received award for best presentation in session.).
90. Axelrad, P., B. K. Bradley, J. Tombasco, S. Mohiuddin, J. Donna, "GEO Satellite Positioning Using GPS Collective Detection," *ION GNSS-2010*, Portland, OR, p. 2706-2716, September 21-24, 2010.
91. Axelrad, P., "Overview of Space Applications of Global Navigation Satellite Systems," Advances in the Astronautical Sciences, Vol. 141, *Proceedings of AAS Guidance and Control 2011*, Breckenridge, CO, p. 23-35, February 4-7, 2011.

92. Bradley, B. K., D.A. Vallado, A. Sibois, P. Axelrad, "Earth Orientation Parameter Considerations for Precise Spacecraft Operations," AAS 11-529, *AAS/AIAA 2011 Astrodynamics Specialist Conference*, Girdwood, AK, August 2, 2011.

93. Gehly, S., B. Jones, P. Axelrad, G. Born, "Minimum L1 Norm Orbit Determination Using a Sequential Processing Algorithm," AAS 12-200, *22nd AAS/AIAA Space Flight Mechanics Meeting,* Charleston, SC*,* January 29-February 2, 2012.

94. Bradley, B. K., B. A. Jones, G. Beylkin, P. Axelrad, "A New Numerical Integration Technique in Astrodynamics," AAS 12-216, *22nd AAS/AIAA Space Flight Mechanics Meeting,* Charleston, SC*,* January 29-February 2, 2012.

95. Barlow, E., P. Axelrad, S. Palo, L. Cornman, R.K. Goodrich, "Detection of Atmospheric Turbulence in GPS-RO Amplitude Spectra," *ION GNSS 2012*, Nashville, TN, p. 3380-3391, September 17-21, 2012.

96. Axelrad, P., "Application of GNSS to Environmental Studies," (Invited) *Proceedings of National Academy of Engineering / Chinese Academy of Sciences GNSS Workshop (Refereed)*, p. 179-188, 2012.

97. Gehly, S., B. Jones, P. Axelrad, "Comparison of Multitarget Filtering Methods as Applied to Space Situational Awareness," AAS 13-765, *22nd AAS/AIAA Astrodynamics Specialist Meeting,* Hilton Head, SC*,* August 11-15, 2013.

98. Bradley, B. K. and P. Axelrad, "Improved Estimation of Orbits and Physical Properties of Objects in GEO," *AMOS – Advanced Maui Optical and Space Surveillance Technologies Conference,* Maui, HI, September 10-15, 2013.

99. Bradley, B.K. and P. Axelrad, "Lightcurve Inversion for Shape Estimation of GEO Objects from Space-Based Sensors," *International Symposium on Space Flight Dynamics (ISSFD)*, Johns Hopkins University, 20 pages, May 7, 2014.

100. Jones, B., S. Gehly, P. Axelrad, "Measurement-based Birth Model for a Space Object Cardinalized Probability Hypothesis Density Filter," *AIAA/AAS Astrodynamics Specialist Conference*, San Diego, CA, August 4-8, 2014.

101. McMahon, J., S. Gehly, P. Axelrad, "Enhancing Relative Attitude and Trajectory Estimation for Autonomous Rendezvous Using Flash LIDAR," *AIAA/AAS Astrodynamics Specialist Conference*, San Diego, CA, August 4-8, 2014.

102. Gehly, S., B. Jones, P. Axelrad, "An AEGIS-CPHD Filter to Maintain Custody of GEO Space Objects with Limited Tracking Data," *AMOS – Advanced Maui Optical and Space Surveillance Technologies Conference,* Maui, HI, 10 pages, September 10-15, 2014.

103. Klein, V., P. Axelrad, J. Veldman, "Characterization of Expected Multipath Error for the NICER X-Ray Telescope Payload," *Proceedings of the 27th International Technical Meeting of The Satellite Division of the Institute of Navigation (ION GNSS+ 2014)*, pp. 2448-2456, Tampa, FL, September 2014.

104. Barlow, E., P. Axelrad, P. Withnell, D. Nuding, "Analysis of Error Sources in Phase Rate Measurements in GPS Radio Occultation," *Proceedings of the 27th International Technical Meeting of The Satellite Division of the Institute of Navigation (ION GNSS+ 2014)*, Tampa, FL, pp. 1478-1491, September 2014.

105. Ashman, B., J. L. Veldman, J. L. Garrison, P. Axelrad, "Evaluation of the GNSS Multipath Environment in Space Proximity Operations: Experimental and Simulation Studies of Code Correlations in Hubble Servicing Mission 4," *Proceedings of the Pacific PNT Meeting of the Institute of Navigation*, Honolulu, HI, April 2015, pp. 863-871.

106. Garcia, J.G., P. Axelrad, P.A. Roncagliolo, C.H. Muravchik, "Fast and Reliable GNSS Attitude Estimation Using a Constrained Bayesian Ambiguity Resolution Technique (C-BART)," *Proceedings of the 28th International Technical Meeting of the Satellite Division of the Institute of Navigation (ION GNSS+ 2015)*, Tampa, FL, pp. 2809-2820, September 2015.

107. Herz, A., B. Jones, E. Herz, D. George, P. Axelrad, S. Gehly, "Heimdall System for MSSS Sensor Tasking," *Proceedings of the Advanced Maui Optical and Space Surveillance Technologies Conference*, Maui, HI, 11 pages, September 15-18, 2015.

108. Gaebler, J.A. and P. Axelrad, "Characterization of Specialized Geosynchronous Elements for Space Situational Awareness Applications," *AIAA/AAS Astrodynamics Specialist Conference, AIAA SPACE Forum,* (AIAA 2016-5503*),* Long Beach, CA, 10 pages, September 2016.

109. Ashman, B. W., J.L. Veldman, P. Axelrad, J.L. Garrison, L.B. Winternitz, L.B., "Validation of GNSS Multipath Model for Space Proximity Operations Using the Hubble Servicing Mission 4 Experiment," *Proceedings of the 29th*

International Technical Meeting of the Satellite Division of the Institute of Navigation (ION GNSS+ 2016), Portland, Oregon, September 2016, pp. 3635-3643. (Received award for best presentation in session.)

110. Herz, A., E. Herz, K. Center, P.D. George, P. Axelrad, S. Mutchler, B. Jones, "Utilizing novel non-traditional sensor tasking approaches to enhance the space situational awareness picture maintained by the Space Surveillance Network," *Proceedings of the Advanced Maui Optical and Space Surveillance Technologies Conference*, Maui, HI, 14 pages, September 20-23, 2016.

111. Klein, V. and P. Axelrad, "Multipath Modeling and Validation for GPS Onboard the International Space Station," *AAS Guidance and Control Conference*, Breckenridge, CO, 11 pages, February 4, 2017.

112. Gaebler, J.A. and P. Axelrad, "Cubesat Cluster Deployment Tracking with a CPHD Filter," *9th International Workshop on Satellite Constellations and Formation Flying*, Boulder, CO, 12 pages, June 21, 2017.

113. Gaebler, J.A., P. Axelrad, P.W. Schumacher, "Boundaries on Range-Range Constrained Admissible Regions for Optical Space Surveillance," *Proceedings of the Advanced Maui Optical and Space Surveillance Technologies Conference*, Maui, HI, 12 pages, September 19-22, 2017.

114. Mutschler, S., P. Axelrad, T. Matsuo, "Harnessing Orbital Debris to Sense the Space Environment," *Proceedings of the Advanced Maui Optical and Space Surveillance Technologies Conference*, Maui, HI, 14 pages, September 19-22, 2017.

115. Strandjord, K.L. and P. Axelrad, "A Framework for Regional GNSS Situational Awareness," *Proceedings of the 29th International Technical Meeting of the Satellite Division of the Institute of Navigation (ION GNSS+ 2017)*, Portland, Oregon, pp. 2452-2466, September 2017.

116. Mashburn, J., A. O'Brien, P. Axelrad, C. Zuffada, S. Lowe, R. Shah, A. Voronovich, V. Zavorotny, "A Comparison of Waveform Model Re-Tracking Methods Using Data from CYGNSS," *Proceedings of IEEE International Geoscience and Remote Sensing Symposium* (IGARSS), Valencia, Spain, pp. 4289-4292, July 2018.

117. Zuffada, C., B. Haines, G. Hajj, Z. Li, S. Lowe, R. Shah, J. Mashburn, P. Axelrad, A. O'Brien, P. Cipollini, V. Zavorotny, A. Voronivich, "Assessing the Altimetric Measurement from CYGNSS Data," *Proceedings of IEEE International Geoscience and Remote Sensing Symposium* (IGARSS), Valencia, Spain, pp. 8292-8295, July 2018.

118. Rybak, M., P. Axelrad, J. Seubert, "Investigation of CSAC Driven One-Way Ranging Performance for CubeSat Navigation," *Proceedings 32nd Annual AIAA/USU Conference on Small Satellites*, SSC18-X-06, 13 pages, August 2018.

119. Strandjord, K.L. and P. Axelrad, "Framework and Techniques for Cooperative Group Situational Awareness in Urban Environments," *Proceedings of the 30th International Technical Meeting of the Satellite Division of the Institute of Navigation (ION GNSS+ 2018)*, Miami, Florida, pp. 253-270, September 2018.

120. Gaebler, J.A. and P. Axelrad, "Label Assignments in CubeSat Cluster Deployment Tracking," *Proceedings of AAS/AIAA Space Flight Mechanics Meeting*, Ka'anapali Maui, AAS 19-540, 15 pages, January 2019.

121. Van Buren, D., S. Palo, P. Axelrad, "High Stability Reference Clock for Small Satellites," *Proceedings of the Precise Time and Time Interval Meeting*, Reston, VA, 21 pages, January 2019.

122. Gaebler, J.A and P. Axelrad, "Improving Orbit Determination of Clustered CubeSat Deployments using Camera-Derived Observations," *Proceedings of the 42nd AAS Rocky Mountain Section Guidance, Navigation, and Control Conference 2019,* Advances in the Astronautical Sciences, Vol. 169, Breckenridge, CO, AAS 19-041, pp. 191-200, February 2019.

123. Boylston, A., J.A. Gaebler, and P. Axelrad, "Extracting CubeSat Relative Motion Using In Situ Deployment Imagery," *Proceedings of the 42nd AAS Rocky Mountain Section Guidance, Navigation, and Control Conference 2019,* Advances in the Astronautical Sciences, Vol. 169, Breckenridge, CO, AAS 19-016, pp. 59-68, February 3, 2019.

124. Loria, E., J. Mashburn, A. O'Brien, P. Axelrad, C. Zuffada, Z. Li, and B. Haines, Towards an Ocean Altimetry Product Using CYGNSS," *Proceedings of IEEE International Geoscience and Remote Sensing Symposium* (IGARSS), Yokohama, Japan, pp. 8700-8702, July 2019.

125. Gaebler, J.A. and P. Axelrad, "Track Initiation for CubeSat Cluster Deployment Tracking," *2019 AAS/AIAA Astrodynamics Specialist Conference,* Portland, ME, AAS 19-862, 11 pages, August 2019.

126. Van Buren, D., S. Palo, P. Axelrad, "Simulation of a High Stability Reference Clock for Small Satellites with Modeled GPS Timing Errors," *Proceedings of the AIAA/USU Conference on Small Satellites*, SSC19-XII-03, 11 pages, http://digitalcommons.usu.edu/smallsat/2019/all2019/159, August 2019.

127. Mutschler, S., P. Axelrad, T. Matsuo, E. Sutton, "Physics-based Approach to Density Estimation and Prediction using Orbital Debris Tracking Data," *AMOS – Advanced Maui Optical and Space Surveillance Technologies Conference,* Maui, HI, September 17-20, 2019.

128. Strandjord, K.L., P. Axelrad, D.M. Akos, S. Mohiuddin, "Improved Urban Navigation with Direct Positioning and Specular Matching," *Proceedings of the 2020 International Technical Meeting of The Institute of Navigation*, San Diego, CA, pp. 787-800, January 21-24, 2020.

129. Rybak., M.M., P. Axelrad, J. Seubert, T. Ely, "Estimation of Thermal and Stochastic Variations of Chip Scale Atomic Clocks for Navigation of a Lunar CubeSat," *Proceedings of the 51st Precise Time and Time Interval Systems Meeting*, San Diego, CA, pp. 221-233, https://doi.org/10.33012/2020.17302, January 21-24, 2020.

130. Khatri, Y, A. Aboaf, D. Dowd, C. Flood, H. Dixon, P. Axelrad, "CSAC Flight Experiment to Characterize On-Orbit Performance," *Proceedings of the AIAA/USU Conference on Small Satellites*, SSC20-XIII-03, https://digitalcommons.usu.edu/smallsat/2020/all2020/46/, August 2020.

131. Conrad, A., P. Axelrad, C. Zuffada, B. Haines, A. O'Brien, E. Loria, "Improved Single Frequency Orbit Determination for the CYGNSS Spacecraft," *Proceedings of the 33rd International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS+ 2020)*, pp. 3875-3887, September 2020 (Virtual).

132. Conrad, A., P. Axelrad, C. Zuffada, B. Haines, A. O'Brien, E. Loria, "Improved Orbit Determination of the CyGNSS Satellites and Its Application to GNSS-R Ocean Altimetry", *IEEE International Geoscience and Remote Sensing Symposium* (IGARSS), September 27 – October 2, 2020 (Virtual).

133. Flood, C., M.Q. LaBarge, L. Schement, H. Dixon, P. Axelrad, "A Testbed for Low-SWaP Atomic Clock Ensemble Development," *Proceedings of the 52nd Annual Precise Time and Time Interval Systems and Applications Meeting*, pp. 287-300. https://doi.org/10.33012/2021.17790, January 2021 (Virtual).

134. Mutschler, S., P. Axelrad, E. Sutton, "Application of SoleiTool for Density Estimation using CubeSat GPS Data," *AMOS – Advanced Maui Optical and Space Surveillance Technologies Conference,* Maui, HI, September 14-17, 2021.

135. Flood, C., W. Watkins, P. Axelrad, "Signal Generation in a Low-SWaP Atomic Clock Ensemble," *Proceedings of the 53nd Annual Precise Time and Time Interval Systems and Applications Meeting*, Long Beach, CA, pp. 45-57, January 2022.

136. Dobbin, M., C. Colpaert, C. Krebs, P. Axelrad, "Characterizing CSAC Performance in a Simulated Mission Environment," *Proceedings of the 44nd Annual AAS Rocky Mountain Section Guidance, Navigation, and Control Conference 2022,* Advances in the Astronautical Sciences, Breckenridge, CO, AAS 22-013, 18 pages, February 2022.

137. Flood, C., P. Axelrad. A.J. Metcalf, B.K. Stuhl, "Estimation Architectures for Precise Time and Frequency Transfer in a LEO Constellation," *2022 Joint Conference of the European Frequency and Time Forum & the IEEE International Frequency Control Symposium (EFTF/IFCS)*, Paris, France, 5 pages, doi: 10.1109/EFTF/IFCS54560.2022.9850585, April 2022.

138. Dobbin, M. and P. Axelrad, "A Flexible Ephemeris Representation for GNSS and Alternative PNT Signal Sources Using B-Splines," *Proceedings of the 35rd International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS+ 2022)*, pp. 799-807, September 2022.

139. Conrad, A., P. Axelrad, S. Desai, B. Haines, "Improved Modeling of the Solar Radiation Pressure for the Sentinel-6 MF Spacecraft," *Proceedings of the 35rd International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS+ 2022)*, pp. 3618-3631, September 2022.

140. Patel, R., C. Flood, P. Axelrad, "Multi-CubeSat Formation Design for a High-Precision Timing and Ranging Experiment in LEO," *Proceedings of the 33rd AAS/AIAA Space Flight Mechanics Meeting*, Austin, TX, January 2023.

141. Flood, C., J. Pedersen, P. Axelrad, "A Multi-Platform Clock Ensemble Testbed," *Proceedings of the 54th Annual Precise Time and Time Interval Systems and Applications Meeting*, Long Beach, CA, pp. 223-235, doi: 10.33012/2023.18683, January 2023.

142. Davies, L. and P. Axelrad, "Arc-Constrained Multi-Target Tracking with Real Radar Observations," *Proceedings of the 45nd Annual AAS Rocky Mountain Section Guidance, Navigation, and Control Conference 2023*, Breckenridge, CO, AAS 22-015, 17 pages, February 2023.

143. Wallace, B., S. Palo, P. Axelrad, J. Marino, N. Rainville, R. Kingsbury, J. Ditomas, M. Shihabi, D. Ogbe, "Development of a Lunar Surface Navigation Pseudolite Testbed," *Proceedings of the 36th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS+ 2023)*, 19 pages, September 2023.

144. Coll Ibars, S., D. Scheeres, P. Axelrad, "Asteroid gravity field estimation using a gravity gradiometer," AIAA 2024-2274, January 2024. Sergio Coll Ibars, Daniel Scheeres and Penina Axelrad. "Asteroid gravity field estimation using a gravity gradiometer," AIAA 2024-2274. *AIAA SCITECH 2024 Forum*. January 2024.

Other Publications

1. Axelrad, P., Near-Earth Orbit Determination and Rendezvous Navigation Using GPS, Master's Thesis, MIT, 1986.
2. Parkinson, B.W. and P. Axelrad, "Techniques for Autonomous GPS Integrity Monitoring," AGARDograph No. 314, *Analysis, Design and Synthesis Methods for Guidance and Control Systems*, p. II1-1-18,1990.
3. Axelrad, P., *A Closed-Loop GPS-Based Orbit Trim System for Gravity Probe B*, Ph. D. Dissertation, Stanford University, 1990.
4. Axelrad, P., Invited essay for "Directions'96" Issue of *GPS World* Magazine, p. 50, December, 1995.
5. Online : "Ten Lessons on Navigation" Authored by Jeffery White, Matt Lippis, Mindy Schaefer Zarske, Penina Axelrad, Janet Yowell. http://www.ion.org/satdiv/education.cfm
6. Axelrad, P. and K.M. Larson, "GNSS Solutions: Is it true that the GPS satellite geometry repeats every day shifted by 4 minutes?" *InsideGNSS* Magazine, p. 16-17, July/August 2006.
7. Axelrad, P., J. Donna, M. Mitchell, S. Mohiuddin, "Collective Detection - Enhancing GNSS Receiver Sensitivity by Combining Signals from Multiple Satellites," *GPS World* Magazine, p. 58-64, January 2010.
8. Axelrad, P. AIAA Member Spotlight Interview, November 2015.
9. Axelrad, P. and J. Gaebler, "Specialized FISST-based Estimation Methods to Enhance Space Situational Awareness in MEO and GEO Orbits," Technical Report AFRL-RV-PS-TR-2016-0114, August 2016.
10. Strandjord, K.L., P. Axelrad, D. Akos, S. Mohiuddin, "Going Direct: Improved Accuracy from Reflected Signals and Path Predictions," *Inside GNSS* Magazine, https://insidegnss.com/strandjord/, April 6, 2020.
11. Flood, C. and P. Axelrad, "Small Satellite Position, Navigation, and Timing Innovations Vol1 – CONTACT Clock Project Testbed," AFRL-RV-PS-TR-2022-0088, https://apps.dtic.mil/sti/trecms/pdf/AD1201196.pdf, 2022.
12. Dobbin, M. and P. Axelrad, "Small Satellite Position, Navigation, and Timing Innovations Vol2 - CONTACT CSAC Experiment for MAXWELL CubeSat," AFRL-RV-PS-TR-2022-0088, https://apps.dtic.mil/sti/trecms/pdf/AD1201197.pdf, 2022.
13. Flood, C. and P. Axelrad, Small Satellite Position, Navigation, and Timing Innovations Vol3 - Two Way Ranging for Time and Frequency Transfer in LEO Constellations, AFRL-RV-PS-TR-2022-0088, https://apps.dtic.mil/sti/trecms/pdf/AD1207132.pdf, 2022.

Invited Talks, Seminars and Colloquia (since 2000)

1. Invited speaker at the Institute for Mathematics and Its Applications, University of Minnesota, IMA "HOT TOPICS" workshop on Mathematical Challenges in Global Positioning System, "Retrieval of Ocean and Land Surface Characteristics Using Measurements of Reflected GPS Signals," August 18, 2000.
2. Invited lecture at Stanford University, "Remote Sensing of Ocean Surfaces Using Bistatic GPS," February 14, 2001.
3. University of Colorado, Faculty Teaching Excellence Program, "Establishing a Teaching Portfolio," March 2001.
4. University of Colorado, College of Engineering and Applied Science Orientation, Faculty Keynote Address, August 23, 2006.
5. Invited speaker for ZONTA Foothills Club, Amelia Earhart Dinner, "On encouraging young women to study science, math, and engineering," Broomfield, CO, January 28, 2007.
6. Invited tutorial seminar "Introduction to Global Navigation Satellite Systems," at 32st Annual Time and Frequency Metrology Seminar, NIST, Boulder, CO, June 14, 2007.
7. "GNSS Applications for Science and the Environment," 2nd International Summer School on GNSS, Berchtesgaden, Germany, July 30, 2008.
8. Invited speaker for Stanford University Department of Aeronautics and Astronautics 50th Anniversary Symposium, "Challenges and Opportunities in Aerospace Education," Palo Alto, CA, May 10, 2008.
9. Invited speaker for National Academy of Engineering / Chinese Academy of Sciences GNSS Workshop, "Application of GNSS to Environmental Studies," Shanghai, China, May 2011.
10. Invited speaker for 2nd Smead Fellow Workshop, "GPS Collective Detection – a new approach for making a little signal go a long way," Vail, CO, May 10, 2012.
11. Invited speaker Georgia Institute of Technology, "How GPS Changes Everything," January 31, 2013.
12. Invited speaker at NASA JPL, "University of Colorado Boulder (CU) Overview of Research & Educational Programs in Aerospace Engineering and Sciences," December 17, 2013.
13. Keynote Speaker, GNSS Futures in the Asia-Pacific Region Workshop at UNSW Australia, July 8, 2014.
14. Invited speaker University of Kansas, "How GPS Changes Everything," February 9, 2015.
15. Invited speaker University of Michigan, "How GPS Changes Everything," February 26, 2015.
16. Invited speaker Texas A&M, "How GPS Changes Everything," April 9, 2015.
17. Invited speaker International Technical Symposium on Navigation and Timing (ITSNT), "Space Applications of GNSS," ENAC, Toulouse, November 15, 2016.
18. Invited speaker University of Illinois Urbana-Champaign, "GPS Reflections," November 28, 2016.
19. Invited panel member, EDU-01: Panel Session. Educating the Engineer of the 2030. Wednesday, AIAA SciTech, January 11, 2017.
20. Invited luncheon speaker for ZONTA Foothills Club, "How GPS Changes Everything," Boulder, CO, January 28, 2017.
21. Invited plenary lecture 59th Israel Annual Conference on Aerospace Sciences (IACAS), "Scientific Applications of Global Navigation Satellite Systems," Tel Aviv, Israel, March 6, 2019.
22. Invited speaker University of Texas Austin, "GNSS Reflections – Modeling multipath for space applications and utilizing reflections for remote sensing," Austin, TX, January 30, 2020.
23. Invited speaker Stanford Center for Position, Navigation, and Time (SCPNT) 15th Annual PNT Symposium, "Tracking Clustered CubeSat Deployments," Virtual, October 27, 2021.
24. Invited tutorial, "CSAC for Positioning, Navigation, and Timing in Space," Precise Time and Time Interval Systems and Applications Meeting PTTI 2022, Long Beach, CA, January 26, 2022.

25. Invited speaker, "The Evolution and Impact of Global Navigation Satellite Systems," Purdue Engineering Distinguished Lecture Series, West Lafayette, IN, March 23, 2022.
26. Invited speaker, "Global Navigation Satellite System origins, unexpected applications, and new directions," CU Boulder Physics Department Colloquium, Boulder, CO, November 30, 2022.
27. Invited speaker, "How GPS Changed Everything," CU on the Weekend, Boulder, CO, April 15, 2023.
28. Invited tutorial, "GNSS theory, observation equation, and error sources," UCAR COSMIC's GNSS Remote Sensing Colloquium, Boulder, CO, June 5, 2023.
29. Invited tutorial, "Introduction to Global Navigation Satellite Systems," Annual Time and Frequency Metrology Seminar, NIST, Boulder, CO, July 10, 2023.
30. Invited tutorial, "Space Applications of GNSS," Institute of Navigation, GNSS+ Conference, Denver, CO, September 11, 2023.

Conference & Workshop Presentations and Posters *(without papers)*

1. Burkert, J., P. Axelrad, L. Cornman, K Goodrich, Scott Palo, Andrew Weekley ,"Turbulence Estimation Techniques for COSMIC Occultation Data," Fourth FORMOSAT-3/COSMIC Data Users Workshop, Boulder, CO, 28 October, 2009.
2. Mashburn, J., P. Axelrad, S. T. Lowe, K. M. Larson, V. Zlotnicki, "An Assessment of the Accuracy of Altimetry Retrievals for the Monterey Bay GNSS+R Experiment", *GNSS+R 2015 Workshop*, Potsdam, Germany.
3. Mashburn, J., P. Axelrad, K. Larson, S. Lowe, "TechDemoSat-1 Land Altimetry and Sea Ice Boundary Detection," USNC-URSI National Radio Science Meeting, Boulder, CO, January 4, 2017.
4. Mashburn, J., P. Axelrad, S. Lowe, and K.M. Larson, "TDS-1 Global Ocean Altimetry and Sea Ice Boundary Zone Detection," *GNSS+R 2017 Workshop*, Ann Arbor, MI, May 25, 2017.
5. Strandjord, K. and P. Axelrad, "Improved Prediction of GPS Satellite Clock Variations Based on Daily Repeat," *ION Joint Navigation Conference*, Dayton, OH, June 6, 2017.
6. Mashburn, J., P. Axelrad, S. T. Lowe, C. Zuffada, D. Masters, "Ocean Surface Altimetry with CYGNSS: A Case Study in Indonesia", *Ocean Surface Topography Science Team Meeting*, poster, Miami, FL, October 23-27, 2017.
7. Mashburn, J., P. Axelrad, S. Lowe, C. Zuffada, D. Masters, "Ocean Surface Altimetry with CyGNSS: An Updated Case Study in Indonesia," American Meteorological Society Annual Meeting, Austin, TX, January 10, 2018.
8. Axelrad, P. and J. Gaebler, "CubeSat Deployment Tracking," FAA COE/CST RA1 Workshop on Space Traffic Management and Space Environment," McLean, VA, February 6, 2018.
9. Mashburn, J., P. Axelrad, K. Larson, C. Zuffada, S. Lowe, "Ocean Surface Altimetry with GNSS-R utilizing data from CyGNSS," 4th International Conference on GPS Radio Occultation, Taipei, Taiwan, April 16, 2018.
10. Mashburn, J., P. Axelrad, C. Zuffada, S. Lowe, G. Hajj, B. Haines, R. Shah, A. O'Brien, E. Loria, "Ocean Surface Altimetry with GNSS-R utilizing data from CyGNSS," CYGNSS Science Team Meeting, Ann Arbor, MI, June 2018.
11. Mutschler, S., P. Axelrad, T. Matsuo, J. Anderson, "An Ensemble Kalman Filtering Approach for Atmospheric Density Estimation Using Orbital Debris," 42nd COSPAR Scientific Assembly, Pasadena, CA, July 2018.
12. E. Loria, J. Mashburn, A. O'Brien, P. Axelrad, and C. Zuffada, "Assessment of a CYGNSS Ocean Altimetry Product Using a Full DDM Approach," 2019 IEEE Specialist Meeting on Reflectometry using GNSS and other Signals of Opportunity, Benevento, Italy, 20-22 May 2019.
13. Mutschler, S., P. Axelrad, T. Matsuo, E. Sutton, "Physics-based Approach to Density Estimation and Prediction using Orbital Debris Tracking Data," (Poster), CEDAR Workshop, Santa Fe, NM, June 2019.
14. Conrad, A., P. Axelrad, C. Zuffada, B. Haines, L. Sparks, A. O'Brien, E. Loria, "CYGNSS Altimetry with Improved Orbits, Re-tracking, and Delay Offsets," CYGNSS Science Team Meeting, Pasadena, CA, January 21, 2020.

15. Klein, V., P. Axelrad, "Simulation and Analysis of GPS Multipath for the GEDI Experiment Onboard the International Space Station," *33rd International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS+ 2020) Best presentation in session*.
16. Axelrad, P., D. Akos, J. Morton, S. Palo, R. Kingsbury, L. Scott, "On Demand PNT (OD-PNT)," *Joint Navigation Conference (JNC) 2021*, Covington, Kentucky, 24-27 August 2021.
17. Littleton-Strand, L., D.M. Akos, P. Axelrad, "Exploring the Potential Role of the Chip Scale Atomic Clock (CSAC) for Low Earth Orbit (LEO) Alternate Position Navigation Timing (AltPNT) Systems," *Joint Navigation Conference (JNC) 2021*, Covington, Kentucky, 24-27 August 2021.
18. Axelrad, P., "Applications of quantum sensing for positioning, navigation, and timing (PNT), *Q-SEnSE Convergence Seminar,* Virtual, 30 November, 2021.
19. Axelrad, P., D. Akos, J. Morton, S. Palo, R. Kingsbury, B. Breitsch, H. Bourne, S. Taylor, M. Dobbin, L. Scott, "On Demand PNT (OD-PNT)," *Joint Navigation Conference (JNC) 2022*, San Diego, CA, June 2022.
20. Breitsch, B., S. Taylor, H. Bourne, D. Akos, P. Axelrad, J. Morton, L. Scott, "Receiver processing for LEO-orbiting on-demand navigation satellite signals," *Joint Navigation Conference (JNC) 2022*, San Diego, CA, June 2022.
21. Axelrad, P., D. Akos, J. Morton, S. Palo, R. Kingsbury, B. Breitsch, H. Bourne, S. Taylor, M. Dobbin, L. Scott, "On Demand PNT (OD-PNT) Test Results," *Joint Navigation Conference (JNC) 2023*, San Diego, CA, June 2023.

Courses Taught (*most recent year shown*)

Statistical Estimation of Dynamical Systems ASEN 5044 (University of Colorado, 2023)

Graduate level course on estimation fundamentals including batch least squares and Kalman Filtering

Introduction to Dynamics and Systems ASEN2003 (University of Colorado, 2023)

Sophomore core course on 2-D dynamics, vibrations, and systems. Includes experimental and design laboratories, group problem solving, traditional lecture, and interactive learning classes (5 credits).

Orbital Mechanics and Attitude Dynamics ASEN3200 (University of Colorado, 2022)

Junior core course on two body orbits, attitude dynamics and control. Includes experimental and design laboratories, group problem solving, traditional lecture, and interactive learning classes (4 credits).

Introduction to Global Navigation Satellite Systems ASEN 5090 (University of Colorado, 2022)

Graduate level course introducing key technologies of GPS to Aerospace, Electrical, Civil Engineering and Physics students.

Spacecraft Attitude Dynamics and Control ASEN 5010 (University of Colorado, 2012)

Graduate level course covering attitude representations and estimation, kinematics, dynamics, and control of 3D rigid body motion.

Aerospace Senior Projects ASEN4018/4028 (University of Colorado, 2019)

Senior capstone design course member of Project Advisory Board or Project Sponsor

AY18-19 VANTAGE Team Sponsor - 2nd prize in Frank J. Redd Student Paper Competition

AY19-20 VISION Team Sponsor

Aerospace Graduate Projects ASEN5018/6028 (University of Colorado, AY2021-2022)

Spring 2019-present – Satellite Timing System Testbed, Funded by AFRL Space Vehicles Directorate

Aerospace Electronics and Communications ASEN3300 (University of Colorado, 2003)

Junior core course introducing basics of analog and digital electronics, computer interfacing, and communications, focusing on hands-on learning and use of laboratory instruments. Includes experimental laboratories, traditional lecture, and interactive learning classes (4 credits).

First Year Engineering Projects GEEN1400 (University of Colorado, 1996)

General Engineering freshman level course providing hands-on experiences in analysis, design, and technical writing.

Radio and Inertial Navigation (University of Colorado, Stanford University, 1995)

Graduate level course on technologies and algorithms for navigation and positioning.

Ph.D. Graduates, University of Colorado Boulder

1. Bruce C. Chesley, 1995 – Boeing Network and Space Systems, El Segundo, CA
   Dissertation – *An Integrated GPS Attitude Determination System for Small Satellites*
2. Lisa M. Ward, 1996 – Ball Aerospace, Boulder, CO
   Dissertation – *Spacecraft Attitude Estimation Using GPS: Methodology and Results*
3. Christopher J. Comp, 1996 – Maxar Technologies, Westminster, CO
   Dissertation – GPS Carrier Phase Multipath Characterization and a Mitigation Technique Using the Signal-to-Noise Ratio
4. James L. Garrison, 1997 –Professor of Aeronautics and Astronautics, Purdue University, West Lafayette, IN
   Dissertation – *Recursive Nonlinear Estimation for Relative Navigation in Elliptical Orbits*
5. Charles P. Behre, 1997 – ITT, Los Angeles, CA
   Dissertation – *GPS Based Attitude Algorithms for Low Cost Satellite Missions*
6. Angela (Reichert) Dorsey, 1999 – NASA Jet Propulsion Laboratory, Pasadena, CA
   Dissertation – *Correction Algorithms for GPS Carrier Phase Multipath Utilizing the Signal-to-Noise Ratio and Spatial Correlation*
7. Franklin Ascarunz, 1999 – Founder SpectraDynamics Inc, Louisville, CO
   Dissertation – *Timing Errors in Two-Way Satellite Time and Frequency Transfer Using Spread Spectrum Modulation*
8. Dolan Highsmith, 2000 – Aerospace Corporation, Chantilly, VA
   Dissertation – *Precise Satellite-to-Satellite GPS Time Transfer in Near Real-Time*
9. Michael Armatys, 2001 – Rockwell Collins, Cedar Rapids, IA
   Dissertation – *Estimation of Sea Surface Winds Using Reflected GPS Signals*
   NASA GSRP, 1998-2000
10. Michael Moreau, 2001 – NASA Goddard Space Flight Center, Greenbelt, MD
    Dissertation – *GPS Receiver Architecture for Autonomous Navigation in High Earth Orbits*
    NASA Graduate Student Research Program Fellowship, 1997-2000
11. Premal Madhani, 2002 – Master Engineer with Broadcom, San Jose, CA
    Dissertation – *GPS Receiver Algorithms for Suppression of Narrowband and Structured Wideband Interference*
12. Dallas Masters, 2004 – Vice President, Signals of Opportunity Program, Muon Space, Boulder, CO
    Dissertation – *Surface Remote Sensing Applications of GNSS Bistatic Radar : Soil Moisture and Aircraft Altimetry*
    John A. Vise Student Excellence Award 2003, NASA GSRP 2000-2004
13. Maria Belmonte Rivas, 2007 – Research Scientist, TU Delft, Netherlands
    Dissertation – *Bistatic Scattering of Global Positioning System Signals from Arctic Sea Ice*
    Zonta Foundation Amelia Earhart Fellowship 2004/2005, NASA Earth Systems Graduate Researcher 2004 - 2007
14. Jan-Peter Weiss, 2007 – UCAR Cosmic Program, Boulder, CO
    Dissertation – *Modeling and Analysis of Multipath in Global Navigation Satellite System Ranging Signals*
    John A. Vise Student Excellence Award 2007, NSF East Asia and Pacific Summer Institute Fellowship, 2006
15. Christopher Lane, 2007 – Enterprise Architect, Chick-fil-A, Atlanta, GA
    Dissertation – *Formation Design and Relative Navigation in High Earth Orbits*
    AIAA Graduate Student Researcher Award 2006
16. Jill (Tombasco) Seubert, 2011 – Deep Space Navigator and Founder, Australis Space Navigation
    Dissertation – *Orbit Estimation of Geosynchronous Objects Via Ground-Based and Space-Based Optical Tracking*
    Zonta International Foundation Amelia Earhart Fellowship 2010, National Defense Science and Engineering Graduate Fellowship 2007-2010, John A. Vise Student Excellence Award 2011, AIAA Orville and Wilbur Wright Graduate Award 2011, College of Engineering and Applied Science Distinguished Recent Alumni Award 2017
17. Ben K. Bradley, 2015 – NASA Jet Propulsion Laboratory, Pasadena, CA
    Dissertation - *Numerical Algorithms for Precise and Efficient Orbit Propagation and Positioning*
    National Defense Science and Engineering Graduate Fellowship 2010-2012, eSpace Entrepreneurship Award 2012, CU-Boulder Summer Dissertation Fellowship 2014

18. Steven Gehly, 2016 – Assistant Professor, Astrodynamics and Space Missions, TU Delft
    Dissertation - *Estimation of Geosynchronous Space Objects Using Finite Set Statistics Filtering Methods*
19. Jake R. Mashburn, 2019 – Radar and Remote Sensing Product Engineer, Spire, Boulder, CO
    Dissertation – *Analysis of GNSS-R Observations for Altimetry and Characterization of Earth Surfaces*
    Co-Advised with Kristine Larson
    UCAR Student Travel Grant 2018
20. John Gaebler, 2020 – Principal Aerospace Engineer, KBR, Maui, HI
    Dissertation – *CubeSat Cluster Deployment Tracking*
    AFRL Space Scholar Summers 2016, 2017, 2019, CU Boulder Graduate Student Travel Grant 2017, GAANN Fellowship Fall 2019.
21. Viliam Klein, 2020 – Southwest Research Institute
    Dissertation - *Advanced GPS Multipath Modeling for Receivers On-Board the International Space Station*
    ION GNSS+ 2020 Best Presentation in Session Award
22. Kirsten Strandjord, 2020 – Assistant Professor, Dept of Aerospace Engineering and Mechanics, University of Minnesota
    Dissertation – *Urban Navigation with Global Satellite Navigation Systems*
    Draper Fellow 2018-2020, John A. Vise Graduate Student Excellence Award 2019, Lockheed Martin Corporation Endowed Graduate Fellowship 2019
23. Damon VanBuren, 2020 (co-advised with Prof Scott Palo) - MITRE
    Dissertation – *Techniques for Precise Timing Onboard Small Satellites*
24. Shaylah Mutschler, 2022 – Research Scientist, Space Environment Technologies
    Dissertation - *Global Thermospheric Density Estimation using CubeSat GPS Data and a Physics-based Space Environment Model*
    H.J. Smead Scholar 2015-2022, AFRL Space Scholar Summer 2016, 2017, NSF Graduate Research Fellowship Program 2017 (Selected but decl), National Defense Science and Engineering Graduate Fellowship 2017-2020, Zonta International Foundation Amelia Earhart Fellowship 2020, John A. Vise Graduate Student Excellence Award 2021
25. Margaret Rybak, 2022 – Navigation Engineer, NASA Jet Propulsion Laboratory, Pasadena, CA
    Dissertation - *Atomic Clock and Inertial Sensor Applications for Space Navigation*
    NASA Education Aeronautics Scholarship and Advanced STEM Training and Research (AS&ASTAR) Harriet Jenkins Fellowship, 2016-present, Aerospace Engineering Sciences Outstanding Teaching Assistant AY2016-2017
26. Alex Conrad, 2023 – Space Technologist II, NASA Jet Propulsion Laboratory, Pasadena, CA
    Dissertation - *Advances in Measurement and Force Modeling for Improved GNSS-based Precise Orbit Determination of CYGNSS and Sentinel-6 MF*
    Graduate Assistantship in Areas of National Need (GAANN) Critical aerospace technologies, AY2020-2021

M.S. Graduates (with thesis), **University of Colorado Boulder**

1. Anne Theurkauf, 2020 (co-advised by Dana Anderson, Physics) – PhD student CU Boulder
   Thesis - *Control of an Optical Lattice for Atom-Based Inertial Sensing*
   Draper Fellow 2018-2020
2. Henry Dixon, 2021 (Mechanical Engineering) – Research Engineer, Integrated Solutions for Systems (IS4S)
   Thesis - *Techniques for Generating a Steered Timing Signal in a Low- Size, Weight, and Power Clock Ensemble*

M.S. Graduates (Research but no thesis), **University of Colorado Boulder**

1. Jiyun Lee, 1999 - Associate Professor, Korea Advanced Institute of Science and Technology
2. Eden (Denton) Speed, 2001 – Lockheed Martin, Boulder, CO
3. Lisa (Reeh) Turner, 2002 – Lockheed Martin, Denver, CO
4. Cove Sturtevant, 2004 – NSF Neon, Boulder, CO
5. Lin Song Stowe, 2006 – MIT Lincoln Laboratory, MA
6. Steven Brown, 2008 – Infinity Systems Engineering, Colorado Springs, CO
7. Julian Greene, 2009 – Blue Origin, Seattle, WA
8. James Burkert, 2010 – Lockheed Martin, Denver, CO
   NASA GSRP 2008-2010
9. Bruno Lesage, 2012 – Lockheed Martin, Valley Forge, PA

10. Jeanette Veldman, 2016 – Ball Aerospace, Boulder, CO
11. Jeff Jenkins 2019 – Rincon Research Inc, Tucson, AZ
12. Luciana Schement 2020-2021 – Lockheed Martin Space Systems, Denver, CO
13. Raj Patel 2021-2023 – Orion Space Solutions, Louisville, CO

Other Graduate Research Students, University of Colorado Boulder

1. Jonah Kisesi, 2010-2012 – GNSS occultations for sensing ionospheric turbulence
   NSF GK-12 Fellowship AY2011-12
2. Stephen Phillips, 2012-2013 – Modeling of autonomous rendezvous and docking
3. John Pratt, PhD 2010-2012 – Clock estimation for iGPS
4. Heather LoCrasto, 2013-2014 - Autonomous rendezvous and docking for commercial space transportation
5. Elliot Barlow, 2009-2016 – GPS radio occultation satellites
   Department of Education, Graduate Assistantship in Areas of National Need (GAANN) Fellowship 2010-2011, ION Best Presentation Award 2014.
6. Eric Barron, 2016-2017 – Satellite clock modeling

Undergraduate Research Students, University of Colorado Boulder

1. Samantha Krenning, 2009 – Undergraduate research assistant, Weak Signal Acquisition
2. Jordan Gomez, 2010 – Undergraduate research assistant, Weak Signal Acquisition
3. Jacob Varey, 2010-2011 - Discovery Learning Apprentice and Undergraduate Research Opportunity
4. Nicholas DiOrio, 2011-2012 – Undergraduate research assistant and Discovery Learning Apprentice
5. Zachary Cuseo 2012-2013 – BS/MS Student, Discovery Learning Apprentice and undergraduate research assistant
6. Alex Mault, Spring 2013 - Undergraduate research assistant, GPS acquisition software
7. Isaac Hayden, summer 2013 - Undergraduate research assistant, Picosat positioning
8. David Thomas, summer 2013 - Undergraduate research assistant, Multipath modeling
9. Thomas Green, 2013-2014 - Undergraduate research assistant, GPS bistatic radar data analysis
10. Caleb Lipscomb, 2013-2014 – Undergraduate Discovery Learning Assistant, Image processing for autonomous rendezvous and docking
11. Davis Peterson, 2015-2016 - Undergraduate Discovery Learning Assistant, Long term GPS orbit evolution
12. Michael Greene, Spring 2017 – Undergraduate research assistant, ArcGIS
13. Diana Mata, Summer 2018 – CU Summer Program for Undergraduate Research (SPUR), Simulating Space Object Measurements for Space Situational Awareness
14. Adam Boylston, Summer-Fall 2018 – Undergraduate research assistant, CubeSat image processing for relative position estimation after deployment, *2019 AAS Breckenridge Conference Student Session 2nd Place Award*
15. Connor Ott, 2018-2019 - Undergraduate Discovery Learning Assistant, Visualization tools for space environment situational awareness
16. Stephen Albert, 2020-2021 – Undergraduate Discovery Learning Apprentice, Modeling the effect of space weather on LEO satellite motion using TIE-GCM
17. Caroline Dixon 2020-2021 – Undergraduate research assistant, Maxwell CSAC experiment
18. Brandon DiLorenzo 2021-2022- CU Summer Program for Undergraduate Research (SPUR) and undergraduate research assistant, Modeling atmospheric density using TIE-GCM
19. Christopher Krebs 2021-2022 - Undergraduate Discovery Learning Apprentice, Characterization of Chip Scale Atomic Clock (CSAC) Performance
20. Justin Pedersen 2022-23 – CU Summer Program for Undergraduate Research (SPUR) and undergraduate research assistant, Clock ensemble development and characterization
21. Aidan Baigley 2023 - CU Summer Program for Undergraduate Research (SPUR) optimization of B-Spline orbit representations

Visiting Students, University of Colorado Boulder

1. Estel Cardellach Gali – Visiting PhD student from Institut d'Estudis Espacials de Catalunya (IEEC-CSIC), 2003
2. Lennox Thompson – RESESS Program (UNAVCO), Undergraduate at Coppin State University, Baltimore, MD, 2006
3. Michael Williams – SMART Program, Undergraduate at UC Irvine, 2004
4. Johan Bejeryd – Visiting MS student from the Institute of Technology of Linkoping University, Sweden, 2008
5. Joseph Meilen – Visiting High School intern, 4 weeks, Summer 2009
6. Antonella Albuja – SMART Program, Undergraduate at University of Iowa, 2010
7. Fabien Gachet – Visiting MS student from Institut Supérieur de l'Aéronautique et de l'Espace, France, 2011

8. Rene van Aken – MS thesis student from the University of the Federal Armed Forces Munich, 2013
9. Nicholas Sweet – Visiting undergraduate student from Concordia University, Canada, 2013
10. Javier Garcia – Fulbright Fellowship PhD student from National University of La Plata, Argentina, 2014-2015
11. Santiago Ozafrain – Fulbright Fellowship PhD student from National University of La Plata, Argentina, Fall 2018

Current Students

1. Christopher Flood – PhD Student, August 2019, Preliminary Exam 8/2020, Comprehensive Exam 2/21/23
   CU College of Engineering and Applied Science Dean's Assistantship AY19-20
   NIST PREP Appointment 2023
2. Laura Davies – PhD Student, August 2020, Preliminary Exam 8/2022
   Draper Scholar AY23-24
3. Mikaela Dobbin – PhD Student, June 2021, Preliminary Exam 8/2022
4. Sergio Coll Ibars – PhD Student, August 2022 (Co-advised with Prof. Scheeres), MS Thesis Defense 12/2023
5. Conner Parker – CU Summer Program for Undergraduate Research (SPUR) student and research assistant, 5/2023
6. William Gravel – MS Student, 5/2023
7. Emily Matteson – MS Student, 8/2023
8. Austin Hunter – Undergraduate Discovery Learning Apprentice 8/2023

PhD and MS Thesis Committee Memberships (not tracked prior to 2010)

1. Eric Vinande - Ph.D. AES, 2010, Prof. Akos, *CU Boulder*
2. James McDonald - Ph.D. ECE, 2010, Prof. Filipovic, *CU Boulder*
3. Ravi Inampudi – Ph.D. AES, 2010, Prof. Schaub, *CU Boulder*
4. Marcus Holzinger - Ph.D. AES, 2011, Prof. Scheeres, *CU Boulder*
5. Nicholas Pedatella - Ph.D. AES, 2011, Prof. Larson, *CU Boulder*
6. Robin Blendan – M.S. AES, 2011, Prof. Schaub, *CU Boulder*
7. Samantha Krenning – M.S. AES, 2011, Prof. Schaub, *CU Boulder*
8. Carl Seubert - Ph.D. AES, 2011, Prof. Schaub, *CU Boulder*
9. Erez Falkenstein – Ph.D. ECE, 2011, Prof. Popovic, *CU Boulder*
10. Kohei Fujimoto – Ph.D. AES 2013, Prof. Scheeres, *CU Boulder*
11. Stephanie Jones – M.S. AES, 2013, Prof. Schaub, *CU Boulder*
12. Jian Yao – Ph.D. Physics, 2014, Prof. Levine, *CU Boulder*
13. Rui Sun – Ph.D. Aerospace Engineering, 2014, Prof. Dr. E. Gill, *Technical University of Delft*
14. Erin Griggs – Ph.D. AES, 2015, Prof. Akos, *CU Boulder*
15. Steven O'Keefe – Ph.D. AES, 2015 Prof. Schaub, *CU Boulder*
16. John Pratt – Ph.D. AES, 2015, Prof. Larson, *CU Boulder*
17. Chen Cao – Ph.D. AES, 2016, Prof. Chu, *CU Boulder*
18. Ryan Handzo – Ph.D. Student AES, Prof. Parker, Comprehensive Exam 11/1/13, *CU Boulder*
19. Daniel (Stu) Bryant – Ph.D. AES, 2017 Prof. Jones, *CU Boulder*
20. Jeroen Geeraert – Ph.D. AES, 2017, Prof. McMahon, *CU Boulder*
21. Erin Kahr – Ph.D. Geomatics Engineering, 2017, Prof. K. O'Keefe, *University of Calgary*
22. Sara Hrbek – Ph.D. AES 2019, Prof. Akos, *CU Boulder*
23. Manuel Eichelberger – Ph.D. External Examiner, 2019, Prof. Dr. R. Wattenhofer, *ETH Zurich*
24. William McGrew – Ph.D. Physics 2020, Dr. S. Diddams, *CU Boulder*
25. Joanna Fulton – Ph.D. AES 2020, Prof. Schaub, *CU Boulder*
26. Andrew French – Ph.D. AES 2020, Prof. McMahon, *CU Boulder*
27. Damian Miralles – Ph.D. AES 2021, Prof. Akos, *CU Boulder*
28. Brian Breitsch – Ph.D. AES 2021, Prof. Morton, *CU Boulder*
29. Marielle Pellegrino – Ph.D. AES 2021, Prof. Scheeres, *CU Boulder*
30. Yang Wang – Ph.D. AES 2021, Prof. Morton, *CU Boulder*
31. Yunxiang (Leo) Liu – Ph.D. AES 2021, Prof. Morton, *CU Boulder*
32. Ian Collett – Ph.D. AES 2021, Prof. Morton, *CU Boulder*
33. Youssef Hassan – Ph.D. Candidate Physics, Dr. A. Ludlow, Comprehensive Exam 5/27/21, *CU Boulder*
34. Dawson Beatty – M.S. AES, 2021, Prof. Ahmed, *CU Boulder*

35. Sergei Bilardi – M.S. AES, 2021, Prof. Morton, *CU Boulder*
36. Brodie Wallace – Ph.D. Candidate AES, Prof. Palo, Comprehensive Exam 12/12/22, *CU Boulder*
37. Catherine LeDesma – Ph.D. Candidate Physics, Prof. Anderson, Comprehensive III Exam 4/25/22, *CU Boulder*
38. Anne Theurkauf – Ph.D. Candidate AES, Profs. Lahijanian and Ahmed, Comprehensive Exam 11/10/23, *CU Boulder*
39. Robert Sasse – Ph.D. Student AES, Prof. Argrow, Comprehensive Exam 10/23, *CU Boulder*
40. Maya Greenstein – M.S. Candidate, 2023, Prof. Thayer, Thesis Defense 11/15/23, *CU Boulder*

Research Funding – Award Total: $17.2M, Award Total as PI: $12.9M

Dates	Title	Sponsor/Agency	PI, Co PI, Co I	Amount
9/1992-9/1993	Analysis of GPS for Marine Kinematic Survey	Stanford Telecommunications, Inc.	PI	$33,103
10/1992-9/1993	GPS Attitude Determination	Naval Research Laboratory	PI – Born Co I	$67,000
9/1993-8/1995	GPS Attitude Determination	Naval Research Laboratory	PI Co I-MacDoran	$115,000
4/1994-11/1994	A Study of GPS Measurement Errors Due to Noise and Multipath Interference	NASA/ Goddard Space Flight Center	PI Co I-MacDoran	$25,000
6/1994-5/1995	GPS Positioning of the Fast Pegasus Oceanographic Buoy for Measurement of Subsurface Ocean Currents	University of Miami	PI - MacDoran Co I	$48, 926
9/1994-3/1995	GPS Attitude Determination Performance	CTA Space Systems	PI	$11,741
9/1994-9/1997	GPS Attitude Determination for Spinning Satellites	Office of Naval Research, AASERT Supplement	PI	$141,750
10/1994-3/1995	Fiber-Optic GPS Orbit Network (FOGON)	Loral Federal Systems	PI - MacDoran Co I	$18,000
7/1995-5/1996	GPS for Rendezvous Navigation Inside and Outside the Constellation	NASA Langley Research Center	PI	$15,000
8/1995-30/1997	Algorithm Development and Testing of the Micro-GPS for SNOE	Jet Propulsion Laboratory	PI	$69,444
9/1995-8/1997	GPS Attitude Determination	Naval Research Laboratory	PI	$140,000
11/1995-8/1997	GPS Attitude and Antenna Baseline Estimation for Space Station Alpha	NASA Johnson Space Center	PI	$104,077
6/1996-1/1997	An Orbit Determination System for the EarlyBird-1 Mission	Earthwatch, Inc.	Co PI Co PI – Davis	$85,445
7/1996-6/1997	Algorithms for Calibration of Multipath Errors Using Micromechanical Gyros	Draper Laboratory	PI	$59,556
7/1997-6/1998	Algorithms for Real-Time Estimation of GPS and Gyro Errors in Spacecraft Attitude Determination	Draper Laboratory	PI	$58,000
5/1997 – 4/1999	Reflected GPS Signals: Theory and Experiments	NASA Langley Research Center	PI –Born Co PI	$220,000
9/1997-8/1999	Spaceborne Differential GPS Applications	Naval Research Laboratory	PI	$110,000
9/1997-8/1998	Attitude Control for Exact-Repeats of Laser-Altimeter Ground Tracks	NASA Goddard Space Flight Center	PI - Born Co PI	$50,000
7/1998-6/1999	Onboard Algorithm for Identification and Compensation of Multipath Sources	Draper Laboratory	PI	$40,000
8/1998-1/1999	IceSat Multipath Study	Ball Aerospace	PI, Co PIs - Gold,Komjathy	$40,000
1/1999-12/2001	GPS Signal Modeling and Performance Analysis for Enhanced Signal Tracking	Data Fusion Corporation	PI	$88,424
9/1999-8/2001	Algorithms for Autonomous GPS Orbit Determination & Formation Flying	NASA Goddard Space Flight Center	PI	$146,780

Dates	Title	Sponsor/Agency	PI, Co PI, Co I	Amount
9/1999-8/2001	Spaceborne GPS-Based Relative Navigation and Time Transfer	Naval Research Laboratory	PI	$90,000
7/2000-2/2001	Ocean wind and land surface satellite (OWLS3)	NASA Headquarters	PI –W. Emery Co PI w/others	$400,000
9/2000-8/2001	Comparison of QuikSCAT and GPS-Derived Ocean Surface Winds	NASA Headquarters	PI Co PIs – Born, Komjathy,	$74,683
1/2001-12/2002	Measurement-Based Multipath Corrections for GPS Sites	National Science Foundation	PI – K. Larson Co PI	$171,908
6/2001-6/2002	Emerging Military Navigation Technology	Draper Laboratory	PI	$25,000
8/2001-6/2002	Algorithms for Autonomous GPS Orbit Determination Supplement	NASA Goddard Space Flight Center	PI	$25,000
9/2001-12/2001	Modeling and Analysis of the NPP Antenna Environment	Ball Aerospace	PI	$8,000
1/2002-12/2004	Terrain Awareness for Small Aircraft Using GPS Bistatic Radar, Digital Elevation Maps, and GIS	NASA Langley Research Center	PI	$260,117
6/2002-6/2003	Spaceborne GPS Accuracy Survey	Ball Aerospace	PI – G. Born Co PI	$20,000
9/2002-8/2003	Analysis of Navigation Algorithm and Measurements for Formation Flying Satellites, in High Earth Orbit	NASA Goddard Space Flight Center	PI	$21,386
9/2002-7/2004	Advanced Multipath Modeling for AF JPALS	ARINC	PI	$419,865
3/2003-9/2003	GPS Bistatic Radar for Target Detection	Raytheon	PI	$32,923
6/2003-5/2007	Assessment of Intersatellite Measurements for Precision Relative Navigation of HEO Satellite Formations	NASA Goddard Space Flight Center	PI	$179,906
7/2003-3/2004	GPS Bistatic Radar	FIRST RF	PI	$36,000
1/2004-1/2006	Multipath Modeling and Analysis for Shipboard Relative GPS	ARINC	PI	$483,720
6/2004-5/2005	GPS Bistatic Phenomenology Study	FIRST RF	PI	$39,348
6/2004-7/2005	GPS Bistatic Radar Receiver Development	Raytheon	PI	$158,700
6/2004-9/2007	A GPS Bistatic Radar for Terrain Awareness	NASA Langley Research Center	PI	$375,954
1/2005-12/2005	Land Based JPALS Follow on Technology Development	ARINC	PI	$212,291
3/2006-1/2007	Sea Based JPALS Technology Development Multipath Analysis	ARINC	PI	$172,479
8/2006-11/2006	JPALS Land Based Technology Development - Filter Comparisons	ARINC	PI	$28,198
4/2008-3/2010	Collaborative Research: Development of GPS as a Soil Moisture Instrument	National Science Foundation	PI – K. Larson Co PI – E. Small, P. Axelrad	$113,128
2/2008-2/2012	Application of High-Rate GPS Occultation Data to Enhance Understanding of Turbulence in the Upper Troposphere	NASA	PI	$545,000

Dates	Title	Sponsor/Agency	PI, Co PI, Co I	Amount
7/2008 – 6/2009	Improving GPS Acquisition and Tracking Performance in Interference Environments	Charles Stark Draper Laboratory	PI	$61,513
6/2009 – 7/2010	Strategies for Low Power, Weak Signal GPS Positioning	Charles Stark Draper Laboratory	PI	$98,500
9/2009 – 8/2012	Graduate Assistantships in Areas of National Need (GAANN) Fellowships in Aerospace Systems	Department of Education	PI - G. Born Co PI - Axelrad (& others)	$174,208
2/2010-1/2012	iGPS Technology Concept Development Support	Coherent Navigation	PI Co PI- K. Larson	$681,873
6/2011 – 9/2012	Space-Based Search, Detection, and Tracking	AFRL	PI - G. Born Co PIs – Axelrad, H Schaub	$300,000
6/2011 – 5/2015	Center of Excellence in Commercial Space Transportation, Task 244, Autonomous Rendezvous and Docking	Federal Aviation Administration	PI	$121,467
6/2012 – 8/2013	Community Initiative for Cellular Earth Remote Observations (CICERO) Pathfinder Mission	GeoOptics, LASP subaward to CCAR	PI – M. McGrath CCAR PI H.Schaub, Co-PI	$198,400
6/2012 – 6/2013	Passive remote sensing of ocean surfaces from a UAV platform using GNSS bistatic radar	Charles Stark Draper Laboratory	PI	$75,000
3/2013-2/2018	Methods for Characterization of Spacecraft Multipath	NASA Goddard Space Flight Center	PI	$403,558
3/2013-10/2013	GNSS collective direct positioning for small satellites in LEO	NASA Goddard Space Flight Center	PI	$12,000
5/2013-5/2014	Collective Detection Based GPS Receiver for Small Satellites	NASA STTR: Emergent Space Technologies	PI	$51,876
7/2013 – 6/2014	Performance assessment and demonstration of remote sensing using GNSS bistatic radar	Charles Stark Draper Laboratory	PI	$110,000
4/2014 – 7/2014	Communications Tracking and Radar	Jet Propulsion Laboratory	PI, Co-PIs R.S. Nerem, K.M. Larson, D.M. Masters	$7,400
8/2014 – 5/2015	Heimdall System for Improved SSA Sensor Tasking	AFRL Phase1 SBIR: Orbit Logic	PI – B. Jones Co-PI	$49,999
10/2014 – 9/2016	GNSS Reflections for Sea-Surface Height	Jet Propulsion Laboratory	PI–K.M. Larson Co PI	$165,650
12/2014 – 5/2016	Specialized FISST-based Estimation Methods to Enhance Space Situational Awareness in MEO and GEO Orbits	Air Force Research Laboratory	PI	$74,999
10/2015 – 9/2016	Navigating CubeSats with One-Way Radiometric Tracking	Jet Propulsion Laboratory	PI	$38,457
1/2016 – 8/2017	GNSS Orbit and Clock Estimation	AFRL SBIR: Braxton Technologies	PI	$215,808

Dates	Title	Sponsor/Agency	PI, Co PI, Co I	Amount
3/2016 – 6/2018	Space Object Sensor Tasking Using Finite Set Statistics	AFRL Phase2 SBIR: Orbit Logic	PI	$86,413
9/2016 – 8/2019	Navigating CubeSats with One-Way Radiometric Tracking	NASA Education (AS&ASTAR) Fellowship (M. Rybak)	PI	$165,000
10/2016-9/2018	GNSS-R retrievals from SMAP	Jet Propulsion Laboratory	PI	$38,233
10/2016-2/2018	Enhanced GPS Situational Awareness	Quantum Research – Army SMDC	PI	$136,549
6/2017-3/2019	Analysis of CYGNSS Data for Retrieval of Sea Surface Topography	Jet Propulsion Laboratory	PI	$135,657
9/2017– 8/2022	Center of Excellence in Commercial Space Transportation, Task 367-CU, CubeSat Cluster Deployment Tracking	Federal Aviation Administration	PI	$248,653
12/2018-11/2022	Small Satellite Position, Navigation, and Timing Innovation	Air Force Research Laboratory	PI	$446,129
5/2019-5/2020	CYGNSS GNSS-R Altimetry Improvement Studies	Jet Propulsion Laboratory	PI	$135,585
9/2019-8/2023	QII-TAQS: Quantum Control of Ultracold Atoms in Optical Lattices for Inertial Sensing for Space Applications	National Science Foundation	PI–D. Anderson Co PI Axelrad & others	$1.928M $343,382 PA share
2/2020-1/2025	On Demand Positioning, Navigation, and Timing	Air Force Research Laboratory	PI Co-PIs: Morton, Akos, Palo	$3.301M
2/2020-11/2020	Sparse Information Orbit Estimation for Proliferated LEO	DARPA – Subcontract from Braxton Technologies	PI Co-PI Gaebler	$74,998
4/2020-6/2023	A Small Satellite Lunar Communications and Navigation System	NASA Ames	PI: S. Palo Co-PIs: Axelrad +3 others	$350,000
2/2021-7/2023	GNSS-based Precise Orbit Determination	Jet Propulsion Laboratory	PI	$205,738
10/2022 – 7/2024	Communications and Position, Navigation, and Timing	Air Force Research Laboratory - Subaward from University of New Mexico	PI	$217,125
1/2023-8/2023	Development of a Cluster Constrained GLMB Filter for Radar Tracking of Large Scale CubeSat Deployments	The Aerospace Corporation	PI	$50,248
5/1/2023-4/30/2025	JANUS-TEC: Establishing an atmospheric observational capability on commercial reusable launch vehicles	NASA – Subaward through JHU/APL	Co-I on overall project CU PI	$56,000

Support for Student Fellowships, Teaching, Educational Development, Scholarship of Teaching and Learning

9/2002-5/2003	Navigation Education Module Development	Institute of Navigation	PI –J. Sullivan Co PI	$20,000
9/2010-1/2011	Activating Student Learning in Lecture and Homework Through Discourse	CU President's Teaching and Learning Collaborative	PI	$1,550
10/2018-9/2022	Graduate Assistantships in Areas of National Need (GAANN) Critical Aerospace Technologies	Department of Education *(includes 25% required university match)*	PI	$1.189M