Curriculum Vitae: Brian E. Gilchrist

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Current Position:

Professor, Dept. of Electrical Engineering and Computer Science (EECS), University of Michigan.
Professor, Dept. of Atmospheric, Oceanic, and Space Sciences (AOSS), University of Michigan.

Education:

- Ph.D. in Electrical Engineering, 1991, Stanford University
- M.S. in Electrical Engineering, 1979, University of Illinois, Urbana
- B.S. in Electrical Engineering, 1977, University of Illinois, Urbana

Research Experience:

OVERVIEW:

Professor Gilchrist specializes in plasma electrodynamic sensors and technological applications principally for in-space applications. His research efforts span in-space plasma measurements, ground-based chamber simulations of high-speed space plasma flows principally to investigate current collection and sheath physics, and the development of advanced space electric propulsion applications. He is Co-PI for the development of the nanoparticle Field Extraction Thruster (nanoFET) concept that was selected by the NASA Institute for Advanced Concepts (NIAC) for Phase 2 level development and now an AFOSR Phase II STTR. He was an instrument PI on the Mars Scout mission concept, The Great Escape. He is in the forefront of efforts to develop space tether technology for scientific and technological applications including electrodynamic tethers as a new propellantless space propulsion technology. He was a Co-I on the NASA MSFC ProSEDS electrodynamic tether experiment providing plasma diagnostics and high-voltage tether control instrumentation. Also, Professor Gilchrist led a team of over 100 students to develop Michigan's first-ever student satellite (called Icarus). He has led the development of an advanced microwave interferometer for highly accurate plasma density and turbulence measurements of space electric propulsion plasma thrusters and designed a successful neutral gas release system for spacecraft charge neutralization. He was PI for the Shuttle Electrodynamic Tether System (SETS) experiment that flew on the STS-75 shuttle mission in 1996 as part of the Tethered Satellite System (TSS) mission. He was also PI for an Air Force effort to investigate fundamental issues associated with propagating artificially generated relativistic electron beams in space. Recently, Professor Gilchrist served the Electrical Engineering and Computer Science Department as interim Chair (2006-2008). Prior to receiving his Ph.D., Prof. Gilchrist held industry R&D and management positions over a twelve year period developing numerous microwave components and sub-systems including the first integrated microwave sampler for aerospace applications. His instructional emphasis is in the areas of electromagnetics, plasma electrodynamics, radiowave link design, systems design, and design of spacecraft systems. He has been a faculty advisor for Michigan's student Solar Car Race Team and the Student Space Systems Fabrication Laboratory (S3FL). He has well over 100 refereed and conference publications.

DETAILS:

Professor Gilchrist is Co-PI in the development of the Nanoparticle Field Emission Thruster (nanoFET). Using highly accelerated nanoparticles it is possible to create a paradigm shift in electric space propulsion technology. The nanoFET concept uses microelectromechanical (MEMS) structures to transport, charge, extract, and electrostatically accelerate nanoparticles for propulsive thrust in new ways that can substantially improve performance and mission capabilities. The nanoFET was selected by NASA's Institute for Advanced Concepts (NIAC) for further development and recently has been funded by AFOSR. Highly accelerated nanoparticles is also being explored for nanoprinting, material processing, and biomedical applications.

Professor Gilchrist was an instrument Co-I on the NASA Scout mission development, The Great Escape (TGE), developed by Southwest Research Institute. He was responsible for the development of the mission's Langmuir Probe (LP) instrument intended to provide measurements of Mars ionsophere plasma density and electron temperature as well as measurements of integrated solar ultraviolet flux outside of the ionosphere.

As a Co-I for NASA's ProSEDS electrodynamic tether propulsion mission, developed is to fly on a Delta-II in 2003, Professor Gilchrist was responsible for providing both plasma diagnostics and high-voltage control instrumentation. This includes a Langmuir probe and spacecraft potential monitor designed to rapidly operate in a variable plasma environment. In addition, he was responsible for providing a high-voltage tether current control and monitoring instrument. Of special interest, was that Professor Gilchrist also lead a group of University of Michigan students (over 100) to build a small, independent instrumented satellite for the ProSEDS mission to be placed at the end of its tether to provide enhanced tether dynamics data to NASA.

He was Principal Investigator for the SETS experiment on the 1996 TSS shuttle mission (STS-75), he lead a team of researchers from the University of Michigan, Utah State University, and Stanford University in the investigation of tether electrodynamic fundamentals in the Earth's ionosphere and the use of space tethers for scientific and technological applications. The SETS team specifically addressed questions pertaining to system level current-voltage characteristics and ionospheric effects as well as the use of tethers as long baseline double probes to measure natural electric fields, as long receiving antennas, as a method to enable simultaneous multipoint in-situ ionospheric measurements, as a remote electrical reference for spacecraft charging studies, and the study of electromagnetic pulse propagation along a conductor in a magnetized plasma. The TSS-1R experimental results, which the SETS team helped generate, have been pivotal in establishing the ability to drive high currents through the ionosphere for power generation and propulsion applications. Professor Gilchrist made specific contributions in identifying mechanisms for the highest tether currents generated during the mission.

Professor Gilchrist was Co-PI for an AFOSR program to make fundamental plasma electromagnetic measurements to support the development and integration of closed-drift, hall-effect electric thrusters for next generation spacecraft. This included establishing quantitative measures of amplitude and phase distortion to electromagnetic signals propagating through plasma plumes. He has led the development of advanced microwave and millimeter wave interferometers for highly accurate plasma density measurements for electric propulsion diagnostics. In addition, techniques using Ion Acoustic Wave (IAW) propagation in a moving plasma to establish ion temperature and drift velocity has been developed by his students. He was also Co-I on a follow-on AFOSR program to develop a high power to develop a high power Hall thruster. He and his students were responsible for developing 17, 35, and 70 GHz interferometers which are being used to investigate small scale plasma structure near the primary ionization and acceleration zones of EP thrusters.

He was PI for a NASA funded study of space tether application to ionospheric/thermospheric research and was organizer for a 1994 international workshop on the subject with over 50 participants from five countries. The unique ability to use space tethers for simultaneous, multipoint measurements was of special interest to the participants. Professor Gilchrist, in 1994, also led a team of University of Michigan students, engineers, and collaborating organizations (NASA Marshall Space Flight Center, Lockheed-Martin Corporation (Denver), Tether Applications Incorporated, University of Texas (Dallas), University of Alabama (Huntsville), and NASA Goddard Space Flight Center) in proposing a space tether mission to the lower thermosphere/ionosphere called AIRSATT (Atmospheric-Ionospheric Research Satellite using Advanced Tether Technology). The AIRSATT mission was selected by the University Space Research Association as one of six (out of sixty-six) proposals for an in-depth Phase 1 study for possible flight as part of a NASA funded program called STEDI (STudent Explorer Demonstration Initiative).

He was also PI for an Air Force program to investigate theoretical issues of propagating artificially generated relativistic electron beams in space. This effort has generated quantitative models describing beam propagation, the scattering by the atmosphere, and the importance of the Earth's magnetic field in confining beam spread. He was responsible for early relativistic particle models used in describing ionization effects in the mesosphere and supported the initial assessment of relativistic electron beam induced modifications to atmospheric electric fields.

Professor Gilchrist was a Co-Investigator on the 1992 high-energy electron beam CHARGE-2B tethered rocket experiment with responsibility for the science design of its neutral gas payload charge-neutralization experiment. He participated in both the VCAP Experiment on the Spacelab-2 Shuttle mission and the CHARGE-2 tethered rocket experiment which was a conducting tether experiment testing some of the TSS concepts.

His doctoral research at Stanford University was divided into two primary areas: a) investigations of electrodynamic effects due to electron beam and neutral gas emissions into a space plasma; and, b) radar and theoretical investigations of energetic electron beam generated artificial plasma density structures in the ionosphere using rockets and spacecraft. His masters thesis research, sponsored in part by a General Electric Fellowship, at the University of Illinois involved implementing an ionospheric total electron content radio measurement experiment optimized for nighttime application in the E and lower F regions of the ionosphere. The experiment was based on Faraday rotation, using a ground based HF transmitter, rocket borne receiver, and digital signal processing to extract the desired signals.

Professor Gilchrist has also held both technical and supervisory positions in industry (Watkins-Johnson Company) over a twelve-year period associated with microwave integrated circuit and subsystem design for radar and ecm applications. Research activities included: phased array radar, low-noise amplifiers, phase-shifters, and microwave sample-and-hold circuits.

Current Research and Professional Interests:

- Investigations of plasma electrodynamics with emphasis to energetic nanoparticles, MEMS based space electric propulsion applications using energetic nanoparticles, space electrodynamic tethered systems, and electron and ion beam effects (e.g. cold-cathode field emission cathodes, relativistic beams),
- Plasma diagnostics (e.g. Langmuir Probes, microwave/millimeter wave interferometer, floating potential monitors), and
- Spacecraft and energy conversion technologies.

Awards, Honors, and Recognitions:

- Service Excellence Award, College of Engineering, University of Michigan, 2009
- Outstanding Student Group Advisor, College of Engineering, University of Michigan, 2003
- Certificate of Special Recognition, College of Engineering, University of Michigan, 2002
- Service Excellence Award, College of Engineering, University of Michigan, 2001
- Faculty Excellence Award, Department of Electrical Engineering and Computer Science, 2000
- Excellence in Research Award, Department of Atmospheric, Oceanic, and Space Sciences, 1997
- Rackham Class Development Financial Award, 1992
- American Geophysical Union Outstanding Student Paper Award, 1988
- General Electric Fellowship - University of Illinois, 1977
- Highest Honors Bronze Tablet - University of Illinois, 1977
- Eta Kappa Nu (National Electrical Engineering Honor Society), 1977
- Edmund J. James Scholar - University of Illinois, 1975

Professional Societies:

American Institute of Astronautics and Aeronautics (Associate Fellow)
Institute of Electrical and Electronics Engineers (senior member)
American Geophysical Union (member)
Sigma Xi, Scientific Research Society

Professional Experience Chronology:

2009-present Founding Director, Multidisciplinary Design Programs at the University of Michigan's College of Engineering. In this role, he is working with a core team of committed faculty and staff to create an educational structure for significant, multidisciplinary design opportunities that engage students in real-world professional practice centered on design-build-test project activities. This initiative is part of an evolving vision for 21st Century engineering education at Michigan.

2006-2008: *Interim Chair*, Electrical Engineering and Computer Science Department at Michigan (*Interim Chair* for Electrical and Computer Engineering in EECS, 2007-2008) (Associate Chair of the Electrical and Computer Engineering Division, 7/2004 – 6/2006). Under his leadership, the Department engaged in a major review of its organizational structure leading to new a leadership model for the Department and for its ECE and CSE Divisions which was then implemented during his tenure.

1991-Present: Professor (Associate, 5/1997-5/2003; Assistant, 9/1991-5/1997) at The University of Michigan in Electrical Engineering and Computer Science (Radiation Laboratory) and the Atmospheric, Oceanic and Space Sciences Department (Space Physics Research Laboratory). Responsibilities include undergraduate and graduate education and research. His instructional emphasis is in the areas of electromagnetics, plasma electrodynamics, radiowave link design, systems design, and spacecraft design.

1989-1994: Deputy Investigator (from 1991) and Program Manager (from 1990) for SETS. Responsibilities included: **a)** development and coordination of mission planning inputs to achieve SETS/TSS-1 science goals; **b)** science experiment design; **c)** overall management of SETS contractual responsibilities including flight hardware and mission support operations; and **d)** all decisions reflecting SETS relations with NASA and other TSS-1 teams. **e)** Led development of functional objectives to meet SETS science requirements for TSS-1 mission and their coordination with mission personnel. (1989-1990: Deputy Program Manager SETS)

1984-1991: Graduate Research Assistant- Research was divided into two areas: **a)** investigations of electrodynamic effects due to electron beam and neutral gas emissions into a space plasma; and, **b)** radar and theoretical investigations of energetic electron beam generated artificial plasma density structures in the ionosphere using rockets and spacecraft including modeling of relativistic electron beam penetration into the atmosphere. Advisor: Professor Peter M. Banks

1978-1989: Watkins-Johnson Company- Held both technical and supervisory positions associated with microwave integrated circuit and subsystem design for radar and ecm applications. Research activities included: phased array radar, low-noise amplifiers, phase-shifters, and microwave sample-and-hold circuits.

1977-1978: Graduate Research Assistant in the University of Illinois Aeronomy Laboratory Rocket Program- Implemented a nighttime ionospheric electron density measurement experiment based on Faraday rotation, using a ground based HF transmitter and a rocket borne receiver. Advisor: Professor Leslie G. Smith

PATENT(S)

- United States Patent – 7,516,610, Scalable Flat-Panel Nano-Particle MEMS/NEMS Thruster, B. Gilchrist, A. Gallimore, M. Keidar, L. Musinski, T. Liu.

PUBLICATIONS

Refereed Publications

52. Deline, C., É. Choiniére, B. Gilchrist, "Assessment of plasma flow effect on Langmuir triple probe operations via kinetic simulation", IEEE Transactions on Plasma Science, in-press *Rev. Sci. Inst.,* 2009.
51. Musinski, L., T. Liu, B. Gilchrist, A. Gallimore, "Electrostatic Charging of Micro- and Nano- Particles for Use with Highly Energetic Applications," *Journal of Electrostatics*, 67, pp. 54-61, 2008.
50. Sanmartín, J. R., E. Choinière, B. E. Gilchrist, J-B. Ferry, and M. Martínez-Sánchez, Bare-Tether Sheath and Current: Comparison of Asymptotic Theory and Kinetic Simulations in a Stationary Plasma, *IEEE Transactions on Plasma Sci*ence, 36 (Issue 5, Part 4), pp. 2851-2858, Oct. 2008.
49. Deline, C., B. Gilchrist, C. Dobson, J. E. Jones, and D. G. Chavers, High accuracy plasma density measurement using hybrid Langmuir probe and microwave interferometer method, *Rev. Sci. Inst.*, 78, 113504, November, 2007 (DOI:10.1063/1.2813885).
48. Choiniére, É. and Brian Gilchrist, Self-Consistent 2-D Kinetic Simulations of High-Voltage Plasma Sheaths Surrounding Ion-Attracting Conductive Cylinders in Flowing Plasmas, *IEEE Transactions on Plasma Sci*ence, V35, No. 1, pp. 7—22, February 2007.
47. Choiniére, É., B. E. Gilchrist, S. Bilén, K. Fuhrhop, and A. Gallimore, Experimental Investigation of Electron Collection to Solid and Slotted Tape Probes in a High-speed Flowing Plasma, *IEEE Transactions on Plasma Sci*ence, V33, No. 4, pp. 131—1323, August 2005.
46. Neubert, T. and B. E. Gilchrist, Relativistic electron beam injection from spacecraft: performance and applications, Adv. Space Research, JASR6924, V34, No. 11, pp. 2409-2412, 2004.
45. Gilchrist, B. E., S. Bilén, É. Choiniére, A. Gallimore, and T. Smith, Analysis of chamber simulations of long collecting probes in high-speed, dense plasmas, *IEEE Transactions on Plasma Sci*ence, V30, No. 5, pp. 2023-2034, Oct. 2002.
44. Neubert, T. and B. E. Gilchrist, Particle simulations of relativistic electron beam injection from spacecraft, *J. Geophys Res.*, 107, No. A8, pp. SIA 9-1 to SIA 9-10, Aug. 2002.
43. Neubert, T. and B. E. Gilchrist, 3D Electromagnetic PIC simulations of relativistic electron pulse injections from spacecraft, *Adv. Space Res.*, 29, No. 9, pp. 1385-1390, 2002.
42. Gilchrist, B. E., K.L. Jensen, A.D. Gallimore, J. Severns, Space Based Applications For FEA Cathodes (FEACs), *Materials Issues in Vacuum Microelectronics: Symposium Proceedings,* (Materials Research Society, Warrendale, PA, 2000) V 621, p R481-R487, 2000.
41. Bilén, S. G. and B. E. Gilchrist, Transient Plasma Sheath Model for Thin Conductors Excited by Negative High Voltage with Application to Electrodynamic Tethers, *IEEE Transactions on Plasma Science*, V28 N6, p 2058-2074, Dec 2000.

40. Khazanov, G. V., M. W. Liemohn, E. N. Krivorutsky, J. U. Kozyra, J. M. Albert, and B. E. Gilchrist, On the influence of the initial pitch angle distribution on relativistic electron beam dynamics, J. *Geophys. Res., 105*, 16093, 2000.
39. Aguero, V. M., B. E. Gilchrist, S. D. Williams, W. J. Burke, L. Krause, L.C. Gentile, "Current collection model characterizing shuttle charging during the tethered satellite system missions." J. Spacecraft & Rockets, *37*, pp. 212-217, Mar-Apr, 2000.
38. S. G. Ohler, B. E. Gilchrist, A. D. Gallimore, "Electromagnetic signal modification in a localized high-speed plasma flow: Simulations and experimental validation of a stationary plasma thruster," *IEEE Transactions on Plasma Science*, Vol.27, no.2, pp.587-594, April 1999.
37. G. V. Khazanov, M. W. Liemohn, E. N. Krivorutsky, J. M. Albert, J. U. Koznra and B. E. Gilchrist, Relativistic electron beam propagation in the Earth's magnetosphere, J. Geophys. Res., *104*, 28587-99, 1999.
36. Raitt, W. J., D. C. Thompson, B. E. Gilchrist, and V. M. Aguero, Electrical charging of space platforms at low earth orbit altitudes, *Adv. Space Res.*, 24, No. 8, pp. 1015-1025, 1999.
35. Khazanov, G. V., M. W. Liemohn, E. N. Krivorutsky, J. U. Kozyra and B. E. Gilchrist, Interhemispheric transport of relativistic electron beams, *Geophys. Res. Lett.*, *26*, No. 5, p. 581-4, 1 March 1999.
34. Indiresan, R., B. Gilchrist, S. Basu, J.-P. Lebreton, E. P. Szuszczweicz, Simultaneous, dual-point, in situ measurements of ionospheric structures using space tethers: TSS-1R observations, *Geophys. Res. Lett.*, 25, 3725-3728, Oct. 1, 1998.
33. Gilchrist, B. E., R. Heelis and W. J. Raitt, Ionospheric Multi-Point Measurements using Tethered Satellite Sensors, Geophysical Monograph 103, Measurement Techniques in Space Plasmas: Fields, American Geophys. Union, edited by R. Pfaff, p. 317-323, 1998.
32. Agüero, V.M., W. J. Burke, B. E. Gilchrist, N. H. Stone, L. C. Gentile, S. D. Williams, D. L. Cooke, D. C. Thompson, C. Bonifazi and J.-P. Lebreton, Current Collection at the Shuttle Orbiter during the Tethered Satellite System Tether Break, *J. Geophys Res*, *104*, 105, 1999.
31. Garvin, C., B. E. Gilchrist, D. S. Grimard, J. W. Grizzle, "Measurement and error evaluation of electrical parameters at plasma relevant frequencies and impedances," *J. Vac. Sci. Technol. A*, Vol. 16, No. 2, p.p. 595-606, March-April, 1998.
30. Gilchrist, B. E., C. Bonifazi, S. G. Bilén, W.J. Raitt, W. J. Burke, N. H. Stone, J. P. Lebreton, "Enhanced electrodynamic tether currents due to electron emission from a neutral gas discharge: Results from the TSS-1R mission," *Geophys. Res. Lett.*,Vol. 25 , No. 4, p. 437-440, 1998.
29. Williams, S. D., B. E. Gilchrist, V. M. Aguero, R. S. Indiresan, D. C. Thompson, and W. J. Raitt, "Measurements of induced potential and natural electric fields using an electrodynamic tether double probe: TSS-1R Results," *Geophys. Res. Lett.*,Vol. 25 , No. 4, p. 445-448, 1998.
28. Thompson, D.C., C. Bonifazi, B.E. Gilchrist, S.D. Williams, W.J. Raitt, J.-P. Lebreton, and W.J. Burke, "The Current-Voltage Characteristics of a Large Probe in Low Earth Orbit: TSS-1R Results," *Geophys. Res. Lett.*,Vol. 25 , No. 4, p. 415-418, 1998.
27. Aguero, V. M., S. D. Williams, B. E. Gilchrist, L. H. Krause, D. C. Thompson, and W. J. Raitt, "Plasma current collection at the shuttle orbiter during TSS-1R high voltage charging," *Geophysical Research Letters.*, 25, No. 5, pp. 729-732, 1998.
26. Gentile, L. C., W. J. Burke, C. Y. Huang, J. S. Machuzak, D. A. Hardy, D. G. Olson, B. E. Gilchrist, J.-P. Lebreton, C. Bonifazi, "Negative shuttle charging during TSS-1R," *Geophys. Res. Lett.*,Vol. 25 , No. 4, pp. 433-436, 1998.
25. Burke, W. J., C. Bonifazi, D. A. Hardy, J. S. Machuzak, L. C. Gentile, D. G. Olson, C. Y. Huang, B. E. Gilchrist, J.-P. Lebreton, C. A. Gurgiolo, "Shuttle charging by tether controlled electron beam," *Geophys. Res. Lett.*,Vol. 25 , No. 5, p. 717-720, 1998.
24. Burke, W. J., W. J. Raitt, D. C. Thompson, J. S. Machuzak, L. C. Gentile, B. E. Gilchrist, C. Y. Huang, D. L. Cooke, D. A. Hardy, D. G. Olson, C. Bonifazi, "Shuttle charging by fixed energy beam emissions," *Geophys. Res. Lett.*,Vol. 25 , No. 5, p. 725-728, 1998.
23. Huang, C. Y., W. J. Burke, D. A. Hardy, M. P. Gough, D. G. Olson, L. C. Gentile, B. E. Gilchrist, C. Bonifazi, W. J. Raitt, D. C. Thompson, "Cerenkov emissions of ion acoustic-like waves generated by electron beams emitted during TSS 1R," *Geophys. Res. Lett.*,Vol. 25 , No. 5, p. 721-724, 1998.
22. Bilen, S. G., V. M. Aguero, Brian E. Gilchrist, and W. John Raitt, "Transient potential modification of large spacecraft due to electron emissions: TSS-1 results", *J. Spacecr Rockets*, vol 34, no 5, pp. 655-661, 1997.
21. Gilchrist, B. E., S. G. Ohler, A. D. Gallimore "Flexible Microwave System to Measure the Electron Number Density and Quantify the Communications Impact of Electric Thruster Plasma Plumes," *Rev. Sci. Inst.*, Vol. 68, No. 2, February, 1997.

20. S. G. Ohler, B. E. Gilchrist, A. D. Gallimore, "Microwave Plume Measurements of a Stationary Plasma Thruster," *J. Propulsion and Power*, vol. 14, No. 6, pp. 1016-1021, November-December, 1998.
19. Neubert, T., B. E. Gilchrist, S. Wilderman, L. Habash, and H.J. Wang, Relativistic electron beam propagation in the Earth's atmosphere: Modeling results, *Geophys. Res. Lett.*, Vol 23, No.9, pp. 1009-1012, May 1, 1996.
18. Bilén, S. G., B. E. Gilchrist, C. Bonifazi, E. Melchioni, "Transient response of an electrodynamic tether system in the ionosphere: TSS-1 first results," Radio Science, Vol. 30, No. 5, 1995.
17. S. G. Ohler, B. E. Gilchrist, A. D. Gallimore, "Non-intrusive electron number density measurements in the plume of a 1 kW arcjet using a modern microwave interferometer," *IEEE Transactions on Plasma Science 23(3)*, 428-435, 1995.
16. T. Neubert, B. Gilchrist, and E. Ungstrup, "AMPAS-a new active experiment mission," *Adv. Space Res. 15(12)*, 3-12, 1995.
15. G. A. Berg, W. J. Raitt, D. C. Thompson, B. E. Gilchrist, N. B. Meyers, P. Rodriguez, and H. R. Anderson, "Overview of the effects of neutral gas releases on high voltage sounding rocket platforms," *Adv. Space Res., 15,* 83-86, 1995.
14. Raitt, W. J., J. Ernstmeyer, N. B. Myers, A. B. White, S. Sasaki, K.-I. Oyama, N. Kawashima, A. C. Fraser-Smith, B. E. Gilchrist and T. J. Hallinan, VLF Wave Experiments in Space using a modulated electron beam, *J. Spacecraft*, *32*, 670-679, 1995.
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12. Aguero, V., P. M. Banks, B. Gilchrist, I. Linscott, W. J. Raitt, D. Thompson, V. Tolat, A. B. White, S. Williams and P. R. Williamson, The Shuttle Electrodynamic Tether System (SETS) on TSS-1, *Il Nuovo Cimento*, Jan-Feb 1994.
11. Bonifazi, C., G. Manarini, J. Sabbagh, F. Svelto, D. C. Thompson, B. E. Gilchrist, P. M. Banks and M. Dobrowolny, Tethered Satellite System (TSS): Preliminary results on the active experiment core equipment, *Il Nuovo Cimento, 16,* 515-538, 1993.
10. Neubert, T., S. Sasaki, B. Gilchrist, P. Banks, P. R. Williamson, A. Fraser-Smith and W. J. Raitt, Observations of plasma wave turbulence generated around large ionospheric spacecraft: effects of motionally induced EMF and of electron beam emission, *J. Geophys. Res.*, *96*, 9639-9654, 1991.
9. Gilchrist, B. E., Measurements of electron beam and neutral gas emissions in a space plasma during an ionospheric modification experiment, Stanford University, *Ph.D.*, 1991.
8. Gilchrist, B.E., P. M. Banks, T. Neubert, P. R. Williamson, N. B. Myers, W. J. Raitt and S. Sasaki, Electron collection enhancement arising from neutral gas jets on a charged vehicle in the ionosphere, *J. Geophys. Res., 95*, 2469-2475, 1990.
7. Neubert, T., M. J. Mandell, S. Sasaki, B. E. Gilchrist, P. M. Banks, P. R. Williamson, W. J. Raitt, N. B. Myers, K. I. Oyama and I. Katz, The sheath structure around a negatively charged rocket payload, *J. Geophys. Res., 95*, 6155-6165, 1990.
6. Neubert, T., P. Banks, B. Gilchrist, A. Fraser-Smith, P. R. Williamson, W. J. Raitt, N. Myers and S. Sasaki, The interactions of an artificial electron beam with the Earth's upper atmospere: effects on spacecraft charging and the near-plasma environment, *J. Geophys. Res., 95*, 12209-12217, 1990.
5. Myers, N. B., W. J. Raitt, A. B. White, P. M. Banks, B. E. Gilchrist and S. Sasaki, CHARGE-2: A sounding rocket experiment to investigate vehicle charging effects due to electron beam emission, *J. Spacecr. Rockets, 27*, 25-37, 1990.
4. Banks, P.M., B. E. Gilchrist, T. Neubert, N. B. Myers, W. J. Raitt, P. R. Williamson, A. C. Fraser-Smith and S. Sasaki, CHARGE-2 rocket observations of vehicle charging and charge neutralization, *Adv. Space Res., 10*, 133-136, 1990.
3. Myers, N. B., W. J. Raitt, B. E. Gilchrist, P. M. Banks, T. Neubert, P. R. Williamson and S. Sasaki, A comparison of current-voltage relationships of collectors in the earth's ionosphere with and without electron beam emission, *Geophys. Res. Lett., 16*, 365-368, 1989.
2. Banks, P.M. and B. E. Gilchrist, Artificial plasma density structures produced by energetic electron beams from rockets and spacecraft, *Geophys. Res. Lett., 12*, 175-178, 1985.
1. Smith, L.G. and B. E. Gilchrist, Rocket observations of electron density in the nighttime E region using Faraday rotation, *Radio Sci., 19*, 913-924, 1984.

Short Communications, Notes, Brief Reports

5. Gilchrist, B. E., Space Electrodynamic Tethers, Part II, *IEEE Instrumentation and Measurement Newsletter*, Winter, 1993.
4. Moore, S.E., B.E. Gilchrist, J.G. Galli, Microwave sampling effective for ultrabroadband frequency conversion, *MSN and Comm. Technology,* February, 1986.

3. Gilchrist, B., R. Fildes, J. Galli, Sampling hikes performance of frequency synthesizers, *Microwaves & RF, 23(1)*, 93-94, 1984.
2. Galli, J., B. Gilchrist, R. Forse, S. Rempel, Integration shrinks microwave front-ends, Parts I-III, *Microwave System News, 10(9)*, 119, 1980.
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Keynote or Invited Presentations

13. Gilchrist, B. E., Space Tethers: From Space Fiction to Space Reality, 13th Annual Aviation/Aerospace Teacher Workshop, Lansing, MI, 2006 May 20.
12. Gilchrist, B. E., Electrodynamic tethers for in-orbit propulsion: Status and technological issues, IUGG2003, Sapparo, Japan, June 30-July 11, 2003.
11. Eric Choiniére and B. E. Gilchrist, Kinetic Modeling of the Electron Current Collection to a Moving Bare Electrodynamic Tether, 28th IEEE International Conference on Plasma Science, Las Vegas, June 18-23, 2001.
10. B. E. Gilchrist, K. L. Jensen, C. M. Marrese , J. G. Severns, A. D. Gallimore, D. Morris, FEA Cathodes (FEACs) for space based applications, 27th IEEE International Conference on Plasma Science, New Orleans, June 4-7, 2000.
9. Gilchrist, B. E. and S. G. Bilén, Ground Simulations of Bare Electrodynamic Tethers in a Dense, High-Speed Plasma Flow, American Geophysical Union Spring Meeting, Washington, D. C., 2000.
8. DARPA, Washington, DC, "System Considerations of Electrodynamic Tethers for Propulsion and Power Generation," May 17, 1999.
7. Gilchrist, B.E. and R. Heelis, "Multiple tethered satellites for ionospheric studies (MTSIS)," Tether Technology Interchange Meeting, Huntsville, AL, Sept. 9-10, 1997.
6. Invited Special Speaker, "Space Tethers - Building Large Structures in Space," American Society of Civil Enginers, Michigan Section 1996 Annual Meeting, Ann Arbor, MI, September 20, 1996.
5. Gilchrist, B. E., W. J. Raitt, M. Dobrowolny, S. D. Williams, V. M. Aguero, R. Indiresan, N. R. Voronka, D. C. Thompson, S. G. Bilén and D. P. Morris, Space Tethers as Distributed Ionospheric Probes: TSS-1R Mission, presented at XXVth URSI General Assembly, Lille, France, 28 August -5 September 1996.
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3. Forum Keynote Speaker on "Space Tethers - How They Work, What They Can Do, and Lessons Learned from the Tethered Satellite System Shuttle Missions," Cascades Amateur Radio Society 2nd Annual Radio Conference, Jackson, MI., August 11, 1996.
2. Keynote Speaker on "Space Tethers for Space Physics Applications," ESA Round Table on Space Tethers, September, 1994, Noordweck, The Netherlands.
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