Samuel Phillip Pullen ("Sam")

Office:	Dept. of Aero/Astronautics Stanford University Stanford, CA 94305-4035 USA +1 (650) 488 – 3816	**Home:**	3 Greenpark Way S. San Francisco, CA 94080 USA +1 (650) 208 – 0971 (mobile)
E-mail:	spullen@stanford.edu	**URL:**	http://www.stanford.edu/~spullen

EDUCATION

Stanford University; Stanford, California
Ph.D., Aeronautics and Astronautics
Graduation Date: June 1996 GPA: 3.9/4.0
Thesis title: *Probabilistic Engineering Design Optimization: Applications to Spacecraft and Navigation Systems*
M.S., Aeronautics and Astronautics (emphasis on guidance and control systems)
Graduation Date: June 1990 GPA: 3.8/4.0

Massachusetts Institute of Technology; Cambridge, Massachusetts
S.B., Aeronautics and Astronautics
S.B., History (emphasis on modern Europe, technology strategy and development)
Graduation Date: June 1989 GPA: 4.8/5.0

EXPERIENCE

Senior Research Engineer, May 1999 – present (part-time since August 2011)
(Research Associate from July 1996 – April 1999)
Hansen Laboratories and Dept. of Aeronautics and Astronautics; Stanford University; Stanford, California

- Head of the Ground Based Augmentation System (GBAS)/Local Area Augmentation System (LAAS) research project, overseeing 5 – 15 engineers and graduate students working on algorithm research, safety assurance, prototype development, and test and validation.
- Developed, installed, and validated the first LAAS ground system prototype (the "Integrity Monitor Testbed") that included all elements and algorithms needed to protect user safety.
- Supported the FAA in developing specifications, algorithms, and test procedures for vendor systems that evolved into the SLS-4000 and -5000 LAAS Ground Facilities. Several key algorithms were first developed and tested in Stanford's Integrity Monitor Testbed.
- Developed original methods for spacecraft reliability and risk assessment for the Gravity Probe-B Relativity Mission developed at Stanford under NASA/MSFC management.
- Provided research support to other projects, including WAAS, JPALS, and PPP integrity verification. Developed the first comprehensive predictions of WAAS performance and availability and extended these tools to support WAAS architecture design optimization.
- Taught graduate-level course, "Space Mechanics," in 1999-2000. Guest lecturer for "Global Positioning Systems" and other courses in Aero/Astro department.

Consultant, January 1996 – present (self-employed and via NavAstro; Los Gatos, California)

- Technical review and support of concepts for integrity verification and certification of train control systems using GNSS and augmented GNSS.
- Technical support of integrity algorithm design, test, and validation for multiple companies developing LAAS/GBAS ground and airborne equipment.

- Expert witness analysis, report generation, and testimony concerning navigation technology, patent rights, and defects, including litigation in U.S. and Canadian courts. Applications include GPS receivers, aircraft, automobiles, and train control systems (see separate list).
- Analysis and development of Advanced RAIM (ARAIM) for military and civilian aircraft.
- Conceptual development of GNSS systems for automated land vehicle guidance, including real-time verification of GNSS integrity at the levels needed for automated driving.
- Technical support of system architecture, algorithm design, and requirements assessment for the U.S. Navy Sea-Based JPALS Program.
- Technical support of the GPS III Modernization effort under contract to the DOD GPS Joint Program Office, including requirements definition and performance simulation.
- Design and development of onboard GPS satellite self-integrity monitoring.
- Technical support of the Johns Hopkins University Applied Physics Laboratory GPS Risk Assessment, including problem formulation, performance simulation, and risk analysis.
- Tutorial presentations on LAAS fundamentals, algorithms, and aviation applications.
- Space satellite and constellation reliability analysis, including pre-launch reliability estimates (using thesis research methodology) and revisions after observing initial behavior in orbit.

Researcher, *on-site*: June - December 1990; *consultant*: January 1991 – September 1997
The RAND Corporation; Santa Monica, California
Examined the current and proposed future basing structures of the U.S. Air Force in Europe. Developed a software tool to model and assess future aircraft basing options. The results of this study were validated by subsequent experience as aircraft were withdrawn from Europe.

ACADEMIC AND PROFESSIONAL SERVICES

- **Editor of "GNSS Solutions" column, *Inside GNSS* magazine**, January 2020 – present
- **Associate Editor for Navigation, *IEEE Transactions on Aerospace and Electronic Systems*,** October 2007 – January 2015
- **Tutorial Instructor** on GNSS augmentations and integrity, ION GNSS 2011 – 2013
- **Reviewer** for IEEE, AIAA, ION, and other journals, 1998 – present
- **Institute of Navigation (ION) Council Member,** 2003 – 2005
- **Session Chair** at multiple ION, IEEE, and other conferences

AWARDS AND HONORS

- Fellow of the Institute of Navigation (ION) (2017)
- ION Early Achievement Award (1999)
- ION GPS/GNSS Conference "Best Paper" Awards (1999, 2000, 2001, 2009)
- National Science Foundation Graduate Fellowship (1989 – 1992)
- Tau Beta Pi and Sigma Gamma Tau engineering honor societies at MIT (1987, 1988)

OTHER SKILLS

- Japanese language ability and extensive familiarity with Japanese business and personal culture, including NSF-supported and consulting engagements in Japan.
- Extensive knowledge of finance, investing, and economics through consulting and private study.

Proficient in programming (C, C++, Python), engineering/statistics applications (Matlab, R), and spreadsheet (Excel) applications.

PATENTS

[P03] R.W. Rose, M.T. Nehrenz, **S. Pullen**, "Radar augmented receiver autonomous integrity monitoring in aircraft," US Patent Filing US20220365224A1, Filed Nov. 30, 2021. https://patents.google.com/patent/US20220365224A1/

[P02] R.W. Rose, M.T. Nehrenz, **S. Pullen**, "Filter augmented receiver autonomous integrity monitoring in aircraft," US Patent Filing US20220365222A1, Filed Nov. 30, 2021. https://patents.google.com/patent/US20220365222A1/

[P01] G. Green, **S. Pullen**, "Self-monitoring satellite system," U.S. Patent No. 6,667,713, Issued Dec. 23, 2003. http://www.google.com/patents/about?id=HoMOAAAAEBAJ&dq=6,667,713

BOOK CHAPTERS AND REPORTS

[B6] S. Datta-Barua, E. Altshuler, T. Walter, **S. Pullen**, "Ionospheric Scintillation Effects on Satellite Navigation," Ch. 20 in *Ionosphere Dynamics and Applications*, C. Huang, G. Lu, et al., Eds., Hoboken, NJ, Wiley-American Geophysical Union (AGU), 2021. https://doi.org/10.1002/9781119815617

[B5] **S. Pullen**, M. Joerger, "GNSS Integrity and Receiver Autonomous Integrity Monitoring (RAIM)," Ch. 23 in *Position, Navigation, and Timing Technologies in the 21st Century*, J. Morton, F. van Diggelen, et al., Eds., Hoboken, NJ: Wiley-IEEE, 2021. https://ieeexplore.ieee.org/book/9304973

[B4] **S. Pullen**, "Ground Based Augmentation Systems," Ch. 31 in *Springer Handbook of Global Navigation Satellite Systems*. P. Teunissen, O. Montenbruck, Eds., Switzerland: Springer AG, 2017. https://www.springer.com/us/book/9783319429267

[B3] J. Rife, **S. Pullen**, "Aviation Applications," Ch. 10 in *GNSS Applications and Methods*. S. Gleason, D. Gebre-Egziabher, Eds., Norwood, MA: Artech House, 2009. http://www.artechhouse.com/Detail.aspx?strIsbn=978-1-59693-329-3

[B2] **S. Pullen**, J. Rife, "Differential GNSS: Accuracy and Integrity," Ch. 4 in *GNSS Applications and Methods*. S. Gleason, D. Gebre-Egziabher, Eds., Norwood, MA: Artech House, 2009. http://www.artechhouse.com/Detail.aspx?strIsbn=978-1-59693-329-3

[B1] T. Corrigan, J. Hartranft, L. Levy, K. Parker, J. Pritchett, A. Pue, **S. Pullen**, T. Thompson, *GPS Risk Assessment Study: Final Report*. Laurel, MD., The Johns Hopkins University Applied Physics Laboratory, VS-99-007. January 1999. http://www.rvs.uni-bielefeld.de/publications/Incidents/DOCS/Research/Other/Article/gps-risk-ass.pdf

JOURNAL PAPERS

[J43] L. Marini-Pereira, A.O. Moraes, **S. Pullen**, "Advanced Warning of Threatening Equatorial Plasma Bubbles to Support GBAS in Low Latitudes," *IEEE Trans. Aerospace and Electronic Systems*, Feb. 2023, pp. 1-14. https://doi.org/10.1109/TAES.2023.3243581

[J42] H. Lee, **S. Pullen**, J. Lee, B. Park, M. Yoon, J. Seo, "Optimal Parameter Inflation to Enhance the Availability of Single-Frequency GBAS for Intelligent Air Transportation," *IEEE Trans. Intelligent Transportation Systems*, Vol. 23, No. 10, Oct. 2022, pp. 17801-17808. https://doi.org/10.1109/TITS.2022.3157138

[J41] B.J. Affonso, A.O. Moraes, , J. Sousasantos, L. Marini-Pereira, **S. Pullen**, "Strong Ionospheric Spatial Gradient Events Induced by Signal Propagation Paths Aligned with Equatorial Plasma Bubbles," *IEEE Trans. Aerospace and Electronic Systems*, Vol. 58, No. 4, Aug. 2022, pp. 2868-2879. https://doi.org/10.1109/TAES.2022.3144622

[J40] L. Marini-Pereira, **S. Pullen**, A.O. Moraes, "Ground-Based Augmentation Systems Operation in Low Latitudes - Part 2: Space Weather, Ionospheric Behavior and Challenges," *J. Aerospace*

Technology and Management, Vol. 13, 2021. https://www.scielo.br/j/jatm/a/hmWtVQL4XFrSWmQVXtpNTWg/

[J39] L. Marini-Pereira, **S. Pullen**, A.O. Moraes, "Ground-Based Augmentation Systems Operation in Low Latitudes - Part 1: Challenges, Mitigations, and Future Prospects," *J. Aerospace Technology and Management*, Vol. 13, 2021. https://www.scielo.br/j/jatm/a/4y64KqSDVGsNVHqhCxyRtfv/

[J38] K.A. Sun, H. Chang, **S. Pullen**, H. Kil, J. Seo, Y.J. Morton, J. Lee, "Markov Chain-Based Stochastic Modeling of Deep Signal Fading: Availability Assessment of Dual-Frequency GNSS-Based Aviation Under Ionospheric Scintillation," *Space Weather*, Vol. 19, No. 9, Sept. 2021. https://doi.org/10.1029/2020SW002655

[J37] D. Kim, M. Yoon, **S. Pullen**, J. Lee, "Closed-form Analysis of Undetected Range Errors due to Ionospheric Impacts for GBAS Category I Operations," *Navigation*, Vol. 68, No. 3, Fall 2021, pp. 507-519. https://doi.org/10.1002/navi.442

[J36] L. Marini-Pereira, A.O. Moraes, **S. Pullen**, "Reexamining Low-Latitude Ionospheric Error Bounds: An SBAS Approach for Brazil," *IEEE Trans. Aerospace and Electronic Systems*, Vol. 57, No. 1, Feb. 2021, pp. 674-689. https://doi.org/10.1109/TAES.2020.3029623

[J35] L. Marini-Pereire, L.F.D. Lourenco, J. Sousasantos, A.O. Moraes, **S. Pullen**, "Regional Ionospheric Delay Mapping for Low-Latitude Environments," *Radio Science*, Vol. 55, No. 12, Dec. 2020, pp. 1-16. https://doi.org/10.1029/2020RS007158

[J34] H. Chang, M. Yoon, **S. Pullen**, L. Marini-Pereira, J. Lee, "Ionospheric Spatial Decorrelation Assessment for GBAS Daytime Operations in Brazil," *Navigation*, Vol. 68, No. 2, Summer 2021, pp. 391-404. https://doi.org/10.1002/navi.418

[J33] M. Yoon, J. Lee, **S. Pullen**, "Integrity Risk Evaluation of Impact of Ionospheric Anomalies on GAST D GBAS," *Navigation*, Vol. 67, No. 2, Summer 2020, pp. 223-234. https://doi.org/10.1002/navi.339

[J32] M. Yoon, D. Kim, **S. Pullen**, J. Lee, "Assessment and mitigation of equatorial plasma bubble impacts on category I GBAS operations in the Brazilian region," *Navigation*, Vol. 66, No. 3, Fall 2019, pp. 643-659. https://doi.org/10.1002/navi.328

[J31] T. Sasaki, T. Shimomura, **S. Pullen**, H. Schaub, "Attitude and Vibration control with Double-Gimbal Variable-Speed Control Moment Gyros," *Acta Astronautica*, Vol. 152, November 2018, Pages 740-751. https://doi.org/10.1016/j.actaastro.2018.08.047

[J30] N. Kubo, H. Tokura, **S. Pullen**, "Mixed GPS–BeiDou RTK with inter-systems bias estimation aided by CSAC," *GPS Solutions*, Vol. 22, No. 1, Jan. 2018. https://link.springer.com/article/10.1007/s10291-017-0670-1

[J29] M. Yoon, J. Lee, **S. Pullen**, J. Gillespie, N. Mathur, R. Cole, J. Rodrigues de Souza, P. Doherty, R. Pradipta, "Equatorial Plasma Bubble Threat Parameterization to Support GBAS Operations in the Brazilian Region," *Navigation*, Vol. 64, No. 3, Fall 2017, pp. 309-321. https://www.ion.org/publications/abstract.cfm?articleID=102720

[J28] S. Saito, S. Sunda, J. Lee, **S. Pullen**, S. Supriadi, T. Yoshihara, M. Terkildsen, F. Lecat, "Ionospheric delay gradient model for GBAS in the Asia-Pacific region," *GPS Solutions*, Vol. 21, No. 4, Oct. 2017, pp. 1937-1947. https://link.springer.com/article/10.1007/s10291-017-0662-1

[J27] J. Lee, **S. Pullen**, S. Datta-Barua, J. Lee, "Real-Time Ionospheric Threat Adaptation Using a Space Weather Prediction for GNSS-Based Aircraft Landing Systems," *IEEE Trans. Intelligent Transportation Systems*, Vol. 18, No. 7, July 2017, pp. 1752-1761. https://ieeexplore.ieee.org/abstract/document/7774997/

[J26] M. Kim, E. Bang, **S. Pullen**, Y.J. Lee, J. Lee, "Feasibility Studies for Applications of Long-Term Ionospheric Anomaly Monitor," *IEEE Trans. Aerospace and Electronic Systems*, Vol. 53, No. 3, June 2017, pp. 1581-1588. https://ieeexplore.ieee.org/abstract/document/7859336/

[J25] M-S. Circiu, M. Meurer, M. Felux, D. Gerbeth, S. Thölert, M. Vergara, C. Enneking, M. Sgammini, **S. Pullen**, F. Antreich, "Evaluation of GPS L5 and Galileo E1 and E5a Performance for Future Multifrequency and Multiconstellation GBAS," *Navigation*, Vol. 64, No. 1, Spring 2017, pp. 149-163. https://www.ion.org/publications/abstract.cfm?articleID=102710

[J24] T. Dautermann, M. Sgammini, **S. Pullen**, "Ionospheric threat simulation for GNSS using the Spirent hardware signal simulator," *GPS Solutions*, Vol. 18, No. 3, July 2014, pp 365-373. http://link.springer.com/article/10.1007/s10291-013-0336-6

[J23] **S. Pullen**, P. Enge, "Using Outage History to Exclude High-Risk Satellites from GBAS Corrections," *Navigation*, Vol. 60, No. 1, Spring 2013, pp. 41-51. https://www.ion.org/publications/abstract.cfm?articleID=102590

[J22] S. Khanafseh, **S. Pullen**, J. Warburton, "Carrier Phase Ionospheric Gradient Ground Monitor for GBAS with Experimental Validation," *Navigation*, Vol. 59, No. 1, Spring 2012, pp. 51-60. https://www.ion.org/search/view_abstract.cfm?jp=j&idno=2567

[J21] J. Seo, J. Lee, **S. Pullen**, P. Enge, S. Close, "Targeted Parameter Inflation within Ground-Based Augmentation Systems to Minimize Anomalous Ionospheric Impact," *AIAA J. Aircraft*, Vol. 49, No. 2, March-April 2012, pp. 587-599. http://preview.tinyurl.com/JA-N2-12

[J20] J. Lee, S, Datta-Barua, G. Zhang, **S. Pullen**, P. Enge, "Observations of Low-Elevation Ionospheric Anomalies for Ground-Based Augmentation of GNSS," *Radio Science*, Vol. 46, Nov. 22, 2011. http://www.agu.org/journals/rs/rs1106/2011RS004776/2011RS004776.pdf

[J19] J. Lee, J. Seo, Y.S. Park, **S. Pullen**, P. Enge, "Ionospheric Gradient Threat Mitigation by Geometry Screening in GNSS Ground Based Augmentation Systems," *AIAA J. Aircraft*, Vol. 48, No. 4, July-Aug. 2011, pp. 1422-1433. http://preview.tinyurl.com/JA-N4-11

[J18] S. Datta-Barua, J. Lee, **S. Pullen**, M. Luo, A. Ene, D. Qiu, G. Zhang, P. Enge, "Ionospheric Threat Parameterization for Local Area Global-Positioning-System-Based Aircraft Landing Systems," *AIAA J. Aircraft*, Vol. 47, No. 4, July-Aug. 2010, pp. 1141-1151. http://preview.tinyurl.com/JA-N4-10

[J17] J. Lee, **S. Pullen**, P. Enge, "Sigma Overbounding using a Position Domain Method for the Local Area Augmentation of GPS," *IEEE Trans. Aerospace and Electronic Systems*, Vol. 45, No. 4, Oct. 2009, pp. 1262-1274. http://preview.tinyurl.com/TAES-N4-09

[J16] **S. Pullen**, Y.S. Park, P. Enge, "Impact and Mitigation of Ionospheric Anomalies on Ground−Based Augmentation of GNSS," *Radio Science*, Vol. 44, Aug. 2009. http://www.agu.org/journals/rs/rs0904/2008RS004084/

[J15] J. Rife, S. Khanafseh, **S. Pullen**, D. De Lorenzo, U.S. Kim, M. Koenig, T.Y. Chiou, B. Kempny, B. Pervan, "Navigation, Interference Suppression, and Fault Monitoring in the Sea-Based Joint Precision Approach and Landing System," *Proc. IEEE*, Vol. 96, No. 12, Dec. 2008, pp. 1958-1975. http://preview.tinyurl.com/PrIE-N12-08

[J14] J. Lee, **S. Pullen**, S. Datta-Barua, P. Enge, "Assessment of Ionosphere Spatial Decorrelation for Global Positioning System-Based Aircraft Landing Systems," *AIAA J. Aircraft*, Vol. 44, No. 5, Sept.-Oct. 2007, pp. 1662-1669. http://preview.tinyurl.com/JA-N5-07

[J13] **S. Pullen**, P. Enge, "An Overview of GBAS Integrity Monitoring with a Focus on Ionospheric Spatial Anomalies," *Indian J. Radio & Space Physics*, Vol. 36, Aug. 2007, pp. 249-260. http://preview.tinyurl.com/IRSP-07

[J12] J. Rife, **S. Pullen**, P. Enge, B. Pervan. "Paired Overbounding for Nonideal LAAS and WAAS Error Distributions," *IEEE Trans. Aerospace and Electronic Systems*, Vol. 42, No. 4, Oct. 2006, pp. 1386-1395. http://preview.tinyurl.com/TAES-N4-06

[J11] J. Lee, **S. Pullen**, P. Enge, B. Pervan, L. Gratton, " Monitoring Global Positioning System Satellite Orbit Errors for Aircraft Landing Systems," *AIAA J. Aircraft*, Vol. 43, No. 3, May-June 2006, pp. 799-808. http://preview.tinyurl.com/JA-N3-06

[J10] J. Lee, **S. Pullen**, P. Enge, "Sigma-Mean Monitoring for the Local Area Augmentation of GPS," *IEEE Trans. Aerospace and Electronic Systems*, Vol. 42, No. 2, April 2006, pp. 625-635. http://preview.tinyurl.com/TAES-N2-06

[J09] J. Rife, **S. Pullen**, "The Impact of Measurement Biases on Availability for Category III LAAS," *Navigation*, Vol. 52, No. 4, Winter 2005-2006, pp. 215-228. http://www.ion.org/search/view_abstract.cfm?jp=j&idno=2408

[J08] D. Gebre-Egziabher, A. Razavi, P. Enge, J. Gautier, **S. Pullen**, B. Pervan, D. Akos, "Sensitivity and Performance Analysis of Doppler-Aided GPS Carrier-Tracking Loops," *Navigation*, Vol. 52, No. 2, Summer 2005, pp. 49-60. http://www.ion.org/search/view_abstract.cfm?jp=j&idno=2392

[J07] M.B. Heo, B. Pervan, **S. Pullen**, J. Gautier, P. Enge, D. Gebre-Egziabher, "Autonomous Fault Detection with Carrier-Phase DGPS for Shipboard Landing Navigation," *Navigation*, Vol. 51, No. 3, Fall 2004, pp. 185-198. http://www.ion.org/search/view_abstract.cfm?jp=j&idno=2376

[J06] B. Pervan, F.C. Chan, D. Gebre-Egziabher, **S. Pullen**, P. Enge, G. Colby, "Performance Analysis of Carrier-Phase DGPS Navigation for Shipboard Landing of Aircraft," *Navigation*, Vol. 50, No. 3, Fall 2003, pp. 181-192. http://www.ion.org/search/view_abstract.cfm?jp=j&idno=2354

[J05] T. Shimomura, **S. Pullen**, "Strictly Positive Real H_2 Controller Synthesis via Iterative Algorithms for Convex Optimization," *AIAA J. Guidance, Control, and Dynamics*, Vol. 25, No. 6, Nov.-Dec. 2002, pp. 1003-1011. http://preview.tinyurl.com/JGCD-N6-02

[J04] B. Pervan, **S. Pullen**, D. Lawrence, K. Gromov, J. Christie, G. Opshaug, V. Lu, P.Y. Ko, P. Enge, B. Parkinson, "Prototype LAAS Architecture Design Considerations," *GPS Solutions*, Vol. 2, No. 1, Summer 1998, pp. 49-61. http://www.springerlink.com/content/u2my9fak3urqp8h6/fulltext.pdf

[J03] B. Pervan, **S. Pullen**, J. Christie, "A Multiple Hypothesis Approach to Satellite Navigation Integrity," *Navigation*, Vol. 45, No. 1, Spring 1998, pp. 61-84. http://www.ion.org/search/view_abstract.cfm?jp=j&idno=6

[J02] B. Pervan, D. Lawrence, K. Gromov, G. Opshaug, J. Christie, P.Y. Ko, A. Mitelman, **S. Pullen**, P. Enge, B. Parkinson, "Flight Test Evaluation of an Alternative Local Area Augmentation System Architecture," *Navigation*, Vol. 45, No. 1, Spring 1998, pp. 31-38. http://www.ion.org/search/view_abstract.cfm?jp=j&idno=3

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MAGAZINE ARTICLES

[A20] **S. Pullen**, F. Rispoli, A. Neri, A. Vennarini, A. Persia, R. Capua, "How can GNSS augmentation services be combined to simultaneously support multiple user classes with demanding but different requirements?", GNSS Solutions column, *Inside GNSS*, Vol. 18, No. 4, July/Aug. 2023 (forthcoming).

[A19] R. Wang, T. Walter, **S. Pullen**, "What are typical features of GNSS satellite faults in recent years? Are there any differences between satellite constellations?", GNSS Solutions column, *Inside GNSS*, Vol. 18, No. 2, Mar./Apr. 2023, pp. 28-35. http://tiny.cc/March23-SP

[A18] **S. Pullen**, J. Lee, G. Nam, K.A. Sun, "How can two-way communications between reference stations and users enhance the performance and integrity of differential GNSS navigation?",

GNSS Solutions column, *Inside GNSS*, Vol. 17, No. 6, Nov./Dec. 2022, pp. 22-29. http://tiny.cc/Nov22-SP

[A17] **S. Pullen**, S. Lo, A. Katz, "How can ground monitoring of GNSS constellations improve on the performance and integrity commitments made by GNSS constellation providers regarding the integrity of their signals and services? What performance benefits might result?", GNSS Solutions column, *Inside GNSS*, Vol. 17, No. 4, July/Aug. 2022, pp. 22-27. http://tiny.cc/July22-SP

[A16] **S. Pullen**, T. Walter, J. Blanch, R. Wang, "What commitments have the various constellation providers made to GNSS users regarding the integrity of their signals and services? How are these commitments transmitted to users, and how can they be updated if circumstances require?", GNSS Solutions column, *Inside GNSS*, Vol. 17, No. 3, May/June 2022, pp. 26-33. https://tiny.cc/May22-SP

[A15] J. Anderson, T. Walter, S. Lo, **S. Pullen**, "How could GNSS users determine in real time that their received navigation signals are authentic? What methods are recommended, and when might they go into operation?", GNSS Solutions column, *Inside GNSS*, Vol. 17, No. 1, Jan./Feb. 2022, pp. 22-27. https://tiny.cc/Jan22-SP

[A14] **S. Pullen**, "To what degree does the greater ionospheric activity in equatorial regions degrade GNSS positioning? How does this degradation occur? What mitigations are available?", GNSS Solutions column, *Inside GNSS*, Vol. 16, No. 5, Sept./Oct. 2021, pp. 20-26. https://tiny.cc/Sept21-SP

[A13] **S. Pullen**, "What is the significance of the NANUs provided by GPS and the similar alerts provided by other GNSS constellations? Are they needed for the use of these systems, and if not, how are they helpful?", GNSS Solutions column, *Inside GNSS*, Vol. 16, No. 3, May/June 2021, pp. 24-30. https://tiny.cc/May21-SP

[A12] **S. Pullen**, "How can the parameters given in the most recent GPS Standard Positioning Service (SPS) Performance Standard (SPS PS) be used to quantify the performance of GPS applications?", GNSS Solutions column, *Inside GNSS*, Vol. 16, No. 1, Jan./Feb. 2021, pp. 18-23. https://tiny.cc/Jan21-SP

[A11] **S. Pullen**, "Can analytical techniques guarantee that GNSS errors are bounded under rare conditions? What techniques are available?", GNSS Solutions column, *Inside GNSS*, Vol. 15, No. 5, Sept./Oct. 2020, pp. 18-26. https://tiny.cc/Sept20-SP

[A10] **S. Pullen**, "Why is bounding GNSS errors under rare or anomalous conditions important, and what makes it difficult?", GNSS Solutions column, *Inside GNSS*, Vol. 15, No. 3, May/June 2020, pp. 28-32. https://tiny.cc/May20-SP

[A09] **S. Pullen**, "What freeware or open-source software packages are available to support GNSS performance evaluations?", GNSS Solutions column, *Inside GNSS*, Vol. 15, No. 1, Jan./Feb. 2020, pp. 46-51. http://tiny.cc/Jan20-SP

[A08] **S. Pullen**, "Lessons Learned from the Development of GNSS Integrity Augmentations," *Coordinates*. Vol. 12, No. 8, Aug. 2016, pp. 8-13. http://mycoordinates.org/lessons-learned-from-the-development-of-gnss-integrity-augmentations/

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[A06] **S. Pullen**, G. Gao, "GNSS Jamming in the Name of Privacy: Potential Threat to GPS Aviation," *Inside GNSS*, Vol. 7, No. 2, March/April 2012, pp. 34-43. http://www.insidegnss.com/auto/marapr12-Pullen.pdf

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[A04] **S. Pullen**, "Expert Advice: Integrity – Lessons from the 2008 Financial Collapse," *GPS World*. Vol. 21, No. 2, Feb. 2010. http://www.gpsworld.com/transportation/aviation/expert-advice-integrity-lessons-2008-financial-collapse-9426

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[T40] "Lessons Learned from the Mitigation of Ionospheric Anomalies on Ground-and Satellite-based GNSS Augmentation," *VIII SBGEA & SimFAST Symposium*, São José dos Campos, Brazil, March 26, 2021.

[T39] "SBAS and GBAS Overview: Fundamentals, Similarities, and Differences," *Seoul National University (SNU) Tutorial*, Seoul, Korea, July 11, 2017.

[T38] "Reliability of GNSS Positioning: Integrity and Continuity for Standalone and Augmented GNSS Users," *Seoul National University (SNU) Tutorial*, Seoul, Korea, July 10, 2017.

[T37] "GNSS Vulnerabilities: Threats and Failure Modes that May Affect GNSS Positioning," *Seoul National University (SNU) Tutorial*, Seoul, Korea, July 10, 2017.

[T36] "Safe Separation of UAVs based on Local-Area DGNSS Networks," *Korea Navigation Institute (KONI) Advanced Navigation System Workshop*, Seoul, Korea, July 7, 2017.

[T35] "Reliability of GNSS Positioning: Integrity and Continuity for Standalone and Augmented GNSS Users," *International Seminars on Positioning and Navigation 2017*, ENAC Toulouse, France, May 12, 2017.

[T34] "Lessons Learned from the Study of Anomalous Ionospheric Gradients and their Impact on GBAS and SBAS," *International Seminars on Positioning and Navigation 2017*, ENAC Toulouse, France, May 11, 2017.

[T33] "GNSS Vulnerabilities: An Overview of Challenges to Safe and Predictable GNSS Positioning," *International Seminars on Positioning and Navigation 2017*, ENAC Toulouse, France, May 10, 2017.

[T32] "Lessons Learned During the Development of GNSS Integrity Monitoring and Verification Techniques for Aviation Users," *International Technical Symposium on Navigation and Timing 2016*, ENAC, Toulouse, France, Nov. 16, 2016.

[T31] "Lessons Learned from Two Decades of Research on GNSS Integrity Verification," *Tokyo University of Marine Science and Technology (TUMST)*, Tokyo, Japan, Nov. 20, 2015.

[T30] "Lessons Learned from Two Decades of Research on GNSS Integrity Verification," *International Symposium on GNSS 2015 (IS-GNSS 2015)*, Plenary Presentation, Kyoto, Japan, Nov. 16, 2015.

[T29] "Development of Ground Based Augmentation of Global Positioning Systems: Addressing the Key Challenges," *Osaka Prefecture University Symposium*, Sakai (Osaka), Japan, Nov. 13, 2015.

[T28] "Safety Analysis and Verification for Users of Global Navigation Satellite Systems (GNSS)," *Osaka Prefecture University Symposium*, Sakai (Osaka), Japan, Nov. 12, 2015.

[T27] "The Use of Threat Models in Aviation Safety Assurance and an Update on Technical Challenges for Ground-Based Augmentation Systems (GBAS)," *Technical University of Munich (TUM) Satellite Navigation Colloquium*, Munich, Germany, July 11, 2014.

[T26] "A Review of GBAS Integrity Risk Mitigation: Focused on Ionospheric Threats to Equatorial Locations and CAT II/III Operations," *German Aerospace Center (DLR) GBAS Workshop*, Oberpfaffenhofen (Munich), Germany, July 10, 2014.

[T25] "Augmented GNSS: Fundamentals and Keys to Integrity and Continuity," *ION GNSS 2013* Tutorial, Nashville, TN, Sept. 16, 2013.

[T24] "Augmented GNSS: Fundamentals and Keys to Integrity and Continuity," *ION GNSS 2012* Tutorial, Nashville, TN, Sept. 18, 2012.

[T23] "Unintentional RF Interference to GNSS: A Growing Problem," *18th Korean GNSS Workshop*, Jeju, Korea, Nov. 3, 2011.

[T22] "The Impact of Personal Privacy Devices on GBAS and Potential Mitigations," *3rd Asia-Oceania Regional Workshop on GNSS*, Jeju, Korea, Nov. 2, 2011.

[T21] "Augmented GNSS: Fundamentals and Keys to Integrity and Continuity," *ION GNSS 2011* Tutorial, Portland, OR, Sept. 20, 2011.

[T20] "Improvements to GBAS Ionospheric Mitigation," *International GBAS Working Group (I-GWG) 11 Meeting*, Osaka, Japan, Feb. 23, 2011.

[T19] "GNSS Research at Stanford University: Recent Activities and Results," *Tokyo University of Mercantile Marine*, Tokyo, Japan, Nov. 15, 2010.

[T18] "Recent Progress on GNSS and Ground-Based Augmentation Systems (GBAS)," *JAXA Chofu Aerospace Center (CAC)*, Chofu, Tokyo, Japan, Nov. 9, 2010.

[T17] "Highlights of Recent Stanford Work on GBAS," *German Aerospace Center (DLR)*, Oberpfaffenhofen (Munich), Germany, Sept. 30, 2010.

[T16] "Ionospheric Anomaly Mitigation: Present and Future," *International GBAS Working Group (I-GWG) 10 Meeting*, Brussels, Belgium, June 3, 2010.

[T15] "Recent Stanford GBAS Research: CAT III and DCPS," *German Aerospace Center (DLR)*, Oberpfaffenhofen (Munich), Germany, March 3, 2010.

[T14] "An Overview of Ground-Based Augmentation of GNSS," *Technical University of Braunschweig*, Braunschweig, Germany, Feb. 24, 2010.

[T13] "Stanford GNSS Research: Recent Activities and Results," *German Aerospace Center (DLR)*, Oberpfaffenhofen (Munich), Germany, Feb. 22, 2010.

[T12] "Local Area Augmentation of the Global Positioning System: An Overview of the Technology and its Development," *Stanford University*, AA 297 Seminar, May 13, 2009.

[T11] "Completion of CAT I LAAS Integrity Analysis and Future Work," *German Aerospace Center (DLR)*, Oberpfaffenhofen (Munich), Germany, Oct. 1, 2008.

[T10] "Fundamentals of Ground Based Augmentation Systems (GBAS) and Key Drivers of GBAS User Performance," *Japan GPS/GNSS Symposium 2007*, Invited Tutorial, Tokyo, Japan, Nov. 20, 2007.

[T09] "LAAS Overview and Highlights of Stanford LAAS Research," *Peking University*, "Digital China" Symposium, Beijing, China, Nov. 16, 2007.

[T08] "LAAS Technical Overview and Key Details from Stanford Research," *Beihang University (BUAA)*, Beijing, China, Nov. 14, 2007.

[T07] "The Fundamentals of Satellite Navigation: Present and Future," *Beihang University (BUAA)*, Beijing, China, Nov. 13, 2007.

[T06] "An Update on LAAS Ionosphere Anomaly Mitigation Strategy for CONUS," *International GBAS Working Group (I-GWG) 6 Meeting*, Mukilteo (Seattle), Washington, July 18, 2007.

[T05] "Ionosphere Anomaly Mitigation for CAT I GBAS Users Outside CONUS," *International GBAS Working Group (I-GWG) 5 Meeting*, Toulouse, France, Nov. 29, 2006.

[T04] "Mitigation of Ionosphere Spatial Anomaly Threat to GBAS," *International GBAS Working Group (I-GWG) 4 Meeting*, Sydney, Australia, Feb. 8, 2006.

[T03] "Update on LAAS Ionosphere Spatial Anomaly Threat Studies," *RTCA Special Committee 159*, Washington, DC, March 8, 2005.

[T02] "Status of CAT I LAAS Ionosphere Anomaly Resolution," *RTCA Special Committee 159*, Washington, DC, Oct. 5, 2004.

[T01] "System Overview, Recent Developments, and Future Outlook for SBAS and GBAS," *Osaka Prefectural University*, Sakai, Osaka, Japan, Nov. 21, 2003.

CONFERENCE PAPERS (*Note*: within numbering, "[Mxy]" = "[C1xy]")

[M58] J. Lee, G. Nam, D. Min, A.K. Sun, **S. Pullen**, "Network-Based Augmentation System (NBAS) Architectures Optimized to Support Urban Air Mobility (UAM)," *Proc. ION ITM 2023*, Long Beach, CA, Jan. 24-26, 2023, pp. 441-453. https://doi.org/10.33012/2023.18603

[M57] **S. Pullen**, S. Lo, I. Colobong, S. Oak, J. Blanch, T. Walter, M. Crews, R. Jackson, S. Young, K. Huttenhoff, "GNSS Constellation Performance Using ARAIM with Inclined Geosynchronous Satellite and Low-Earth-Orbit Satellite Augmentation," *Proc. ION ITM 2023*, Long Beach, CA, Jan. 24-26, 2023, pp. 664-678. https://doi.org/10.33012/2023.18661

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[M55] L. Marini-Pereira, A.O. Moraes, **S. Pullen**, "A Simple and Effective Approach to Real-Time Ionospheric Monitoring for GBAS in Low Latitudes," *Proc. ION GNSS+ 2022*, Denver, CO, Sept. 19-23, 2022, pp. 2954-2969. https://doi.org/10.33012/2022.18339

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[M53] F. Rispoli, A. Vennarini, A. Vizzarri, R. Capua, A. Neri, **S. Pullen**, "On the GNSS Augmentation Services for the ERTMS Train Control and Connected Car Applications: Technical Synergies and Opportunities," *Proc. ION GNSS+ 2022*, Denver, CO, Sept. 19-23, 2022, pp. 1514-1528. https://doi.org/10.33012/2022.18423

[M52] G. Nam, D. Min, N.M. Kim, J. Lee, **S. Pullen**, "Optimal Smoothing and Monitor Strategies for Dual-Frequency Dual-Constellation (DFDC) LADGNSS under Anomalous Ionospheric Conditions," *Proc. ION ITM 2022*, Long Beach, CA, Jan. 25-27, 2022, pp. 1156-1174. https://doi.org/10.33012/2022.18166

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[M49] A. Katz, **S. Pullen**, S. Lo, J. Blanch, T. Walter, A. Katronick, M. Crews, R. Jackson, "ARAIM for Military Users: ISM Parameters, Constellation-Check Procedure and Performance Estimates," *Proc. ION ITM 2021*, Virtual Meeting, Jan. 25-28, 2021, pp. 173-188. https://doi.org/10.33012/2021.17812

[M48] R. Capua, A. Filip, A. Neri, **S. Pullen**, F. Rispoli, P. Salvatori, C. Stallo, "A Multi-sensor Platform for High Integrity Multi-modal Positioning System," *Proc. ION GNSS+ 2020*, Virtual Meeting, Sept. 21-25, 2020, pp. 362-386. https://doi.org/10.33012/2020.17608

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[M45] H. Chang, M. Yoon, J. Lee, **S. Pullen**, L.M. Pereira, "Assessment of Ionospheric Spatial Decorrelation for Daytime Operations of GBAS in the Brazilian Region," *Proc. ION ITM 2019*, Reston, VA, Jan. 28-31, 2019, pp. 618-631. https://doi.org/10.33012/2019.16673

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[M41] J. Lee, M. Kim, J. Lee, **S. Pullen**, "Integrity Assurance of Kalman-filter Based GNSS/IMU Integrated Systems against IMU faults for UAV Applications," *Proc. ION GNSS+ 2018*, Miami, FL, Sept. 24-28, 2018, pp. 2484-2500. https://doi.org/10.33012/2018.15977

[M40] S. Khanafseh, M. Joerger, T. Walter, **S. Pullen**, J. Blanch, K. Doherty, L. Norman, L. de Groot, B. Pervan, "GNSS Multipath Error Modeling for Automotive Applications,"*Proc. ION GNSS+ 2018*, Miami, FL, Sept. 24-28, 2018, pp. 1573-1589. https://doi.org/10.33012/2018.16107

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[M37] **S. Pullen**, J. Lee, M. Kim, D. Kim, J. Lee "Coordinated UAV Operations Based on Local-Area Differential GNSS Navigation and Guidance," *Proc. 5th ENRI Int'l. Workshop on ATM/CNS 2017 (EIWAC 2017)*, Tokyo, Japan, Nov. 14-16, 2017. https://www.enri.go.jp/eiwac/eiwac_2017_eng.html

[M36] **S. Pullen**, R. Cassell, B. Johnson, M. Brenner, D. Weed, L. Cypriano, M. Topland, M. Stakkeland, B. Pervan, M. Harris, S. Saito, J. Lee, B. Clark, S. Beauchamp, J. Dennis, "Impact of Ionospheric Anomalies on GBAS GAST D Service and Validation of Relevant ICAO SARPs Requirements," *Proc. ION GNSS+ 2017*, Portland, OR, Sept. 25-29, 2017, pp. 2085-2105. https://www.ion.org/publications/abstract.cfm?articleID=15135

[M35] T. Cashin, B. El-Arini, V. Massimini, R. Niles, A. Odeh, G. Zheng, **S. Pullen**, C.-G. Wei, G. Shu, "Development and Implications of the Singapore GBAS Ionospheric Threat Model (GITM)," *Proc. ION GNSS+ 2017*, Portland, OR, Sept. 25-29, 2017, pp. 1429-1449. https://www.ion.org/publications/abstract.cfm?articleID=15320

[M34] S. Lo, **S. Pullen**, J. Blanch, P. Enge, A. Neri, V. Palma, M. Salvitti, C. Stallo, "Projected Performance of a Baseline High Integrity GNSS Railway Architecture under Nominal and Faulted Conditions," *Proc. ION GNSS+ 2017*, Portland, OR, Sept. 25-29, 2017, pp. 2148-2171. http://web.stanford.edu/group/scpnt/gpslab/pubs/papers/Lo_IONGNSS_2017_Railway.pdf

[M33] T. Sasaki, T. Shimomura, **S. Pullen**, H. Schaub, "Attitude and Vibration Control for a Flexible Spacecraft with Double-Gimbal Variable-Speed Control Moment Gyros," *Proc. 3rd IAA Conference on Dynamics and Control of Space Systems (DYCOSS 2017)*, Moscow, Russia, May 30 – June 1, 2017. http://hanspeterschaub.info/Papers/Sasaki2017.pdf

[M32] D. Kim, M. Yoon, J. Lee, **S. Pullen**, D. Weed, "Monte Carlo Simulation for Impact of Anomalous Ionospheric Gradient on GAST-D GBAS," *Proc. ION Pacific PNT 2017*, Honolulu, HI, May 1-4, 2017, pp. 47-55. https://www.ion.org/publications/abstract.cfm?articleID=15049

[M31] A. Neri, V. Palma, F. Rispoli, **S. Pullen**, S. Zhang, S. Lo, P. Enge, "A Method for Multipath Detection and Mitigation in Railway Control Applications," *Proc. ION GNSS+ 2016*, Portland, OR, Sept. 12-16, 2016, pp. 1843-1855. https://www.ion.org/publications/abstract.cfm?articleID=14650

[M30] M. Yoon, D. Kim, J. Lee, S. Rungruengwajiake, **S. Pullen**, "Assessment of Equatorial Plasma Bubble Impacts on Ground-Based Augmentation Systems in the Brazilian Region," *Proc. ION ITM 2016*, Monterey, CA, Jan. 25-28, 2016, pp. 368-379. http://ion.org/publications/abstract.cfm?articleID=13423

[M29] **S. Pullen**, J. Lee, M. Yoon, "Optimal Scheduling of Arrivals at Low-Latitude Airports under Severe Ionospheric Spatial Gradients," *Proc. 4th ENRI Int'l. Workshop on ATM/CNS 2015 (EIWAC 2015)*, Tokyo, Japan, Nov. 17-19, 2015. http://comm.stage.ac/eiwac2015/en/index.html

[M28] **S. Pullen**, P. Enge, "Online ARAIM Architecture Evaluation to Support a Single GNSS Constellation," *Proc. ION GNSS+ 2015*, Tampa, FL, Sept. 14-18, 2015, pp. 375-405. http://ion.org/publications/abstract.cfm?articleID=12824

[M27] J. Lee, M. Yoon, **S. Pullen**, J. Gillespie, N. Mathur, R. Cole, J.R. de Souza, P. Doherty, R. Pradipta, "Preliminary Results from Ionospheric Threat Model Development to Support GBAS Operations in the Brazilian Region," *Proc. ION GNSS+ 2015*, Tampa, FL, Sept. 14-18, 2015, pp. 1500-1506. http://ion.org/publications/abstract.cfm?articleID=13040

[M26] M-S. Circiu, M. Felux, B. Belabbas, M. Meurer, J. Lee, M. Kim, **S. Pullen**, "Evaluation of GPS L5, Galileo E1 and Galileo E5a Performance in Flight Trials for Multi Frequency Multi

Constellation GBAS," *Proc. ION GNSS+ 2015*, Tampa, FL, Sept. 14-18, 2015, pp. 897-906. http://ion.org/publications/abstract.cfm?articleID=12967

[M25] M. Yoon, D. Kim, J. Lee, **S. Pullen**, "Multi-dimensional Verification Methodology of Ionospheric Gradient Observation during Plasma Bubble Events in the Brazilian Region," *Proc. ION Pacific PNT 2015*, Honolulu, HI, April 20-23, 2015, pp. 748-762. https://www.ion.org/publications/abstract.cfm?articleID=12762

[M24] M-S. Circiu, M. Felux, S. Thölert, F. Antreich, M. Vergara, M. Sgammini, C. Enneking, **S. Pullen**, "Evaluation of GPS L5 and Galileo E1 and E5a Performance for Future Multi Frequency and Multi Constellation GBAS," *Proc. ION ITM 2015*, Dana Point, CA, Jan. 26-28, 2015, pp. 374-382. http://ion.org/publications/abstract.cfm?articleID=12636

[M23] **S. Pullen**, P. Enge, "GPS III Accuracy and Integrity Improvements Using ARAIM with Shorter Age of Data," *Proc. ION GNSS+ 2014*, Tampa, FL, Sept. 8-12, 2014, pp. 3352-3362. http://ion.org/publications/abstract.cfm?articleID=12457

[M22] M. Kim, K. Kim, J. Lee, **S. Pullen**, "High Integrity GNSS Navigation and Safe Separation Distance to Support Local-Area UAV Networks," *Proc. ION GNSS+ 2014*, Tampa, FL, Sept. 8-12, 2014, pp. 869-878. http://ion.org/publications/abstract.cfm?articleID=12424

[M21] **S. Pullen**, "The Use of Threat Models in Aviation Safety Assurance: Advantages and Pitfalls," *Proc. 2014 Intl. Symp. on Certification of GNSS Systems & Services (CERGAL 2014)*, Dresden, Germany, July 7-8, 2014.

[M20] J. Lee, S. Datta-Barua, **S. Pullen**, "Conceptual Study of Real-time Ionospheric Threat Adaptation Using Space Weather Forecasting for GNSS Augmentation Systems," *Proc. ION ITM 2014*, San Diego, CA, Jan. 27-29, 2014, pp. 645-656. http://ion.org/publications/abstract.cfm?articleID=11538

[M19] M-S. Circiu, M. Felux, P. Remi, L. Yi, B. Belabbas, **S. Pullen**, "Evaluation of Dual Frequency GBAS Performance Using Flight Data," *Proc. ION ITM 2014*, San Diego, CA, Jan. 27-29, 2014, pp. 645-656. http://ion.org/publications/abstract.cfm?articleID=11535

[M18] H. Tokura, H. Yamada, N. Kubo, **S. Pullen**, "The Use of Multiple GNSS Constellations with Strict Quality Constraints for Achieving High Accuracy in Urban Environments," *Proc. ION ITM 2014*, San Diego, CA, Jan. 27-29, 2014, pp. 488-498. http://ion.org/publications/abstract.cfm?articleID=11518

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