

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

GOOGLE LLC, SAMSUNG ELECTRONICS CO., LTD., AND
SAMSUNG ELECTRONICS AMERICA, INC.,
PETITIONERS,

v.

NARISTE NETWORKS PTY. LTD.,
PATENT OWNER.

CASE IPR2023-01374
PATENT RE48,206

DECLARATION OF DR. SAMUEL PULLEN

TABLE OF CONTENTS

CURRENT EXHIBIT LIST	iii
CLAIM LISTING	i
I. INTRODUCTION	1
II. PROFESSIONAL BACKGROUND AND QUALIFICATIONS.....	2
A. Prior Testimony	5
III. RELEVANT TIME.....	5
IV. LEVEL OF ORDINARY SKILL IN THE ART	5
V. MATERIALS CONSIDERED	6
VI. INTERPRETATION OF THE CLAIMS	6
A. Claims 37, 40, and 43: “at least one of a current radio position and a position error of said mobile device”	6
B. Claims 37, 40, and 43: “position error of said mobile device determined from the wireless communications network”	7
VII. ISSUES CONCERNING PETITIONERS USE OF U.S. PATENT NO. 5,982,324 (“WATTERS”)	9
A. Claims 37[b] 40[c], and 43[c]: Watters Does Not Disclose using a “Position Error of Said Mobile Device” to Determine When to Power on a GPS Module.....	9
B. Claims 37[b] 40[c], and 43[c]: Watters Does Not Disclose using “A Current Position . . . of Said Mobile Device Determined from the Wireless Communications Network” to Determine When to Power On a GPS Module	13
C. Claims 39/42/45: Watters Does Not Disclose “wherein said determining when said embedded GPS module should be powered on is also dependent on at least one of; a last satellite position; a last position determined by the GPS; and a last time determined by the GPS.”	16

VIII. ISSUES CONCERNING PETITIONERS' USE OF U.S. PATENT PUB. NO. 2002/0151314 ("NOHARA").....	17
A. Claims 37[b] 40[c], and 43[c]: Nohara Does Not Disclose Using a "Position Error of Said Mobile Device" to Determine When to Power On a GPS Module.....	17
IX. DECLARATION	27

CURRENT EXHIBIT LIST

No.	Brief Description
1001	U.S. Patent No. RE48,206
1002	Declaration of Scott Andrews
1003	Curriculum Vitae of Scott Andrews
1004	Prosecution History of U.S. Patent No. RE48,206
1005	U.S. Patent No. 5,982,324 to Watters (“Watters”)
1006	U.S. Patent Publication No. 20020151314 to Nohara (“Nohara”)
1007	U.S. Patent No. 6,975,941 to Lau (“Lau”)
1008	INTENTIONALLY LEFT BLANK
1009	INTENTIONALLY LEFT BLANK
1010	INTENTIONALLY LEFT BLANK
1011	INTENTIONALLY LEFT BLANK
1012	INTENTIONALLY LEFT BLANK
1013	INTENTIONALLY LEFT BLANK
1014	INTENTIONALLY LEFT BLANK
1015	INTENTIONALLY LEFT BLANK
1016	INTENTIONALLY LEFT BLANK
1017	INTENTIONALLY LEFT BLANK
1018	INTENTIONALLY LEFT BLANK
1019	INTENTIONALLY LEFT BLANK
1020	Claim Mapping Table
1021	Nariste Networks Pty. Ltd.’s Sur-Reply in Opposition to Defendants’ Rule 12(b)(6) Motion to Dismiss Under 35 U.S.C. § 251 and the Rule Against Recapture
1022	Yilin Zhao, Vehicle Location and Navigation Systems 43–81 (Illustrated ed. 1997).
1023	U.S. Patent No. 5,592,173 to Lau et al (“Lau”)
1024	U.S. Patent No. 6,748,224 to Chen et al (“Chen”)
1025	U.S. Patent No. 6,889,053 to Chang et al (“Chang”)
1026	U.S. Patent No. 5,663,734 to Krasner et al (“Krasner”)
1027	U.S. Patent No. 5,594,453 to Rodal et al (“Rodal”)
1028	U.S. Patent No. 7,409,188 to Syrjarinne et al (“Syrjarinne”)

No.	Brief Description
1029	U.S. Patent Publication No. 20050083230 to Harvey et al (“Harvey”)
1030	Xinrong Li, Kaveh Pahlavan, and Jacques Beneat, Performance of TOA estimation Techniques in Indoor Multipath Channels 911–915 (2002).
1031	Flowchart, https://en.wikipedia.org/w/index.php?title=Flowchart&oldid=1169392868 (last visited Aug. 30, 2023).
1032	Central processing unit, https://en.wikipedia.org/w/index.php?title=Central_processing_unit&oldid=1172444772 (last visited Aug. 30, 2023)
1033	Samir S. Soliman and Charles E. Wheatley, Geolocation technologies and applications for third generation wireless 229–251 (2002).
1034	Samir Soliman, Parag Agashe, Ivan Fernandez, Alkinoos Vayanos, Peter Gaal, and Milan Oljaca, gpsOne™: A hybrid position location system 330–335 (2000).
1035	A. M. Turing, On Computable Numbers, With an Application to the Entscheidungsproblem 230–265 (1936).
1036	Defendants’ Motion to Transfer Venue to the Northern District of California Under 28 U.S.C. § 1404(a)
1037	Defendants’ Rule 12(b)(6) Motion to Dismiss Under 35 U.S.C. § 251 and the Rule Against Recapture
1038	Nariste Networks Pty. Ltd.’s Response in Opposition to Defendants’ Rule 12(b)(6) Motion to Dismiss Under 35 U.S.C. § 251 and the Rule Against Recapture
1039	Defendants’ Reply in Support of Rule 12(b)(6) Motion to Dismiss Under 35 U.S.C. § 251 and the Rule Against Recapture (Dkt. 23)
1040	Plaintiff’s Disclosure of Asserted Claims and Infringement Contentions and Identification of Document Production Accompanying Disclosure
2001	Declaration of Dr. Samuel Pullen
2002	Prosecution History of U.S. Patent No. 8,022,870
2003	Marius Specht, Experimental Studies on the Relationship Between HDOP and Position Error in the GPS System, Metrology and Measurement Systems, Vol. 29 No1, pp. 17-36 (2022)
2004	U.S. Patent No. 6,061,021 to Zibell (Zibell)

No.	Brief Description
2005	U.S. Patent No. 5,894,266 to Wood, Jr. et al (“Wood”)
2006	U.S. Patent No. 6,424,843 to Reitmaa et al (“Reitmaa”)
2007	P. Misra and P. Enge, Global Positioning System: Signals, Measurement, and Performance, Ganga-Jamuna Press, 2 nd Ed., 2006.
2008	F.J. Bueche and E. Hecht, Schaum’s Outline of Theory and Problems of College Physics, McGraw-Hill, 9th Ed., 1997.
2009	E.D. Kaplan and C.J. Hegarty, Eds., Understanding GPS: Principles and Applications, Artech House, 2 nd Ed., 2006.
2010	B. Parkinson, J. Spilker, P. Axelrad, P. Enge, Eds., Global Positioning System: Theory and Applications, Volume I, American Institute of Aeronautics and Astronautics (AIAA), 1996.
2011	S. Liao, Why GPS-dependent Apps Deplete Your Smartphone Battery, The Verge (Aug. 17, 2018)
2012	M. Sullivan, <i>A Brief History of GPS</i> , PCWorld (Aug. 9, 2012), available at https://www.pcworld.com/article/461346/a-brief-history-of-gps.html
2013	E. Eason, <i>Smartphone Battery Inadequacy</i> , Stanford University (Dec. 17, 2020), available at http://large.stanford.edu/courses/2010/ph240/eason1/ .

CLAIM LISTING

	Limitation
37[pre]	A method of acquiring a position on a mobile wireless communication device for a wireless communications network, said mobile wireless communication device possessing wireless communications capability for said wireless communications network and an embedded GPS module for GPS capability, said GPS referring to GPS-based techniques, said method comprising:
37[a]	determining when said embedded GPS module should be powered on, said embedded GPS module then being powered on,
37[b]	said when said embedded GPS module should be powered on being dependent on at least one of a current radio position and a position error of said mobile device determined from the wireless communications network, said wireless communications network being different from said GPS.
38	The method according to claim 37, wherein said powered on comprises said module powering up from a low-power mode such as a TricklePower power-down mode.
39	The method according to claim 37, wherein said determining when said embedded GPS module should be powered on is also dependent on at least one of; a last satellite position; a last position determined by the GPS; and a last time determined by the GPS.
40[pre]	A mobile wireless communication device for a wireless communications network, said mobile wireless communication device possessing wireless communications capability for said wireless communications network and an embedded GPS module for GPS capability, said GPS referring to GPS-based techniques, said mobile wireless communication device comprising:
40[a]	an embedded GPS module providing a GPS capability for said mobile wireless communication device;
40[b]	and means for determining when said embedded GPS module should be powered on, said embedded GPS module then being powered on,
40[c]	said determining when said embedded GPS module should be powered on being dependent on at least one of a current radio position and a position error of said mobile device determined from the wireless communications network, said wireless communications network being different from said GPS.
41	The mobile device according to claim 40, wherein said powered on comprises said module powering up from a low-power mode such as a TricklePower power-down mode.

	Limitation
42	The mobile device according to claim 40, wherein said determining when said embedded GPS module should be powered on is also dependent on at least one of; a last satellite position; a last position determined by the GPS; and a last time determined by the GPS.
43[pre]	A computer program product for a mobile wireless communication device for a wireless communication network, said mobile wireless communication device possessing wireless communications capability for said wireless communications network and an embedded GPS module for GPS capability, said GPS referring to GPS-based techniques, said computer program product embodied on computer readable storage medium, said computer program product for acquiring a GPS position on said mobile wireless communication device, comprising:
43[a]	a first portion designed to interface with the GPS capability of said mobile wireless communication device;
43[b]	and a second portion designed to determine when said embedded GPS module should be powered on, said embedded GPS module then being powered on,
43[c]	said determining when said embedded GPS module should be powered on being dependent on at least one of a current radio position and a position error of said mobile device determined from the wireless communications network, said wireless communications network being different from said GPS.
44	The computer program product according to claim 43, wherein said powered on comprises said module powering up from a low-power mode such as a TricklePower power-down mode.
45	The computer program product according to claim 43, wherein said determining when said embedded GPS module should be powered on is also dependent on at least one of; a last satellite position; a last position determined by the GPS; and a last time determined by the GPS.

I. INTRODUCTION¹

¶1. My name is Dr. Samuel (“Sam”) Pullen. I have been retained by Nariste Networks Pty. Ltd. (“Patent Owner” or “Nariste”) to provide my expert assessment and technical opinions in connection with the above captioned inter partes review (“IPR”) of U.S. Patent No. Patent RE48,206 (“’206 Patent” or “Patent-at-Issue”), Ex. 1001.

¶2. Specifically, I have been asked to provide my opinions regarding specific aspects of the how a person of ordinary skill in the art (“POSITA”) would understand certain teachings and aspects of the references that Petitioners put forth vis-à-vis the Patent-at-Issue.

¶3. This declaration is based on information currently available to me. I reserve the right to expand, modify, or supplement my opinions if I become aware of evidence or information that was not available for review at the time I drafted this declaration.

¶4. Nariste is paying me at a rate of \$400 per hour plus expenses for my study and testimony in this case. This compensation is not contingent upon my performance, the outcome of this IPR, or any issues involved in or related to this IPR.

¹ All emphasis is added in this report unless otherwise noted.

II. PROFESSIONAL BACKGROUND AND QUALIFICATIONS

¶5. My Curriculum Vitae (“CV”), detailing my background and qualifications, is submitted herewith as Appendix 1. I am a part-time Senior Research Engineer in the Department of Aeronautics and Astronautics at Stanford University. I have worked with navigation system technology, such as GPS and Global Navigation Satellite System (“GNSS”) navigation systems, inertial navigation systems, communication systems, and test procedures to support such systems for more than 25 years. My experience includes requirements and specification development, system development, system implementation, and verification testing. I am familiar with the subject matter of this case and consider myself an expert in, among other things, the fundamentals of navigation systems, GNSS (satellite) and related navigation systems, the fusion of GNSS with other navigation technologies, communications between these systems and others (users and control facilities), and the application of those technologies to aircraft, ships, land vehicles, and autonomous systems.

¶6. I received two Bachelor of Science degrees from the Massachusetts Institute of Technology in 1989, one in Aeronautics and Astronautics and the other in History. I received a Master of Science degree in Aeronautics and Astronautics, with an emphasis on guidance and control systems, from Stanford in 1990, and I received my Ph.D. in Aeronautics and Astronautics from Stanford in 1996. My Ph.D.

thesis is entitled “Probabilistic Engineering Design Optimization: Applications to Spacecraft and Navigation Systems.”

¶7. From 1996 through the present, I have worked as a consultant (mostly self-employed and also for NavAstro of Los Gatos, California) on many projects involving navigation systems, including the conceptual development of GNSS systems and their applications to aviation, rail, automotive, maritime, and autonomous users. I have also worked on the GPS III Modernization efforts for the DOD GPS Joint Program Office. In addition, I have supported projects outside of navigation and GNSS, including safety analysis, risk assessment and management, and system optimization under risk and uncertainty.

¶8. In 1996, upon completing my Ph.D., I began working at the Hansen Experimental Physics Laboratory at Stanford University. While at this Laboratory, I developed, installed, and validated the first LAAS ground system prototype that included all the real-time integrity verification algorithms needed to meet the LAAS safety requirements. I also provided research support to several projects, including the Wide Area Augmentation System, Satellite-based Augmentation Systems, and JPALS integrity verification. I also provided technical support for algorithm design, testing, and validation for Local Area Augmentation System (LAAS) and Ground-based Augmentation System (GBAS), and for system architecture, algorithm design, and requirements assessment of the U.S. Navy’s Joint Precision Approach and

Landing System (JPALS). I also taught a graduate-level course called “AA279 - Space Mechanics,” and I was a guest lecturer for the “Global Positioning Systems” course and other courses in the Aero/Astro department. In 2007, I moved to the Aeronautics and Astronautics Department and continued my work, expanding it to include the integrity of other GNSS constellations and applications such as Precise Point Positioning (PPP) and the combination of GNSS with other sensors.

¶9. I have been recognized for my contributions to the technology and development of navigation systems and have served on several professional committees. For example, I received the Institute of Navigation Early Achievement Award in 1999 and have been honored with the ION GPS/GNSS Conference “Best Paper” Award four times—in 1999, 2000, 2001, and 2009. Also, I currently serve as a reviewer for industry journals such as IEEE, AIAA, and ION, and I was the Associate Editor for Navigation for *IEEE Transactions on Aerospace and Electronic Systems* from 2007-2015. I have also chaired several conferences for ION, IEEE, and others. I was elected as a Fellow of the ION in 2017.

¶10. In addition to my professional recognition, I am a co-inventor of U.S. Patent No. 6,667,713, entitled “Self-monitoring satellite system.” As shown in my CV (Exhibit 1), I have also authored or co-authored more than 200 book chapters, reports, journal papers, industry magazine articles, and conference papers on various topics related to navigation systems, including GBAS, GNSS, GPS, and have been

an invited speaker at more than 30 navigation-related conference and seminars since 2003.

A. Prior Testimony

¶11. As a technical consultant (see paragraph 3), I have testified as an expert at trial and by deposition within the last 5 years, as detailed in Appendix 2.

III. RELEVANT TIME

¶12. I have been asked to assume that the Patent-at-Issue has an effective priority date of September 2, 2004 (“Effective Priority Date”).

¶13. To the extent that I cite to exhibits created or published after the Effective Priority Date, I consider the reference to still be relevant to what a POSITA would have understood at or around the time of the invention.

IV. LEVEL OF ORDINARY SKILL IN THE ART

¶14. I understand that Petitioners have proposed that a person of ordinary skill in the art (“POSITA”) for the ’206 Patent “would have had a bachelor's degree in electrical engineering, computer engineering, computer science, or a related field, and at least two years of experience in the research, design, development, and/or testing of GPS and/or cellular positioning devices and techniques, and related firmware and software, or the equivalent, with additional education substituting for experience and vice versa” Pet. 7 (citing Andrews Dec’1 ¶¶33–69).

¶15. I understand that Patent Owner generally concurs with Petitioner description.

¶16. It is my opinion that I would at least qualify as a person of ordinary skill in the art at the relevant time, and that I exceed this level of knowledge, experience, and education so that I am qualified to provide an expert opinion in this proceeding.

¶17. I have approached my analysis from the perspective of a POSITA as of the Effective Priority Date. To the extent that I cite documents that were created or published after the Effective Priority Date, I believe that their teachings are still instructive.

V. MATERIALS CONSIDERED

¶18. In forming my opinions expressed herein, I have considered the items listed in the “Current Exhibit” list beginning on page iii and the Petition.

VI. INTERPRETATION OF THE CLAIMS

A. Claims 37, 40, and 43: “at least one of a current radio position and a position error of said mobile device”

¶19. I understand that Petitioner claims to apply both a “disjunctive” and “conjunctive” construction of this term. Because Patent Owner has argued that this term should be construed in a “disjunctive” manner and because I understand that a “disjunctive” interpretation of this term is broader, I have only provided an analysis with respect to the “disjunctive” interpretation.

B. Claims 37, 40, and 43: “position error of said mobile device determined from the wireless communications network”

¶20. In analyzing the Petition and Dr. Scott Andrews’ Declaration (Ex. 1002), I believe Petitioners arguments rely on a definition of “position error” which deviates from how it would be conventionally understood by a POSITA. Position error is typically expressed in units of distance in the coordinate frame that position is determined (e.g., the World Geodetic Standard (WGS) 84). For example, a position of a mobile device may be expressed with an error of 50 meters or 100 meters in one or multiple axes.² In radionavigation, range measurements are made in units of time and then converted to units of distance by multiplying by the speed of light in vacuum (c). Position is computed from multiple range measurements and thus remains in units of distance. Ex. 2003, Ex. 2007, pp. 12-49.

¶21. After reviewing the ’206 Patent and its prosecution history, it is my opinion that a POSITA reading the claims of the ’206 Patent would understand that the ’206 Patent uses the term “position error” in the conventional manner. First, the ’206

² Position errors, like many other measurements, can be “normalized” and characterized as unitless numbers when the distance they represent has been normalized by a relevant statistical parameter that also has units of distance, such as the standard deviation of position error. In this case, the normalized position error would be in units of [e.g.] meters / meters. In all cases, the fundamental unit of position error is distance.

Patent describes the manner of calculating position error that is consistent with position error being expressed in units of distance. In describing a way that position error can be calculated, the '206 Patent states: “the difference between a predicted position and the actually position measured at time t can be used to formulate the position error.” Ex. 1001 at 6:43-46. A POSITA would understand that “difference” between two positions is expressed in units of distance.

¶22. Additionally, I understand that during prosecution of the original patent of which the '206 Patent is a reissue, U.S. Patent No. 8,022,870 ('870 Patent), the applicant and inventor, Dr. Robert Malaney, characterized position error as having units of distance. Ex. 2002 at pp. 303-304, November 7, 2010 Response and Amendment. In particular, the applicant provides a “real-world example” of using position error reported by a wireless network to control GPS power supply. *Id.* In this example, the inventor characterizes position error as follows “[i]magine the mobile application requires only a 100-meter location accuracy . . . If the reported error was less than 100 meters, the GPS power would not be turned on.” *Id.*

¶23. Because the inventor used “position error” in a manner consistent with the conventional definition of “position error” in both the specification of the '206 Patent and during prosecution of the '870 Patent, a POSITA would recognize that “position error” as used in the claims of the '206 Patent would have its conventional definition of having units of distance.

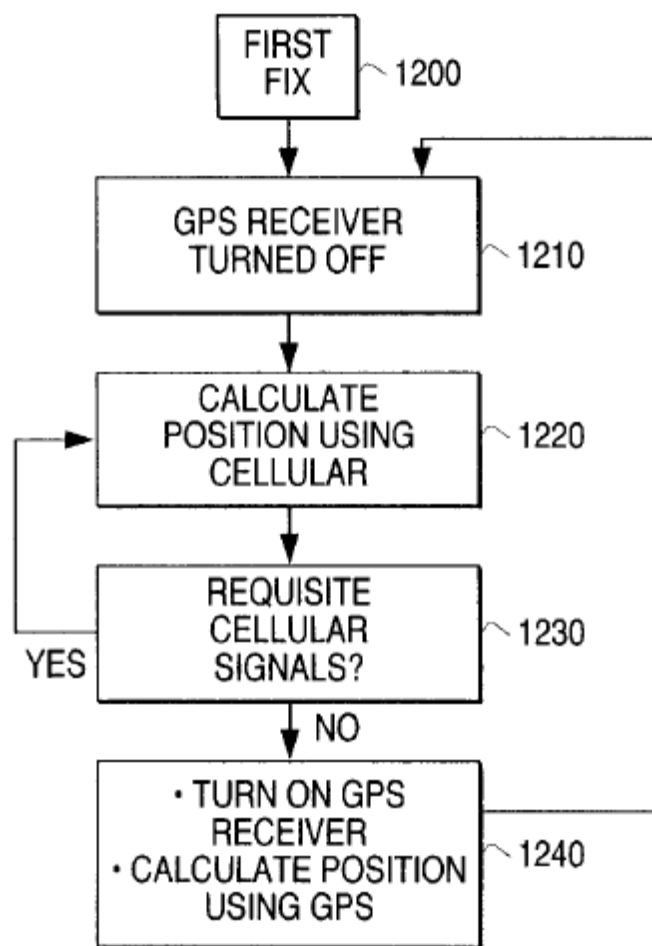
¶24. Additionally, claims 37, 40, and 43 recite that the “position error of said mobile device” is “determined from the wireless communications network.” A POSITA would understand that such determination refers to a calculation of position error using the wireless communications network. One way that position error could be “determined from the wireless communications network” is demonstrated by comparing a position measured from the wireless communication network with a position predicted by a real-time error estimator, such as a neural network, as described by the ’206 Patent. See, e.g., Ex. 1001 at 6:34-65, 7:3-21.

¶25. Other methods of determining position error from a wireless communication network are also known to POSITAs. One example is determining position from a wireless communications network at a location with a known position, such as at a survey marker, and comparing these two positions.

VII. ISSUES CONCERNING PETITIONERS USE OF U.S. PATENT NO. 5,982,324 (“WATTERS”)

A. Claims 37[b] 40[c], and 43[c]: Watters Does Not Disclose using a “Position Error of Said Mobile Device” to Determine When to Power on a GPS Module

¶26. The Petition argues that Watters discloses “determin[ing] when said embedded GPS module should be powered on being depending on. . . a position error of said mobile device determined from the wireless communications network” by virtue of Watters’ Fig. 12 (Pet. at 28), which I have reproduced below:

FIG. 12

Watters, Fig. 2.

¶27. The Petition argues that “step 1230 determines whether that cellular position signal has the requisite accuracy for continued use.” Pet. at 29. However, in my opinion, a POSITA would not have interpreted Fig. 12 of Watters or its corresponding description in the specification as disclosing the use of “position error of said mobile device determined from the wireless communications network” to “when said embedded GPS module should be powered on.” Fig. 12 of Watters is

clear that it only turns on GPS if the necessary cellular signals to calculate a position are not present. Watters discloses that “[a]t block 1230, a determination is made whether the requisite number of signals in the cellular network infrastructure are available for calculating position (e.g., three signals in the TDOA approach).” Watters at 22:50-54. A POSITA would recognize that in circumstances where the position *cannot* be calculated, position error also cannot be calculated. For example, Watters would turn on the GPS when no cellular signals are present. A POSITA would recognize that when no cellular signals are present, neither position nor position error could be determined from the cellular network.

¶28. The Petition’s reliance on Watters’ other discussion of “multi-path errors” and that “less frequent updates needed if ... cellular network infrastructure signals are known to be of good accuracy,” Pet. at 30-31, is likewise flawed. While Watters may generally disclose that signals “known” to have high accuracy produce a need for less frequent updates, Watters does not disclose making a determination of when to power on an embedded GPS receiver depending on a position error of said mobile device determined from the wireless communications network. Watters does not disclose determining the position error of a mobile device from the wireless communications network at all.

¶29. The Andrews Declaration discusses several sources of error in range measurements that propagate into position solution errors. Ex. 1002, ¶¶60-63.

Andrews describes these errors as “somewhat deterministic,” but this is incorrect. Ex. 1002, ¶63. Instead, the presence of these errors is known, but the magnitude (size) of these errors is not known because the knowledge needed to calculate them is not present. Instead, these errors are modeled as random variables, and probability distributions are assigned to them based on *a priori* knowledge (e.g., multipath errors are likely to be larger in urban areas with many buildings compared to open fields with few buildings). These distributions are themselves imperfect but at least provide a means to estimate the likely variations in both the range and position domains. Ex. 2003, Ex. 2007, pp. 48-49, pp. 147-194.

¶30. Note that, if the errors referenced by Andrews were deterministic and were known (or at least accurately estimated) in real time, these errors would be subtracted out of range measurements or position solutions, making them significantly more accurate (but still with some degree of random error). This is the principle behind Differential GPS (DGPS), which uses range error estimates derived by GPS “reference” receivers at known locations to compute corrections that are broadcast to nearby users, who subtract these corrections from their own measurements and thus remove most of the error (specifically, errors that are the same at both reference and user receivers will be removed). Ex. 2007, pp. 185-194.

B. Claims 37[b] 40[c], and 43[c]: Watters Does Not Disclose using “A Current Position . . . of Said Mobile Device Determined from the Wireless Communications Network” to Determine When to Power On a GPS Module

¶31. Watters teaches powering on its GPS receiver based on neither the current position nor the position error of the mobile device. Fig. 12 of Watters shows that if the position can be calculated from the cellular network, then the mobile device of Watters will continue to calculate its position from the cellular network. Therefore, the determination of when to power on Watters’ GPS receiver is not dependent on the position at all, but instead whether there are not enough signals to calculate a position at step 1230.

¶32. Watters also discloses alternatives to only turning the GPS on if there are insufficient cellular signals at step 1230:

Alternative inquires at block 1230 include determining how long (in time) it has been since the last GPS update and/or how far (in space) the mobile terminal has moved since the last GPS update. If a predetermined amount of time has passed, such as two minutes, or the mobile terminal has moved a predetermined distance, such as 100 meters, then a GPS update would be called for and the process proceeds to block 1240.

Watters at 22:57-64.

¶33. The Petition argues that this disclosure “teaches dependency on ‘current radio position” because “[a] POSITA would have understood that determining ‘how far’ a device has traveled *requires* knowing the starting position and the current position at the time the determination is made.” Pet. at 29-30 (emphasis added). I disagree. A

POSITA would recognize there are several ways to calculate distance traveled. For example, distance traveled can be calculated by simply multiplying a mobile device's velocity by the amount of time it has been traveling at that velocity.

¶34. For example, a well-known kinematic equation taught in high school physics gives the displacement s (distance traveled) in one dimension as a function of velocity (v), acceleration (a), and time elapsed (t):

$$s = v t + \frac{1}{2} a t^2$$

Ex. 2008, pp. 13-14. Note that, using this equation the displacement s is not dependent on the starting position $x(t=0)$.

¶35. Methods for determining velocity were well known to a POSITA at the time of Watters' filing. One method was to use the Doppler shift of a radio signal. Ex. 2004, 2:16-48. When a radio receiver (for example a GPS, cellular, WiFi, or other radio signal receiver) moves toward or away from the source of a signal, the wavelength of that signal is decreased or increased in proportion to the relative velocity of the receiver and the source of the signal. This is referred to as Doppler shift and is well-known to POSITAs. Doppler shift can be measured with respect to any radio signal; for example, with respect to a single cellular tower. By measuring the Doppler shift of a received signal, a mobile device could calculate its velocity, which can then be used to determine the distance it has moved during a selected time interval.

¶36. Alternatively, data from accelerometers present in a mobile device could be integrated (via calculus) over a selected time interval to determine how far the mobile device has moved. (This is how the kinematic equation for displacement shown in paragraph 34 was derived.) At the time Watters was filed, the concept of incorporating accelerometers in mobile devices was well known to POSITAs. Ex. 2005 9:24-31; Ex. 2006 7:47-10:4 (discussing inclusion of an “inertia sensor”). As Ex. 2006 notes, any information provided by an accelerometer (“inertia sensor” in the parlance of Ex. 2006), is “relative” and “only measures a position change from an initial position.” *Id.* 9:45-48. A POSITA would understand that a calculation of the distance a mobile device has moved using information from accelerometers does not use a position of that mobile device. It only uses the information gathered from the accelerometer from the location and/or time where the mobile device begins to move.

¶37. Because Watters describes using a time period since the last GPS measurement or a distance traveled as alternatives, a POSITA would recognize that using distance traveled instead of just a time period may provide the advantage of compensating for a fast-moving object. In this case, using distance traveled for a fast-moving mobile device could shorten the interval before GPS is turned on when compared to a fixed time interval. However, using only distance traveled can lead to disadvantages that a POSITA would recognize compared to using position of a

mobile device determined from the wireless network. For example, a mobile device that moves in a circle around a base station may move a sufficient distance to cause the system of Watters to turn its GPS on but end up exactly in the same position as it was in originally. Utilizing position to make the determination as claimed by the '206 Patent may prove advantageous in such a situation by decreasing the number of times the GPS module is activated, thereby conserving battery resources.

C. Claims 39/42/45: Watters Does Not Disclose “wherein said determining when said embedded GPS module should be powered on is also dependent on at least one of; a last satellite position; a last position determined by the GPS; and a last time determined by the GPS.”

¶38. In my opinion, Watters does not contain any disclosure of using a “last satellite position” to determine when to power on its GPS module. The Petition states that “the last position determined by the GPS is also dependent on the position of at least four GPS satellites” and that therefore Watter’s decision to power on its GPS receiver is “also based on ‘a last satellite position’ as well.” Petition at 36-37. I disagree with this statement. The position of the GPS receiver (i.e., a mobile device) is not *dependent* on the positions of any GPS satellites. In other words, a mobile device’s position solution will not change just because the GPS satellites are moving.

¶39. GPS satellites are in constant motion orbiting the Earth with known orbits whose orbital parameters (ephemerides) are communicated to GPS receivers in the GPS navigation message, and each completes one orbit around the Earth approximately every 12 hours.

¶40. A POSITA would readily understand that a stationary mobile device with a GPS receiver would report the same GPS position (because it has not moved) at any time during the day, even though the GPS satellites have moved. More precisely, GPS satellite motion changes the geometry matrix that expresses the three-dimensional line of sight from a GPS receiver to each satellite. Because the measured pseudoranges to these satellites also change accordingly, the position of a stationary receiver will not change due to predictable satellite motion. Ex. 2007, pp. 129-133, 200-220.

VIII. ISSUES CONCERNING PETITIONERS' USE OF U.S. PATENT PUB. NO. 2002/0151314 ("NOHARA")

A. Claims 37[b] 40[c], and 43[c]: Nohara Does Not Disclose Using a "Position Error of Said Mobile Device" to Determine When to Power On a GPS Module

¶41. In my opinion, Nohara does not teach the claims because Nohara does not teach using a "position error" to determine when to power on a GPS module as recited by Claim elements 37[B], 40[C], or 43[C]. This is the case because the "HDOP" of Nohara is not a "position error" in the way a POSITA would understand the term.

¶42. I understand that Nohara states that "[t]he value HDOP shall be regarded as the positioning error quantified on the plane in the horizon system of coordinates." I also understand that Nohara was originally filed and published in Japan.

¶43. As stated in Nohara, HDOP stands for “Horizontal Dilution of Precision.” Ex. 1006, ¶144. HDOP is one of several different Dilution of Precision measurements that may be computed. Ex. 2003 at 22. Other DOP measurements include VDOP (Vertical dilution of precision), PDOP (Position (3D) dilution of precision), TDOP (Time dilution of precision), and GDOP (Geometric dilution of precision). *Id.*; Ex. 2007, pp. 208-209. What all DOP measurements have in common is that they are a not a measurement of the actual error in position of a mobile device but instead can be used to relate errors in the range measurements (needed to determine a position) to the error in the resulting position solution.

¶44. In Nohara, HDOP is calculated using entries in the “covariance matrix,” which is a description of how range errors and user-to-transmitter geometry combine within a system. HDOP is a thus a direct result of the geometry of the system in which the measurements are taking place.

¶45. The standard definition of HDOP (and the other DOPs) is only based on the transmitter-to user geometry. This geometry is represented by a “geometry matrix” of dimensionless entries which are the direction cosines of the elements of the unit vector between the estimated user location and each transmitter followed by a “1” to represent the one-to-one relationship between transmitter clock error and range measurement error. This matrix is called “G” in Ex. 2007 and “A” in the Nohara patent. Ex. 2007, pp. 202-204. Ex. 1006, ¶138.

¶46. The “pseudoinverse” of the geometry matrix is given by (in the notation of Ex. 2007, p. 207):

$$\mathbf{H} = (\mathbf{G}^T \mathbf{G})^{-1}$$

and HDOP is then given by (Ex. 2007, p. 208-209):

$$HDOP = \sqrt{H_{11}^2 + H_{22}^2}$$

Where H_{11} and H_{22} represent the 1st and 2nd diagonal elements of $\mathbf{H}$ and correspond to the position axes “1” and “2”. Note that, because the elements of $\mathbf{G}$ are unitless, the elements of $\mathbf{H}$ are also unitless. Ex. 2007, pp. 208-209.

¶47. Nohara uses the same approach as shown above, where Nohara’s unitless matrix “ A ” is the equivalent of “ $\mathbf{G}$ ” of Ex. 2007. A POSITA would therefore understand that the calculation $(A^T \cdot A)^{-1}$ would result in a dimensionless matrix with dimensionless entries. Equations 7 and 8 of Nohara ($A \cdot \delta X = \delta R$ and $\delta X = A^{-1} \cdot \delta R$, respectively) also demonstrate to a POSITA that “ A ” is dimensionless because δX (the vector of unknown position errors in three dimensions and time) and δR (the vector of unknown range measurement errors) both have units of length. Therefore, “ A ” being dimensionless maintains the dimensions of each side of the equation. Ex. 1006, ¶141.

¶48. Nohara states that HDOP is derived from the entries of the matrix $(A^T \cdot A)^{-1}$, which Nohara refers to as the “covariance matrix.”

$$(A^T \cdot A)^{-1} = \begin{bmatrix} \sigma_{xx}^2 & \sigma_{xy}^2 & \sigma_{xs}^2 \\ \sigma_{yx}^2 & \sigma_{yy}^2 & \sigma_{ys}^2 \\ \sigma_{sx}^2 & \sigma_{sy}^2 & \sigma_{ss}^2 \end{bmatrix}$$

Ex. 1006, ¶142, equation (10).

HDOP in Nohara is then defined analogously to the HDOP shown above using the first two diagonal elements of the $(A^T \cdot A)^{-1}$ matrix as follows: $HDOP = \sqrt{\sigma_{xx}^2 + \sigma_{yy}^2}$

Ex. 1006, 144. The calculation of $(A^T \cdot A)^{-1}$ would result in the individual entries σ_{xx}^2 and σ_{yy}^2 being dimensionless, and therefore HDOP would also be dimensionless.

¶49. However, while $(A^T \cdot A)^{-1}$ would normally be the same as $(G^T G)^{-1}$ in the equation above, Nohara also inconsistently relates $COV(\delta X)$ with $(A^T \cdot A)^{-1}$ as shown in Nohara's equation (9) below:

$$\begin{aligned} COV(\delta X) &= A^{-1} \cdot COV(\delta R) \cdot (A^{-1})^T \\ &\cong (A^T \cdot A)^{-1} \end{aligned}$$

Ex. 1006, ¶141-142, equation (9); Ex. 2009, pp, 663-664.

Although the upper equation of equation (9) relates $COV(\delta R)$ (having units of distance squared) to $COV(\delta X)$ (also having units of distance squared) through the dimensionless matrix “A” —which is consistent with equations 7 and 8 discussed

above—Nohara does not discuss the assumptions needed to draw the “near” equivalency shown in the lower equation of equation (9). The lower equation of equation (9) inconsistently suggests that $COV(\delta X)$ (having units of distance squared) is approximately equal to $(A^T \cdot A)^{-1}$, which, as discussed above, Nohara defined as unitless until the appearance of equation (9).

¶50. A POSITA would understand that the covariance matrices $COV(\delta R)$ and $COV(\delta X)$ express the statistical variation of each element of the unknown vectors δR (range errors from each transmitter) and δX (position error and time axes) and have units of distance squared. Ex. 2007, pp. 207-211, equation (6.16); Ex. 2009, pp. 322-333. Although inconsistent with the conventional, dimensionless definition of HDOP, the elements of the pseudoinverse matrix $(A^T \cdot A)^{-1}$ defined in Nohara could be interpreted as weighting factors having units of distance squared. Ex. 1006, ¶142.

¶51. Nohara refers to the elements of $(A^T \cdot A)^{-1}$ as “... variances having the properties of weighting factors which affect the positioning precision depending on the communication environment between the base stations A, B, and C, and the positioning apparatus 10.” Ex. 1006, ¶143. Interpreting the covariance entries σ_{xx}^2 and σ_{yy}^2 as having units of distance squared, Nohara’s equation (11) would result in a “weighted” version of HDOP in units of distance. The key distinction between the standard “unitless” HDOP and the weighted HDOP of Nohara is that the former is solely a function of user-to-transmitter geometry, while the latter is a function of

both user-to-transmitter geometry and the estimated covariances of range measurement errors expressed by $COV(\delta R)$. However, even if $COV(\delta R)$ is incorporated into HDOP to form a weighted HDOP, this weighted HDOP is still fundamentally only a statistical characterization of unknown position error and cannot be used to determine the actual position error because both HDOP and range measurement error ($COV(\delta R)$) are merely statistical representations of position error.

¶52. When HDOP is a unitless parameter, an estimate of the standard deviation of horizontal position error is given by $\sigma_R HDOP$, where σ_R is a scalar parameter expressing the standard deviation of each range measurement (which is assumed to be the same for each measurement). Ex. 2003, pp. 18; Ex. 2007, pp. 208-209; Ex. 2009, pp. 328-332. When HDOP is a parameter with units of distance, the standard deviation of horizontal position error is simply HDOP itself. Ex. 1006, ¶143-144.

¶53. Whether HDOP is expressed as a unitless parameter or a parameter with units of distance, HDOP by itself cannot provide a position error, and a POSITA would have recognized that HDOP and position error, while related, are separate and that HDOP only *characterizes* the two-dimensional position error but does not determine it. Ex. 2007, pp. 208-209. Without additional information, the statistical distribution of the actual (unknown) horizontal position error is itself not precisely known but can be approximately modeled by a one-dimensional Gaussian (Normal) probability

distribution with zero mean and the calculated standard deviation or by a two-dimensional (elliptical) Gaussian distribution with standard deviations σ_{xx} and σ_{yy} for the two horizontal axes. Ex. 2007, pp. 214-216; Ex. 2009, pp. 328-332.

¶54. Investigations continue to this day regarding the relationship between position error and HDOP. Ex. 2003. For example, in *Experimental Studies on The Relationship Between HDOP and Position Error in the GPS System*, the author investigated the empirical relationship between position error and HDOP based on collected GPS receiver data. *Id.* The title of this article alone makes it clear that a POSITA would regard HDOP and position error as being different. The abstract of this paper explains that “[t]he variability of the UERE causes the actual measurements (despite an exact theoretical mathematical correlation between the HDOP value and the position error) to indicate that position errors differ for the same HDOP value.” *Id.*, p. 17. UERE stands for “User Equivalent Range Error” and expresses the error in range measurements – it is analogous to δR in Nohara, as explained above. *Id.*

Although Ex. 2003 discusses the relationship between position error and HDOP in the context of a GPS system, a POSITA would recognize that the same analysis would apply in the context of position determination using stationary transmitters, such as the base stations of Nohara. Mathematically, the calculation of

HDOP is identical for the satellites of a GPS system and the base stations of Nohara.

Ex. 2003, p. 22. Recall that HDOP is defined in Nohara as:

$$HDOP = \sqrt{\sigma_{xx}^2 + \sigma_{yy}^2} \quad (11)$$

Ex. 1006 ¶144, and HDOP is defined in Ex. 2003 in the same manner as the dimensionless version given above:

$$HDOP = \sqrt{A_{xx} + A_{yy}}, \quad (14)$$

Ex. 2003, p. 22.

¶55. Ex. 2003 explains that position error is a function of both HDOP and UERE. *Id.*, p. 17. This was well known by a POSITA at the time of filing of the '206 Patent, as it is described in multiple chapters of the best-known early reference to GPS positioning. Ex, 2010, pp. 35-36, 470-483. UERE is a function of numerous errors that arise from a variety of sources, including errors in the model of base station or GPS satellite from which a signal is received as well as the environment around the user equipment (i.e. the “mobile device”). Ex. 2003 at 18-20.

¶56. Because position error is a function of both UERE and HDOP, and because of the variability of UERE in real time, a POSITA would recognize that HDOP alone is not enough to determine position error. There are circumstances in which there is a small HDOP (i.e. “good” geometrically arrangement of the GPS satellites or base stations), which may appear to suggest a low position error, but in reality the actual

position error is quite large, and *vice versa*. Ex. 2003, Fig. 2. Ex. 2003 shows that, for a given HDOP, position error distributions can be calculated (*Id.*), but position error itself can vary widely and stochastically at a certain HDOP. *Id.*, Fig. 5.

¶57. Fig. 5 of Ex. 2003 is shown below. The curves at the bottom represent the observed probability density functions of 2-D position error for different values of (unitless) HDOP between 0.6 and 1.0. Even if HDOP is known, the variation in actual 2-D position error is large; thus, position error cannot be determined from HDOP alone. Comparing the curves for HDOP = 0.6 and 1.0, for example, shows that there is a significant probability that position error for HDOP = 0.6 exceeds that for HDOP = 1.0. The 95th percentile 2-D error (denoted as R95 in Ex. 2003) in this set of collected data is shown to be 2.048 meters for HDOP = 0.6 and 2.889 for HDOP = 1.0. Ex. 2003, Fig. 5, pp. 29-30. If all else were equal, one would expect R95 for HDOP = 1.0 to exceed R95 for HDOP = 0.6 by the ratio of these two HDOP values, i.e., $1.0 / 0.6 = 1.67$. The actual ratio from the data in Fig. 5 is $2.889 / 2.048 = 1.41$, indicating that HDOP alone is a very rough measure of the distribution of position error. The difference between these ratios is even larger for HDOP = 0.6 and HDOP = 0.9 ($0.9/0.6 = 1.5$ between HDOPs; $2.493/2.048 = 1.22$ between R95 values).

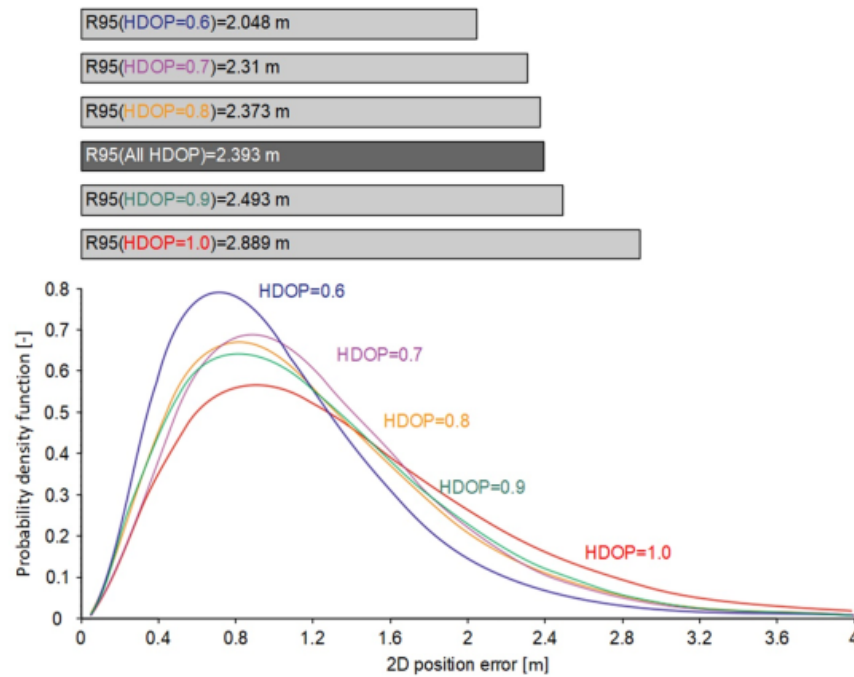


Fig. 5. GPS position error PDFs, determined separately for HDOP values (in the range of 0.6–1.0), together with R95 measures, calculated separately for measurements with a constant HDOP value.

¶58. Accordingly, a POSITA would have recognized that, despite the fact that Nohara refers to HDOP as a position error, the HDOP of Nohara and actual position error as it is conventionally understood are different, although related, quantities. Nohara’s HDOP characterizes the statistical likelihood that position errors may have certain values, but HDOP is not a determination of what the position error is. A POSITA would recognize that “determine when said embedded GPS module should be powered on being depending on. . . a position error of said mobile device determined from the wireless communications network” as recited by the claims of the ’206 Patent is different from Nohara’s use of HDOP derived from base station measurements. Because position error cannot be calculated from knowledge of

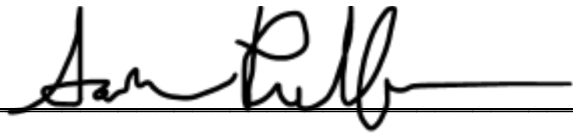
HDOP alone, a POSITA would recognize that determining when power on a GPS receiver based on one quantity or the other will have different outcomes and that one cannot be substituted for the other.

IX. DECLARATION

¶59. In signing this declaration, I recognize that the declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross examination on the subject matter of this declaration. If cross examination is required of me, I will appear for cross examination within the United States during the time allotted for cross examination.

¶60. I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true. Further, these statements are made with the knowledge that willful false statements are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and may jeopardize the validity of the Patent-at-Issue.

Executed on July 5th, 2024 at 11 AM CDT.

/s/  _____

Dr. Samuel Pullen

Samuel Phillip Pullen (“Sam”)

Office:	Dept. of Aero/Astronautics Stanford University Stanford, CA 94305-4035 USA +1 (650) 208 – 0971 (mobile)	Home:	3 Greenpark Way S. San Francisco, CA 94080 USA
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.

APPENDIX 1

- 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-Pereira, 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
- [J01] P. Enge, T. Walter, **S. Pullen**, C. Kee, Y.C. Chao, Y.J. Tsai, “Wide Area Augmentation of the Global Positioning System,” *Proc. IEEE*, Vol. 14, No. 8, Aug. 1996, pp. 1063-1088. <http://preview.tinyurl.com/PrIE-N8-96>

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/>
- [A07] M-S. Circiu, M. Felix, **S. Pullen**, “Galileo E1 and E5a Performance for Multi Frequency and Multi Constellation GBAS,” *GPS World*. Vol. 26, No. 4, April 2015, pp. 30-35.
<http://elib.dlr.de/96245/1/GPS%20World%20-%20%20April%202015%20.pdf>
- [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>

- [A05] **S. Pullen**, T. Walter, P. Enge, "Integrity for Non-Aviation Users," *GPS World*. Vol. 22, No. 7, July 2011. <http://www.gpsworld.com/transportation/road/integrity-non-aviation-users-11847>
- [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>
- [A03] M. Petovello, **S. Pullen**, J. Syrjärinne, L. Wirola, "Quantifying the performance of navigation systems and standards for assisted-GNSS," *Inside GNSS*, Vol. 3, No. 6, Sept./Oct. 2008. <http://www.insidegnss.com/auto/sep0ct08-gnssolutions.pdf>
- [A02] T. Langenstein, **S. Pullen**, H. Jun, D. Yun, C. Kee, B. Parkinson, "Centimeter-Accuracy Indoor Navigation Using GPS-Like Pseudolites," *GPS World*. Vol. 12, No. 11, Nov. 2001. <http://www.gpsworld.com/wireless/indoor-positioning/centimeter-accuracy-indoor-navigation-using-gps-like-pseudolites-716>
- [A01] D. Akos, M. Luo, **S. Pullen**, P. Enge, "Ultra-Wideband and GPS: Can They Co-Exist?" *GPS World*. Vol. 12, No. 9, Sept. 2001. <http://www.gpsworld.com/gps/ultra-wideband-and-gps-can-they-co-exist-1483>

INVITED TALKS (Since 2003)

- [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.

APPENDIX 1

- [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>
- [M56] Y. Zhang, N. Kubo, **S. Pullen**, “Evaluation of QZSS Centimeter Level Augmentation System (CLAS): Open-Sky to Urban Environments and Geodetic to Low-Cost Receivers,” *Proc. ION GNSS+ 2022*, Denver, CO, Sept. 19-23, 2022, pp. 2729-2750. <https://doi.org/10.33012/2022.18517>
- [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>
- [M54] G. Nam, K.A. Sun, **S. Pullen**, “Networked UAV Detection and Alerting of Ionospheric Anomalies within LADGNSS Navigation Framework,” *Proc. ION GNSS+ 2022*, Denver, CO, Sept. 19-23, 2022, pp. 1529-1536. <https://doi.org/10.33012/2022.18424>
- [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>

- [M51] **S. Pullen**, S. Lo, A. Katz, J. Blanch, T. Walter, A. Katronick, M. Crews, R. Jackson, "Ground Monitoring to Support ARAIM for Military Users: Alternatives for Rapid and Rare Update Rates," *Proc. ION GNSS+ 2021*, St. Louis, MO, Sept. 20-24, 2021, pp. 1481-1527. <https://doi.org/10.33012/2021.18159>
- [M50] G. Nam, D. Kim, N.M. Kim, J. Lee, **S. Pullen**, "Enhanced Local-Area DGNSS for Autonomous Vehicle Navigation: Optimal Smoothing Strategy," *Proc. ION GNSS+ 2021*, St. Louis, MO, Sept. 20-24, 2021, pp. 4080-4096. <https://doi.org/10.33012/2021.18066>
- [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>
- [M47] K.A. Sun, H. Chang, J. Lee, J. Seo, Y.J. Morton, **S. Pullen**, "Performance Benefit from Dual-Frequency GNSS-based Aviation Applications under Ionospheric Scintillation: A New Approach to Fading Process Modeling," *Proc. ION ITM 2020*, San Diego, CA, Jan. 21-24, 2020, pp. 889-899. <https://doi.org/10.33012/2020.17184>
- [M46] P. Salvatori, C. Stallo, A. Coluccia, **S. Pullen**, S. Lo, A. Neri, "An Augmentation and Integrity Monitoring Network for Railway and Automotive Transportation," *Proc. ION ITM 2019*, Reston, VA, Jan. 28-31, 2019, pp. 790-801. <https://doi.org/10.33012/2019.16724>
- [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>
- [M44] M. Yoon, J. Lee, **S. Pullen**, "Integrity Risk Evaluation of Impact of Ionospheric Anomalies on GAST D GBAS," *Proc. ION ITM 2019*, Reston, VA, Jan. 28-31, 2019, pp. 100-112. <https://doi.org/10.33012/2019.16685>
- [M43] **S. Pullen**, "A Review of GNSS Anomalies, Existing Mitigations, and Extensions to Autonomous Users," *Proc. 16th IAIN World Congress 2018*, Makuhari, Chiba, Japan, Nov. 28 – Dec. 1, 2018. <https://iaion2018.org/>
- [M42] **S. Pullen**, J. Kilfeather, J. Goddard, T. Nowitzky, B. Shah, W. Doong, A. Welton, D. Kagan, K. Greer, "Enhanced Navigation, Robustness, and Safety Assurance for Autonomous Vehicles as part of the Globalstar Connected Car Program," *Proc. ION GNSS+ 2018*, Miami, FL, Sept. 24-28, 2018, pp. 1538-1565. <https://doi.org/10.33012/2018.16106>
- [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>
- [M39] P. Salvatori, C. Stallo, **S. Pullen**, S. Lo, P. Enge, "Use of SBAS Corrections with Local-Area Monitoring for Railway Guidance and Control Applications," *Proc. IEEE/ION PLANS 2018*, Monterey, CA, April 23-26, 2018, pp. 1379-1387. <https://www.ion.org/publications/abstract.cfm?articleID=15815>
- [M38] C. Hegarty, K. Bean, O. Julien, S. Kalyanaraman, A.J. Van Dierendonck, **S. Pullen**, K. Shallberg, S. Ericson, "Updated Assessment of GNSS Intrasytem and Intersystem Interference for Airborne

- Equipment,” *Proc. ION ITM 2018*, Reston, VA, Jan. 29 – Feb. 1, 2018, pp. 611-625.
<https://www.ion.org/publications/abstract.cfm?articleID=15558>
- [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. Thörlert, 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>
- [M17] **S. Pullen**, P. Enge, S. Shaw, C. Frey, J. Frey, M. Souder, “The Impact of GPS Modernization on Standalone User Performance and Integrity with ARAIM,” *Proc. ION GNSS 2013*, Nashville, TN, Sept. 16-20, 2013, pp. 2637-2653.
<https://www.ion.org/publications/abstract.cfm?jp=p&articleID=11179>
- [M16] **S. Pullen**, D. Manandhar, H. Torimoto, “Analysis and Testing of Optimal Navigation Message Rate for IMES,” *Proc. ION GNSS 2013*, Nashville, TN, Sept. 16-20, 2013, pp. 408-415.
<https://www.ion.org/publications/abstract.cfm?jp=p&articleID=11285>
- [M15] **S. Pullen**, J. Lee, “Guidance, Navigation, and Separation Assurance for Local-Area UAV Networks: Putting the Pieces Together,” *Proc. ION Pacific PNT 2013*, Honolulu, HI, April 23-25, 2013, pp. 902-914. <https://www.ion.org/publications/abstract.cfm?articleID=11051>
- [M14] **S. Pullen**, “Managing Separation of Unmanned Aerial Vehicles Using High-Integrity GNSS Navigation,” *Proc. 3rd ENRI Int’l. Workshop on ATM/CNS 2013 (EIWAC 2013)*, Tokyo, Japan, Feb. 19-22, 2013. http://www.enri.go.jp/eiwac/eiwac_2013_eng.html
- [M13] **S. Pullen**, P. Enge, J. Lee, “Local-Area Differential GNSS Architectures Optimized to Support Unmanned Aerial Vehicles (UAVs),” *Proc. ION ITM 2013*, San Diego, CA, Jan. 28-30, 2013.

- [M12] M. Kim, J. Lee, **S. Pullen**, J. Gillespie, "Optimized GNSS Network Station Selection to Support the Development of Ionospheric Threat Models for GBAS," *Proc. ION ITM 2013*, San Diego, CA, Jan. 28-30, 2013, pp. 559-570. <https://www.ion.org/publications/abstract.cfm?articleID=10890>
- [M11] M. Kim, J. Lee, **S. Pullen**, J. Gillespie, "Data Quality Improvements and Applications of Long-Term Monitoring of Ionospheric Anomalies for GBAS," *Proc. ION GNSS 2012*, Nashville, TN, Sept. 17-21, 2012, pp. 2159-2174. http://waas.stanford.edu/papers/JiyunLee_Automated_Iono_Analysis_ITM2012.pdf
- [M10] E. Bang, J. Lee, J. Seo, **S. Pullen**, S. Close, "Automated Ionospheric Front Velocity Estimation Algorithm for Ground-Based Augmentation Systems," *Proc. ION ITM 2012*, Newport Beach, CA, Jan. 30-Feb. 1, 2012, pp. 1570-1580. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=10035
- [M09] J. Lee, S. Jung, M. Kim, J. Seo, **S. Pullen**, S. Close, "Results from Automated Ionospheric Data Analysis for Ground-Based Augmentation Systems (GBAS)," *Proc. ION ITM 2012*, Newport Beach, CA, Jan. 30-Feb. 1, 2012, pp. 1451-1461. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=10029
- [M08] **S. Pullen**, G. Gao, C. Tedeschi, J. Warburton, "The Impact of Uninformed RF Interference on GBAS and Potential Mitigations," *Proc. ION ITM 2012*, Newport Beach, CA, Jan. 30-Feb. 1, 2012, pp. 780-789. http://waas.stanford.edu/~www/papers/gps/PDF/PPDInterference_Pullen_Gao_ITM2012.pdf
- [M07] B. Belabbas, P. Remi, M. Meurer, **S. Pullen**, "Absolute Slant Ionosphere Gradient Monitor for GAST-D: Issues and Opportunities," *Proc. ION GNSS 2011*, Portland, CA, Sept. 19-23, 2011, pp. 2993-3002. <https://www.ion.org/publications/abstract.cfm?articleID=9856>
- [M06] **S. Pullen**, P. Enge, "Using Outage History to Exclude High-Risk Satellites from GBAS Corrections," *Proc. ION GNSS 2011*, Portland, CA, Sept. 19-23, 2011, pp. 3040-3051. <http://waas.stanford.edu/papers/OutageHistorySVExclusionGNSS2011C58Pullen.pdf>
- [M05] J. Lee, E. Bang, S. Yung, **S. Pullen**, "Automated Front Speed Computation of Ionospheric Anomalies for Ground-Based Augmentation Systems," Poster Paper, *Proc. 13th Int'l. Ionospheric Effects Symp. (IES2011)*, Alexandria, VA, May 17-19, 2011. <http://www.ies2011.com>
- [M04] J. Lee, S. Jung, **S. Pullen**, "Enhancements of Long Term Ionospheric Anomaly Monitoring for the Ground-Based Augmentation System," *Proc. ION ITM 2011*, San Diego, CA, Jan. 24-26, 2011, pp. 930-941. http://ion.org/search/view_abstract.cfm?jp=p&idno=9539
- [M03] **S. Pullen**, T. Walter, P. Enge, "SBAS and GBAS Integrity for Non-Aviation Users: Moving Away from 'Specific Risk'," *Proc. ION ITM 2011*, San Diego, CA, Jan. 24-26, 2011, pp. 533-545. http://ion.org/search/view_abstract.cfm?jp=p&idno=9495
- [M02] **S. Pullen**, M. Luo, T. Walter, P. Enge, "Using SBAS to Enhance GBAS User Availability: Results and Extensions to Enhance Air Traffic Management," *Proc. ENRI Int'l. Workshop on ATM/CNS 2010 (EIWAC 2010)*, Paper EN-030, Tokyo, Japan, Nov. 10-12, 2010. <http://www.enri.go.jp/eiwac/2010/pdf/gaiyo/EN-030.pdf>
- [M01] Y.S. Park, **S. Pullen**, P. Enge, "A Study of Severe Multipath Errors for the Proposed GBAS Airport Surface Movement Application," *Proc. ION GNSS 2010*, Portland, OR, Sept. 21-24, 2010, pp. 2661-2671. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=9373
- [M00] J. Lee, S. Jung, E. Bang, **S. Pullen**, P. Enge, "Long Term Monitoring of Ionospheric Anomalies to Support the Local Area Augmentation System," *Proc. ION GNSS 2010*, Portland, OR, Sept. 21-24, 2010, pp. 2651-2660. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=9372
- [C99] S. Khanafseh, F. Yang, B. Pervan, **S. Pullen**, J. Warburton, "Carrier Phase Ionospheric Gradient Ground Monitor for GBAS with Experimental Validation," *Proc. ION GNSS 2010*, Portland, OR,

- Sept. 21-24, 2010, pp. 2603-2610. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=9368
- [C98] K. Suzuki, **S. Pullen**, P. Enge, T. Ono, "Evaluation of Dual-Frequency GBAS Performance using Data from Public Receiver Networks," *Proc. ION GNSS 2010*, Portland, OR, Sept. 21-24, 2010, pp. 2592-2602. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=9367
- [C97] Y.S. Park, **S. Pullen**, P. Enge, "Enabling LAAS Airport Surface Movement: Mitigating the Anomalous Ionospheric Threat," *Proc. IEEE/ION PLANS 2010*, Indian Wells, CA, May 4-6, 2010, pp. 667-679. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=8989
- [C96] H. Tang, **S. Pullen**, P. Enge, L. Gratton, B. Pervan, M. Brenner, J. Scheitlin, P. Kline, "Ephemeris Type A Fault Analysis and Mitigation for LAAS," *Proc. IEEE/ION PLANS 2010*, Indian Wells, CA, May 4-6, 2010, pp. 654-666. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=8988
- [C95] T. Murphy, M. Harris, **S. Pullen**, Y.S. Park, "GBAS Differentially Corrected Positioning Service Ionospheric Anomaly Errors Evaluated in an Operational Context," *Proc. ION ITM 2010*, San Diego, CA, Jan. 25-27, 2010, pp. 394-410. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=8820
- [C94] **S. Pullen**, "Providing Integrity for Satellite Navigation: Lessons Learned (Thus Far) from the Financial Collapse of 2008 – 2009," *Proc. ION GNSS 2009*, Savannah, GA, Sept. 22-25, 2009, pp. 1305-1316. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=8540
- [C93] Y.S. Park, **S. Pullen**, P. Enge, "Enabling the LAAS Differentially Corrected Positioning Service (DCPS): Design and Requirements Alternatives," *Proc. ION GNSS 2009*, Savannah, GA, Sept. 22-25, 2009, pp. 1149-1158. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=8523
- [C92] **S. Pullen**, "Satellite Navigation Integrity Assurance: Lessons Learned from Hurricane Katrina," *Proc. ION GNSS 2008*, Savannah, GA, Sept. 16-19, 2008 (presentation only). <http://preview.tinyurl.com/GNSS08-pres>
- [C91] N. Kubo, **S. Pullen**, "Instantaneous RTK Positioning Based on User Velocity Measurements," *Proc. ION GNSS 2008*, Savannah, GA, Sept. 16-19, 2008, pp. 1406-1417. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=8053
- [C90] **S. Pullen**, Y.S. Park, P. Enge, "The Impact and Mitigation of Ionosphere Anomalies on Ground-Based Augmentation of GNSS," *Proc. 12th Int'l. Ionospheric Effects Symp. (IES 2008)*, Alexandria, VA, May 13-15, 2008, pp. 263-270. <http://waas.stanford.edu/~www/papers/gps/PDF/PullenIES08.pdf>
- [C89] Y.S. Park, **S. Pullen**, P. Enge, "Mitigation of Anomalous Ionosphere Threat to Enhance Utility of LAAS Differentially Corrected Positioning Service (DCPS)," *Proc. IEEE/ION PLANS 2008*, Monterey, CA, May 6-8, 2008, pp. 285-293. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=7821
- [C88] S. Ramakrishnan, J. Lee, **S. Pullen**, P. Enge, "Targeted Ephemeris Decorrelation Parameter Inflation for Improved LAAS Availability during Severe Ionosphere Anomalies," *Proc. ION NTM 2008*, San Diego, CA, Jan. 28-30, 2008, pp. 354-366. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=7694
- [C87] **S. Pullen**, "Worldwide Trends in GNSS Development and their Implications for Civil User Performance and Safety," *Proc. Japan GPS/GNSS Symposium 2007*, Tokyo, Japan, Nov. 20-22, 2007. <http://waas.stanford.edu/~www/papers/gps/PDF/PullenJapanGNSS07.pdf>
- [C86] S. Datta-Barua, T. Walter, **S. Pullen**, P. Enge, "Modeling the 20 November 2003 Ionosphere Storm with GRACE," *Proc. ION GNSS 2007*, Fort Worth, TX, Sept. 25-28, 2007, pp. 2840-2848. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=7635

- [C85] Y.S. Park, G. Zhang, **S. Pullen**, J. Lee, P. Enge, "Data-Replay Analysis of LAAS Safety During Ionosphere Storms," *Proc. ION GNSS 2007*, Fort Worth, TX, Sept. 25-28, 2007, pp. 404-414. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=7455
- [C84] J. Rife, **S. Pullen**, P. Enge, "Evaluating Fault-Mode Protection Levels at the Aircraft in Category III LAAS," *Proc. ION 63rd Annual Meeting*, Cambridge, MA, April 23-25, 2007, pp. 356-371. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=7266
- [C83] G. Zhang, J. Lee, S. Datta-Barua, **S. Pullen**, P. Enge, "Low-Elevation Ionosphere Spatial Anomalies Discovered from the 20 November 2003 Storm," *Proc. ION NTM 2007*, San Diego, CA, Jan. 22-24, 2007. <http://waas.stanford.edu/~wwu/papers/gps/PDF/ZhangIONNTM07.pdf>
- [C82] H. Konno, **S. Pullen**, J. Rife, P. Enge, "Ionosphere Monitoring Methodology for Hybrid Dual-Frequency LAAS," *Proc. ION GNSS 2006*, Fort Worth, TX, Sept. 26-29, 2006, pp. 409-424. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=6882
- [C81] J. Lee, M. Luo, **S. Pullen**, Y.S. Park, P. Enge, M. Brenner, "Position-Domain Geometry Screening to Maximize LAAS Availability in the Presence of Ionosphere Anomalies," *Proc. ION GNSS 2006*, Fort Worth, TX, Sept. 26-29, 2006, pp. 393-408. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=6900
- [C80] **S. Pullen**, J. Rife, P. Enge, "Prior Probability Model Development to Support System Safety Verification in the Presence of Anomalies," *Proc. IEEE/ION PLANS 2006*, San Diego, CA, April 25-27, 2006, pp. 1127-1136. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=6759
- [C79] J. Lee, **S. Pullen**, S. Datta-Barua, P. Enge, "Assessment of Nominal Ionosphere Spatial Decorrelation for LAAS," *Proc. IEEE/ION PLANS 2006*, San Diego, CA, April 25-27, 2006, pp. 506-514. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=6679
- [C78] J. Rife, **S. Pullen**, T. Walter, E. Phelts, B. Pervan, P. Enge, "WAAS-Based Threat Monitoring for a Local Airport Monitor (LAM) that Supports Category I Precision Approaches," *Proc. IEEE/ION PLANS 2006*, San Diego, CA, April 25-27, 2006, pp. 468-482. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=6676
- [C77] J. Seo, J. Rife, **S. Pullen**, T. Walter, P. Enge "Field Data Analysis for a Range-Based Local Airport Monitor for WAAS," *Proc. ION NTM 2006*, Monterey, CA, Jan. 18-20, 2006, pp. 748-758. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=6579
- [C76] H. Konno, **S. Pullen**, J. Rife, P. Enge, "Evaluation of Two Types of Dual-Frequency Differential GPS Techniques under Anomalous Ionosphere Conditions," *Proc. ION NTM 2006*, Monterey, CA, Jan. 18-20, 2006, pp. 735-747. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=6578
- [C75] M. Luo, **S. Pullen**, S. Datta-Barua, G. Zhang, T. Walter, P. Enge, "LAAS Study of Slow-Moving Ionosphere Anomalies and Their Potential Impacts," *Proc. ION GNSS 2005*, Long Beach, CA, Sept. 13-16, 2005, pp. 2337-2349. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=6439
- [C74] M. Koenig, J. Rife, **S. Pullen**, P. Enge, "Optimizing Channel Selection for the JPALS Land-based Integrity Monitor Dual Frequency Implementation," *Proc. ION GNSS 2005*, Long Beach, CA, Sept. 13-16, 2005, pp. 62-72. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=6195
- [C73] B. Peterson, **S. Pullen**, B. Pervan, G. McGraw, T. Skidmore, S. Anderson, "Investigation of Common Architectures for Land and Sea-Based JPALS," *Proc. ION GNSS 2005*, Long Beach, CA, Sept. 13-16, 2005, pp. 26-37. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=6191
- [C72] T. Walter, **S. Pullen**, J. Rife, J. Seo, P. Enge, "The Advantages of Local Monitoring and VHF Data Broadcast for SBAS," *Proc. ENC GNSS 2005*, Munich, Germany, July 19-22, 2005. <http://waas.stanford.edu/~wwu/papers/gps/PDF/WalterENCGNSS05.pdf>

- [C71] Y. Yun, C. Kee, J. Rife, M. Luo, **S. Pullen**, P. Enge, "Detecting RFI Through Integrity Monitoring at a DGPS Reference Station," *Proc. ION 61st Annual Meeting*, Cambridge, MA, June 27-29, 2005, pp. 795-804. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=6141
- [C70] J. Rife, **S. Pullen**, "The Impact of Measurement Biases on Availability for CAT III LAAS," *Proc. ION 61st Annual Meeting*, Cambridge, MA, June 27-29, 2005, pp. 759-773. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=6138
- [C69] J. Rife, **S. Pullen**, T. Walter, P. Enge, "Vertical Protection Levels for Local Airport Monitor for WAAS," *Proc. ION 61st Annual Meeting*, Cambridge, MA, June 27-29, 2005, pp. 745-758. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=6137
- [C68] H. Konno, **S. Pullen**, M. Luo, P. Enge, "Analysis of Ionosphere Gradient Using Japan GEONET Data," *Proc. ION NTM 2005*, San Diego, CA, Jan. 24-26, 2005, pp. 1118-1129. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=6079
- [C67] M. Koenig, J. Rife, J. Gautier, **S. Pullen**, P. Enge "Development of the JPALS Land-based Integrity Monitor Test Platform," *Proc. ION NTM 2005*, San Diego, CA, Jan. 24-26, 2005, pp. 182-189. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=5981
- [C66] A. Ene, D. Qiu, M. Luo, **S. Pullen**, P. Enge, "A Comprehensive Ionosphere Storm Data Analysis Method to Support LAAS Threat Model Development," *Proc. ION NTM 2005*, San Diego, CA, Jan. 24-26, 2005, pp. 110-130. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=5976
- [C65] **S. Pullen**, P. Enge, "A Civil User Perspective on Near-Term and Long-Term GPS Modernization," *Proc. Japan GPS/GNSS Symposium 2004*, Tokyo, Japan, Nov. 17-19, 2004. <http://waas.stanford.edu/~www/papers/gps/PDF/PullenJapanGNSS04.pdf>
- [C64] J. Rife, **S. Pullen**, B. Pervan, "Core Overbounding and its Implications for LAAS Integrity," *Proc. ION GNSS 2004*, Long Beach, CA, Sept. 21-24, 2004, pp. 2810-2821. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=5964
- [C63] M. Luo, **S. Pullen**, A. Ene, D. Qiu, T. Walter, P. Enge, "Ionosphere Threat to LAAS: Updated Model, User Impact, and Mitigations," *Proc. ION GNSS 2004*, Long Beach, CA, Sept. 21-24, 2004, pp. 2771-2785. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=5961
- [C62] L. Gratton, S. Khanafseh, B. Pervan, **S. Pullen**, J. Warburton, "Experimental Observations and Integrity Monitor Applications of LAAS IMLA Carrier Phase Measurements," *Proc. ION GNSS 2004*, Long Beach, CA, Sept. 21-24, 2004, pp. 2259-2270. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=5910
- [C61] D. Akos, J. Weiss, T. Murphy, **S. Pullen**, "Airborne Multipath Investigation via a GPS Software Receiver," *Proc. ION GNSS 2004*, Long Beach, CA, Sept. 21-24, 2004, pp. 1822-1831. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=5866
- [C60] **S. Pullen**, P. Enge, "Satellite Integrity Monitoring Concepts for GPS/Galileo Augmentation Systems," *Proceedings of ION GNSS 2004*, Long Beach, CA., Sept. 21-24, 2004, pp. 1674-1682. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=5848
- [C59] T.Y. Chiou, S. Alban, S. Atwater, J. Gautier, **S. Pullen**, P. Enge, D. Akos, D. Gebre-Egziabher, B. Pervan, "Performance Analysis and Experimental Validation of a Doppler-Aided GPS/INS Receiver for JPALS Applications," *Proc. ION GNSS 2004*, Long Beach, CA, Sept. 21-24, 2004, pp. 1609-1618. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=5841
- [C58] J. Rife, **S. Pullen**, B. Pervan, P. Enge, "Paired Overbounding and Application to GPS Augmentation," *Proc. IEEE PLANS 2004*, Monterey, CA, April 26-29, 2004, pp. 439-446. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1309027

- [C57] L. Gratton, B. Pervan, **S. Pullen**, "Orbit Ephemeris Monitors for Category I LAAS," *Proc. IEEE PLANS 2004*, Monterey, CA, April 26-29, 2004, pp. 429-438. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1309026
- [C56] M.B. Heo, B. Pervan, J. Gautier, **S. Pullen**, P. Enge, D. Gebre-Egziabher, "Robust Airborne Navigation Algorithms for SRGPS," *Proc. IEEE PLANS 2004*, Monterey, CA, April 26-29, 2004, pp. 175-183. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1308991
- [C55] A. Mitelman, R.E. Phelts, D. Akos, **S. Pullen**, P. Enge, "Signal Deformations on Nominally Healthy GPS Satellites," *Proc. ION NTM 2004*, San Diego, CA, Jan. 26-28, 2004. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=5593
- [C54] M. Luo, **S. Pullen**, T. Walter, P. Enge, "Ionosphere Spatial Gradient Threat for LAAS: Mitigation and Tolerable Threat Space," *Proc. ION NTM 2004*, San Diego, CA, Jan. 26-28, 2004, pp. 490-501. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=5526
- [C53] C. Kee, H. So, J. Kim, H. Jun, P. Enge, **S. Pullen**, "Effect of the Error in the Line-of-Sight Unit Vector on Pseudolite-Based Positioning Systems," *Proc. ION NTM 2004*, San Diego, CA, Jan. 26-28, 2004, pp. 181-189. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=5494
- [C52] D. Gebre-Egziabher, A. Razavi, P. Enge, J. Gautier, D. Akos, **S. Pullen**, B. Pervan, "Doppler Aided Tracking Loops for SRGPS Integrity Monitoring," *Proc. ION GPS/GNSS 2003*, Portland, OR, Sept. 9-12, 2003, pp. 2562-2571. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=5442
- [C51] **S. Pullen**, J. Lee, G. Xie, P. Enge, "CUSUM-Based Real-Time Risk Metrics for Augmented GPS and GNSS," *Proc. ION GPS/GNSS 2003*, Portland, OR, Sept. 9-12, 2003, pp. 2275-2287. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=5412
- [C50] M. Luo, **S. Pullen**, J. Dennis, H. Konno, G. Xie, T. Walter, P. Enge, S. Datta-Barua, T. Dehel, "LAAS Ionosphere Spatial Gradient Threat Model and Impact of LGF and Airborne Monitoring," *Proc. ION GPS/GNSS 2003*, Portland, OR, Sept. 9-12, 2003, Portland, OR., Sept. 9-12, 2003, pp. 2255-2274. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=5411
- [C49] A.J. Van Dierendonck, C. Hegarty, **S. Pullen**, "A More Complete and Updated Methodology for Assessing Intrasystem and Intersystem Interference for GPS and Galileo," *Proc. ION GPS/GNSS 2003*, Portland, OR, Sept. 9-12, 2003, pp. 1484-1493. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=5331
- [C48] J. Lee, **S. Pullen**, G. Xie, P. Enge, "LAAS Position-Domain Monitor Analysis and Failure-Test Verification," *Proc. 21st Int'l. Comm. Sat. Sys. Conf.*, Yokohama, Japan, AIAA 2003-2418, April 15-19, 2003. <http://preview.tinyurl.com/AIAA03-2>
- [C47] G. Xie, **S. Pullen**, M. Luo, P. Enge, "Detecting Ionospheric Gradients with the Cumulative Sum (CUSUM) Method," *Proc. 21st Int'l. Comm. Sat. Sys. Conf.*, Yokohama, Japan, AIAA 2003-2415, April 15-19, 2003. <http://preview.tinyurl.com/AIAA03-1>
- [C46] M. Luo, G. Xie, D. Akos, **S. Pullen**, P. Enge, "Radio Frequency Interference Validation Testing for LAAS Using the Stanford Integrity Monitor Testbed," *Proc. ION NTM 2003*, Anaheim, CA, Jan. 22-24, 2003, pp. 233-242. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=3767
- [C45] **S. Pullen**, T. Walter, P. Enge, "System Overview, Recent Developments, and Future Outlook for WAAS and LAAS," *Proc. Japan GPS Symposium 2002*, Tokyo, Japan, Nov. 11-13, 2002, pp. 45-56. <http://waas.stanford.edu/~www/papers/gps/PDF/PullenTokyo02.pdf>
- [C44] P.L. Normark, D. Akos, G. Xie, **S. Pullen**, M. Luo, P. Enge "The Integrity Monitor Testbed and Multipath Limiting Antenna Test Results," *Proc. ION GPS 2002*, Portland, OR, Sept. 24-27, 2002, pp. 2596-2601. http://ion.org/search/view_abstract.cfm?jp=p&idno=2284

- [C43] **S. Pullen**, M. Luo, G. Xie, J. Lee, R.E. Phelts, D. Akos, P. Enge, "LAAS Ground Facility Design Improvements to Meet Proposed Requirements for Category II/III Operations," *Proc. ION GPS 2002*, Portland, OR, Sept. 24-27, 2002, pp. 1934-1947. http://ion.org/search/view_abstract.cfm?jp=p&idno=2212
- [C42] M. Koenig, D. Gebre-Egziabher, **S. Pullen**, U.S. Kim, P. Enge, B. Pervan, F.C. Chan, G. Colby, "Sensitivity Analysis of the JPALS Shipboard Relative GPS Measurement Quality Monitor," *Proc. ION GPS 2002*, Portland, OR, Sept. 24-27, 2002, pp. 1900-1916. http://ion.org/search/view_abstract.cfm?jp=p&idno=2209
- [C41] A. Mitelman, D. Akos, **S. Pullen**, P. Enge, "Estimation of ICAO Threat Model Parameters for Operational GPS Satellites," *Proc. ION GPS 2002*, Portland, OR, Sept. 24-27, 2002, pp. 12-19. http://ion.org/search/view_abstract.cfm?jp=p&idno=1998
- [C40] M. Luo, **S. Pullen**, D. Akos, G. Xie, S. Datta-Barua, T. Walter, P. Enge "Assessment of Ionospheric Impact on LAAS Using WAAS Supertruth Data," *Proc. ION 58th Annual Meeting/CIGTF 21st Guidance Test Symp.*, Albuquerque, NM, June 24-26, 2002, pp. 175-186. http://ion.org/search/view_abstract.cfm?jp=p&idno=950
- [C39] S. Datta-Barua, T. Walter, **S. Pullen**, M. Luo, J. Blanch, P. Enge "Using WAAS Ionospheric Data to Estimate LAAS Short Baseline Gradients," *Proc. ION NTM 2002*, San Diego, CA, Jan. 28-30, 2002, pp. 523-530. http://ion.org/search/view_abstract.cfm?jp=p&idno=246
- [C38] M. Koenig, D. Gebre-Egziabher, **S. Pullen**, U.S. Kim, P. Enge, B. Pervan, F.C. Chan, G. Colby, "Analysis of Reference Antenna Motion on the JPALS Shipboard Integrity Monitor," *Proc. ION NTM 2002*, San Diego, CA, Jan. 28-30, 2002, pp. 382-389. http://ion.org/search/view_abstract.cfm?jp=p&idno=231
- [C37] **S. Pullen**, G. Xie, P. Enge, "Soft Failure Diagnosis and Exclusion for GBAS Ground Facilities," *Proc. Royal Inst. Nav. (RIN) NAV 01*, London, UK, Nov. 6-8, 2001. <http://www-leland.stanford.edu/~spullen/RIN-NAV-01.pdf>
- [C36] **S. Pullen**, J. Lee, M. Luo, B. Pervan, F.C. Chan, L. Gratton, "Ephemeris Protection Level Equations and Monitor Algorithms for GBAS," *Proc. ION GPS 2001*, Salt Lake City, UT, Sept. 11-14, 2001, pp. 1738-1749. http://ion.org/search/view_abstract.cfm?jp=p&idno=1852
- [C35] R.E. Phelts, A. Mitelman, **S. Pullen**, D. Akos, P. Enge, "Transient Performance Analysis of a Multicorrelator Signal Quality Monitor," *Proc. ION GPS 2001*, Salt Lake City, UT, Sept. 11-14, 2001, pp. 1700-1710. http://ion.org/search/view_abstract.cfm?jp=p&idno=1850
- [C34] P.L. Normark, G. Xie, D. Akos, **S. Pullen**, M. Luo, J. Lee, P. Enge, B. Pervan "The Next Generation Integrity Monitor Testbed for Ground System Development and Validation Testing," *Proc. ION GPS 2001*, Salt Lake City, UT, Sept. 11-14, 2001, pp. 1200-1208. http://ion.org/search/view_abstract.cfm?jp=p&idno=1798
- [C33] L. Vidarsson, **S. Pullen**, G. Green, "Satellite Autonomous Integrity Monitoring and its Role in Enhancing GPS User Performance," *Proc. ION GPS 2001*, Salt Lake City, UT, Sept. 11-14, 2001, pp. 690-702. http://ion.org/search/view_abstract.cfm?jp=p&idno=1751
- [C32] M. Luo, D. Akos, M. Koenig, G. Opshaug, **S. Pullen**, P. Enge, B. Erlandson, S. Frodge, "Testing and Research on Interference to GPS from UWB Transmitters," *Proc. ION GPS 2001*, Salt Lake City, UT, Sept. 11-14, 2001, pp. 1-13. http://ion.org/search/view_abstract.cfm?jp=p&idno=1697
- [C31] J. Lee, **S. Pullen**, G. Xie, P. Enge, "LAAS Sigma-Mean Monitor Analysis and Failure-Test Verification," *Proc. ION 57th Annual Meeting/CIGTF 20th Guidance Test Symp.*, Albuquerque, NM, June 11-13, 2001, pp. 694-704. http://ion.org/search/view_abstract.cfm?jp=p&idno=909
- [C30] G. Xie, **S. Pullen**, M. Luo, P.L. Normark, D. Akos, J. Lee, P. Enge, B. Pervan "Integrity Design and Updated Test Results for the Stanford LAAS Integrity Monitor Testbed," *Proc. ION 57th*

- Annual Meeting/CIGTF 20th Guidance Test Symp.*, Albuquerque, NM, June 11-13, 2001, pp. 681-693. http://ion.org/search/view_abstract.cfm?jp=p&idno=908
- [C29] B. Pervan, **S. Pullen**, I. Sayim, "Sigma Estimation, Inflation, and Monitoring in the LAAS Ground System," *Proc. ION GPS 2000*, Salt Lake City, UT, Sept. 19-22, 2000, pp. 1234-1244. http://ion.org/search/view_abstract.cfm?jp=p&idno=1525
- [C28] G. McGraw, T. Murphy, M. Brenner, **S. Pullen**, A.J. Van Dierendonck, "Development of the LAAS Accuracy Models," *Proc. ION GPS 2000*, Salt Lake City, UT, Sept. 19-22, 2000, pp. 1212-1223. http://ion.org/search/view_abstract.cfm?jp=p&idno=1523
- [C27] **S. Pullen**, M. Luo, S. Gleason, G. Xie, J. Lee, D. Akos, P. Enge, B. Pervan, "GBAS Validation Methodology and Test Results from the Stanford LAAS Integrity Monitor Testbed," *Proc. ION GPS 2000*, Salt Lake City, UT, Sept. 19-22, 2000, pp. 1191-1201. http://ion.org/search/view_abstract.cfm?jp=p&idno=1521
- [C26] C. Kee, H. Jun, D. Yun, B. Kim, Y. Kim, B. Parkinson, T. Langenstein, **S. Pullen**, J.T. Lee, "Development of Indoor Navigation System Using Pseudolites," *Proc. ION GPS 2000*, Salt Lake City, UT, Sept. 19-22, 2000, pp. 1038-1045. http://ion.org/search/view_abstract.cfm?jp=p&idno=1504
- [C25] M. Luo, D. Akos, **S. Pullen**, P. Enge, B. Erlandson, S. Frodge, "Interference to GPS from UWB Transmitters," *Proc. ION GPS 2000*, Salt Lake City, UT, Sept. 19-22, 2000, p. 981-992. http://ion.org/search/view_abstract.cfm?jp=p&idno=1497
- [C24] A. Mitelman, R.E. Phelts, D. Akos, **S. Pullen**, P. Enge, "A Real Time Signal Quality Monitor for GPS Augmentation Systems," *Proc. ION GPS 2000*, Salt Lake City, UT, Sept. 19-22, 2000, pp. 862-871. http://ion.org/search/view_abstract.cfm?jp=p&idno=1483
- [C23] B. Pervan, **S. Pullen**, J. Andreacchi, P. Enge, "Characterizing the Effect of Ionospheric Divergence and Decorrelation on LAAS," *Proc. ION GPS 2000*, Salt Lake City, UT, Sept. 19-22, 2000, pp. 653-661. http://ion.org/search/view_abstract.cfm?jp=p&idno=1460
- [C22] K. Gromov, D. Akos, **S. Pullen**, P. Enge, B. Parkinson, "GIDL: Generalized Interference Detection and Localization System," *Proc. ION GPS 2000*, Salt Lake City, UT, Sept. 19-22, 2000, pp. 447-457. http://ion.org/search/view_abstract.cfm?jp=p&idno=1437
- [C21] A.J. Van Dierendonck, D. Akos, **S. Pullen**, R.E. Phelts, P. Enge "Practical Implementation Considerations in the Detection of GPS Satellite Signal Failures," *Proc. IAIN World Congress/ION 56th Annual Meeting*, San Diego, CA, June 26-28, 2000, pp. 250-259. http://ion.org/search/view_abstract.cfm?jp=p&idno=773
- [C20] D. Akos, E. Phelts, A. Mitelman, **S. Pullen**, P. Enge "GPS-SPS Signal Quality Monitor," *Proc. IEEE PLANS 2000*, San Diego, CA, March 13-16, 2000. <http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=00838274>
- [C19] D. Akos, R.E. Phelts, **S. Pullen**, P. Enge, "Signal Quality Monitoring: Test Results," *Proc. ION NTM 2000*, Anaheim, CA, Jan. 26-28, 2000, pp. 536-541. http://ion.org/search/view_abstract.cfm?jp=p&idno=65
- [C18] M. Luo, **S. Pullen**, J. Zhang, S. Gleason, G. Xie, J. Yang, D. Akos, P. Enge, "Development and Testing of the Stanford LAAS Ground Facility Prototype," *Proc. ION NTM 2000*, Anaheim, CA, Jan. 26-28, 2000, pp. 210-219. http://ion.org/search/view_abstract.cfm?jp=p&idno=25
- [C17] L. Levy, A. Pue, T. Thompson, **S. Pullen**, "GPS Risk Assessment for Civil Aviation," *Proc. ION GPS 1999*, Nashville, TN, Sept. 14-17, 1999, pp. 2121-2130. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=3371

- [C16] C. Kee, D. Yun, H. Jun, B. Parkinson, T. Langenstein, **S. Pullen**, "Precise Calibration of Pseudolite Positions in Indoor Navigation System," *Proc. ION GPS 1999*, Nashville, TN, Sept. 14-17, 1999, pp. 1499-1508. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=3306
- [C15] S. Matsumoto, **S. Pullen**, M. Rotkowitz, B. Pervan, "GPS Ephemeris Verification for Local Area Augmentation System (LAAS) Ground Stations," *Proc. ION GPS 1999*, Nashville, TN, Sept. 14-17, 1999, pp. 691-704. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=3216
- [C14] K. Gromov, D. Akos, **S. Pullen**, P. Enge, B. Parkinson "Interference Direction Finding for Aviation Applications of GPS," *Proc. ION GPS 1999*, Nashville, TN, Sept. 14-17, 1999, pp. 115-124. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=3159
- [C13] J. Christie, P.Y. Ko, A. Hansen, D. Dai, **S. Pullen**, B. Pervan, B. Parkinson "The Effects of Local Ionospheric Decorrelation on LAAS: Theory and Experimental Results," *Proc. ION NTM 1999*, San Diego, CA, Jan. 25-27, 1999, pp. 769-777. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=730
- [C12] **S. Pullen**, G. Opshaug, A. Hansen, T. Walter, P. Enge, B. Parkinson "A Preliminary Study of the Effect of Ionospheric Scintillation on WAAS User Availability in Equatorial Regions," *Proc. ION GPS 1998*, Nashville, TN, Sept. 15-18, 1998, pp. 687-699. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=3000
- [C11] **S. Pullen**, B. Parkinson, "Optimal Augmentation of GPS using Inexpensive Geosynchronous Navigation Satellites," *Proc. ION GPS 1997*, Kansas City, MO, Sept. 16-19, 1997, pp. 1271-1281. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=2874
- [C10] B. Pervan, **S. Pullen**, D. Lawrence, K. Gromov, J. Christie, G. Opshaug, V. Lu, P.Y. Ko, P. Enge, B. Parkinson, "Development, Implementation, and Testing of a Prototype LAAS Architecture," *Proc. GNSS 97*, Munich, Germany, April 21-25, 1997. http://waas.stanford.edu/~www/papers/gps/PDF/prototype_laas_bsp97.pdf
- [C09] **S. Pullen**, P. Enge, B. Parkinson, "Control System Optimization with Unbounded Uncertainty: Application to Aircraft Precision Approach Using GPS," *Proc. IEEE CDC '96*, Kobe, Japan, Dec. 11-13, 1996, Vol. 2, pp. 1339-1340. <http://ieeexplore.ieee.org/search/srchabstract.jsp?tp=&arnumber=572689>
- [C08] **S. Pullen**, B. Pervan, P. Enge, B. Parkinson, "A Comprehensive Integrity Verification Architecture for On-Airport LAAS Category III Precision Landing," *Proc. ION GPS 1996*, Kansas City, MO, Sept. 17-20, 1996, pp. 1623-1634. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=2699
- [C07] Y.C. Chao, **S. Pullen**, P. Enge, B. Parkinson "Study of WAAS Ionospheric Integrity," *Proc. ION GPS 1996*, Kansas City, MO, Sept. 17-20, 1996, pp. 781-788. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=2610
- [C06] **S. Pullen**, Y.C. Chao, P. Enge, B. Parkinson, "Effects of Local Ionospheric Anomalies on Navigation Performance and Integrity Using WAAS," *Proc. IEEE PLANS '96*, Atlanta, GA, April 22-26, 1996, pp. 574-581. <http://ieeexplore.ieee.org/search/srchabstract.jsp?tp=&arnumber=509130>
- [C05] **S. Pullen**, P. Enge, B. Parkinson, "Global Optimization of GPS Augmentation Architectures using Genetic Algorithms," *Proc. ION GPS 1995*, Palm Springs, CA, Sept. 12-15, 1995, pp. 1403-1415. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=2502
- [C04] **S. Pullen**, P. Enge, B. Parkinson, "A New Method for WAAS Coverage Prediction," *Proc. ION Annual Meeting 1995*, Colorado Springs, CO, June 5-7, 1995, pp. 501-513. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=1036

APPENDIX 1

- [C03] **S. Pullen**, B. Parkinson, “System Design under Uncertainty: Evolutionary Optimization of the Gravity Probe-B Spacecraft,” *Proc. Parallel Problem Solving from Nature – PPSN III*, Jerusalem, Israel, Oct. 9-14, 1994, pp. 598-607. <http://www.springerlink.com/content/y0348016p2275385/>
- [C02] **S. Pullen**, P. Enge, B. Parkinson, “Simulation-Based Evaluation of WAAS Performance: Risk and Integrity Factors,” *Proc. ION GPS 1994*, Salt Lake City, UT, Sept. 20-23, 1994, pp. 975-983. http://www.ion.org/search/view_abstract.cfm?jp=p&idno=3914
- [C01] **S. Pullen**, B. Pervan, B. Parkinson, “A New Approach to GPS Integrity Monitoring using Prior Probability Models and Optimal Threshold Search,” *Proc. IEEE PLANS '94*, Las Vegas, NV, April 12-15, 1994, pp. 739-746. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=303384&tag=1

Sam Pullen Consulting

14914 Turret Run
San Antonio, TX 78248 USA
Tel: +1 (650) 208 - 0971
spullen@stanford.edu

Past and Ongoing Expert Witness Engagements Since 2015
(in Chronological Order by Start Date)

Last Updated: 13 June 2024

Party Representing	Law Firm Supporting	Opposing Party	Start - End Dates	Activities (to Date)	Nature of Dispute
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Reports, depositions, trial testimony	Patent infringement regarding Positive Train Control (PTC) system design
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Reports, depositions	Patent infringement and trade secret misappropriation regarding use of airborne vehicles as communication relays
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Reports, trial testimony	Trade secret misappropriation regarding Positive Train Control (PTC) system design
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Reports, depositions, and trial testimony	Patent reexamination regarding use of GPS for vehicle navigation (court case pending)
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Reports	Patent infringement regarding portable devices to provide player assistance for sports participants
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Reports, source code reviews, depositions, trial testimony	Patent dispute at U.S. International Trade Commission (ITC) regarding techniques for rapid acquisition of GPS signals
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Reports	Patent IPR regarding use of GPS with wireless communication technologies

APPENDIX 2
Sam Pullen Consulting
14914 Turret Run
San Antonio, TX 78248 USA
Tel: +1 (650) 208 - 0971
spullen@stanford.edu

Past and Ongoing Technical Work Engagements since 2015
(in Chronological Order by Start Date)
Last Updated: 17 July 2023

Client	Start - End Dates	Activities (to Date)	Nature of Work
Dept. of Aero/Astronautics, Stanford University	2011 – present	Technical research, algorithm and system development, document preparation and review, research publications	Development of GNSS and GNSS augmentation systems and algorithms to support aviation, land, marine, and UAV users
[REDACTED]	[REDACTED]	Technical work, algorithm development, document review	Development of GNSS augmentation techniques for railway navigation and control
[REDACTED]	[REDACTED]	Technical work, patent application, and research publications	Development of satellite-based systems to augment existing GNSS to support automotive users.
[REDACTED]	[REDACTED]	Technical work, algorithm development, document preparation and review, research publications	Development of GNSS augmentation techniques for railway and automobile navigation and control
[REDACTED]	[REDACTED]	Technical work, patent applications, technical and safety document preparation	Development of enhanced GNSS navigation methods for future airborne vehicles