Expert Report of
Douglas C. Schmidt, Ph.D.

Public Redacted Version

IN THE SUPERIOR COURT OF THE STATE OF ARIZONA

IN AND FOR THE COUNTY OF MARICOPA

STATE OF ARIZONA, *ex rel.* MARK BRNOVICH, Attorney General, Plaintiff, v. GOOGLE LLC, A Delaware Limited Liability Company, Defendant.	No. CV2020-006219 Assigned to the Hon. Timothy Thomason **(COMPLEX CALENDAR)**

Expert Report of Douglas Craig Schmidt, Ph.D.

HIGHLY CONFIDENTIAL – ATTORNEYS' EYES ONLY
PURSUANT TO PROTECTIVE ORDER

Nashville, TN
May 4, 2022

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I. SCOPE OF RETENTION AND SUMMARY OF CONCLUSIONS

1. My full name is Douglas Craig Schmidt. I reside in Nashville, TN. I have been retained by counsel for the State of Arizona to assess whether a study entitled Google Data Collection I published on August 15, 2018 supports or refutes the conclusions reached in the November 16, 2021 Declaration of Seth Nielson, Ph.D.

2. The August 15, 2018 study, Google Data Collection, analyzed Google's collection of data from daily use of an Android device. The Google Data Collection study (the "2018 Study") is attached as Appendix 1. If called to testify in this matter, I may discuss the methodology and results of the 2018 Study.

3. I designed the 2018 Study to replicate an average user's daily activities using an Android mobile phone device. The researcher carried the device throughout the day. Prior to the study, the phone was wiped by conducting a factory data reset and configured as a new device with default settings left on to avoid prior user information associated with the device. A new Google account was created with Location History turned on.

4. The 2018 Study empirically evaluated how Google collects user data in a variety of ways. One way that Google collects data are "active," with the user directly communicating information to Google, as for example by signing in to any of its widely used applications such as YouTube, Gmail, Search etc. Other ways for Google to collect data are "passive" means, whereby an app is instrumented to gather information while it's running. Google's passive data gathering methods arise from platforms (e.g., Android and Chrome), applications (e.g., Search, YouTube, Maps), publisher tools (e.g., Google Analytics, AdSense) and advertiser tools (e.g., AdMob, AdWords). The extent and magnitude of Google's passive data collection had largely been overlooked by past studies on this topic.

5. To understand what data Google collects, the 2018 study drew on four key sources:

a. Google's My Activity[1] and Takeout[2] tools, which describe information collected during the use of Google's user-facing products;

b. Data intercepted as it is sent to Google server domains while Google or 3rd-party products are used;

c. Google's privacy policies (both general and product-specific); and

d. Other 3rd-party research that has examined Google's data collection efforts.

6. Through the combined use of above resources, the 2018 Study provided a unique and relatively comprehensive view of Google's data collection approaches and delved deeper into specific types of information it collects from users.

7. The November 16, 2021 Declaration of Seth Nielson was filed in support of the State's Response to Google's Motion for Summary Judgment. In Dr. Nielson's Declaration, he summarizes how certain Google technologies perform and reaches certain conclusions regarding how Google's products and services operate. The November 16, 2021 Declaration of Seth Nielson (the "Nielson Declaration") is attached as Appendix 2.

8. If called to testify in this matter, I may prepare additional demonstrative exhibits or summarize the information I describe in this report, as permitted by the Court. I may also run additional experiments and compare those results to the results to my 2018 study. I may further refer to documents and information on which I have relied, as disclosed in Appendix _ and throughout this report. I may further refer and rely upon documents I did not rely upon, but reviewed as part of my engagement.

9. As discussed below, I understand than AP Article published on August 13, 2018, led the Arizona Attorney General to initiate an investigation of Google's practices concerning user location data, which in turn led to the present litigation by the State of Arizona against Google. My 2018 study was published just two days after the AP Article.

[1] "My Activity," *Google*, available at https://myactivity.google.com/myactivity
[2] "Download your data," *Google*, available at https://takeout.google.com/settings/takeout?pli=1

10. I was asked to consider whether and to what extent my 2018 study supports or refute the conclusions reached by Dr. Nielson in his declaration.

11. It is my opinion that paragraphs 29, 31, 33, 98 and 99 of the Nielson Declaration are supported by the results of the 2018 Study.

II. QUALIFICATIONS

12. I am the Cornelius Vanderbilt Professor of Engineering in the Department of Electrical Engineering and Computer Science at Vanderbilt University in Nashville, TN, where I also serve as the Associate Provost for Research Development and Technologies and the co-Director of the Data Science Institute. My research spans a broad range of software systems, including distributed object computing, middleware platforms, real-time operating systems, and distributed real-time and embedded systems. I became a Full Professor with tenure at Vanderbilt University in January 2003.

13. I have been a full-time university professor since 1994. I was previously a tenured professor at the University of California, Irvine in the Electrical and Computer Engineering department, from 2000 to 2003, and before that at Washington University in St. Louis, MO in the Computer Science and Engineering department and the Mallinckrodt Institute of Radiology, from 1994 to 1999. In addition, I served as the Chief Technology Officer and Deputy Director for the Software Engineering Institute (SEI) at Carnegie Mellon University from 2010 to 2012, where I led the SEI's research, development, and operational efforts related to software engineering and cyber-security.

14. I received my Doctor of Philosophy (Ph.D.) degree in Computer Science from the University of California (UC) Irvine in Irvine, CA in 1994. I also earned a Master's Degree in Computer Science from UC Irvine in 1990, as well as a Bachelor's Degree in Sociology in 1984 and Master's Degree in Sociology in 1986 from the College of William and Mary in Williamsburg, VA. I first started programming in 1983 when I was an undergraduate student taking statistics courses. From 1985 through 1994 I learned how to program in

Pascal, C, C++, Ada, Prolog, and Lisp, both at the College of William and Mary and at UC Irvine. A copy of my curriculum vitae is attached as Appendix A to this report.

15. For the past three decades, my research has focused on distributed real-time and embedded (DRE) systems, which has yielded the ACE, Java ACE, TAO, and CIAO middleware frameworks. The millions of lines of object-oriented code in these frameworks provide layers of infrastructure and distribution middleware that simplify the development of concurrent and networked software apps and services. These middleware frameworks constitute some of the most successful examples of software research and development (R&D) ever transitioned from research to industry, being widely used by thousands of companies and agencies worldwide in many domains, including national defense and homeland security, datacom/telecom, financial services, healthcare, and online gaming.

16. My research on DRE systems has been funded by various organizations, including both federal agencies, such as Defense Advanced Research Project Agency (DARPA), National Science Foundation (NSF), NASA, NIH, the U.S. Air Force, and the U.S. Navy, as well as leading companies, such as Northrup Grumman, Raytheon, Lockheed-Martin, Boeing, McDonnell-Douglas, General Electric, Siemens Medical Engineering, and Kodak Health Imaging Systems. My funded projects from Siemens Medical Engineering and Kodak Health Imaging Systems created software that was integrated into medical modalities that went through FDA approval processes, so I am familiar with these certification regimes.

17. In addition, during my stint as a program manager at DARPA from 2000 to 2003, I led the national research and development effort on resilient networking and middleware software for DRE systems, which focused on the systematic use of adaptation, supported by redundancy, heterogeneity, and use of computer network security mechanisms. During this time, I also co-chaired the Software Design and Productivity (SDP) Coordinating Group of the U.S. government's multi-agency Networking and Information Technology Research and Development (NITRD) Program, which helped formulate the national interagency software research agenda.

18. Besides my academic and research experience, from 2010 to 2014, I served as a member of the United States Air Force Scientific Advisory Board (SAB), where I was the Vice Chair of the SAB's Cyber Situational Awareness study, which conducted a comprehensive review of the U.S. Air Force's tactics, techniques, and procedures related to secure network-centric mission operations. I have also served on the Advisory Board for the U.S. Naval Air Systems Command (NavAir) Future Airborne Capability Environment (FACE) and was a co-lead of a task force on "Published Open Interfaces and Standards" for the U.S. Navy's Open Systems Architecture initiative.

19. For over 30 years, I have conducted and supervised many research projects involving a wide range of software-related topics, including patterns, optimization techniques, and empirical analyses of communication protocol stacks, web servers, and object-oriented middleware frameworks for distributed real-time embedded systems and mobile-/web-based cloud computing applications. I have published 650+ scholarly articles and technical papers, and I am the co-author/editor of 10+ books or book-length manuscripts on various topics, including software architecture, network programming, object-oriented frameworks, distributed and real-time systems, open-source middleware platforms, and web-/mobile-based cloud computing applications.

20. My work has been cited 44,900+ times across a comprehensive spectrum of high-impact publications, and my current h-index score is 88, which reflects the impact of my publications on scholarly literature in the field of computer science. I have also supervised the research of more than 40 PhD and Master's graduate students to date. Together with conducting and publishing my own research, I have served on the editorial board of many journals, including publications by IEEE and the ACM, and I have been a guest editor of many special issue journals based on my research expertise. I have also received other honors and awards, including election to professional organizations, engagements for invited talks, and the 2015 Award for Excellence in Teaching from the Vanderbilt University Department of Electrical Engineering.

21. In addition to my research and teaching experience, I have decades of hands-on programming experience with a variety of different programming languages. I began programming with C in 1985 and have programmed with object-oriented languages since 1986, when I began to program with C++. I have programmed with Java and other related object-oriented languages since the mid-1990s and early 2000s. Starting in 1991, while at the University of California Irvine, I led the development of one of the first C++ object-oriented frameworks for concurrent and networked middleware and applications (ACE). Starting in 1996, I developed one of the first Java object-oriented frameworks for concurrent and networked middleware and applications (Java ACE).

22. Since 1990, I have taught more than 2,000 students in dozens of face-to-face courses on network programming to both undergraduate and graduate students at UC Irvine, Washington University in St. Louis, and Vanderbilt University. Since 2013, I have taught mobile cloud computing to more than 400,000 students in online courses, including Massive Open Online Courses (MOOCs) on the Coursera platform, which have focused on technologies like mobile cloud computing and mobile app programming with Android, Java, and JavaScript, as well as cloud service programming with various web services frameworks, such as Spring and Node.js.

23. Together with my regular course offerings, over the past 30 years I have also taught 600+ short-courses and tutorials on many subjects, including: object-oriented design patterns and programming techniques; systems programming and network programming for UNIX and Windows; object-oriented and functional programming languages; concurrent and parallel programming in Java and Android; and various courses on distributed systems, real-time and embedded systems, TCP/IP, web apps, and services, compiler construction, algorithms, and data structures.

24. I have also conducted research and published papers on topics related to Google's data collection practices, specifically, the 2018 Study discussed above.

III. BACKGROUND

25. I have read the Complaint filed by the Attorney General of Arizona against Google. I understand from the Complaint that the State alleges Google uses deceptive and unfair business practices to obtain information about the location of its users which Google then uses for geotargeting advertisements. The Complaint notes, as did my 2018 Study, that most people likely associate Google with its popular products and services, including Google Search, Google Maps, the Google Chrome browser, YouTube, and Android, but these products and services are not Google's principal business. From a revenue perspective, Google's principal business is selling advertisements and displaying them to the users of Google's products and services.

26. I understand from the Complaint that the State alleges the tactics Google deploys to surveil users' locations include willfully deceptive and unfair acts and practices within the meaning of the Arizona Consumer Fraud Act. The State alleges that one aspect of Google's deceptive conduct came into public view with the August 2018 publication of an Associated Press article entitled, "Google tracks your movements, like it or not."[3] The article discusses Google's Location History service, which enables users to view where they have been. Google provided users the ability to disable Location History. At the same time, Google told users that "with Location History off, the places you go are no longer stored." The AP article revealed that even with Location History off, Google would surreptitiously collect location information through other settings such as Web & App Activity and use that information to sell ads. My 2018 Study had already been under way when the article came out, but it is consistent with my findings.

27. I understand that the Arizona Attorney General conducted an investigation into Google's conduct. I understand that the investigation, as reflected in the allegations of the Complaint, indicates that Google's deceptive and unfair conduct extends well beyond the incorrect statements in its Location History disclosure.

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[3] https://apnews.com/article/north-america-science-technology-business-ap-top-news-828aefab64d4411bac257a07c1af0ecb

28. The Complaint includes the following allegations:

a. As described in the AP article, with Location History off, Google continues to collect location information through Web & App Activity. Through Web & App Activity, Google logs information relating to a user's activity on Google websites and apps, such as conducting a search on Google Search. One component of this information is a user's location. Nevertheless, at least until early-to mid-2018, Google's disclosures during account creation made no mention of the fact that location information was collected through Web & App Activity, which is defaulted to "on."

b. Devices running the Android operating system have a device-level location setting. Google tells users that "the types of data we collect depend in part on your device and account settings. For example, you can turn your Android device's location on or off using the device's settings app." One could conclude from this disclosure that "off means off"—i.e., that Google simply will not collect, store or exploit user location information when a device's location setting is turned off. However, that conclusion is not true. Instead, since at least around April 2019, Google operates on the principle that "off means coarse"—in other words, Google reduces the precision with which it collects and uses a user's information when a device's location setting is off, but does not stop the collection and use of that information altogether. Before around April 2019, Googel was still collecting precise location information in this context.

c. Google's WiFi settings mislead users about Google's collection and use of location information. There are two relevant settings—WiFi scanning and WiFi connectivity. Only the WiFi scanning setting is presented within location settings, which would lead a one to conclude that turning it off would result in Google no longer discerning a user's location through WiFi scans. However, that conclusion is also not true. In particular, even with WiFi scanning off, Google may still obtain location information from WiFi scans if WiFi connectivity is on.

d. In recent versions of Android, individual Google apps ask for the user's permission to use their location data. One could conclude that, if the user denies this app-level permission to an app, that app will not be able to use the user's location. However, this conclusion is not true—Google apps that are denied permission by the user can still obtain location information from other Google apps and products that have been granted permission.

e. The "off means coarse" deception also manifests in ads personalization. As explained above, the State alleges that Google serves personalized ads to its users based in part on information Google has about a user's location. Google purports, however, to allow users to opt out of ads personalization by turning off a setting of that name ("GAP"). But contrary to what one would expect, turning ads personalization off does not stop Google from presenting ads based on a user's location. Rather, Google will instead simply present ads based on more general location information.

f. Google also has a second ads service ("DoubleClick") through which it serves ads on third-party websites. The setting that controls DoubleClick's service of location-based ads resides in a completely separate user interface from the GAP setting. Moreover, like the GAP setting, if a user turns off the DoubleClick setting, Google will still target the user with DoubleClick ads based on the user's coarse location. The DoubleClick setting has no effect on the GAP setting, and vice versa. Thus, a user who thought she had opted out of receiving ads based on her location is wrong on two counts: (1) Google still serves her location-based ads (based on her coarse location) via that same service and (2) Google also serves location-based ads (based on more precise location signals) via the other service.

g. Users are more likely to disable their device's location setting if they are readily offered such a setting. The State alleges this was demonstrated by a substantial increase in devices with location turned off in versions of Android that included a location toggle in the device's easily accessed Quick Settings pane.

Google viewed the large increase as a problem to solve, so it removed this setting from the Quick Settings pane of devices it manufactured, and it sought—successfully—to convince other manufacturers using Android to do the same on the basis of incorrect and misleading information.

29. I understand from the Complaint that users, including in Arizona, have come to rely on Google's products and services on a daily basis. At the same time, through deceptive and unfair acts and practices, the State alleges that Google makes it impractical if not impossible for users to meaningfully opt-out of Google's collection of location information, should the users seek to do so. I further understand from the Complaint that the State alleges that Google has engaged in these deceptive and unfair acts and practices with the purpose of enhancing its ability to collect and profit from user location information.

30. Google's gathering and utilization of user location data is supported by the November 16, 2021 Declaration of Seth Nielson. For purposes of this Report, I have reviewed and focused on the conclusions in Dr. Nielson's declaration that relate to the Google Data Collection study I completed in 2018. I conclude that Dr. Nielson's declaration aligns and is supported by my 2018 Study.

31. Dr. Nielson testified that Google uses devices, services, and software to track user location.[4] Google tracks location even when location permission are denied.[5] Google also tracks location information even if all location related settings are turned off or denied.[6] The location data that is obtained from these practices is used by Google to serve ads that are targeted to a user's location.[7]

[4] Nielson Decl. ¶ 27–29.
[5] Nielson Decl. ¶ 32.
[6] Nielson Decl. ¶¶ 33-34
[7] Nielson Decl. ¶¶ 36.

IV. THE NIELSON DECLARATION AND THE 2018 STUDY

32. The Nielson Declaration discusses several aspects of Google's technology and was filed in support of the State's Response to Google's Motion for Summary Judgment.

33. In particular, in paragraphs 26 through 37, Dr. Nielson presents a "Summary of Preliminary Opinions." Some of these preliminary opinions are supported by my 2018 Study, as discussed below.

A. Android Phones Are Devices Used to Track User Location.

34. The Nielson Declaration concludes in paragraph 29 that "[w]hen a consumer purchases an Android Device, he or she receives a device that Google uses to track that user's location."

35. This conclusion is supported by the 2018 Study. In particular, my 2018 Study found that both the Android operating system and the Chrome browser send data to Google even in the absence of any user interaction.[8] 2018 Study, at 3, 23-25.

36. In particular, the results of the 2018 Study revealed that with normal daily usage of an Android device, Google requests information from the device more than 90 times per hour. Approximately 20% of these requests relate to the device's location.[9] These requests were sent to URLs like "loc/m/api," which is a specific service endpoint that receives HTTP requests specifically for the purposes of locating the user. These requests can either be to translate a set of WiFi access points into a precise location or to record the location of an observed set of access points, which enables Google to provide precise location even if a good GPS signal isn't available. In some cases, therefore, the request contains a precise location, whereas in others it contains a set of observed access points and their signal strengths, from which Google responds with a precise location.

[8] 2018 Study, at 3, 23-25.
[9] 2018 Study, at 24.

37. In addition, Google tracks users through the user's WiFi Scanning setting, even when the WiFi setting is turned off. For example, the 2018 Study showed that on a short 15-minute walk around a residential neighborhood, the test Android device sent nine location requests to Google. These requests contained approximately 100 unique BSSIDs of public and private Wi-Fi signals, which Google can use to infer a user's location.[10]

38. Android devices further send data to Google that indicates whether a user is still, walking, running, bicycling, or riding on a train or car. Sensors (such as the accelerometer) on a device running Google Android track these activities with high precision.[11]

39. To assess the extent of the location data (among other data) communicated to Google, the test Android device was left stationary with no interaction, but with Google Chrome left running in the background. The Android phone sent approximately 14 location signals to Google per hour.[12] These requests were sent to URLs like "loc/m/api," which is a specific service endpoint that receives HTTP requests specifically for the purposes of locating the user. These requests can either be to translate a set of WiFi access points into a precise location or to record the location of an observed set of access points, which enables Google to provide precise location even if a good GPS signal isn't available. In some cases, therefore, the request contains a precise location, whereas in others it contains a set of observed access points and their signal strengths, from which Google responds with a precise location.

40. The results of the 2018 Study illustrate that through the constant data requests (even when the phone isn't actively being used), the location requests using the phone's built-in sensors, and the use of private and public WiFi networks to determine a user's location, Android phones are essentially a tracking device Google uses to constantly assess the user's location. These results support the conclusion in paragraph 29 of the Nielson Declaration.

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[10] 2018 Study, at 12.
[11] 2018 Study, at 12-13.
[12] 2018 Study at 13-14.

B. Google Collects User Location Information from its Apps and Services.

41. The Nielson Declaration concludes in paragraph 31 that "Google also collects users' location information from its own apps and services, some of which are pre-installed on the mobile device, whereas others are downloaded."

42. This conclusion is supported by the 2018 Study. In particular, the results of the 2018 Study showed that Google collected location signals both through the Chrome browser and Google Maps.[13]

43. The Chrome browser gathers user location information through IP Address and using BSSIDs from public and private WiFi networks.[14] Google further collected location data through Chrome even when the Android phone was kept stationary, as discussed above.[15]

44. Collection through the Chrome browser was magnified when a user actively uses Chrome on a daily basis. The results of the 2018 Study indicated that when a user visited the average number of websites an internet user visits per day[16], Google would request the user's location approximately 450 times over a 24-hour period through the Chrome browser.[17]

45. The results of the 2018 Study also showed that Google Maps stores a user's location and provides a historical timeline of places visited by the user who is signed into Google Maps using their Google account.[18]

46. The results of the 2018 Study with respect to the location data collected by Google through the Chrome browser and Google Maps support the conclusion in paragraph 31 of

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[13] 2018 Study at 10-15, 23-24, 28-29.
[14] 2018 Study at 10-11.
[15] 2018 Study at 13- 15.
[16] As supported by Nielsen, discussed in footnote 57 to the 2018 Study.
[17] 2018 Study at 23-24.
[18] 2018 Study, at 28-29.

the Nielson Declaration. Both the Chrome browser and Google Maps constantly collect user location data and return that information to Google.

C. Through IPGeo and [redacted], Google Obtains User Location Data from IP Address.

47. The Nielson Declaration concludes in paragraph 33 that, "[t]hrough its IPGeo and [redacted] services, Google also obtains user location data from IP Addresses."

48. I understand that, according to the Nielson Declaration, that "[b]esides using an Android phone's signals and sensors to obtain a user's location, Google also determines user location through IP Address, including through Google's (Static) IP Geo and [redacted]."[19]

49. The Nielson Declaration further indicates that "Google has a service called IPGeo that translates IP addresses into geographic locations . . . Despite that name, this service [redacted]."[20]

50. Based on descriptions of IPGeo and [redacted] in paragraphs 33, 98 and 99 of the Nielson Declaration, it is my opinion that the results of the 2018 Study support the conclusion reached in the Nielson Declaration that Google collects and uses WiFi signals to determine location.

51. In particular, the results of the 2018 Study illustrate that Google uses WiFi access points to further refine location determined through IP Address. For example, on a 15-minute walk around a residential neighborhood, the Android device sent nine location requests to Google using approximately 100 unique BSSIDs of public and private Wi-Fi access points.[21]

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[19] Nielson Declaration, at ¶ 98.
[20] Nielson Declaration, at ¶ 99.
[21] 2018 Study at 11-12.

V. CONCLUSION

52. Paragraphs 29, 31, 33, 98, and 99 of the Nielson Declaration are supported by the results and conclusions drawn from the 2018 Study as explained in the paragraphs above.

53. Based on my review of the Nielson Declaration, none of the Preliminary Opinions are contradicted by the 2018 Study.

VI. EXPERT DISCLOSURES

54. Expert's Name, Address, and Qualifications: Douglas Craig Schmidt, 125 Apline Court, Franklin TN 37069. My qualifications are discussed in Section II, above, and my CV is attached as Appendix 3.

55. All publications I have authored over the past ten years are listed in my CV, attached as Appendix 3.

56. My opinions and the basis and reasons for them are described above and are further described in the 2018 Study, which I incorporate by reference.

57. All facts and data I considered in forming my opinion are described above and are further described in the 2018 Study, which I corporate by reference, the Nielson Declaration, and the State's Complaint, which I incorporate by reference.

58. I incorporate by reference all publications, articles, and reports cited in the 2018 Study as documents I have relied upon for my opinions. In addition, I similarly incorporate by reference the content of the 2018 Study and the Neilson Declaration.

59. For my work in this matter, I am being compensated my rate of $550 per hour. My compensation is not contingent on the outcome of the proceedings or substance of my conclusions.

60. Below is a list of all cases where I have testified in a trial or hearing over the past four years:

a. July 2018, Testified in support of IBM in the IBM vs. Groupon case. Case No. Civ A. N. 16-122-LPS-CJB.

b. February 2019, Testified in support of C3IoT in the E2.0 vs. C3IoT case. Case No. 1:15-cv-00530-GMS.

c. May 2020, Testified in support of Cisco in the Centriptal vs. Cisco case. Civil Action No. 2:18-cv-00094-HCM-LRL.

d. March 2022, Testified in support of Droplets in the Droplets vs. Yahoo case. Civil Action No. 12-CV-03733-JST.

May 4, 2022
Nashville, TN

Douglas C. Schmidt

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Douglas Craig Schmidt, Ph.D.

APPENDIX 1

Institute for Software-Integrated Systems

Technical Report

TR#: ISIS-20-201

Title: Google Data Collection

Authors: Douglas C. Schmidt

<u>Google Data Collection</u>

Professor Douglas C. Schmidt, Vanderbilt University

August 15, 2018

I. EXECUTIVE SUMMARY

1. Google is the world's largest digital advertising company.[1] It also provides the #1 web browser,[2] the #1 mobile platform,[3] and the #1 search engine[4] worldwide. Google's video platform, email service, and map application have over 1 billion monthly active users each.[5] Google utilizes the tremendous reach of its products to collect detailed information about people's online and real-world behaviors, which it then uses to target them with paid advertising. Google's revenues increase significantly as the targeting technology and data are refined.

2. Google collects user data in a variety of ways. The most obvious are "active," with the user directly and consciously communicating information to Google, as for example by signing in to any of its widely used applications such as YouTube, Gmail, Search etc. Less obvious ways for Google to collect data are "passive" means, whereby an application is instrumented to gather information while it's running, possibly without the user's knowledge. Google's passive data gathering methods arise from platforms (e.g. Android and Chrome), applications (e.g. Search, YouTube, Maps), publisher tools (e.g. Google Analytics, AdSense) and advertiser tools (e.g. AdMob, AdWords). The extent and magnitude of Google's passive data collection has largely been overlooked by past studies on this topic.[6]

3. To understand what data Google collects, this study draws on four key sources:

a. Google's My Activity[7] and Takeout[8] tools, which describe information collected during the use of Google's user-facing products;

b. Data intercepted as it is sent to Google server domains while Google or 3rd-party products are used;

c. Google's privacy policies (both general and product-specific); and

d. Other 3rd-party research that has examined Google's data collection efforts.

4. Through the combined use of above resources, this study provides a unique and comprehensive view of Google's data collection approaches and delves deeper into specific types of information it collects from users. This study highlights the following key findings:

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[1] "Google and Facebook tighten grip on US digital ad market," *eMarketer*, Sept. 21, 2017, available at https://www.emarketer.com/Article/Google-Facebook-Tighten-Grip-on-US-Digital-Ad-Market/1016494
[2] "Market share or leading internet browsers in the United States and worldwide as of February 2018," *Statista,* February 2018, available at https://www.statista.com/statistics/276738/worldwide-and-us-market-share-of-leading-internet-browsers/
[3] "Global OS market share in sales to end users from 1st quarter 2009 to 2nd quarter 2017," *Statista*, August 2017, available at https://www.statista.com/statistics/266136/global-market-share-held-by-smartphone-operating-systems/
[4] "Worldwide desktop market share of leading search engines from January 2010 to October 2017," *Statista,* Feb. 2018, available at https://www.statista.com/statistics/216573/worldwide-market-share-of-search-engines/
[5] Google 10K filings with the SEC, 2017, available at https://abc.xyz/investor/pdf/20171231_alphabet_10K.pdf
[6] Please see Appendix section IX.F for a list of past studies/news reports on Google data collection
[7] "My Activity," *Google*, available at https://myactivity.google.com/myactivity
[8] "Download your data," *Google*, available at https://takeout.google.com/settings/takeout?pli=1

a. Google learns a great deal about a user's personal interests during even a single day of typical internet usage. In an example "day in the life" scenario, where a real user with a new Google account and an Android phone (with new SIM card) goes through her daily routine, Google collected data at numerous activity touchpoints, such as user location, routes taken, items purchased, and music listened to. Surprisingly, Google collected or inferred over two-thirds of the information through passive means. At the end of the day, Google identified user interests with remarkable accuracy.

b. Android is a key enabler of data collection for Google, with over 2 billion monthly active users worldwide.[9] While the Android OS is used by Original Equipment Manufacturers (OEMs) around the world, it is tightly connected with Google's ecosystem through Google Play Services. Android helps Google collect personal user information (e.g. name, mobile phone number, birthdate, zip code, and in many cases, credit card number), activity on the mobile phone (e.g. apps used, websites visited), and location coordinates. In the background, Android frequently sends Google user location and device-related information, such as apps usage, crash reports, device configuration, backups, and various device-related identifiers.

c. The Chrome browser helps Google collect user data from both mobile and desktop devices, with over 2 billion active installs worldwide.[10] The Chrome browser collects personal information (e.g. when a user completes online forms) and sends it to Google as part of the data synchronization process. It also tracks webpage visits and sends user location coordinates to Google.

d. Both Android and Chrome send data to Google even in the absence of *any* user interaction. Our experiments show that a dormant, stationary Android phone (with Chrome active in the background) communicated location information to Google 340 times during a 24-hour period, or at an average of 14 data communications per hour. In fact, location information constituted 35% of all the data samples sent to Google. In contrast, a similar experiment showed that on an iOS Apple device with Safari (where neither Android nor Chrome were used), Google could not collect any appreciable data (location or otherwise) in the absence of a user interaction with the device.

e. After a user starts interacting with an Android phone (e.g. moves around, visits webpages, uses apps), passive communications to Google server domains increase significantly, even in cases where the user did not use any prominent Google applications (i.e. no Google Search, no YouTube, no Gmail, and no Google Maps). This increase is driven largely by data activity from Google's publisher and advertiser products (e.g. Google Analytics, DoubleClick, AdWords)[11]. Such data constituted 46% of all requests

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[9] Dave Burke, "Android: celebrating a big milestone together with you," *Google,* May 17, 2017, available at https://www.blog.google/products/android/2bn-milestone/

[10] Frederic Lardinois, "Google says there are now 2 billion active Chrome installs," *TechCrunch,* Nov. 10, 2016, available at https://techcrunch.com/2016/11/10/google-says-there-are-now-2-billion-active-chrome-installs/

[11] Google recently rebranded AdWords as "Google Ads" and DoubleClick as "Google Ad Manager"

to Google servers from the Android phone. Google collected location at a 1.4x higher rate compared to the stationary phone experiment with no user interaction. Magnitude wise, Google's servers communicated 11.6 MB of data per day (or 0.35 GB/month) with the Android device. This experiment suggests that even if a user does not interact with any key Google applications, Google is still able to collect considerable information through its advertiser and publisher products.

f. While using an iOS device, if a user decides to forgo the use of *any* Google product (i.e. no Android, no Chrome, no Google applications), and visits only non-Google webpages, the number of times data is communicated to Google servers still remains surprisingly high. This communication is driven purely by advertiser/publisher services. The number of times such Google services are called from an iOS device is similar to an Android device. In this experiment, the total magnitude of data communicated to Google servers from an iOS device is found to be approximately half of that from the Android device.

g. Advertising identifiers (which are purportedly "user anonymous" and collect activity data on apps and 3rd-party webpage visits) can get connected with a user's Google identity. This happens via passing of device-level identification information to Google servers by an Android device. Likewise, the DoubleClick cookie ID (which tracks a user's activity on the 3rd-party webpages) is another purportedly "user anonymous" identifier that Google can connect to a user's Google Account if a user accesses a Google application in the same browser in which a 3rd-party webpage was previously accessed. Overall, our findings indicate that Google has the ability to connect the anonymous data collected through passive means with the personal information of the user.

Contents

II. A DAY IN THE LIFE OF A GOOGLE USER

5. To illustrate the multitude of touchpoints between Google and an individual, as well as the extent of information collected during these interactions, an experiment was designed where a researcher carried an Android mobile phone device[12] during a day's activities. The mobile phone was wiped by conducting a factory data reset[13] and configured as a new device to avoid prior user information associated with the device.[14] A new Google account was created (username "Jane"), so that Google had no prior knowledge of the user and had no advertising interests associated with the account. Researcher then went about a normal day using the mobile phone associated with the new Google account.

6. The data collected by Google was checked using two tools provided by Google: My Activity[15] and Takeout.[16] The My Activity tool shows data collected by Google from any Search-related activities, use of Google applications (e.g. YouTube video plays, Maps search, Google Assistant), visits to 3rd-party web pages (while logged in to Chrome), and clicks on advertisements. The Google Takeout tool provides a more comprehensive information about all historical user data collected via Google's applications (e.g. it contains all past email messages on Gmail, search queries, location collection, and YouTube videos watched). We synthesized the collected data and used it to depict key information collection events in the form of a "day in the life" of the user "Jane," as shown in Figure 1.

7. In the activity shown in Figure 1, as well as throughout the rest of this document, the collected data is categorized in two broad subgroups: *active* and *passive*. Active data is defined as information directly exchanged between the user and a Google product, whereas passive data is defined as information exchanged in the background without any obvious notification to the user. An example of active data collection occurred when Jane submitted a keyword in the Search tool bar and that search query was collected by Google. An example of passive data collection occurred when Jane's location was sent to Google after she entered a search query.

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[12] LG X Power device with Android 6.0 version installed

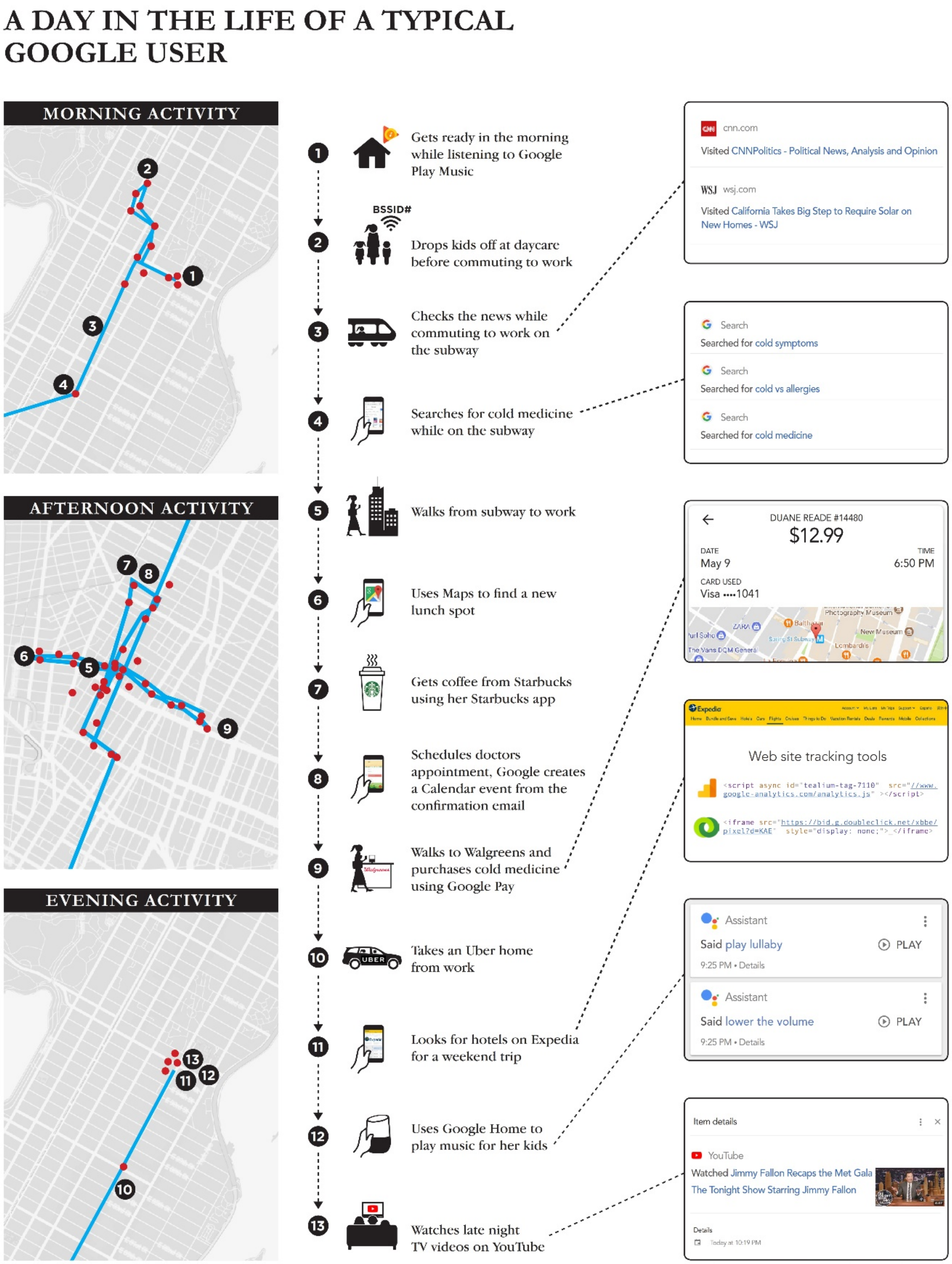
[13] The factory data reset deletes all login data for Google services and other accounts, system and app data and settings, all downloaded apps, digital rights management licenses, music, images, documents and backups, and other usage data from the internal storage of the device.

[14] Researchers used LG X Power device that was wiped clean to the default factory settings and given new SIM card in order to ensure that no data was stored on the phone and that phone numbers could not be linked with any past usage.

[15] "My Activity," Google, available at https://myactivity.google.com/myactivity

[16] "Download your data," Google, available at https://takeout.google.com/settings/takeout?pli=1

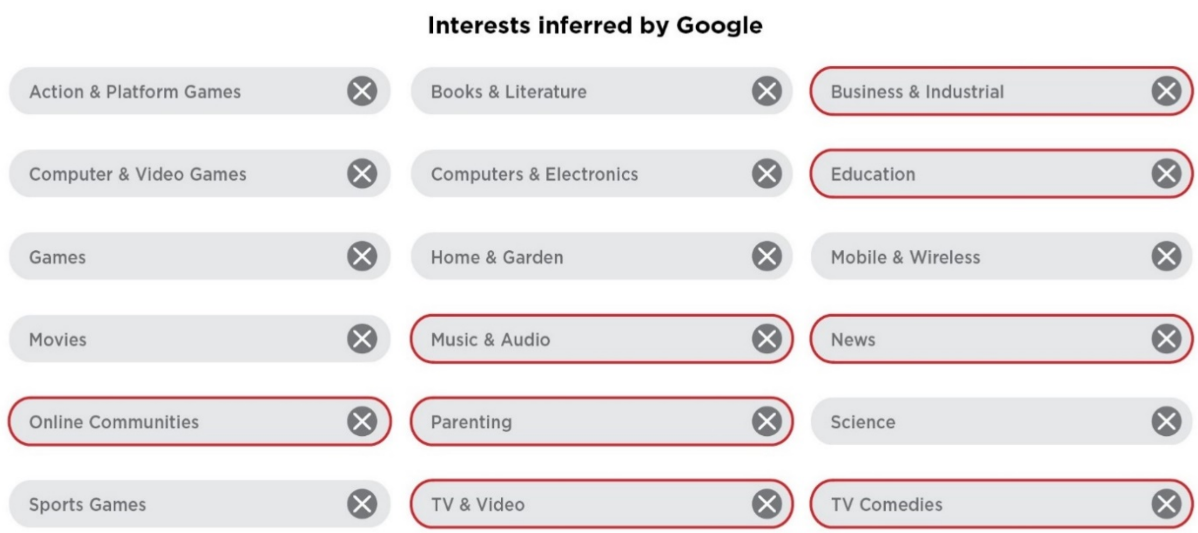
Figure 1: Day in the life of Jane, highlighting touchpoints where Google collects data



8. Analysis of key touch points during a normal day in the life of Jane suggested that the number of "passive" data collection events outnumbered the "active" events by approximately two-to-one (a detailed breakdown of characterization of active vs passive data collected appears in Table 3 of the Appendix section IX. A).

9. Google analyzes the collected data to assess user interests, which it then applies to target users with appropriate ads. For example, Google provides a list of interests that it has inferred from a user's activities, available via the "topics you like" section in the Google's Ad Personalization webpage.[17] Figure 2 shows such a list that Google associated with Jane's account after a day's worth of activity. In total, Google attributed 18 interests to Jane, eight of which (shown by colored borders) closely matched Jane's usage and activities.[18]

Figure 2: Google's assessment of Jane's interest at the end of the day



10. Although My Activity and Takeout tools are helpful in assessing the amount of active data collected after a user interacts with Google's products, they do not paint a complete picture of the size and scale of Google's data collection. A comprehensive understanding of which requires a review of Google's product-specific privacy policies, as well as analyses of the actual data traffic passed to Google servers during the instances of a user's interaction with its services. Results derived from these resources are covered later in this report.

III. DATA COLLECTION THROUGH ANDROID AND CHROME PLATFORMS

[17] "Ads personalization," *Google*, last accessed on August 15 2018, available at https://adssettings.google.com/authenticated
[18] It's unclear as to why other interests that have no connection with Jane's activities during the day show up in this list, though perhaps Google uses historical analysis of similar interests from other users to create associated recommendations.

11. Android and Chrome are Google's key platforms that aid in significant user data collection due to their extensive reach and frequency of usage. By January 2018, Android captured 53% of the total US mobile OS market (Apple iOS held 45%)[19] and as of May 2017 there were more than 2 billion monthly active Android devices worldwide.[20]

12. Google's Chrome browser held more than 60% share of all internet browser usage in the world with over 1 Billion monthly active users as reported in the 2017 Q4 10K filing.[21] Both platforms facilitate the use of Google and 3rd-party content (e.g. 3rd-party websites and 3rd-party apps) and hence provide Google access to a wide range of personal, web activity, and location information.

A. Personal information and activity data collection

13. To download and use apps from Google Play Store on an Android device, a user must have (or create) a Google Account, which becomes a key gateway through which Google collects personal information, including user name, email, and phone number. If a user registers for services such as Google Pay[22], Android also collects the user's credit card information, zip code, and birth date. All this information becomes part of a user's personal information associated with their Google Account.

14. While Chrome does not mandate sharing additional personal information gathered from users, it does have the capability to capture such information. For example, Chrome collects a range of personal information via its form "autofill" feature, and such form fields typically include user name, address, phone number, login name, and passwords.[23] Chrome stores form fill information on a user's local drive, however, if the user logs in to Chrome using Google Account and enables its "Sync" feature, this information gets sent to and stored on Google servers. Chrome could also learn about the language(s) a person speaks during their interactions with its translate feature, which is enabled by default.[24]

15. In addition to personal data, both Chrome and Android send Google information about a user's web browsing and mobile app activities, respectively. Any webpage visit is automatically tracked and collected under

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[19] "Subscriber share held by smartphone operating systems in the United States from 2012 to 2018," *Statista,* May 2018, available at https://www.statista.com/statistics/266572/market-share-held-by-smartphone-platforms-in-the-united-states/

[20] Dave Burke, "Android: celebrating a big milestone together with you," *Google,* May 17, 2017, available at https://www.blog.google/products/android/2bn-milestone/

[21] Google 10K filings with the SEC

[22] "Google Chrome privacy whitepaper," *Google,* March 6, 2018, available at https://www.google.com/chrome/privacy/whitepaper.html#payments

[23] "Google Chrome privacy whitepaper," *Google,* March 6, 2018, available at https://www.google.com/chrome/privacy/whitepaper.html#autofill

[24] "Google Chrome privacy whitepaper," *Google,* March 6, 2018, available at https://www.google.com/chrome/privacy/whitepaper.html#translate

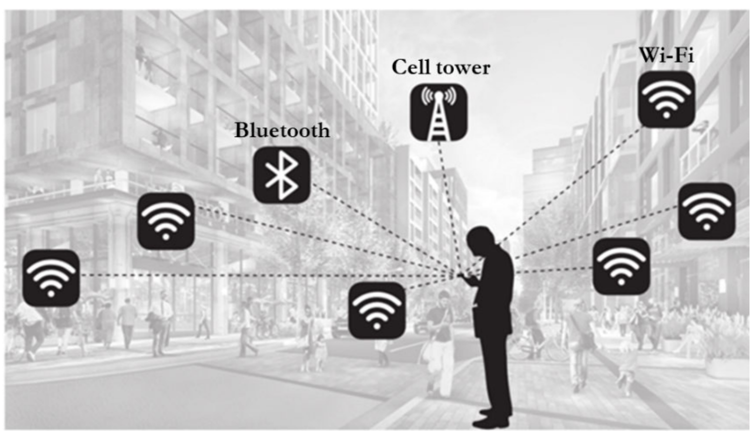
user credentials by Google if the user is signed in to Chrome. Chrome also collects information about a user's browsing history, passwords, website-specific permissions, cookies, download history, and add-on data.[25]

16. Android sends periodic updates to Google servers, including device type, cell service carrier name, crash reports, and information about apps installed on the phone.[26] It also notifies Google whenever any app is accessed on the phone (e.g. Google knows when an Android user accesses their Uber app).

B. User location data collection

17. Android and Chrome platforms meticulously collect user location and movement information using a variety of sources, as depicted by Figure 3. For example, a "coarse location" assessment can be done by using GPS coordinates on an Android phone or through a network's IP address on a desktop/laptop device. The user location accuracy can be improved further ("fine location") through the use of nearby cell tower IDs or via scanning the device-specific BSSIDs or basic service set identifiers, assigned to the radio chipset used in nearby Wi-Fi access points.[27] Android phones can also use information from the Bluetooth beacons registered with Google's Proximity Beacon API.[28] These beacons not only provide user's geolocation coordinates, but could also pinpoint exact floor levels in buildings.[29]

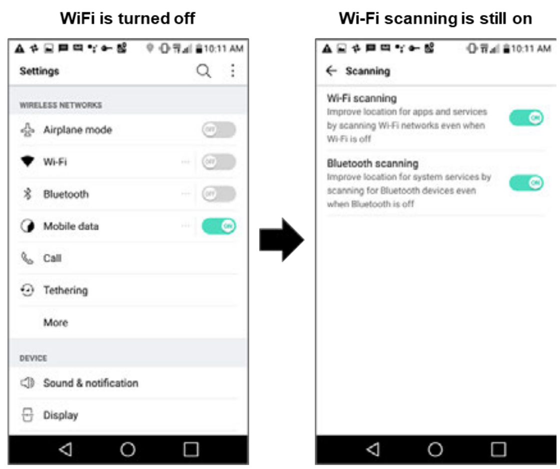
<u>Figure 3: Android and Chrome use multiple ways to locate a mobile user</u>



[25] "Google Chrome Privacy Notice," *Google*, March 6, 2018, available at https://www.google.com/intl/en/chrome/browser/privacy
[26] https://policies.google.com/privacy?hl=en&gl=us#infocollect
[27] To understand how location data is sent to Google servers in more depth, our researchers analyzed the data traffic from a mobile phone from a user in motion, applying the method described in Appendix section VIII.C.
[28] "Google beacon platform, proximity beacon API," *Google,* last accessed on August 15 2018, available at https://developers.google.com/beacons/proximity/guides
[29] "Google beacon platform, proximity beacon API," *Google,* last accessed on August 15 2018, available at https://developers.google.com/beacons/proximity/guides

18. It's hard for an Android mobile user to "opt out" of location tracking. For example, on an Android device, even if a user turns off the Wi-Fi, the device's location is still tracked via its Wi-Fi signal. To prevent such tracking, Wi-Fi scanning must be explicitly disabled in a separate user action, as shown in Figure 4.

<u>Figure 4: Android collects data even if Wi-Fi is turned off by user</u>



19. The ubiquity of Wi-Fi hubs has made location tracking quite frequent. For example, during a short 15-minute walk around a residential neighborhood, an Android device sent nine location requests to Google. The request collectively contained ~100 unique BSSIDs of public and private Wi-Fi access points.

20. Google can ascertain with a high degree of confidence whether a user is still, walking, running, bicycling, or riding on a train or a car. It achieves this by tracking an Android mobile user's location coordinates at frequent time intervals in combination with the data from onboard sensors (such as an accelerometer) on mobile phones. Figure 5 shows an example of such data communicated with the Google servers while the user was walking.

<u>Figure 5: Snapshot from a Google user location upload</u>


```
"activityReadings": [
    {
        "activities": [
            {
                "confidence": 99,
                "type": "onFoot"
            },
            {
                "confidence": 99,
                "type": "walking"
            },
            {
                "confidence": 1,
                "type": "unknown"
            }
        ],
        "timestampMs": 1527095517507
    },
```


C. An assessment of passive data collection by Google through Android and Chrome

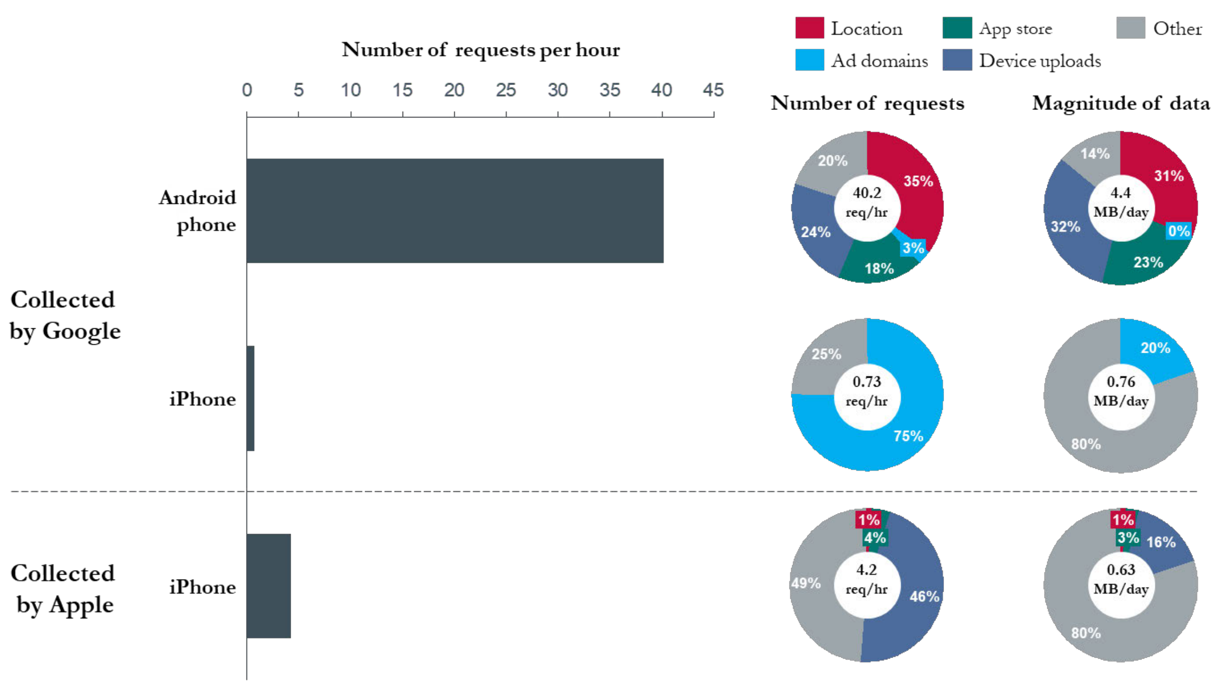
21. Active data that Android or Chrome platforms collect and send to Google as a result of users' activities on these platforms can be assessed through the MyActivity and Takeout tools. Of potentially greater interest, however, is the passive data that these platforms collect, which goes beyond location data and which remains relatively unrecognized by the users. To assess the type and frequency of occurrence of such collection in greater detail an experiment was conducted that monitored traffic data sent to Google from mobile phones (both Android and iPhone) using the method discussed in Section IX.D in the Appendix. For comparison's sake, this experiment also included the analysis of data sent to Apple via an iPhone device.

22. For simplicity, the phones were kept stationary, with no user interaction. On the Android phone a single Chrome browser session remained active in the background, whereas on the iPhone the Safari browser was used. This configuration provided an opportunity for systematic analysis of the background collection that Google performs purely through Android and Chrome, as well as collection that occurs in the absence of those (i.e. from iPhone device), without any additional collection requests generated by other products and applications (e.g. YouTube, Gmail, App usage).

23. Figure 6 shows a summary of the results obtained from this experiment. The x-axis indicates the number of times the phones communicated with Google (or Apple) servers, whereas the y-axis indicates the phone type (Android or iPhone) and server domain type (Google or Apple) with which data packets were exchanged by the phones. The colored legend describes the broad categorization of the type of data requests identified by the domain address of the server. A complete list of domain addresses belonging within each category appears in Table 5 of Section IX.D of the Appendix.

24. During a 24-hour time period the Android device communicated ~900 data samples to a variety of Google server endpoints. Of these, ~35% (or approximately 14/hour) were location-related. Google ad domains received only ~3% of the traffic, which is mainly due to the fact that the mobile browser was not actively used during the collection period. The remaining ~62% of communications with the Google server domains were roughly divided between requests to Google's Play App store, Android's uploads of device-related data (such as crash reports and device authorization), and other data which were predominantly in the category of Google services background calls and refreshes.

Figure 6: Traffic data sent from idle Android and iPhone mobiles



25. Figure 6 shows that the iPhone device communicated with Google domains at more than an order of magnitude (~50x) lower frequency than the Android device, and that Google did not collect any user location during the 24-hour experiment timeframe via iPhone. This result highlights the fact that the Android and Chrome platforms play an important role in Google's data collection.

26. Additionally, the iPhone device's communication with Apple's servers were 10x less frequent than the Android device's communications with Google. Location data made up a very small fraction (~1%) of the net data sent to Apple servers from the iPhone, with Apple receiving location-related communications once every day on an average.

27. Magnitude wise, Android phones communicated 4.4 MB of data per day (~130MB per month) with Google servers, which is 6x more than what Google servers communicated through the iPhone device.

28. As a reminder, this experiment was conducted using a stationary phone with no user interaction. As a user becomes mobile and starts interacting with their phone, the frequency of communications with Google's servers increases considerably. Section V of this report summarizes results from such an experiment.

IV. DATA COLLECTION THROUGH PUBLISHER AND ADVERTISER TECHNOLOGIES

29. A major source for Google's user activity data collection stems from its publisher- and advertiser-focused tools, such as Google Analytics, DoubleClick, AdSense, AdWords, and AdMob. These tools have tremendous reach, e.g. over 1 million mobile apps use AdMob,[30] over 1 million advertisers use AdWords,[31] over 15 million websites use AdSense,[32] and over 30 million websites use Google Analytics.[33]

30. During the writing of this report Google rebranded AdWords as "Google Ads" and DoubleClick as "Google Ad Manager", however there were no changes instituted in the core product functionalities including information collection by these products.[34] Therefore, for the purpose of this report the names are kept unchanged to avoid confusion that may occur with related domain names (such as doubleclick.net).

31. There are two main groups of users of Google's publisher- and advertiser-focused tools:

- *Website and app publishers*, which are organizations that own websites and create mobile apps. These entities use Google's tools to (1) make money by allowing the display of ads to visitors on their websites or apps, and (2) better track and understand who is visiting their websites and using their apps. Google's tools place cookies and run scripts in the browsers of website visitors that help determine a user's identity, track their interest in content, and follow their online behavior. Google's mobile app libraries track use of apps on mobile phones.

- *Advertisers*, which are organizations that pay to have banner, video, or other ads delivered to users as they browse the Internet or use apps. These entities apply Google's tools to target specific profiles of people for advertisements to increase the return on their marketing investments (better targeted ads generally yield higher click-through rates and conversions). Such tools also enable advertisers to analyze their audiences and measure the efficacy of their digital advertising by tracking which ads were clicked with what frequency and by providing insight into the profiles of people who clicked on ads.

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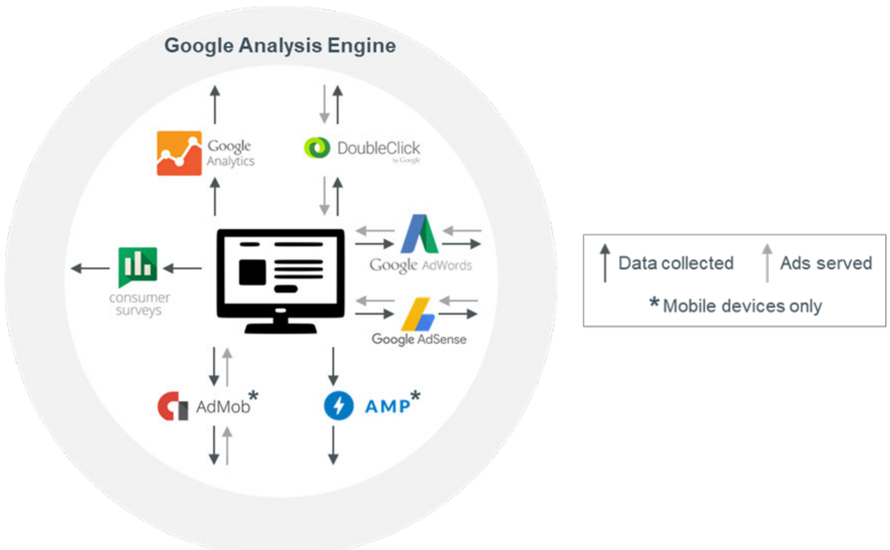
[30] "AdMob by Google," *Google*, last accessed on August 15 2018, available at https://www.google.com/admob/
[31] "Hear form our happy customers," *Google,* last accessed on August 15 2018, available at https://adwords.google.com/home/resources/success-stories/
[32] "Websites using Google Adsense," *BuiltWith,* last accessed on August 15 2018, available at https://trends.builtwith.com/websitelist/Google-Adsense
[33] Google Analytics usage statistics," *BuiltWith,* April 2018, available at https://trends.builtwith.com/analytics/Google-Analytics
[34] Garett Sloane, "Google to retire Doubleclick and AdWords names in a rebrand of its as business," *Ad Age,* available at http://adage.com/article/digital/google-waves-goodbye-doubleclick-ad-business-evolves/314046/

32. Together, these tools collect information about user activities on websites and in apps, such as content visited, and ads clicked. They work in the background—largely unnoticeable by users. Figure 7 shows some of these key tools, with arrows indicating data collected from users and ads served to users.

Figure 7: Google products aimed at publishers and advertisers[35]



33. The information collected by such tools includes a non-personal identifier that Google can use to send targeted advertisements without identifying the unique individual's personal information. These identifiers can be device- or session-specific, as well as permanent or semi-permanent. Table 1 lists a set of such identifiers. To provide users greater anonymity during information collection for ad targeting, Google has recently shifted towards using semi-permanent device unique identifiers (e.g. GAIDs).[36] Further sections go in detail about how these tools collect user data and the use of such identifiers during the data collection process.

Table 1: Identifiers passed to Google

Identifier	Type	Description
GAID/IDFA	Semi-Permanent	Alphanumeric string for Android / iOS devices to allow targeted mobile ads. Resettable by users.
Client ID	Semi-Permanent	ID created the first time a cookie is stored on the browser. Used to link browsing sessions together. Resets when browser cookies are cleared.
IP address	Semi-Permanent	A unique string of number that identifies the network through which a device is accessing the Internet.

[35] "Our products," *Google,* last accessed on August 15 2018, available at https://www.google.com/about/products/
[36] "Best practices for unique identifiers," *Google,* last accessed on August 15 2018, available at https://developer.android.com/training/articles/user-data-ids

Android device ID	Semi-Permanent	Randomly generated number when a device is first booted up. Used to identify the device. It is in the process of being phased out of advertising. Resets with a factory reset of a device.
Google Services Framework (GSF)	Semi-Permanent	Randomly assigned number when a user first logs into Google services on a device. Used to identify a unique device. Resets with a factory reset of a device.
IEMI / MEID	Permanent	Identifier used in mobile communication standards. Unique for each mobile phone.
MAC address	Permanent	Unique 12-character identifier for a piece of hardware (e.g. router).
Serial number	Permanent	Alphanumeric string used to identify a device.

A. Google Analytics and DoubleClick

34. DoubleClick and Google Analytics (GA) are Google's leading products in user behavior tracking and webpage traffic analyses on desktop and mobile devices. GA is used by ~75% of the top 100,000 most visited websites.[37] DoubleClick cookies are associated with more than 1.6 million websites.[38]

35. GA uses short pieces of tracking code (called "page tags") embedded in a website's HTML code.[39] After a webpage loads per a user's request, the GA code calls an "analytics.js" file residing on Google's servers. This program transfers a "default" snapshot of user data at that moment, which includes visited webpage address, page title, browser information, current location (derived from IP address), and user language settings. GA scripts use cookies to track user behavior.

36. GA script, the first time when it's run, generates and stores a browser-specific cookie on the user's computer. This cookie has a unique client identifier or Client ID (see Table 1 for details).[40] Google uses the unique identifier to link previously stored cookies that capture a user's activity on a particular domain as long as the cookie does not expire, or the user does not clear the cookies cached on their browser.[41]

37. While a GA cookie is specific to the particular domain of the website that user visits (called a "1st-party cookie"), a DoubleClick cookie is typically associated with a common 3rd-party domain (such as

[37] Google Analytics usage statistics," *BuiltWith,* April 2018, available at https://trends.builtwith.com/analytics/Google-Analytics
[38] "DoubleClick market share," *Datanyze,* last accessed on August 15 2018, available at https://www.datanyze.com/market-share/ad-exchanges/doubleclick-market-share
[39] GA or other tags can also be implemented through Google Tag Manage (GTM) without changing the functionality of the page tag
[40] "Cookies and user identification," *Google*, last accessed on August 15 2018, available at https://developers.google.com/analytics/devguides/collection/analyticsjs/cookies-user-id
[41] "Cookies and user identification," *Google*, last accessed on August 15 2018, available at https://developers.google.com/analytics/devguides/collection/analyticsjs/cookies-user-id

doubleclick.net). Google uses such cookies to track user interaction across multiple 3rd-party websites.[42] When a user interacts with an advertisement on a website, DoubleClick's conversion tracking tools (e.g. Floodlight) places cookies on a user's computer and generates a unique client ID.[43] Thereafter, if the user visits the advertised website, the stored cookie information gets accessed by the DoubleClick server, thereby recording the visit as a valid conversion.

B. AdSense, AdWords and AdMob

38. AdSense and AdWords are Google tools that serve ads on websites and in Google Search results, respectively. More than 15 million websites have AdSense installed to display sponsored ads.[44] Likewise, more than 2 million websites and apps that make up the Google Display Network (GDN) and reach over 90% of Internet users[45] display AdWords ads.

39. AdSense collects information about whether an ad was displayed on the publisher's webpage. It also collects how the user interacted with the ad, such as clicking an ad or tracking the curser movement over an ad.[46] AdWords enables advertisers to serve search ads on Google Search, display ads on publisher pages, and overlay ads on YouTube videos. To track user click-through and conversion rates, AdWords ads place a cookie on users' browsers to identify the same user if they later visit the advertiser's website or complete a purchase.[47]

40. While AdSense and AdWords collect data on mobile devices as well, their ability to get user information on mobile devices is limited since mobile apps do not share cookie data between them, an isolation technique known as 'sandboxing,'[48] which makes it hard for advertisers to track user behavior across mobile apps.

41. To address this issue, Google and other companies use mobile "ad libraries" (such as AdMob) that are integrated into the apps by their developers for serving ads in mobile apps. These libraries compile and run with the apps and send to Google data that is specific to the app to which they belong, including GPS locations, device make, and device model when apps have the appropriate permissions. As observed through the data

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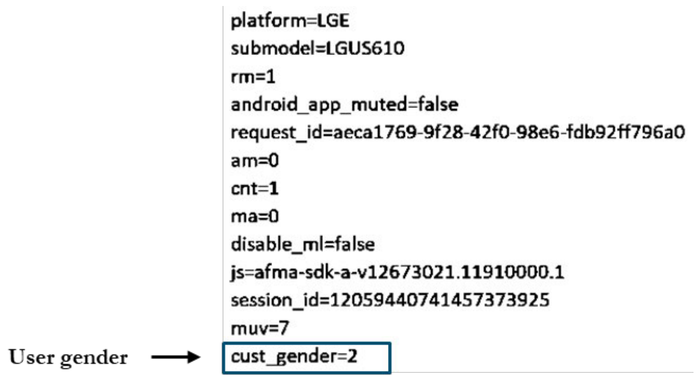
[42] "DoubleClick search help," *Google,* last accessed on August 15 2018, available at https://support.google.com/ds/answer/7298761?hl=en
[43] "DoubleClick search help," *Google,* last accessed on August 15 2018, available at https://support.google.com/ds/answer/2903014?hl=en&ref_topic=6054260
[44] "Websites using Google Adsense," *BuiltWith,* last accessed on August 15 2018, available at https://trends.builtwith.com/websitelist/Google-Adsense
[45] "Google Ads Help," *Google,* last accessed on August 15 2018, available at https://support.google.com/google-ads/answer/2404191?hl=en
[46] "AdSense help, privacy and security," *Google,* last accessed on August 15 2018, available at https://support.google.com/adsense/answer/9897?hl=en
[47] "Evaluating ad performance on the Search Network," *Google,* last accessed on August 15 2018, available at https://support.google.com/adwords/answer/2404037?hl=en; "About conversion tracking," *Google,* last accessed on August 15 2018, available at https://support.google.com/adwords/answer/1722022?hl=en
[48] This approach is similar to desktops, where cookies are not shared between browsers.

traffic analyses (Figure 8), and confirmed through Google's own developer webpages,[49] such libraries can also send user-personal data, such as age and gender, to Google whenever app developers explicitly pass these values to the library.

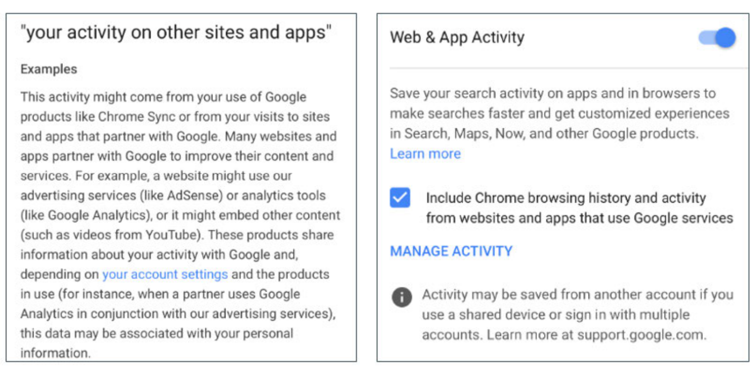
<u>Figure 8: Snapshot of information sent back to Google when an application is launched</u>



C. Association of passively collected data with personal information

42. As discussed above, Google collects data through publisher and advertiser products and associate such data with a variety of semi-permanent, anonymous identifiers. Google however, has the ability to associate these IDs with a user's personal information. This is insinuated by the statements made in Google's privacy policy, excerpts of which are shown in Figure 9. The left text box clearly states that Google may associate data from advertising services and analytics tools with a user's personal information, depending upon the user's account settings. This arrangement is enabled by default, as shown in the right text box.

<u>Figure 9: Google's privacy page for 3rd-party websites collection and association with personal information[50][51]</u>



[49] "Google APIs for Android," *Google,* last accessed on August 15 2018, available at https://developers.google.com/android/reference/com/google/android/gms/ads/doubleclick/PublisherAdRequest.Builder
[50] "Google privacy and terms," *Google,* last accessed on August 15 2018, available at https://policies.google.com/privacy/example/your-activity-on-other-sites-and-apps
[51] "Google https://myaccount.google.com/activitycontrols

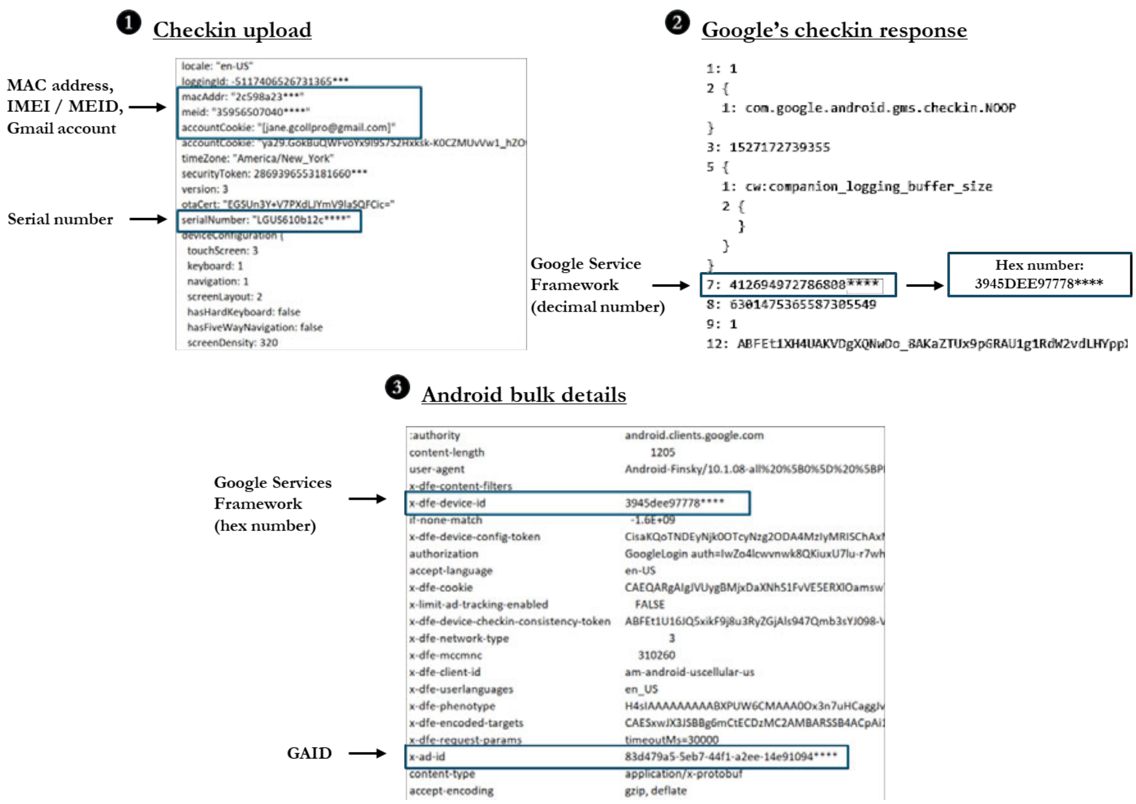
43. Furthermore, an analysis of data traffic exchanged with Google servers (summarized below) identified two key examples (one on Android and the other in Chrome) that point to Google's ability to correlate anonymously collected data with users' personal information.

1) <u>Mobile advertising identifier may get de-anonymized through data sent to Google by Android</u>

44. Analyses of data traffic communicated between an Android phone and Google server domains suggest a possible way through which anonymous identifiers (GAID in this case) can get associated with a user's Google Account. Figure 10 describes this process through a series of three key steps.

45. In step 1, a "checkin" data is sent to the URL *android.clients.google.com/checkin*. This particular communication provides an Android data sync to Google servers and contains Android log information (e.g. recovery log), kernel messages, crash dumps, and other device-related identifiers. A snapshot of a partially decoded checkin request sent to Google's server from Android is shown in Figure 10.

<u>Figure 10: Device identifiers are sent together with account information in Android check in requests</u>



46. As pointed out by the labeled boxes, through the checkin process, Android sends to Google a variety of important device-related permanent identifiers, including device MAC address, IMEI /MEID, and device

serial number. Moreover, these requests also contain the Android user's Gmail ID. The data present in checkin uploads enable Google to connect a user's personal information with Android device permanent identifiers.

47. In step 2, the reply to the checkin request comes from the Google server. This message contains a Google services framework identifier (GSF ID)[52] that is similar to the actual "Android ID"[53] (see Table 1 for descriptions).

48. Step 3 entails another instance of communication where the same GSF ID (from step 2) is sent to Google together with the GAID. Figure 10 shows one such data transmit to *android.clients.google.com/fdfe/bulkDetails?au=1*.

49. Through the above three data exchanges, Google receives the information needed to connect a GAID with permanent device identifiers as well as users' Google Account IDs.

50. These intercepted data exchanges with Google servers from an Android phone show how Google can connect anonymized information collected on an Android mobile device via DoubleClick, Analytics or AdMob tools with the user's personal identity. During the 24-hour data collection from a stationary and dormant Android phone two instances of checkin communications with Google servers were observed. Additional analysis is needed, however, to determine if such information exchange occurs with a certain periodicity or if it is triggered by specific activities on the phones.

2) <u>DoubleClick cookie ID gets connected with user's personal information on Google Account</u>

51. The previous section explained how Google can de-anonymize user identity via the passive, anonymized data it collects from an Android mobile device. This section shows how such de-anonymization can also occur on a desktop/laptop device.

52. Anonymized data on desktops/laptops is collected via cookie-based identifiers (e.g. Cookie ID), which are typically generated by Google's ad and publisher products (e.g. DoubleClick) and stored on a user's local mass storage. The experiment presented below assessed whether Google can connect such identifiers (and hence information associated with them) with a user's personal information. This experiment involved the following ordered steps:

1. Opened a new (no saved cookies, e.g. Private or Incognito) browser session (Chrome or other),

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[52] "Difference between Android ID and device ID," *Stack Exchange,* Dec. 2016, available at https://android.stackexchange.com/questions/162448/difference-between-android-id-and-device-id

[53] Patrick Ahlbrecht, "What's the difference between the GSF ID and the Android ID," *Onyxbits,* March 2016, available at https://blog.onyxbits.de/whats-the-difference-between-the-gsf-id-and-the-android-id-208/

2. Visited a 3rd-party website that used Google's DoubleClick ad network,

3. Visited the website of a widely used Google service (Gmail in this case),

4. Signed in to Gmail.

53. After completion of step 1 and 2, as part of the page load process, the DoubleClick server received a request when the user first visited the 3rd-party website. This request was part of a series of requests comprising the DoubleClick initialization process started by the publisher website, which resulted in the Chrome browser setting a cookie for the DoubleClick domain. This cookie stayed on user's computer until it expired or until the user manually cleared coolies via the browser settings.

54. Thereafter, in step 3, when the user visited Gmail, they are prompted to log in with their Google credentials. Google manages identity using a "single sign on (SSO)" architecture, whereby credentials are supplied to an account service (signified by *accounts.google.com*) in exchange for an "authentication token," which can then be presented to other Google services to identify the users. In step 4, when a user accesses their Gmail account, they are effectively signing into their Google Account, which then provides Gmail with an authorization token to verify the user's identity. [54] This process is outlined by Figure 24 in Section IX.E in the Appendix.

55. In the last step of this sign-on process, a request is sent to the DoubleClick domain. This request contains both the authentication token provided by Google and the tracking cookie set when the user visited the 3rd-party website in step 2 (this communication is shown in Figure 11). This allows Google to connect the user's Google credentials with a DoubleClick cookie ID. Therefore, if the users do not clear browser cookies regularly, their browsing information on 3rd-party webpages that use DoubleClick services could get associated with their personal information on Google Account.

<u>Figure 11: Request to DoubleClick.net includes Google's authentication token and past cookies</u>

[54] The advantage of the extra authentication step is that the user's browser can later use the same authentication token to confirm user identity on other Google services (due to this process a sign-on in any particular Google application enables an automatic sign-on all others in the same browser session).

56. It has thus far been established that Google collects a wide variety of user data through its publisher and advertiser tools, without a direct knowledge of the user. While such data is collected with user-anonymous identifiers, Google has the ability to connect this collected information with a user's personal credentials stored in their Google Account.

57. It's worth pointing out that Google's passive user data collection from 3rd-party webpages cannot be prevented using popular ad blocking tools,[55] as such tools are designed primarily to prevent the occurrence of advertisements while users browse through 3rd-party webpages.[56] The next section takes a closer look at the magnitude of such data collection.

V. AMOUNT OF DATA COLLECTED DURING A MINIMAL USE OF GOOGLE PRODUCTS

58. This section examines the details surrounding Google's data collection through its publisher and advertiser services. To understand such data collection, an experiment is designed which entailed a user going through her daily life using a mobile phone (akin to "day in the life" described before), while deliberately *avoiding* the use of any direct Google products (i.e. avoiding Search, Gmail, YouTube, Maps, etc.), except for the Chrome browser.

59. To keep the experiment as realistic as possible, various consumer usage studies[57,58] were used to form a daily usage profile of a typical mobile phone user, thereafter, any direct interactions with Google's products were omitted from the profile. Section IX.F in the Appendix describes the websites and apps used in this experiment.

60. The experiment was replicated on both Android and iOS devices and the HTTPS data sent to Google and Apple servers were monitored and analyzed using a similar method explained in previous sections. The results are summarized in Figure 12. During the 24-hour time period (which includes the night time stationary/dormant timeframe), the majority of calls from the Android phone were made to Google's location and publisher/advertisement service domains (e.g. DoubleClick, Analytics). Google collected user location in ~450 instances, which is ~1.4x times the experiment presented in Section III.C, which involved a stationary phone.

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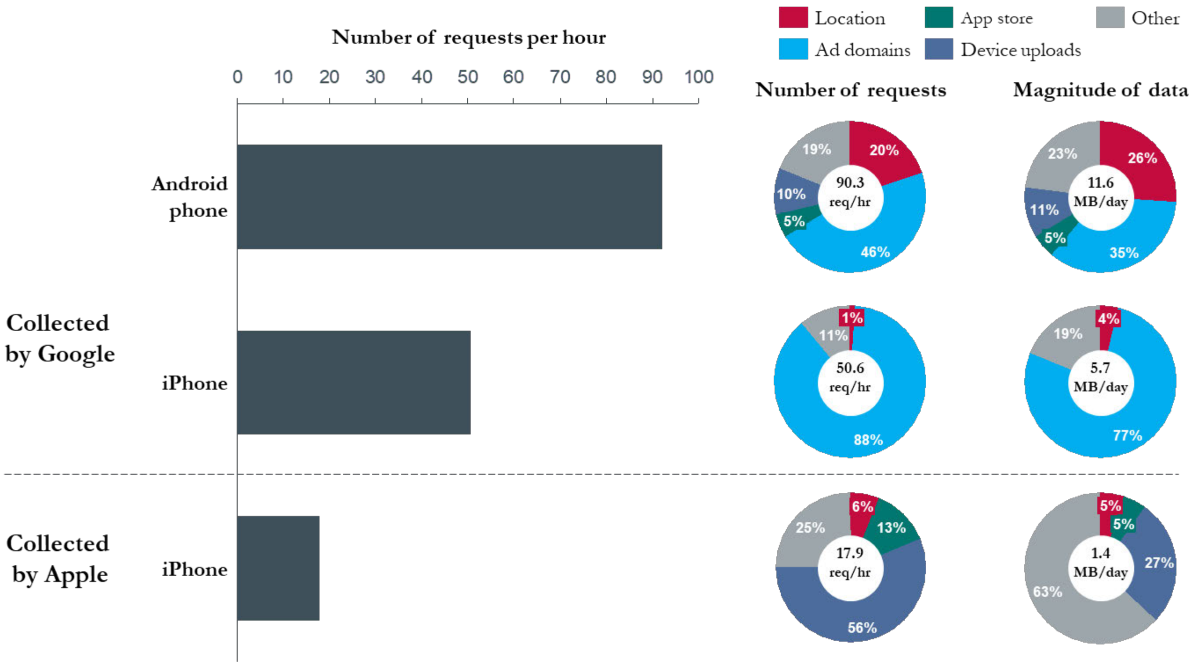
[55] "How many users block Google Analytics, measured in Google Analytics," *Quantable,* Dec. 2017, available at https://www.quantable.com/analytics/how-many-users-block-google-analytics/

[56] "Ad blocking: who blocks ads, why and how to win them back," *iab.,* 2016, available at https://www.iab.com/wp-content/uploads/2016/07/IAB-Ad-Blocking-2016-Who-Blocks-Ads-Why-and-How-to-Win-Them-Back.pdf

[57] The average person visited 88 webpages per day in 2010. "Nielsen provides topline U.S. web data for March 2010," *Nielsen,* April 2010, available at http://www.nielsen.com/us/en/insights/news/2010/nielsen-provides-topline-u-s-web-data-for-march-2010.html

[58] 55% of web traffic comes from mobile devices. Eric Enge, "Mobile vs desktop usage: mobile grows but desktop still a big player in 2017," *Stone Temple,* April 2017, available at https://www.stonetemple.com/mobile-vs-desktop-usage-mobile-grows-but-desktop-still-a-big-player-in-2017/

Figure 12: Information requests from mobile devices during a day of typical use



61. Google servers communicated significantly lower number of times with an iPhone device compared to Android (45% less). However, the number of calls to Google's advertising domains were similar from both devices - an expected outcome since the usage of 3rd-party webpages and apps was similar on both devices. One notable difference was that the location data sent to Google from an iOS device is practically non-existent. In the absence of Android and Chrome platforms—or the use of any other Google product—Google becomes significantly limited in its ability to track the user location.

62. The total number of calls to Apple servers from an iOS device was much lower, just 19% the number of calls to Google servers from an Android device. Moreover, there are no ad-related calls to Apple servers, which may stem from the fact that Apple's business model is not as dependent on advertising as Google's. Although Apple does obtain some user location data from iOS devices, the volume of data collected is much (16x) lower than what Google collects from Android.

63. Magnitude wise, Android phones communicated 11.6 MB of data per day (~350 MB per month) with Google servers. On the other hand, the iPhone device communicated just half that amount. The amount of data particularly associated with Google's ad domains remained very similar across both the devices.

64. The iPhone device communicated an order of magnitude less data to Apple servers than what the Android device exchanged with Google servers.

65. Overall, even in the absence of user interaction with Google's most popular applications, a user of an Android phone and the Chrome browser still sends a significant amount of data to Google, the majority of which is associated with location and calls to ad server domains. Although an iPhone user is insulated from Google's location collection in this narrow experiment, Google still captures a similar amount of ad-related data.

66. The next section describes the data collected by Google's popular applications, such as Gmail, YouTube, Maps, and Search.

VI. DATA COLLECTED FROM GOOGLE'S KEY POPULAR APPLICATIONS AIMED AT INDIVIDUALS

67. Google has dozens of constantly evolving products and services (a list is available in Table 4 in Section IX.B of the Appendix). These products are often accessed through—or associated with—a Google Account, which enables Google to directly link user activity details from its application-oriented products and services to a user profile. In addition to product usage data, Google also collects device-related identifiers and location data when Google's products and services are accessed.[59]

68. Some of Google's applications (e.g. YouTube, Search, Gmail, and Maps) are central to the basic tasks that many users conduct daily through their desktop or mobile devices. Table 2 describes the reach of these key products. This section explains how each of these prominent applications collect user information.

Table 2: Worldwide reach of Google's top application products

Product	Active users
Search	Greater than 1B monthly active users, 90.6% search engine market share[60]
YouTube	Greater than 1.8 billion logged-in monthly active users[61]
Maps	Greater than 1 billion monthly active users[62]
Gmail	1.2 billion registered users[63]

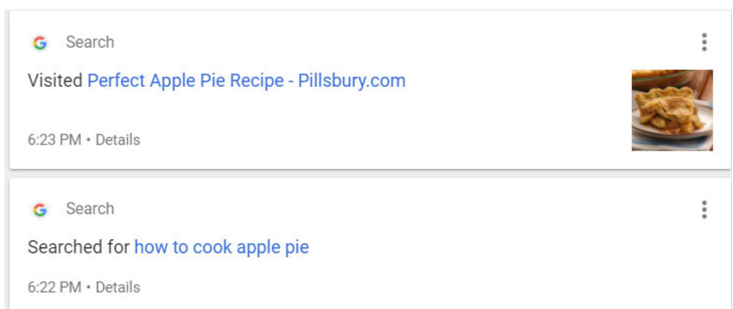
[59] "Google privacy and terms," *Google,* last accessed on August 15 2018, available at https://policies.google.com/privacy
[60] "Search engine market share worldwide," *StatCounter Global Stats,* April 2018, available at http://gs.statcounter.com/search-engine-market-share#monthly-201704-201804
[61] Devindra Hardawar, "YouTube gets 1.8 billion logged-in viewers monthly," *Engadget,* May 3, 2018, available at https://www.engadget.com/2018/05/03/youtube-1-8-billion-viewers/
[62] Google 10K filings with the SEC, 2017, available at https://abc.xyz/investor/pdf/20171231_alphabet_10K.pdf
[63] Motek Moyen, "Gmail is very popular but Google still won't fix a security vulnerability," *Seeking Alpha,* July 17, 2017, available at https://seekingalpha.com/article/4088241-gmail-popular-google-still-fix-security-vulnerability

A. Search

69. Google Search is the most popular web search engine in the world,[64] with over 11 billion search queries per month in the United States alone.[65] In addition to serving ranked webpage results in response to users' general queries, Google operates other search-based tools, such as Google Finance, Flights, News, Scholar, Patents, Books, Images, Videos, and Hotels. Google uses its search products to collect data related to search queries, browsing history, and ad-click/purchase activity. For example, Google Finance collects information on the type of stocks users may be tracking, whereas Google Flights tracks users' travel bookings and search requests.

70. Whenever Search is used, Google collects location data via various means of assessing locations on mobile or desktop devices, as discussed in previous sections. Google records all search activity a user conducts and links it back to their Google Account if the user is logged in. Figure 13 shows an example of information collected by Google about a user's keyword search and page visit.

<u>Figure 13: An example search data collection taken from user's My Activity page</u>



71. In addition to being the default search engine on Chrome and Google devices, Google Search is also the default option on other 3rd-party browsers and applications through various distribution agreements. For example, Google recently became the default search engine on Mozilla's Firefox browser[66] in key geographic locations (including US and Canada), a position owned by Yahoo previously. Similarly, Apple switched from

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[64] "Search engine market share worldwide," *StatCounter Global States,* April 2018, available at http://gs.statcounter.com/search-engine-market-share#monthly-201704-201804

[65] "Number of explicit core search queries powered by search engines in the United States as of January 2018 (in billions)," *Statista,* Feb. 2018, available at https://www.statista.com/statistics/265796/us-search-engines-ranked-by-number-of-core-searches/

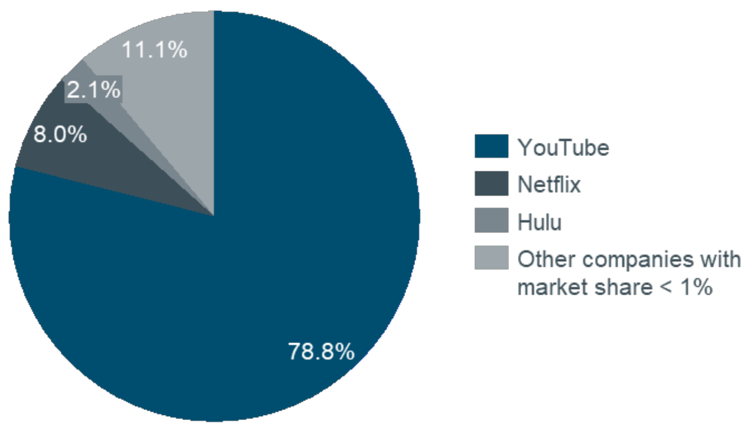
[66] Denelle Dixon, "Firefox features Google as default search provider in the U.S., Canada, Hong Kong and Taiwan," *The Mozilla Blog,* Nov. 14, 2017, available at https://blog.mozilla.org/blog/2017/11/14/firefox-features-google-as-default-search-provider-in-the-u-s-canada-hong-kong-and-taiwan/

Microsoft's Bing to Google for Siri web search results on iOS and Mac devices.[67] Google has similar agreements in place with OEMs,[68] which helps reach mobile customers.

B. YouTube

72. YouTube provides users a platform for uploading and viewing video content. It has more than 180 million users in the USA alone and has the distinction of being the second-most visited website in the US,[69] ranked only behind Google Search. Among online streaming media companies, YouTube has almost 80% market share in terms of monthly user visits (as shown in Figure 14). The amount of content uploaded and viewed on YouTube is substantial; ~400 hours of video are uploaded every minute[70] and ~1 billion hours of video are watched daily on the YouTube platform.[71]

<u>Figure 14: Comparison of leading multimedia websites monthly visits in the United States[72]</u>



73. YouTube can be accessed by users via desktops (web browser), mobile devices (app and/or web browser), and Google Home (through a paid subscription service called YouTube Red). Google collects and stores search history, watch history, playlists, subscriptions, and comments on videos. All this information is marked with a date and time stamp of when the activity took place.

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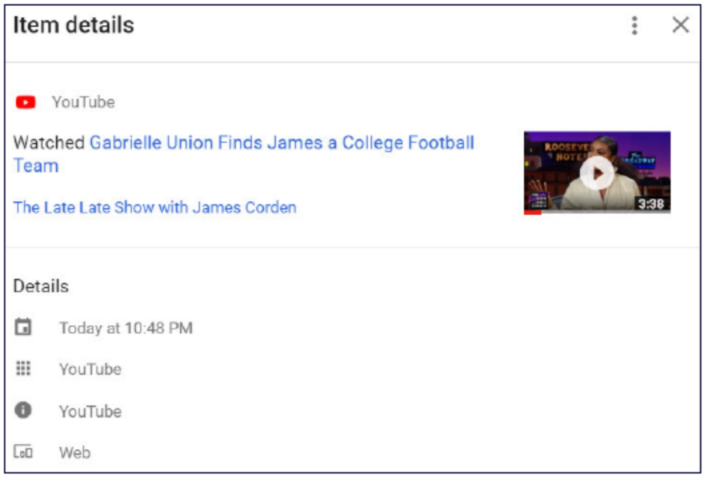
[67] Matthew Panzarino, "Apple switches from Bing to Google for Siri web search results on iOS and Spotlight on Mac," Sept. 25, 2017, available at https://techcrunch.com/2017/09/25/apple-switches-from-bing-to-google-for-siri-web-search-results-on-ios-and-spotlight-on-mac/
[68] "Google's Android mobile application distribution agreement with OEMs leaked, reveals lots of strict conditions," *Microsoft and Technology News,* Feb. 13, 2014, available at https://mspoweruser.com/mobile-application-distribution-agreement/
[69] "Top Sites in United States," *Alexa,* available at https://www.alexa.com/topsites/countries/US
[70] "Hours of video uploaded to YouTube every minute as of July 2015," *Statista,* July 2015, available at https://www.statista.com/statistics/259477/hours-of-video-uploaded-to-youtube-every-minute/
[71] Darrell Etherington, "People now watch 1 billion hours of YouTube per day," *TeachCrunch*, Feb. 28, 2017, available at https://techcrunch.com/2017/02/28/people-now-watch-1-billion-hours-of-youtube-per-day/
[72] "Leading multimedia websites in the United States in November 2016, based on market share of visits," *Statista,* Dec. 2016, available at https://www.statista.com/statistics/266201/us-market-share-of-leading-internet-video-portals/

74. If a user is signs into their Google Account on any Google application inside a browser (e.g. Chrome, Firefox, Safari), Google recognizes the user's identity, even if the video is accessed through a non-Google website (e.g. YouTube videos played through CNN.com). This feature allows Google to track a user's YouTube usage across multiple 3rd-party platforms. Figure 15 shows an example of YouTube data collected.

Figure 15: An example of YouTube data collection from My Activity



75. Google also offers a separate YouTube product for children, known as YouTube Kids, which is intended as a "family friendly" version of YouTube with parental control features and video filters. Google collects information from YouTube Kids, including device type, operating system, unique device identifiers, log information, and details of how the service was used. Google then uses this information to deliver limited advertisements that are non-clickable, and which have restrictions on format, time length, and site-served.[73]

C. Maps

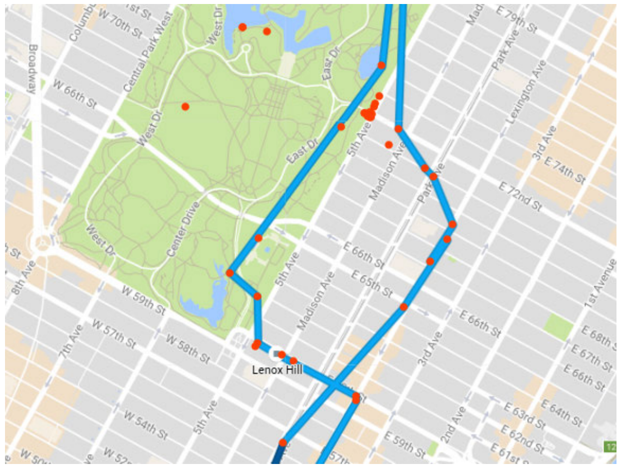
76. Maps is Google's flagship navigation app. Google Maps can ascertain user's travel routes, speed, and places that a user visits frequently (e.g. home, work, restaurants, and businesses). This information provides Google with a window into a user's interests (e.g. food and shopping preferences), movement, and behavior.

77. Maps uses IP address, GPS, cell signal, and Wi-Fi access point data to calculate a device's location. The latter two are collected from the device through which Maps is used and sent to Google for location assessment through its Location API. This API provides rich details about a user, including geographic coordinates, whether the user is stationary or moving, speed, and probabilistic determination of user's mode of transport (e.g. bike, car, train, etc.).

[73] "Advertising on YouTube Kids," *Google,* last accessed on August 15 2018, available at https://support.google.com/youtube/answer/6168681?hl=en

78. Maps stores a historical timeline of places visited by a user signed in to Maps using their Google account. Figure 16 shows an example of such a user's timeline.[74] The red dots indicate location coordinates captured by Maps while the user is on the move; the blue connecting lines are Maps projection of the actual route the user took.

<u>Figure 16: Example Google Maps "Timeline" from an actual user</u>



79. The accuracy of location information captured by navigation applications enables Google to not only target ad audiences, but also helps deliver ads to users as they approach stores.[75] In addition, Google Maps uses this information to generate real-time traffic updates.[76]

D. Gmail

80. Gmail stores all messages (sent/received), sender name, email address, and date/time of messages sent or received. Since Gmail acts as a central mail repository for many people, it can ascertain their interests by scanning email content, identifying merchant addresses through their promotional emails or sales receipts sent to emails, and learn about a user's plans (e.g. dinner reservations, doctor's appointments,). Since users may use their Gmail ID for other 3rd-party platforms (e.g. Facebook, LinkedIn), Gmail can scan any content that comes from them in the form of an email (e.g. notifications, messages).

81. From its inception in 2004 until at least late 2017, Google may have scanned the contents of Gmail emails to improve ad targeting and search results, as well as filter spam. In the summer of 2016, Google went a step further and changed its privacy policy to enable it to combine formerly anonymous web-browsing data

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[74] "My Activity," *Google*, available at https://myactivity.google.com/myactivity
[75] "The Home Depot earns 8X in-store ROI with mobile display ads," *Google,* Sept. 2016, available at https://www.thinkwithgoogle.com/intl/en-aunz/advertising-channels/mobile/home-depot-roi-mobile-display-ads/
[76] "Google Map's real-time traffic layer…," *Spatial Unlimited,* March 2011, available at https://shreerangpatwardhan.blogspot.com/2011/03/google-maps-real-time-traffic-layer.html

of its subsidiary DoubleClick (which serves customized ads across the Internet) with the personally-identifying data Google has through its other products, including Gmail.[77] The result was that "…the DoubleClick ads that follow people around on the web may now be customized to them based on keywords they used in their Gmail. It also meant that Google could now build a complete portrait of a user by name, based on everything they write in email, every website they visit, and the searches they conduct."[78]

82. Toward the end of 2017, Google announced it would discontinue the practice of Gmail message-based personalization of ads.[79] Recently, however, Google clarified that it is still scanning Gmail messages for some purposes.[80]

VII. PRODUCTS WITH HIGH FUTURE POTENTIAL FOR DATA AGGREGATION

83. Google has additional products that show future potential for market adoption and data collection, including AMP, Photos, Chromebook, Assistant, and Pay. Additionally, Google is able to use third party data vendors to collect user information. The following sections describe these in greater detail.

84. There are other Google applications that may not be widely used, however for completeness, data collection through them is presented in Section VIII.B of the Appendix.

A. Accelerated Mobile Pages (AMP)

85. Accelerated Mobile Pages (AMP) is an open-source initiative spearheaded by Google to enable quicker load times for websites and ads. AMP converts conventional HTML and JavaScript code into a more simplified version developed by Google[81] and caches the AMP-validated webpages in Google's network of servers for faster access.[82] AMP delivers page links through Google search results, as well as 3rd-party platforms, such as LinkedIn and Twitter. As the AMP page reports: "AMP's ecosystem includes 25 million domains, 100+ technology providers and leading platforms, that span the areas of publishing, advertising, e-commerce, local and small businesses, and more!"[83]

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[77] Julia Angwin, "Google has quietly dropped ban on personally identifiable web tracking," *ProPublica,* Oct. 21, 2016, available at https://www.propublica.org/article/google-has-quietly-dropped-ban-on-personally-identifiable-web-tracking

[78] Suzanne Monyak, "Google changed a major privacy policy four months ago, and no one really noticed," *Slate,* Oct. 21, 2016, available at http://www.slate.com/blogs/future_tense/2016/10/21/google_changed_a_major_privacy_policy_and_no_one_really_noticed.html

[79] Mark Bergen, "Google will stop reading your emails for Gmail ads," *Bloomberg,* June 23, 2017, available at https://www.bloomberg.com/news/articles/2017-06-23/google-will-stop-reading-your-emails-for-gmail-ads

[80] Ben Popken, "Google sells the future, powered by your personal data," *NBC News,* May 10, 2018, available at https://www.nbcnews.com/tech/tech-news/google-sells-future-powered-your-personal-data-n870501

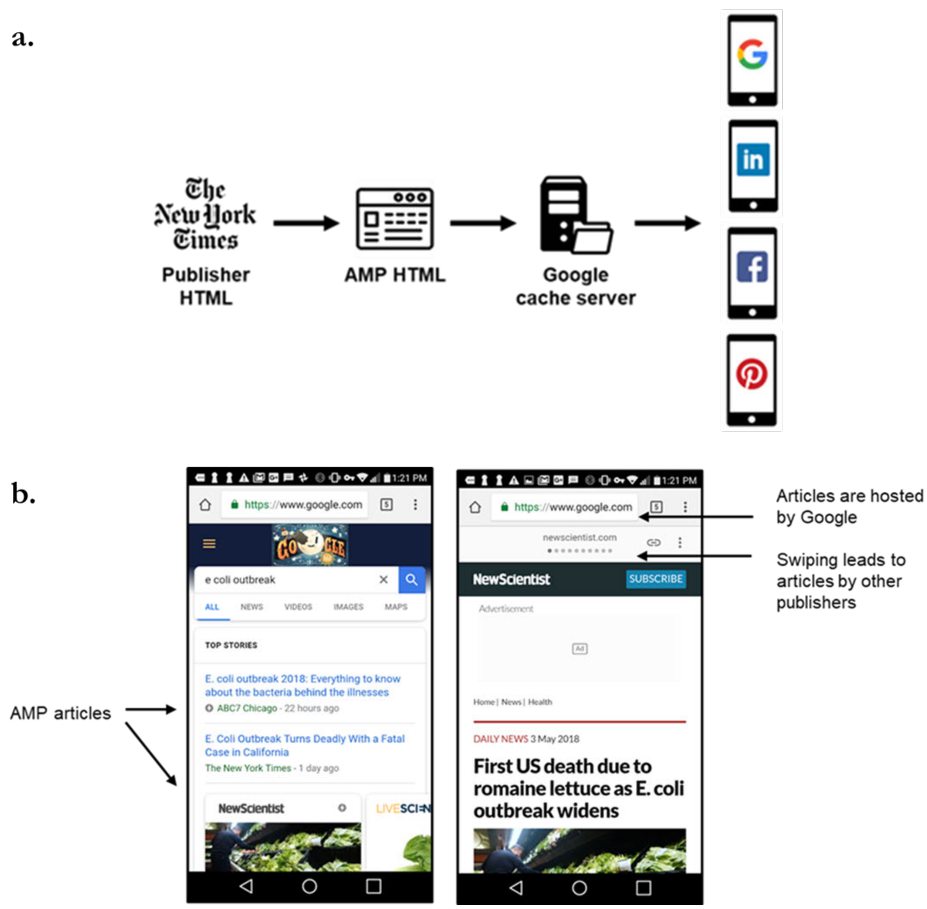
[81] "AMP HTML specification," *AMP,* last accessed on August 15 2018, available at https://www.ampproject.org/docs/fundamentals/spec

[82] "Load AMP pages quickly with Google AMP Cache," *Google,* last accessed on August 15 2018, available at https://developers.google.com/amp/cache

[83] "An open source effort to improve the content ecosystem for everyone," *AMP*, last accessed on August 15 2018, available at https://www.ampproject.org/learn/overview

86. Figure 17a describes the steps leading to the delivery of an AMP page accessed via Google Search. Please note that the provider of content through AMP does not need to provide their own a cache server, as this is something that Google provides for securing optimal delivery speeds to users. Since the AMP cache is hosted on Google servers, when an AMP link is clicked through Google Search, the domain address shows up from a Google.com domain rather than from a publisher's own domain. This is shown through snapshots taken from an example keyword search in Figure 17b.

Figure 17: Regular web page vs AMP page



87. Users can access content from multiple publishers whose articles appear in search results while navigating the AMP carousel, all while staying within the Google domain. In effect, the AMP cache operates as a content delivery network (CDN) owned and operated by Google.

88. By creating an open-source tool, complete with a CDN, Google has attracted a large user base for serving mobile websites and advertisements that constitute a significant amount of information (e.g. the content itself, page views, ads served, and information on whom that content is being delivered). All of this information

is available to Google by virtue of it residing on Google's CDN servers, thereby providing Google far more data than it otherwise could access.

89. AMP is highly user-centric, i.e. it delivers a much faster and improved browsing experience to users without the clutter of pop-ups and sidebars. Although AMP is a major shift in the way content is cached and delivered to users, Google's privacy policy associated with AMP is quite general.[84] In particular, Google is able to collect webpage usage information (e.g. server logs and IP address) from requests sent to AMP cache servers. Moreover, regular pages are converted into AMP via the use of AMP APIs.[85] Google can therefore access applications or websites ("API clients") and use any submitted information through the API in accordance with its general policies.[86]

90. Like regular webpages, AMP webpages track usage data via Google Analytics and DoubleClick. In particular, they collect information on page data (e.g. domain, path, and page title), user data (e.g. client ID, time zone), browsing data (e.g. unique page view ID and referrer), browser info, and interaction and events data.[87] Although Google's modes of data collection have not changed with AMP, the *amount* of data collected has increased since visitors are spending 35% more time on web content that loads with Google AMP versus standard mobile pages.[88]

B. Google Assistant

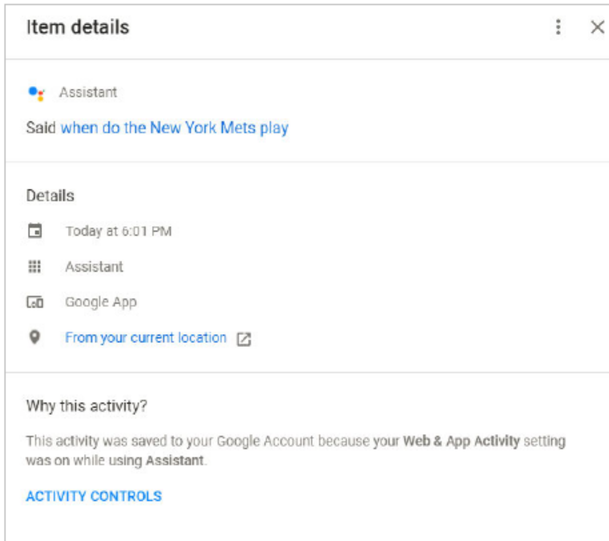
91. Google Assistant is a virtual personal assistant accessed through mobile phones and smart devices. It is a popular virtual assistant, alongside Apple's Siri, Amazon's Alexa, and Microsoft's Cortana.[89] Google Assistant is accessed through the home button of mobile devices with Android 6.0 or higher. It can also be accessed through a dedicated app on iOS devices[90], as well as smart speakers, such as Google Home. Google Assistant performs numerous functions, such as sending texts, looking up emails, controlling music, searching photos, getting answers to questions about the weather or traffic, and controlling smart home devices.[91]

92. Google collects all Google Assistant queries, whether audio or typed. It also collects the location where the query occurred. Figure 18 shows the content of a query stored by Google. In addition to its use on Google's

[84] "AMP on Google privacy and terms," *Google,* last accessed on August 15 2018, available at https://developers.google.com/amp/cache/policies
[85] "Link to AMP content," *Google,* last accessed on August 15 2018, available at https://developers.google.com/amp/cache/use-amp-url
[86] "Google APIs terms of service," *Google*, last accessed on August 15 2018, available at https://developers.google.com/terms
[87] "Tracking accelerated mobile pages (AMP)," *Google,* last accessed on August 15 2018, available at https://support.google.com/analytics/answer/6343176?hl=en&ref_topic=7378717
[88] John Saroff, "The new speed of mobile engagement," *Chartbeat,* June 5, 2017, available at http://blog.chartbeat.com/2017/06/05/the-new-speed-of-mobile-engagement
[89] Tripp Mickle, "'I'm not sure I understand' – how Apple's Siri lost her mojo," *The Wall Street Journal,* June 7, 2017, available at https://www.wsj.com/articles/apples-siri-once-an-original-now-struggles-to-be-heard-above-the-crowd-1496849095
[90] "Google Assistant," *Google,* last accessed on August 15 2018, available at https://assistant.google.com/platforms/phones/
[91] "Google Assistant," *Google,* last accessed on August 15 2018, available at https://assistant.google.com/platforms/phones/

Home speakers, Google Assistant is enabled on various other speakers produced by 3rd-parties (e.g. Bose wireless headphones). Overall, Google Assistant is available on more than 400 million devices.[92] Google can collect data via all these devices since Assistant queries go through Google's servers.

Figure 18: Example of detail collected from Google Assistant query



C. Photos

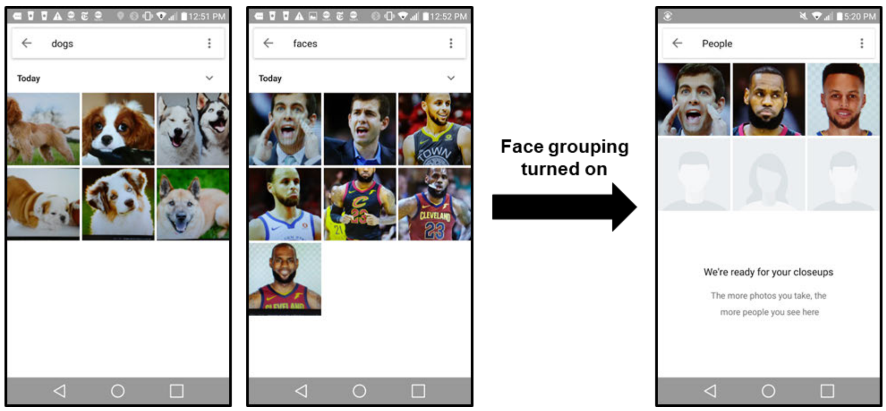
93. Google Photos is used by more than 500 million people globally and stores more than 1.2 billion photos and videos every day.[93] Google records the time and GPS coordinates for every photo taken. Google uploads images to the Google cloud and conducts image analysis to identify a broad set of objects, such as modes of transportation, animals, logos, landmarks, text, and faces.[94] Google's face detection capabilities even enable the detection of emotional states associated with faces in photos uploaded and stored in their cloud.[95]

94. Google Photos conducts this image analysis by default when the product is used, but will not distinguish between individual people unless the user gives the app permission.[96] If a user provides permission for Google to group similar faces together, Google identifies different people using facial recognition

[92] Scott Huffman, "New devices and more: what's in store for the Google Assistant this year." *Google,* Jan. 9, 2018, available at https://www.blog.google/products/assistant/new-devices-more-google-assistant-ces-2018
[93] Anil Sabharwal, "500 million people using Google Photos, and three new ways to share," *Google,* May 17, 2017, available at https://blog.google/products/photos/google-photos-500-million-new-sharing/
[94] "Cloud vision API," *Google,* last accessed on August 15 2018, available at https://cloud.google.com/vision/
[95] "Cloud vision API," *Google,* last accessed on August 15 2018, available at https://cloud.google.com/vision/
[96] "Find people, things, and places in your photos," *Google,* last accessed on August 15 2018, available at https://support.google.com/photos/answer/6128838?co=GENIE.Platform%3DAndroid&hl=en

technology and enables users to share photos based on its "face grouping" technology.[97,98] Examples of Google's image classification capabilities with and without face grouping permission from the user are shown in Figure 19. Google uses Photos to assemble a vast trove of identifying facial information, which has become the subject of recent lawsuits[99] by certain states.

<u>Figure 19: Example image recognition in Google Photos</u>



D. Chromebook

95. Chromebook is Google's tablet computer running on the Chrome operating system (Chrome OS) which allows users to access applications on the cloud. While Chromebook holds a very small fraction of the PC market, it's growing rapidly, especially in computing devices for the K-12 category, where it held 59.8% of the market in Q2 2017.[100] Since Chromebook is accessed through a Google Account, a user is always signed on to all of Google's applications while accessing them on a Chromebook device. Chromebook's data collection is similar to the Google Chrome browser, which is covered in section II.A. Chromebooks also allow cookies from Google and 3rd-party domains to track user activity, similar to any other notebook or PC device.

96. Many K-12 schools use Chromebooks to access Google's products via its GSuite for Education service. Google states that data collected from such use is not used for targeted advertising.[101] Students are shown ads, however, if they use additional services (such as YouTube or Blogger) on Chromebooks provided through their educational institutions.

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97 Anil Sabharwal, "500 million people using Google Photos, and three new ways to share," *Google,* May 17, 2017, available at https://blog.google/products/photos/google-photos-500-million-new-sharing/

98 "Share your Google Photos library with a partner," *Google*, last accessed on August 15 2018, available at https://support.google.com/photos/answer/7378858#filterbyface

99 Amy Korte, "Federal court in Illinois rules biometric privacy lawsuit against Google can proceed," *Illinois Privacy,* March 8, 2017, available at https://www.illinoispolicy.org/federal-court-in-illinois-rules-biometric-privacy-lawsuit-against-google-can-proceed/

100 "Mobile PC sales in to US K-12 education starting to slow as the market looking toward replacement cycles," *Future Source Consulting,* Dec. 6, 2017, available at https://www.futuresource-consulting.com/Press-Q3-2017-Mobile-PC-Sales-in-Education-1217.html

101 "Chromebooks privacy and security," *Google,* last accessed on August 15 2018, available at https://drive.google.com/file/d/0B__OTXR_u3RbcFB3Y01xUVhaalU/view

E. Google Pay

97. Google Pay is a digital payments service that allows users to store credit card, bank account, and PayPal information to make payments in stores, on websites, or within apps using Google Chrome or a connected Android device.[102] Pay is the means by which Google collects verified user address and phone numbers, as these are associated with charge accounts. In addition to personal information, Pay also collects transaction information, such as date and amount of transaction, merchant location and description, type of payment used, descriptions of the items purchased, any photo that a user choose to associate with the transaction, names and email addresses of the seller and buyer, the user's description of the reason for transaction, and any offers associated with the transaction.[103] Google treats this information as personal information under its general privacy policy. It therefore can use this information across its products and services for enriched advertising.[104] Google's privacy settings allow for such a use of collected data by default.[105]

F. User data collected from 3rd-party data vendors

98. Google collects 3rd-party data in addition to information they collect directly from their services and applications. For example, in 2014 Google announced that it would begin tracking sales in brick-and-mortar stores by buying credit and debit card transaction data. Such data covered 70% of all credit and debit transactions in the US.[106] It contained the name of the individual, as well as the time, location, and amount of their purchase.[107]

99. 3rd-party data is also used to support Google Pay, including verification services, information arising from Google Pay transactions at merchant locations, payment methods, identity of card issuers, information regarding access to balances in the Google payment account, carrier and operator billing information, and consumer reports.[108] For sellers, Google may obtain information from credit bureaus or business information services.

100. Although the 3rd-party user information that Google currently receives is limited in scope, it has already attracted the attention of governmental authorities. For example, the FTC announced an injunction against

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[102] "Google Pay," *Google,* last accessed on August 15 2018, available at https://pay.google.com/about/
[103] "Google Payments privacy notice," *Google*, Dec. 14, 2017, available at https://payments.google.com/payments/apis-secure/u/0/get_legal_document?ldo=0&ldt=privacynotice&ldl=en
[104] "Google Payments privacy notice," *Google*, Dec. 14, 2017, available at https://payments.google.com/payments/apis-secure/u/0/get_legal_document?ldo=0&ldt=privacynotice&ldl=en
[105] "Google payments center," *Google,* available at https://payments.google.com/payments/home?page=privacySettings#privacySettings:
[106] "Google plans to track credit card spending," *BBC,* May 26, 2017, available at http://www.bbc.com/news/technology-40027706
[107] Elizabeth Dwoskin and Craig Timberg, "Google now knows when its users go to the store and buy stuff," *The Washington Post,* May 23, 2017, available at https://www.washingtonpost.com/news/the-switch/wp/2017/05/23/google-now-knows-when-you-are-at-a-cash-register-and-how-much-you-are-spending/?utm_term=.281715f8e215
[108] "Google Payments privacy notice," *Google*, Dec. 14, 2017, available at https://payments.google.com/payments/apis-secure/u/0/get_legal_document?ldo=0&ldt=privacynotice&ldl=en

Google in July 2017 with respect to how Google's collection of consumer purchasing data infringes upon electronic privacy.[109] The injunction challenges Google's claim that they can protect consumer privacy throughout the process using their algorithm. Although further action has not yet occurred, the FTC injunction is an example of public concern with the amount of consumer data that Google collects.

VIII. CONCLUSION

101. Google counts a large percentage of the world's population as its direct customers, with multiple products leading their markets globally and many surpassing 1 billion monthly active users. These products are able to collect user data through a variety of techniques that may not be easily graspable by a general user. A major part of Google's data collection occurs while a user is not directly engaged with any of its products. The magnitude of such collection is significant, especially on Android mobile devices. And while such information is typically collected without identifying a unique user, Google distinctively possesses the ability to utilize data collected from other sources to de-anonymize such a collection.

[109] FTC Complaint, request for investigation, injunction, and other relief submitted by The Electronic Privacy Information Center, available at https://epic.org/privacy/ftc/google/EPIC-FTC-Google-Purchase-Tracking-Complaint.pdf

IX. APPENDIX

A. Characterization of active vs passive data collection from "day in the life" of a user

Table 3: Active and passive Google data collection

Number	Description	Active collection	Passive collection
1	Gets ready in the morning while listening to Google Play Music	• Music interests	• Morning location
2	Drops kids off at daycare before commuting to work		• Walked to a daycare location
3	Checks the news while commuting to work on the subway		• Traveling on the subway • News pages visited
4	Searches for cold medicine while on the subway	• Records search queries	• Traveling on the subway
5	Walks from subway to work		• Commute path to work address
6	Uses Maps to find a new lunch spot	• Destination entered into Maps	• Dining interests
7	Gets coffee from Starbucks using her Starbucks app		• Walks to a Starbucks • Opens Starbucks app
8	Schedules doctor's appointment, Google creates a Calendar event from the confirmation email		• Event details of the doctor appointment
9	Walks to Walgreens and purchases cold medicine using Google Pay	• Purchase details	• Walks to a Walgreens
10	Takes an Uber home from work		• Commute path to home address via car • Use of Uber app
11	Looks for hotels on Expedia for a weekend trip		• Webpage interaction via DoubleClick cookies & Google Analytics
12	Uses Google Home to play music for her kids	• Google Home search query	• Location of Google Home

13	Watches videos on YouTube	• YouTube activity

B. List of Google products

Table 4: List of Google Products

Category	Products
1. Applications	**Watch, Listen and Play** YouTube, Google Play Music, Chromecast, Google Play Movies and TV
	Browser Chrome
	Search Search, Finance, Flights, News, Scholar, Patents, Books, Images, Videos, Hotels
	Navigation Maps, Waze
	Productivity tools Drive, Docs, Sheets, Slides, Forms
	Social & communications Gmail, Allo, Hangouts, Duo, Google+, Translate
	Storage and organization Photos, Contacts, Calendar, Keep
	Personal Assistant Google voice assistant
2. Operating systems	**Android** Phones, Wear, Auto
	Chrome Chromebook
3. Services	Fiber, DNS, Project Fi, Google pay
4. Devices	Home, Wi-Fi router, Chromecast, Nest, Daydream View

C. Data collection from other prominent Google products

a) Google Play Music and Play Movies and TV

102. Google Play Music, Play Movies and TV are on-demand services that offer streaming of music, podcasts, TV shows, and movies. These services can be thought of as the Google equivalent of Apple iTunes. Like YouTube, these services collect information about user search, bought/rent/played content, information about users' geography (through IP address), and device information.

b) Waze

103. Waze got acquired by Google in 2013 and operates as a Google subsidiary. In contrast to Maps, Waze is a crowd-sourced app where user-supplied data (such as GPS location coordinates, travel times, traffic info, accidents, police monitoring, blocked roads, and construction) is analyzed to provide routing and real-time travel condition updates. In addition to location information collected through the mobile device, Waze collects information about use of its services from the device Waze is installed on, including mobile device name, operating system, web page visits, information viewed on app, app content use/created, and ads viewed and clicked.

104. Waze works like a social network and provides users the ability to befriend other users and create an online community of local drivers.[110] Users can link their phone's contact list, Facebook, or Twitter accounts, which Waze then uses to match with friends on platforms who are also using Waze's service. Overall, Waze gives Google the ability to access more real-time user data, as well as information on acquaintances that may or may not be using a Google Account.

c) Google Docs and Drive

105. Google's productivity tools (Docs, Sheets, Slides, Forms, and Drive – which are part of the broader "G Suite" of products) are cloud-based applications used by both individuals and enterprises. Google's G Suite privacy policies[111] prohibit Google from scanning stored data for advertising purposes on enterprise versions. In contrast, the free versions of these tools are governed by Google's general privacy policy, so Google may access the information for ad targeting.

106. After an individual registers for a Google Account, Google provides free storage space (currently 15GB) on Google Drive to share across products including Gmail, Photos, and Docs. Google's Terms of Service indicate that Google retains the license to use the stored data in variety of ways, including reproducing,

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[110] J.D. Biersdorfer, "Getting social with Waze," *The New York Times,* Sept. 20, 2017, available at https://www.nytimes.com/2017/09/20/technology/personaltech/getting-social-with-waze.html

[111] "Google Cloud help, privacy," *Google,* last accessed on August 15 2018, available at https://support.google.com/googlecloud/answer/6056650?hl=en

modifying, communicating, and publishing.[112] Although all user data stored in Google Drive is encrypted, it's not a "zero-knowledge encryption"[113] since Google manages the data encryption key.

d) Video chat and social messaging apps

107. Google Hangouts is a communication platform, akin to Skype, and a part of Google's G Suite cloud-connected apps. Users can start and join video conferences or group conversations from the Hangout app available on Android and iOS, through a web browser, from the Hangouts desktop app or Chrome extension, and from other Google products (e.g. Gmail and Calendar).[114] Google stores details of these exchanges (including conference call and conversation time stamps), participant information, and message content. These details are available to users and can be downloaded via the Google Takeout tool.[115] Figure 20 shows some data recorded from a Google Hangouts conversation, including participant names, participant IDs, and the contents of the conversation.

Figure 20: Google Takeout recordings of a Google Hangouts Conversation

108. In addition to the enterprise-focused Hangouts, Google also offers an instant messaging app called Allo, which is available for Android and iOS or through web browsers.[116] Google records and stores all messages communicated through Allo by default (unless the user invokes incognito mode).[117]

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[112] "Google Drive terms of service," *Google,* last accessed on August 15 2018, available at https://www.google.com/drive/terms-of-service

[113] Fergus O'Sullivan, "What exactly is zero-knowledge in the cloud and how does it work?," *Cloudwards,* June 16, 2017, available at https://www.cloudwards.net/what-exactly-is-zero-knowledge-in-the-cloud-and-how-does-it-work

[114] "GSuite learning center," *Google,* last accessed on August 15 2018, available at https://gsuite.google.com/learning-center/products/hangouts/get-started/#!/

[115] "Download your data," *Google*, available at https://takeout.google.com/settings/takeout?pli=1

[116] Sean Keach, "Google Allo just got a major upgrade – but do we really need it?," *Trusted Reviews,* Aug. 16, 2017, available at http://www.trustedreviews.com/news/google-allo-3261336

[117] Russell Brandom, "Google backs off on previously announced Allo privacy feature," *The Verge,* Sept. 21, 2016, available at https://www.theverge.com/2016/9/21/12994362/allo-privacy-message-logs-google

109. Google offers an app called Google Duo that is a dedicated mobile video chat app. It is available both on Android and iOS, but not on desktop/laptop computers. Users can call or video chat each other and even connect with users on the Android operating system who have not downloaded the app.[118] Once installed, Google Duo has access to a user's profile data, contacts, camera, microphone, Wi-Fi connection information, and device ID and call information.[119] Google also stores the time stamps of when the apps are used and provides this info to the users via Google Takeout.

e) Google+

110. Google+ is a social media network launched in 2011 as a competitor to Facebook. Although Google does not release statistics on Google+'s active users, it is now primarily a place for niche communities.[120] A user can choose to follow other users, organize the users they follow into groups (e.g. best friends vs. work colleagues), start "Communities," or join existing ones (e.g. "Photography enthusiasts"). Posts from followed users and communities then appear in the user's home feed.

111. Google Takeout shows several types of Google+ data that Google stores. Google compiles vCards from the profiles of all the people a user follows (in Takeout, this information is contained within the "Google+ Circles" folder). Google also collects in HTML format all content posted by a user, which is contained in the "Google+ Stream" folder of Takeout, as shown in Figure 21. Posted photos also are saved within Google Photos.

Figure 21: Example of Google+ posted content saved by Google

f) Translate

112. Google Translate is a free machine translation service supporting over 100 languages that is available on the web and through apps for Android and iOS. It is also integrated into Google Assistant and Google Chrome, as well as being available to 3rd-party developers through a paid API.[121] Altogether, it serves more than 500 million monthly users.[122] If users have the Google Translate app on their phone, they can use the app to

118 Swapna Krishna, "Google Duo allows you to call people who don't have the app," *Engadget,* Jan. 12, 2018, available at https://www.engadget.com/2018/01/12/google-duo-call-android-users-without-app
119 Google informs the user of this access when the user downloads the app.
120 Karissa Bell, "Google+ isn't dead and these are the people astill using it the most," *Mashable,* Jan. 18, 2017, available at https://mashable.com/2017/01/18/who-is-using-google-plus-anyway/#_lP0PXr.eiqZ
121 "Google Cloud, pricing," *Google,* last accessed on August 15 2018, available at https://cloud.google.com/translate/pricing
122 Gideon Lewis-Kraus, "The great A.I. awakening," *The New York Times,* Dec. 14, 2016, available at https://www.nytimes.com/2016/12/14/magazine/the-great-ai-awakening.html

translate languages within other apps, such as WhatsApp.[123] Although Google states that it does not track Google Translate web queries[124]—and these queries do not appear in a user's Search history or elsewhere in Google Takeout—Google's privacy policy does allow it to store them for short period of time and occasionally for longer period for debugging and other testing.[125]

g) Calendar

113. Google Calendar is a scheduling tool that enables users to keep track of their daily and weekly activities. It is widely used on both desktop and mobile devices, with more than 500 million downloads from the Google Play Store.[126] Personal information, such as an individual's name and contact information, is often associated with a Calendar user.

114. By using calendars, users provide Google with details (such as the time, location, and contact information) for all participants of an event. Google states that the app has access to "read calendar events plus confidential information."[127] As part of this information collection, Google reads and stores the email addresses of all members included in a calendar event, regardless of their Google affiliation.[128] As long as one person on a calendar invitation is using Google Calendars, therefore, Google records the contact information for every other person on the invitation.

h) Keep

115. Google Keep is a note-taking tool that allows the user to take notes that sync between devices associated with their Google account. Keep has been downloaded more than 100 million times from the Google Play Store.[129] Google collects and stores all contents of the notes, as well as the time they were created.[130] Figure 22 shows Google Keep notes recorded by Google. Google scans and classifies the notes that are created based on their contents. Examples of classification categories are food, places, and travel.

123 "Google Translate," *Google,* available at https://translate.google.com/intl/en/about
124 "Google Translate help," *Google,* last accessed on August 15 2018, available at https://support.google.com/translate/answer/6142479?co=GENIE.Platform%3DDesktop&hl=en&oco=0
125 "Access to the Google Cloud API," *Google,* last accessed on August 15 2018, available at https://cloud.google.com/translate/faq
126 "Google Calendar," *Google Play Store,* last accessed on August 15 2018, available at https://play.google.com/store/apps/details?id=com.google.android.calendar
127 "Google Calendar," *Google Play Store,* last accessed on August 15 2018, available at https://play.google.com/store/apps/details?id=com.google.android.calendar
128 "Download your data," *Google*, available at https://takeout.google.com/settings/takeout?pli=1
129 "Google Keep," *Google Play Store,* last accessed on August 15 2018, available at https://play.google.com/store/apps/details?id=com.google.android.keep&hl
130 "Download your data," *Google*, available at https://takeout.google.com/settings/takeout?pli=1

<u>Figure 22: Example of Google Keep notes, accessed from Google take out</u>

```
      </style></head>
<body><div class="note"><div class="heading"><div class="meta-icons">

</div>
Apr 26, 2018, 11:06:04 AM</div>

<div class="content">Grocery list:<br>- pasta<br>- tomatoes<br>- lettuce <br>- salad
dressing <br>- salmon <br>- lemon<br>- capers <br>- Bread<br>- butter<br>- milk<br>-
eggs<br>- bacon<br>- OJ<br>- </div>

</div></body></html>
```

i) Chromecast

116. Like Apple TV, Google Chromecast is a device that acts as an interface to watch videos from a variety of applications (e.g. Netflix, YouTube, Hulu, Play Store), as well as to project video from smartphones and computers onto larger televisions and monitors. Every Cast device has a unique identifier that is associated with a user's Google Account during registration.

117. Google uses Chromecast to collect system activity, crash reports, and usage data, such as details about the use of casting functionality of devices, including the apps and domains that are casted.[131] Chromecast uses Google Cast, which is a software platform that enables seamless streaming of audio/video between devices on the same network.[132] In addition to a multitude of other Google products (e.g. Google Home) that use Cast functionality, the Cast platform is also used by 3rd-party devices using "Chromecast built-in" (e.g. TVs and video gaming consoles[133]), that offer similar functionality. Google also collects usage data and crash reports from 3rd-party Cast devices.[134]

j) Google DNS

118. Google launched a free Domain Name System (DNS)[135] service, called Google Public DNS, in December of 2009. Google DNS is aimed at improving web browsing experience by enhancing speed, security, and accuracy.[136] In December 2014, Google Public DNS was reported to be serving 400 billion responses.[137]

119. To detect abuse (such as DDoS attacks) and to fix problems, Google Public DNS keeps a temporary log of full IP addresses that it deletes within 24-48 hours. For longer-term efforts to debug and prevent abuse,

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131 "Chromecast help," *Google,* last accessed on August 15 2018, available at https://support.google.com/chromecast/answer/6076570?hl=en
132 "Google Cast," *Google,* last accessed on August 15 2018, available at https://developers.google.com/cast
133 "What is Google Cast and Chromecast," *Shield,* last accessed on August 15 2018, available at https://shield.nvidia.com/blog/what-is-googlecast-chromecast
134 "Chromecast help," *Google,* last accessed on August 15 2018, available at https://support.google.com/chromecast/answer/6076570?hl=en
135 DNS services translate domain names into IP addresses and thus are necessary to navigate the web.
136 "Google Public DNS," *Google,* last accessed on August 15 2018, available at https://developers.google.com/speed/public-dns/faq
137 "Google Public DNS and location-sensitive DNS responses," *Google Webmaster Central Blog,* Dec. 15, 2014, available at https://webmasters.googleblog.com/2014/12/google-public-dns-and-location.html

Google keeps non-personally-identifiable city/metro-level location information for two weeks, and randomly samples a small subset for permanent storage.[138]

k) Google Wi-Fi router

120. Google began rolling out a mesh Wi-Fi router, Google Wi-Fi, in December 2016. Mesh routers allow a user to extend access to a Wi-Fi network across a larger area with additional connected routers. By December of 2017, Google Wi-Fi became the best mesh Wi-Fi system in the USA according to data from the NPD Group.[139] The information it collects[140] falls into the following three categories:

- Cloud services, which include broadcast information from connected devices (such as a device name like "Jane's iPhone"), infer information from connected devices (such as manufacture's name like Samsung), connection status, data transfer speed and historical consumption, network settings and information about wireless environment (e.g. other routers in the area). It does collect connected device information and data usage.
- Wi-Fi stats, which include anonymous data usage, crash reports and device performance information.
- Wi-Fi app stats, which includes usage and crash reports.

121. According to Google, the Wi-Fi router does not track the websites visited or collect the content of network traffic.[141]

l) Nest

122. In January 2014, Google acquired Nest, which is a home automation company.[142] Nest's product line includes many smart home devices, including thermostats, cameras, doorbells, alarm systems, locks and smoke/CO detectors.[143] In addition, Nest lists more than 100 3rd-party products that can integrate with Nest, ranging from refrigerators to beds.[144]

123. Nest devices collect a variety of information, including not only users' direct adjustments to the devices, but also data on the environment within the home. For example, the Nest Learning Thermostat collects data (such as temperature, humidity, ambient light, and movement) and thus knows when people are at home and even in what rooms.[145] When a user connect 3rd-party products that integrate with Nest, Nest shares

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138 "Google Public DNS," *Google,* available at https://developers.google.com/speed/public-dns/privacy
139 Jillian D'Onfro, "The surprising use case that has made Google Wifi one of the company's sleeper hits," *CNBC,* Dec. 18, 2017, available at https://www.cnbc.com/2017/12/18/google-wifi-mesh-technology-sales-stats.html
140 "Google Wifi help," *Google,* last accessed on August 15 2018, available at https://support.google.com/wifi/answer/6246642?hl=en
141 "Google Wifi help," *Google,* last accessed on August 15 2018, available at https://support.google.com/wifi/answer/6246642?hl=en
142 "Google to acquire Nest," *Alphabet,* Jan. 13, 2014, available at https://abc.xyz/investor/news/releases/2014/0113.html
143 Nest homepage, available at https://nest.com/
144 "Works with Nest," Nest, last accessed on August 15 2018, available at https://nest.com/works-with-nest/
145 "Privacy statement for Nest products and services," *Nest,* last accessed on August 15 2018, available at https://nest.com/legal/privacy-statement-for-nest-products-and-services/

information with those parties but informs the user about what information is being shared.[146] Nest does not share data with other 3rd-parties, such as partner energy or insurance companies, without first gaining a user's consent.[147]

124. On its website, Nest states that Nest accounts and Google accounts are not linked (unless a user chooses to integrate with Google products and services) and that Google does not sell Nest data. Recently, however, data sharing concerns have arisen from an announcement[148] by Google concerning the merger of Nest and Google hardware teams.[149] In addition, concerns have been raised in the media about the future links between Google, Nest, and 3rd-party electrical and insurance companies.[150]

m) Google Fiber

125. Google Fiber is a broadband, Internet protocol (IP) TV, and Voice-Over-Internet-Protocol (VOIP) phone service connecting users via ultra-high-speed fiber-optic networks that extend all the way to their residences,[151] known as Fiber Internet, Fiber TV, and Fiber Phone, respectively. Google's efforts to deploy extensive networks of fiber optic cables were hampered by physical costs and negotiations with local municipalities. Google Fiber is therefore now expanding to new cities via Webpass (an Internet service provider acquired by Google), which delivers similarly high speeds through existing wireless and Ethernet technologies.[152]

126. Fiber Internet collects technical information connected to a user's Google Account, but does not share account details with other Google properties without the user's additional consent.[153] Fiber Internet requires user consent before associating a user's Google Account with other information, such as sites visited or content of communications.[154]

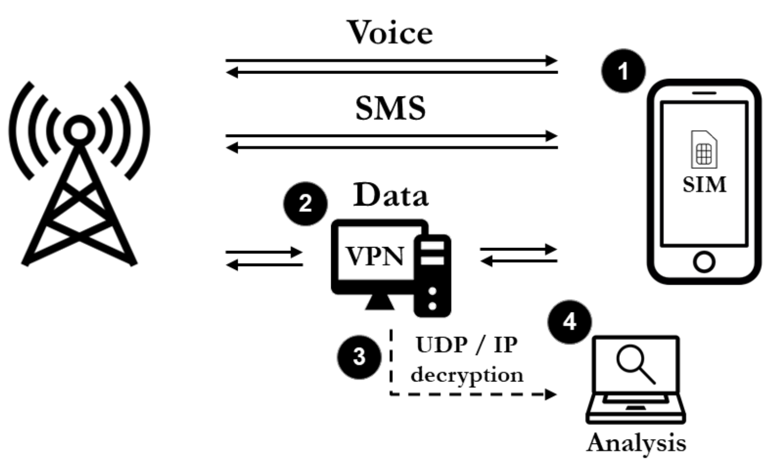
[146] "Privacy statement for Nest products and services," *Nest,* last accessed on August 15 2018, available at https://nest.com/legal/privacy-statement-for-nest-products-and-services/
[147] "Privacy statement for Nest products and services," *Nest,* last accessed on August 15 2018, available at https://nest.com/legal/privacy-statement-for-nest-products-and-services/
[148] Rick Osterloh, "Nest to join forces with Google's hardware team," *Nest,* Feb. 7, 2018, available at https://blog.google/topics/hardware/nest-join-forces-googles-hardware-team/
[149] Leo Kelion, "Google-Nest merger raises privacy issues," *BBC,* Feb. 8, 2018, available at http://www.bbc.com/news/technology-42989073
[150] Casey Johnston, "What Google can really do with Nest, or really, Nest's data," *Ars Technica,* Jan. 15, 2014, available at https://arstechnica.com/information-technology/2014/01/what-google-can-really-do-with-nest-or-really-nests-data/
[151] Ryan Waniata, "Comcast killer: Google Fiber touches down in Austin with its new TV and internet devices," *Digital Trends,* Dec. 3, 2014, available at https://www.digitaltrends.com/home-theater/google-fiber-tv-hands-on
[152] Nick Statt, "Google Fiber-owned Webpass is bringing its wireless gigabit internet to Denver," *The Verge,* Feb. 22, 2017, available at https://www.theverge.com/2017/2/22/14703142/google-fiber-webpass-denver-expansion-gigabit-Internet and https://gizmodo.com/what-happened-to-google-fiber-1792440779
[153] "Google Fiber privacy notice," *Google,* last accessed on August 15 2018, available at https://fiber.google.com/legal/privacy
[154] "Google Fiber privacy notice," *Google,* last accessed on August 15 2018, available at https://fiber.google.com/legal/privacy

127. Fiber TV collects information on programs and applications used and associates it with the user's Google Account.[155] Likewise, Fiber Phone collects usage information (e.g. logs of call history, voicemails, SMS messages, and recorded conversations) and associates it with a user's Google Account.[156] Although this information is not shared with 3rd-parties unless a user provides consent, information may be shared with 3rd-parties for external processing and for legal reasons. While Google does not explicitly mention the use of Fiber TV/phone for ad targeting, its general privacy policy does allow the use of collected personal information for targeting purposes. Moreover, Google states it will share Google Fiber user's non-personal identifiable information publicly with content providers, publishers, advertisers, and/or connected sites.[157]

D. Method for location traffic monitoring

128. To capture the requests being sent to Google server domains from a mobile phone, our study employs a "man-in-the-middle" (MITM) technique using the "MITM Proxy" tool. While previous studies that analyze similar data employed a Wi-Fi hotspot to act as an intermediary between mobile phone and Google servers, the present study uses a virtual private network (VPN) on a mobile phone to analyze data sent through Wi-Fi networks as well as the cellular network.

<u>Figure 23: Example VPN setup used to analyze data shared with Google</u>



The specific steps performed to configure and conduct the experiments are described below:

1. The mobile devices used in the data collection experiments[158] were factory reset to ensure that no previously installed applications or adjusted settings affected traffic to and from the phone. Upon

[155] "Google Fiber privacy notice," *Google,* last accessed on August 15 2018, available at https://fiber.google.com/legal/privacy
[156] "Google Fiber privacy notice," *Google,* last accessed on August 15 2018, available at https://fiber.google.com/legal/privacy
[157] "Google Fiber privacy notice," *Google,* last accessed on August 15 2018, available at https://fiber.google.com/legal/privacy
[158] Devices include an LG X Power with Android 6.0 version installed and an iPhone 5 with iOS 10.3.3 installed

reactivation, the devices were configured with the suggested default settings. The devices were then equipped with new SIM cards to obtain new cell phone numbers.

2. A VPN connection was setup with a remote proxy computer using VPN settings/functionality provided by the phone operating system. An IPsec/LT2P with a PSK authentication setup was chosen. The VPN configuration enabled the remote proxy to intercept and record the data transmitted from the mobile phones. Due to the nature of the type of signals emitted from a phone, the VPN set up is unable to intercept voice and SMS data sent from the mobile devices. However, it captured all TCP traffic to and from the device, including HTTP and HTTPS traffic.

3. HTTPS software certificates were installed on the mobile devices to enable decryption of the data traffic captured. VPN configuration allowed the routing of all HTTP and HTTPS traffic through the mitmproxy program[159] using iptables.[160] This program then performed SSL decryption using its own certificate to decrypt the traffic and dump it to HAR (HTTP Archive) files for analysis.

4. Analysis of decrypted HTTP and HTTPS traffic data mainly involved categorization of server requests into key segments using the request header info. Tables 5 and 6 detail the traffic headers that were identified as transmitting data to/from Google and Apple.

129. In specific cases, requests to Google were further decoded to analyze the information that was passed at a more granular level. One specific request to Google that was further decoded was the "Google location API," designated by the /loc/m/api endpoint. The location specifications were reverse engineered by removing the message header and decoding the compressed protobuf message.[161] The decoded location API contained Wi-Fi and network scans that were used to determine the location of the device.

Table 5: Notable Google server domains communicating with mobile phone devices

Segment	Pathway header	Description
Ad domains	doubleclick.net	Sends data to and from DoubleClick
	google-analytics.com	Sends data to and from GA
	googletagmanager.com	Implements webpage tags
	googletagservices.com	Implements webpage tags
	googlesyndication.com	Retrieves and displays ads
	adservice.google.com	Calls the AdWords network

[159] https://mitmproxy.org/
[160] "iptables(8) – Linux man page," *Die.net,* available at https://linux.die.net/man/8/iptables
[161] Additional information on the decoding method can be found here: "Reverse engineering: Google Location protobuf specifications," *Esther Codes,* accessed March 2018, available at https://web.archive.org/web/20180213201547/https://esther.codes/reverse-engineering-google-location-gms-specification/

	google.com/ads/	Ad measurement and user lists
	gstatic.com	Loads ads on the page
	google.com/adsense	Calls AdSense
	google.com/pagead	Serves page ads
Location	google.com/loc/m/api	Sends back nearby network and Wi-Fi information
	googleapis.com/userlocation/v1/reports	Sends back user movement information (i.e. walking, running, biking, driving, etc.)
	googleapis.com/placesandroid	Matches determined location with businesses, etc. (Google Places)
	maps.googleapis.com/maps	Retrieves detailed information based on a place ID or a place search
	clients4.google.com/glm/mmap	Sends user's location information to retrieve map data
Google Play API	play.googleapis.com/log/batch	Device activity logging information
	play.googleapis.com/play/log/timestamp	Updates a cookie and reports the time
	play.googleapis.com/play/log?format	Play Store/Services log upload
Device auth. and upload	googleapis.com/batch	Device information and updates
	clients4.google.com/chrome-sync	Chrome browser synchronization
	googleapis.com/experimentsandconfigs	testing/experiment config download
	android.clients.google.com/backup/backup	Device backup
	android.clients.google.com/auth	Device authorization
	android.clients.google.com/checkin	Device identifying information and activity
	android.clients.google.com/	Authentication with Google services
Other	cdn.ampproject.org	Retrieving data from the AMP CDN
	google.com/xjs	Communication with Google Search
	google.com/gen	Communications with Google Search that transmit cookie data
	clients4.google.com/ukm	Chrome speed information
	inbox.google.com/sync	Mail synchronization
	mail.google.com/mail/ads	Mail ad refresh
	google.com/complete/search	Sends character level information to enable the search autocomplete function
	Googleapi.com/	Other Google APIs include Google services (i.e. YouTube, Calendar, etc.)

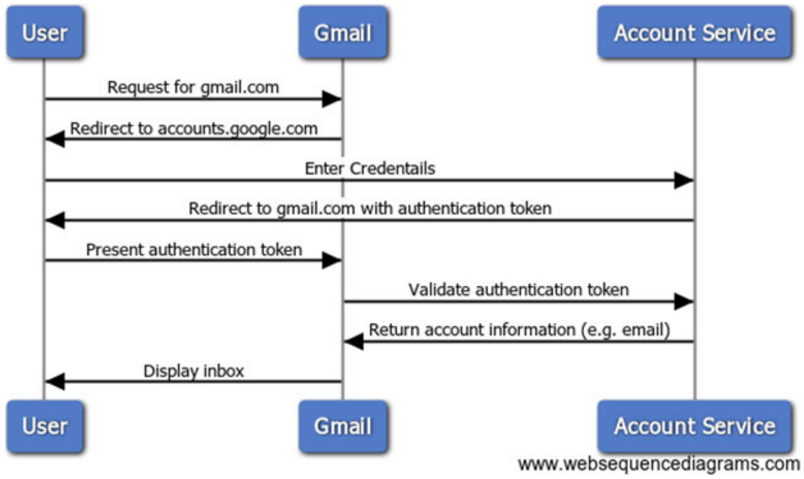
	Google.com/	Other miscellaneous calls to Google's domain

Table 6: Notable Apple server domains communicating with mobile phone devices

Segment	Pathway header	Description
Location	geosrc=wifi,73.xxx&kb_ime=en_US&key=beagle1626&latlng=40.xxx,-74.xxx&locale=en_US	Passes location coordinates back to Apple when using the browser
	cl2.apple.com	Calls to the core location server
	gs-loc.apple.com	Apple location services
App store	us-east-1.blobstore.apple.com/apple	Communicates with the Apple store; includes Apple ID
Device auth. and upload	mesu.apple.com/assets/com_apple_MobileAsset	Details mobile configurations and settings
	bookmarks.icloud.com	Syncs mobile behavior with the cloud
	ckdatabase.icloud.com/api	Communicates device authorization tokens and syncs with iCloud
	keyvalueservice.icloud.com/sync	Syncs mobile device behavior
Other	api-glb-nyc.smoot.apple.com/	Miscellaneous Apple APIs
	gsp64-ssl.ls.apple.com	Provides device information when the phone accesses websites via Safari
	gspe35-ssl.ls.apple.com/geo_manifest/dynamic/config?application=geod	Loads map tiles, but does not pass location information
	configuration.apple.com/configurations/pep/config/geo/networkDefaults	Communicates the settings of the location collection tools

E. Google sign in authentication sequence

Figure 24: Authentication sequence



F. Usage profile for mobile data collection experiments

130. A usage profile was designed to simulate a typical user's interaction with their mobile phone throughout the course of a day. A variety of statistics that describe peoples' online behavior and mobile phone usage were integrated to create the profile, as described below.

131. The designed profile visited 45 webpages during the course of the day based on website visit statistics from a 2010 Nielsen study, which indicates that the average person visits 88 webpages per day[162] and a 2017 Stone Temple study, which states that roughly 50-55% of webpage visits come from mobile devices.[163] The 45 webpage visits were evenly split between 5 top non-Google news and sports domains.[164] When the phone was not being used to visit webpages the browser was left running in the background of the phone. The resulting usage profile represents a conservative user as the number of webpage visits per day is likely to have increased since the 2010 Nielsen study.

132. The usage profile also included a variety of non-Google mobile applications. Top non-Google applications were selected from the social media, shopping, travel, and health categories. These applications included Facebook, Instagram, Snapchat, Pinterest, Amazon Shopping, Walmart, Starbucks, Yelp, and Six Pack

[162] "Nielsen provides topline U.S. web data for March 2010," Nielsen, April 2010, available at http://www.nielsen.com/us/en/insights/news/2010/nielsen-provides-topline-u-s-web-data-for-march-2010.html
[163] Eric Enge, "Mobile vs desktop usage: mobile grows but desktop still a big player in 2017," *Stone Temple,* April 2017, available at https://www.stonetemple.com/mobile-vs-desktop-usage-mobile-grows-but-desktop-still-a-big-player-in-2017/
[164] The domains selected were New York Time, CNN, The Guardian, ESPN, and Crickbuzz. The websites were identified by using Alexa's lists, available at https://www.alexa.com/topsites/category

in 30 Days. These apps were opened periodically throughout the day to simulate a typical user who spends approximately 2.5 hours in mobile app per day, as reported by eMarketer.[165]

G. Past articles that relate to Google's data collection practices

Table 7: Summary of other Google data collection studies

Title	Relevant findings	Author, Date
AP Exclusive: Google tracks your movements, like it or not[166]	Google is tracking users' location even when location services are disabled	Ryan Nakashima August 2018
Australian regulator investigates Google data harvesting from Android phones[167]	Google "harvest" about 1GB of data from Android devices per month	Oracle May 2018
How to Keep Google From Owning Your Online Life[168]	It is very difficult for the average consumer to avoid Google products	WSJ, May 2018
Google tracking phones even when they are disconnected?[169]	Google tracks phones even when phones are "disconnected" (no SIM cards, airplane mode, Wi-Fi off)	Fox News, Feb. 2018
Google collects Android users' locations even when location services are disabled[170]	Google collects Android location when location services are turned off	Quartz Nov. 2017

165 "eMarketer reveals new estimates for mobile app usage," *eMarketer,* April 2017, available at https://www.emarketer.com/Article/eMarketer-Unveils-New-Estimates-Mobile-App-Usage/1015611

166 Ryan Nakashima, "AP Exclusive: Google tracks your movements, like it or not," *AP*, August 13, 2018, available at https://apnews.com/828aefab64d4411bac257a07c1af0ecb

167 Anne Davis, "Australian regulator investigates Google data harvesting from Android phones," *The Guardian,* May 13, 2018, available at https://www.theguardian.com/technology/2018/may/14/australian-regulator-investigates-google-data-harvesting-from-android-phones

168 David Pierce, "How to Keep Google From Owning Your Online Life," *The Wall Street Journal,* May 8, 2018, available at https://www.wsj.com/articles/how-to-keep-google-from-owning-your-online-life-1525795372

169 Brett Larson, "Google tracking phones even when they are disconnected?," *Fox News,* Feb 11, 2018, available at http://video.foxnews.com/v/5731183327001/?#sp=show-clips

170 Keith Collins, "Google collects Android users' locations even when location services are disabled," *Quartz,* November 17, 2017, available at https://qz.com/1131515/google-collects-android-users-locations-even-when-location-services-are-disabled/

Google is permanently nerfing all Home Minis because mine spied on everything I said 24/7[171]	The Google Home mini was saving recording when the device was not activated with "OK Google" *Google claims to have resolved the issue	Artem Russakovskii Oct. 2017
Online Tracking: A 1-million-site Measurement and Analysis[172]	Google can track users ~80% of websites using its cookies.	Princeton University 2016
Why Do Android Smartphones Guzzle the Most Data?[173]	Android devices consume more data (2.2GB/month) than other smartphones	Ericsson Dec. 2013
Data leakage from Android smartphones[174]	Android passes anonymous IDs along with devices IDs such as Mac address and IMIE	Lasse Øverlier June 2012

H. Clarifications

133. Our understanding of the data being sent to Google through its Android platform is limited to Android 6.0 version only. This study does not capture any updates/patches that may have been implemented on later versions that may affect Android's communications with the Google servers. While new versions of Android are currently present in the market, Android 6.0 is still the most widely used version.[175] Additionally, while we took utmost precaution for classifying the pathway headers by their purpose (e.g., location, ad, device upload, app store), it is possible that some headers may serve multiple purposes (e.g., ad as well as location). These aspects are not captured in our study. Consequently, the description presented for these headers may not be exhaustive with respect to the purpose they serve.

I. About the author

134. Professor Douglas Schmidt is a software system expert with over 30+ years conducting, supervising, and researching the development of software for distributed middleware systems and their applications in

[171] Artem Russakovskii, "Google is permanently nerfing all Home Minis because mine spied on everything I said 24/7," *Android Police,* October 10, 2017, available at https://www.androidpolice.com/2017/10/10/google-nerfing-home-minis-mine-spied-everything-said-247/

[172] Englehardt, Steven, and Arvind Narayana, "Online Tracking: A 1-million-site Measurement and Analysis," *ACM CCS,* 2016, available at http://randomwalker.info/publications/OpenWPM_1_million_site_tracking_measurement.pdf

[173] Brian Chen, "Why Do Android Smartphones Guzzle the Most Data?," *The New York Times,* December 31, 2013, available at https://bits.blogs.nytimes.com/2013/12/31/why-do-android-smartphones-guzzle-the-most-data/

[174] Lasse Øverlier , "Data leakage from Android smartphones," *Norwegian Defense Research Establishment,* June 6, 2012, available at https://www.ffi.no/no/Rapporter/12-00275.pdf

[175] "Mobile & Tablet Android Version Market Share Worldwide," *statcounte*r, available at http://gs.statcounter.com/android-version-market-share/mobile-tablet/worldwide

networking and security, machine learning and smart-grid, design patterns, and more. He has authored 10+ books and 600+ papers that have been collectively cited over 38,000 times. Professor Schmidt has over 30 years of experience teaching these concepts both in-classroom and online to over 200,000 students in total.

135. Professor Schmidt has participated in 20+ prior expert engagements spanning expert report production and oral testimony both through deposition and at trial. His consulting work has ranged from patent and copyright litigation matters to advising both private and public entities on various issues relating to software infrastructure and design. He earned his PhD and MS in Computer Science from the University of California, Irvine in 1994 and 1990, respectively.

136. Professor Schmidt is currently the Cornelius Vanderbilt Professor of Computer Science at Vanderbilt University. Prior to Vanderbilt, he held several directorial and C-level positions in both academic and industry settings including the Software Engineering Institute at Carnegie Mellon University, the Information Technology Office at the Defense Advanced Research Project Agency (DARPA), the Federal Government, as well as several technology start-ups.

APPENDIX 2

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IN THE SUPERIOR COURT OF THE STATE OF ARIZONA

IN AND FOR THE COUNTY OF MARICOPA

STATE OF ARIZONA, *ex rel.* MARK BRNOVICH, Attorney General, Plaintiff, v. GOOGLE LLC, A Delaware Limited Liability Company, Defendant.	No. CV2020-006219 **DECLARATION OF SETH NIELSON** Assigned to the Hon. Timothy Thomason **(COMPLEX CALENDAR)**

Pursuant to Rule 80(c) of the Arizona Rules of Civil Procedure, I, Seth Nielson, declare as follows:

Background

1. I am a subject matter expert in areas of cybersecurity, computer networking, and software architecture. I am a co-founder of Source Code Discovery, LLC, a computer software analysis and review company. Furthermore, I hold appointments at the University of Texas at

Austin as an Adjunct Associate Professor in the department of Computer Science and as a Cybersecurity Fellow in the Robert Strauss Center for International Security and Law.

2. I have been working professionally in the field of computer security since August of 2005 and within the field of computer science generally since June 2000. My experience includes graduate-level teaching, academic research, industry employment, and consulting practice.

3. I received my B.S. in Computer Science from BYU in April of 2000. After graduation (from 2001 through 2003), I worked as a software engineer at Metrowerks (formerly Lineo, Inc.), where I had substantial responsibilities relating to software architecture, computer networking, and technical project management.

4. While working at Lineo/Metrowerks, I also returned to BYU to pursue my Master's degree in Computer Science. In addition to the graduate level course work in wireless computer networks and compilers, I pursued graduate research in software engineering topics, with a special emphasis on how programmers think while creating and modifying code. During my course work, I took a special topics class called "Programmer Cognition" as well as a graduate-level neuroscience class from the Psychology department.

5. My research included a study of computer architectural patterns and how those patterns might need to change as programming languages change and evolve. Based on my research, I proposed a concept called "Design Dysphasia," wherein a programmer or software developer becomes trapped in their approach to solving problems based on the paradigms and design approaches of the programming language. My research was published as "Design dysphasia and the pattern maintenance cycle," in the Journal Information and Software Technology August 2006. This work also was a major component of my Master's thesis.

6. Another part of my Master's thesis was the identification of how certain programming language concepts can be "mixed" together. I investigated practical mechanisms

whereby the Python programming language could be extended to support features known as "functional programming" and "logic (or declarative) programming." Languages with this mix of features are known as "multi-paradigm" programming languages.

7. After finishing my Master's degree, I moved to Houston, Texas in 2004 to begin a Ph.D. program at Rice University. At this point, my interest in computer security took priority over my interests in programming languages and software engineering, and my classes and research were directed to that topic.

8. During the 2004 fall semester of my Ph.D. program at Rice University, I identified a security vulnerability in the Google Desktop Search that could have allowed hackers to compromise users' computers and obtain private information. After contacting Google and assisting them in closing the vulnerability, we published the details of our investigation.

9. In 2005, I completed an internship at Google, where I designed and implemented a solution to privacy loss in Google Web Accelerator. The Google Web Accelerator was designed to increase the speed of browsing the Internet. Once installed on a user's computer, the browser would request all content through a Google Proxy. The proxy performed pre-fetching and extensive caching in order to provide fast and responsive service to the user. At the time of my internship, news reports had identified odd problems in which users of the Accelerator were accessing other individual's private pages. During my internship, I designed and implemented a prototype solution for this issue in C++.

10. My Ph.D. Thesis was entitled "Designing Incentives for Peer-to-Peer Systems."

11. From 2005 through 2008, with the approval of my PhD adviser, I worked as a Security Analyst for Independent Security Evaluators (ISE). Much of my early work was spent developing a software encryption library, including the necessary tests and procedures for FIPS-certification. The encryption library provided advanced operations such as secure data splitting and recovery.

12. In 2009, I went to work full time for ISE as a Security Analyst and later as a Senior Security Analyst. I built a number of advanced projects including a parallel-program for massive code coverage analysis, GPU hardware-accelerated AES encryption, and encrypted file-system prototypes.

13. In addition to the software development, I also performed security evaluation services that included port-scanning analyses, security protocol analysis using formal and exploratory methods, and investigated security breaches.

14. In 2011, I began work as a Research Scientist at Harbor Labs and continued with that consulting firm until fall 2015. I worked with a wide range of clients, specializing in network security, network communications, software architecture, and programming languages. I analyzed an extensive collection of commercial software, including software related to secure email, cloud-based multimedia delivery, document signing, anti-virus and anti-intrusion, high-performance routing, networking protocol stacks in mobile devices, PBX telecommunications software, VoIP, and peer-to-peer communications. I also reviewed technology and source code for multiple clients related to accusations of theft and/or misappropriation of trade secrets. These engagements included an analysis of C, C++, Java, Python, and other source code languages in high-frequency trading, e-commerce, and other similar systems.

15. For other clients, I have "resurrected" or re-created legacy software systems. For example, I assisted one client to make code from the mid 90's operational. I helped them identify the most compatible components from an old CVS repository, obtain the necessary legacy hardware and software to rebuild the source code, and diagnose why the separate components weren't completely compatible with each other. Using tools from the era (*i.e.*, the mid-90's), I identified and fixed these issues in C++ and Java code, and successfully demonstrated the operational system.

16. In other similar examples, I re-created basic software in x86 Assembly code that mimicked the behavior of 1990's era viruses, wrote a file transfer system similar to FTP in pre-2.0 Java, and demonstrated the use of a command-line antivirus software adapted for router/gateway scanning.

17. In March 2016, I founded Crimson Vista, Inc. as a boutique computer security engineering company. Similar to the work that I did at Harbor Labs, I continue to provide technical expertise to a wide range of clients in areas of programming languages, computer networks, and network security. My expertise in the area of "security engineering" provides comprehensive analysis, design, and insight into cybersecurity concerns before, during, and after development.

18. I have also provided technical guidance to an antitrust team in the United States Department of Justice. Although the technologies and parties are confidential, I can disclose that I provided in-person training on technical topics and analyses of competing security products.

19. More recently, I have been retained by clients, including a Fortune 100 financial institution, to provide them with post-data-breach analyses of what went wrong, the impact of the lost data, and guidance on resolution. In these engagements, I provided reverse engineering of the data to demonstrate how an attacker can or would use the compromised information, analyzed software development to determine when the system became vulnerable, and helped identify impacted customers that had been missed in the investigations.

20. I also continue to perform a wide range of code reviews for diverse technologies including CAD software, video game systems, digital mobile radios, video streaming, and digital rights management.

21. Moreover, I maintain ties to academia. I have held adjunct appointments at Johns Hopkins University from 2014 to 2019. From July 2016 to July 2019, I also held an appointment as the Director of Advanced Research Projects in the Johns Hopkins University Information Security Institute.

22. I am now an adjunct professor at the University of Texas at Austin. I teach the undergraduate Network Security and Privacy class in the Computer Science department. I also teach the Introduction to Cybersecurity Technology class in the Law School.

23. I am also the co-founder of Source Code Discovery, LLC. Our company is specialized for source code review for computer security concerns, audit/compliance, and litigation support.

24. I am also the author of "Cryptography in Python: Learning Correct Cryptography by Example."

25. I have been retained by the State of Arizona as a technical expert regarding the functionality of Google's products and services as relevant to this case.

Summary of Preliminary Opinions

26. I have been asked by the State to explain and opine on certain technical aspects of Google's collection and use of location information through apps, products, and services.

27. Google and its partners sell Google devices, services, and software that possess the ability to track a user's location.

28. These devices, services, and software include hardware devices like Google's Nexus and Pixel phones and the Google Home system; Google apps like Search and Maps; products, services and settings like Location History ("LH") and Web & App Activity ("WAA"); and Google's Android operating system (collectively, "Google products").

29. When a consumer purchases an Android device, he or she receives a device that Google uses to track that user's location. From a technical perspective, much of the functionality that Google uses to track user's location is built into the operating system at the time that the device is sold to the consumer. In other words, when a consumer purchases an Android device, he or she receives a device that has been configured to provide Google with ability to collect, store, and exploit a user's location information through the software on the device.

30. When a user purchases an Android device, the user must also activate and set up his or her phone, which includes the presentation of a variety of disclosures and settings relating to Google's collection of location data.

31. Google also collects users' location information from its own apps and services, some of which are pre-installed on the mobile device, whereas others are downloaded.

32. Google's Android operating system also enables Google apps (and possibly third party apps) to obtain a user's location even when a user denies those apps permission.

33. Through its IPGeo and [redacted] services, Google also obtains user location data from IP addresses, even if a user turns off all location-related settings, to serve ads. Google uses this IP address data to locate users in a much more accurate way than is otherwise available to the public.

34. Through these IPGeo and [redacted] services, nearly all transactions with Google products or services become an opportunity for Google to collect and exploit the user's location information—even if the user has disabled the location related settings.

35. Google uses an internal service called [redacted] to calculate a "best" location for a user from a variety of location signals.

36. Google's sales of ads make use of the location information that Google collects through the practices described. Google likewise uses the location information collected as noted above for targeted advertisements and to track "conversions" of such ads to physical store visits through its [redacted]/Store Visits service.

37. My opinion is based on my analysis of documents, testimony, and other discovery produced in this matter and my general expertise and experience as described above.

Android

38. Android is an operating system used on devices like smartphones.

39. Some versions of Android are open-source, meaning that anyone can modify the source code and install it on a compatible device. Such modifications are called "Android forks." (Ex. 93 (9/25/2019 Chai EUO Tr.) at 139:9–140:9).

40. Google, however, develops its own proprietary versions of the Android operating system for its own devices and devices offered by its various partners.

41. While third-party device manufacturers ("OEMs") are theoretically free to pre-install any Android fork on their phones, the vast majority of Android devices sold in the U.S. have Google's version. (Ex. 49 (2/28/2020 Berlin EUO Tr.) at 448:9–17).

42. Google precludes OEMs from pre-installing its Google Play Store (*i.e.*, Google's app marketplace) or any Google apps (such as Search or Maps) on other versions of Android. (Ex. 93 (9/25/2019 Chai EUO Tr.) at 137:20–140:21; Ex. 4 (3/6/2020 Menzel EUO Tr.) at 74:17–75:4, 76:7–13; Google's 7/15/2020 Mot. to Dismiss at 14).

43. Google's own version of Android contains Google Mobile Services ("GMS"), which enables Google to collect location information from users. (Ex. 93 (9/25/2019 Chai EUO Tr.) at 137:20–139:6).

44. GMS (and more specifically, Google Play Services within GMS) contains Android's Location Services. (Ex. 93 (9/25/2019 Chai EUO Tr.) at 63:4–9, 64:6–13, 68:21–23, 139:1–6). In particular, GMS contains a Google Location Management Service and Google Location Service ("GLS," also known as Google Location Accuracy or "GLA"). (Ex. 139 (GOOG-GLAZ-00019292) at 296).

45. Through Android's GMS, Google collects and stores location data via a variety of sensors and signals. (Ex. 93 (9/25/2019 Chai EUO Tr.) at 137:21–139:6, 144:8–16). These include the device's GPS chip, WiFi chip, cell network connection, barometer, gyroscope, magnetometer, and accelerometer. (*Id.* at 66; Ex. 139 (GOOG-GLAZ-00019292) at 295).

46. The raw location data collected by these sensors and signals are aggregated by something called the Fused Location Provider ("FLP") API. (Ex. 93 (9/25/2019 Chai EUO Tr.) at 66:12–23; Ex. 139 (GOOG-GLAZ-00019292) at 295).

47. The FLP is also part of Google's Android operating system. (Ex. 4 (3/6/2020 Menzel EUO Tr.) at 69:25–70:3). According to Mr. Jack Menzel (who worked on and developed the FLP at Google), although there are pieces of FLP that can be invoked on the open source version of Android, Google's proprietary version of Android also includes an FLP that runs on devices used with Google Play Services. (*Id.* at 70:8–71:1).

48. "API" stands for application programming interface. An API acts as a connection between two sets of computing systems and allows those systems to communicate with each other. In this context, the FLP API acts as a unified interface for location requests on the Android device. In other words, Google software both on and off the device, as well as third party apps, use the FLP API for location information.

49. As its name suggests, the FLP merges the various raw location data into a "fused location." (Ex. 33 (Google's 2/21/2020 Responses to CIDs 1–3) at 59–60; Ex. 93 (9/25/2019 Chai EUO Tr.) at 60:19–61:6, 66:12–23).

50. When on-device apps and services request a device location, GMS (including through FLP) provides this fused location. (Ex. 93 (9/25/2019 Chai EUO Tr.) at 63:10–18, 64:5–13). GMS also reports data to Google's backend servers. (Ex. 64 (7/11/2019 McGriff EUO Tr.) at 74:10–16; Ex. 93 (9/25/2019 Chai EUO Tr.) at 62:8–15, 68:1–23; Ex. 139 (GOOG-GLAZ-00019292) at 295).

51. Because the location services just described (like FLP) are part of GMS, they are pre-installed on a vast majority of all Android phones sold in the U.S. (as discussed above).

52. These include a Location History ("LH") client, a Web & App Activity ("WAA") client, Google Location Accuracy ("GLA," or Google Location Services ("GLS")), device location (or "location master"), WiFi scanning, WiFi, and app-level location permissions.

53. The location data that Google collects from GLS is used in geo-targeting users with ads. (Ex. 7 (GOOG-GLAZ-00235728) at 734).

Google's Location-Related Settings

54. As noted above, through its Android operating system, Google presents a number of location-related settings (*i.e.*, settings through which it collects or saves location data).

55. Some of these settings (like LH and WAA) are account-level settings. (Answer ¶ 38). This means they are associated with a user's Google account, regardless of the specific device a user uses. (Ex. 63 (7/12/2019 Monsees EUO Tr.) at 134:11–135:4).

56. Information associated with an account is associated with a "GAIA ID," which ID is unique to the account. (Ex. 134 (2/27/2020 Berlin EUO Tr.) at 53:10–13, 157:10–13). A GAIA ID is associated with a single Google account. (*Id.*). A user's Google account (and thus a GAIA ID) can be associated with multiple devices. (Ex. 63 (7/12/2019 Monsees EUO Tr.) at 370:14–371:4). The location information collected and stored by account-level settings is stored against a user's GAIA ID, and thus can be associated with any of the user's signed-in devices. (Ex. 134 (2/27/21 Berlin EUO Tr.) at 206:20–207:25, 208:1–9; Ex. 49 (2/28/21 Berlin EUO Tr.) at 455:14–19).

57. Other settings (like the device location) are device-level settings, which are those that are specific to a given hardware device, like a smartphone or tablet. (*See* Ex. 140 (GOOG-GLAZ-00000054) at 055).

58. Yet other settings (like app-level location permissions) are app-level settings, which are particular to a specific app. (*See* Ex. 93 (9/25/2019 Chai EUO Tr.) at 273:19–24).

Google's Location History and Timeline Products

59. Location History is an account-level setting offered by Google that has an associated user-facing product called Timeline. (Ex. 33 (Google's 2/21/2020 Responses to CIDs 1–3) at 18).

60. Google describes LH as a setting that "saves a private map . . . of where the user goes with his or her signed-in devices, even when the user is not using a Google service." (*Id.*)

61. "Opting in to Location History allows Google to build a user's Timeline . . . of the places the user's devices have been and to provide more personalized features across Google products and services . . . ." (*Id.*).

62. Timeline is a user-facing product that allows users to view and manage the location data collected by LH. (Ex. 64 (7/11/2019 McGriff EUO Tr.) at 218:13–219:5).

63. In Android devices, Google obtains location data for LH through something it calls User Location Reporting ("ULR"). (*Id.* at 68:14–69:18; Ex. 33 (Google's 2/21/2020 Responses to CIDs 1–3) at 60). As described above, ULR is part of GMS and thus obtains location information from Android sensors and signals. *See also* (Ex. 64 (7/11/2019 McGriff EUO at Tr.) at 66:8–67:20.

64. When the user purchases a device and signs into her Google account during device setup, the device can immediately begin uploading location information via Location History. (*See* Ex. 141 (GOOG-GLAZ-00001389) at 392).

65. LH is, by design, integrated into Google devices such as Android phones. On the device itself ULR (discussed above) transmits information collected by LH to Google's backend services and infrastructure. (Ex 117 (Google's 4/30/2020 Responses to 4th CID) at 12, 17).

66. I understand Google's witness has tried to disassociate LH from the transaction for purchasing an Android device. (McGriff Decl. ¶ 3). From a technical perspective, this is not quite accurate. Rather, a user of an Android device needs to be signed into his or her account—or create an account—when purchasing an Android device in order to meaningfully use it. (Ex. 50 (GOOG-GLAZ-00000058) at 93 ("Without a Google Account, you won't be able to: Download apps,

music, games, and other content from Google Play; Back up your apps to Google, and sync Google services like Calendar and Contacts with your device; Activate device protection features.")).

67. The "Google Store Sales Terms" likewise confirm this. Google witness Abhijit Ravi attaches (as Exhibit A to his declaration) a current copy of the "Google Store Sales Terms" that "went live in October 2017." (Ravi Decl. ¶ 5). Mr. Ravi says that a user must "consent to the Google Store Sales Terms" in order to "purchase a device from the Google Store." (*Id.*) Under the heading "Use of the Device" (Ravi Decl., Ex. A at 6), the "Google Store Sales Terms" explain as follows: "In order to make use of any enhanced functionality of your Device, you may have to sign in to your Google account or open a Google account if you do not yet have one." To my understanding, the functionality of an Android device would be severely limited if a user does not sign into a Google account. I would expect such an occurrence (*i.e.*, a user buying an Android device with Google's version of Android and not signing into or creating a Google account) would be exceedingly rare.

68. Under "Use of the Device," the "Google Store Sales Terms" also confirm that the user not only agrees to comply with any agreements applicable to use of the Device but also "any software on the Device." This "software" would include Google's Android operating system, which is sold with the Android device.

69. Another internal Google service known as [redacted] mapping infrastructure is in place before a consumer purchases or uses any Google product or service.

70. LH data is also used by other Google products, such as by Google Maps, Find My Device, Contacts, GMS, Google Keep, Google Pay, Search, YouTube, and many others. (Ex. 33 (Google's 2/21/2020 Responses to CIDs 1–3) at 66–68; Ex. 64 (7/11/2019 McGriff EUO Tr.) at 220:3–14).

71. The location information collected through LH is also a signal that can be used by Google for advertising. (Ex. 64 (7/11/2019 McGriff EUO Tr.) at 224:2–7).

72. Google also uses information collected through LH to track "conversions" of such ads to physical store visits. For example, Google's "Store Visits"—referred to as "[redacted] at Google—uses Location History information to ascertain whether a user visits a physical store after viewing an advertisement. (Ex. 3 (5/21/2020 Hennessy EUO Tr.) at 193:4–10, 247:3–11; Ex. 33 (Google's 2/21/2020 Responses to CIDs 1–3) at 16). According to Google, Store Visits shows advertisers how an increase in ad spending will increase conversions. (*Id.*).

73. Within its Android operating system, Google also sometimes runs promos (akin to advertisements) that are designed to encourage users to turn on their LH setting. (Ex. 89 (GOOG-GLAZ-00205674) at 688; Ex. 52 (10/7/2021 McGriff Dep. Tr.) at 70:8–71:23).

<u>Google's Web & App Activity and My Activity Products</u>

74. Web & App Activity ("WAA") is another account-level setting that tracks the user's location via the user's activities while using Google products, such as Search. (Ex. 33 (Google's 2/21/2020 Responses to CIDs 1–3) at 18–19).

75. The location data saved via WAA is saved to "My Activity," which is a user-facing product where users can view and manage the location data (and other data) saved by WAA. (Ex. 63 (7/12/2019 Monsees EUO Tr.) at 188:22–189:2).

76. The location signals saved by WAA include device location (discussed above) and location derived from IP address (discussed further below). (*Id.* at 87:17–88:6).

77. The location information collected and stored through WAA is used by Google in generating geo-targeted ads. (Ex. 143 (GOOG-GLAZ-00171510) at 511; Ex. 63 (7/12/2019 Monsees EUO Tr.) at 111:12–25).

78. WAA is enabled by default when a user sets up her account. (Ex. 63 (7/12/2019 Monsees EUO Tr.) at 174:13–176:18).

79. Android users could obtain the benefit of Google's apps and services without enabling LH or WAA. (Ex. 9 (GOOG-GLAZ-00299120) at 139, lines 4–15). For example, users "can still use Google Maps with web and app activity and location history off." (*Id.* lines 21–22). "[T]he same goes for Google search." (*Id.* lines 34–35).

80. Yet, Google prompts users to enable these settings (or not disable WAA), which then enables Google to store more precise location data for the user and exploit that location data for Google's products and services. For example, Google apps and services "have a prompt encouraging [users] to take on a new feature and as part of that, location history would be switched on." (*Id.* at 141, lines 42–44).

<u>Google's Location-Collection Practices Are Part of the Android Devices</u>

81. I understand that, in the above-captioned action, the State alleges a number of deceptive and unfair acts, practices, and omissions by Google. Many of the acts, practices, and omissions challenged by the State are embedded in the Google software that comes with Android phones, as discussed above.

82. For example, the State alleges that even if LH is off, Google nonetheless collects user location information through the WAA setting. (Compl. ¶¶ 50–53). As I explained above, Google collects user location information using aspects of Google's propriety Android operating system, which is pre-installed on most Android phones sold in the United States. Although a user could theoretically disable it, the WAA setting is on by default—regardless of whether LH was enabled in the first place or disabled. Further, although WAA is an account level setting, an

Android user must either sign into an existing Google account or creates a new one as part of the set-up process for a newly purchased phone in order to meaningfully use it, as mentioned above.

83. Google also uses its operating system on Android phones to collect users' location information in other important ways, which I understand the State alleges to be unfair and deceptive. For example, on devices sold with Google's proprietary software, there are two settings relevant to WiFi including "WiFi scanning" and "WiFi connectivity." (Compl. ¶ 71). Even when the "WiFi scanning" setting is off, Google still obtains users' location information from WiFi scans if "WiFi connectivity" is enabled. These settings that enable Google to collect location information—in manners that the State alleges are deceptive and unfair—are embedded into Google's proprietary Android operating system that is pre-installed on most Android devices sold in the United States.

84. When purchasing an Android phone, a consumer in Arizona gets a device that Google can use to track his or her location. Google obtains that information through various settings, such as WAA, WiFi scanning, and others, which are built into Google's Android operating system that is pre-installed on Android phones.

85. Additionally, Google promulgates software updates for its proprietary version of Android (and even for the open source version of Android) from time to time.

86. I understand that the State also alleges unfair and deceptive acts, practices, and omissions, as it relates to Google's policy that it calls "off means course." (Compl. ¶¶ 87–92). No matter which location-related settings (like WiFi scanning, LH, WAA, or even device location) a user turns off, Google collects, saves, and uses the user's location data from IP address. (Ex. 81 (5/8/2020 Rothfuss EUO Tr.) at 271:23–272:1; Ex. 49 (2/28/2020 Berlin EUO Tr.) at 517:15–23; Ex. 3 (5/21/2020 Hennessy EUO Tr.) at 103:5–7). Thus, even when a user believes his or her device's location is "off," Google is still collecting and using the user's location data.

<u>Google Collects Users' Location Information From Its Apps</u>

87. Google also collects a user's location information from its own apps, whether installed on Android devices or iOS devices.

88. Google periodically updates the operating system, and major changes are noted with a new name. Historically, I understand the major versions of Android were named alphabetically after desserts (*e.g.*, "**C**upcake," "**D**onut," "**É**clair," "**F**royo," "**G**ingerbread," "**H**oneycomb," "**I**ce Cream," "**J**elly Bean," "**K**itKat," "**L**ollipop," "**M**arshmallow," "**N**ougat," "**O**reo," and "**P**ie"). I also understand that, more recently, Google has reverted to more convention names starting with Android 10, Android 11, and (currently) Android 12.

89. On Android devices before Android Marshmallow (which was publicly introduced in 2015), Google had an "install-time" permissions model. This meant that the operating system would execute prompts seeking a user's permission for an app to obtain the user's location when the app was installed for the first time. (Ex. 93 (9/25/2019 Chai EUO Tr.) at 215:19–216:7).

90. On Android devices beginning with Android Marshmallow, Google started using "runtime permissions" for its operating system. (*Id.* at 215:12–18). Runtime permissions are permissions that a user chooses when running the app. In other words, when a user opens an app, the user is asked whether he or should would like to grant the app access to location information. According to Google, if a user denies runtime location permissions to an app, that app should not be able to access the user's location. (*Id.* at 163:3–12; Ex. 109 (GOOG-GLAZ-00027697.R) at 700.R; Ex. 102 (GOOG-GLAZ-00000381) at 381).

91. Google's apps can actually obtain a user's location even if the user denies the app location runtime permissions.

92. For example, when a user denies a Google app location runtime permission (thus purportedly denying the app access to the user's location), that app can still obtain the user's location through a "backdoor"—e.g., through Google's backend systems, which may have stored the user's locations via other Google apps/products and/or from earlier times. (*See* Ex. 103

(GOOG-GLAZ-00005829) at 829–32; Ex. 104 (GOOG-GLAZ-00060013.R at 013.R); Ex. 122 (GOOG-GLAZ-00198467) at 469 ("[redacted]"); Ex. 123 (GOOG-GLAZ-00150448.R) at 449.R (Google Assistant "[redacted] permissions from other apps); Ex. 124 (GOOG-GLAZ-00027379.R) at 379.R–83.R (indicating that "cross-product data use . . . may hurt user trust if we are providing locations to XYZ via the ULR-loophole when the user has explicitly denied it," and that Google has been aware of the issue "for 2+ years"); Ex. 125 (GOOG-GLAZ-00027688.R) at 689.R; Ex. 109 (GOOG-GLAZ-00027697.R) at 697.R; Ex. 127 (GOOG-GLAZ-00033771) at 772).

93. Google's documents suggest that this behavior is even possible by third-party apps. Ex. 103 (GOOG-GLAZ-00005829) at 831.

94. One way Google can do this is via LocationContext, which is, I believe (based on my review of the materials), a standardized format for location that enables Google's servers to pass location information between each other rather than querying a location from a centralized source. Thus, apps would be able to obtain location via LocationContext from other Google products via this "loophole," and allow Google's apps and systems to pass a user's location directly to each other rather than obtaining from a centralized source.

95. Google and its engineers have been aware of this "loophole" or "bypass" (as Google's own engineers described it) since at least Android Marshmallow was released back in 2015. (Ex. 124 (GOOG-GLAZ-00027379.R) at 383.R, 384.R).

96. As far as I can tell, Google has not made any settings that would prevent this from occurring. On the contrary, as of February 2017, Google acknowledged that "this loophole existed for 2+ years" and that "[t]here were a bunch of products already out of compliance." (*Id.* at 383). Moreover, I understand that this "loophole" is "on the ads revenue stream," which contributed to

preventing Google from finding a fix. (Ex. 103 (GOOG-GLAZ-00005829) at 831). I also understand that this broken behavior was approved by "a very senior group of" Google employees. (*Id.*).

97. In other words, while Google's operating systems (starting with Marshmallow) indicates that apps only obtain the users' location information if authorized through runtime settings, it turns out that the apps can obtain the users' location information regardless of the users' selection during runtime settings.

Google's IPGeo and [redacted] Services

98. Besides using Android's signals and sensors to obtain a user's location, Google also determines user location through IP address, including through Google's (Static) IP Geo and [redacted] Services.

99. Google has a service called IPGeo that translates IP addresses into geographic locations. (Ex. 135 (GOOG-GLAZ-00226213) at 234). Despite the name, this service [redacted]. (Ex. 134 (2/27/2020 Berlin EUO Tr.) at 99:24–100:10).

100. Before April or May 2019, the granularity of the location Google calculated using IP address was an area equal to 1 kilometer squared that had at least 1000 users. (Ex. 144 (GOOG-GLAZ-00163856); Ex. 119 (9/13/2021 Eriksson Dep. Tr.) at 172:12–173:11). After May 2019, the area was expanded to 3 kilometers squared that had at least 1000 users. (Ex. 144 (GOOG-GLAZ-00163856); Ex. 145 (GOOG-GLAZ-00086932)).

101. I understand Google suggests that Internet-connected devices are generally assigned a new IP address each time they connect to the Internet. (Eriksson Decl. ¶ 6). This is not quite right. At least some Internet-connected devices are assigned a static IP address that does not change when they connect to the Internet. Further, even when and if an Internet-connected device

is re-assigned an IP address, it is often assigned a new IP address within the same pool (or "block" as Mr. Eriksson described in ¶ 5 of his declaration) as the old IP address.

102. More fundamentally, I understand Google's witnesses have pointed out that all devices communicate on the Internet with an IP address, and that Google must obtain that IP address in order to provide Internet-enabled services. (Eriksson Decl. ¶ 4). Nothing, however, requires Google to (i) store users' IP addresses for an extended period of time, (ii) use those IP addresses to calculate as fine a location as it does, or (iii) use users' IP addresses to serve users ads (besides perhaps confirming country-level location for purposes of, for example, ensuring compliance with specific countries' laws when serving ads). In this regard, Google's statements are a smokescreen, which cover up the fact that Google is using IP address to do much more than provide Internet-enabled services.

103. Additionally, Google's internal documents describe how its IPGeo service has a much better ability to locate users than other IP address mapping services. (Ex. 44 (GOOG-GLAZ-00244861) at 862 (describing "the methods developed by the Google IPGeo team" as "unique and industry-leading" and as Google's "secret sauce"), 863 (noting that Google patents its IPGeo methods), 864 (describing algorithms that "supplement the resulting insights [from IP address] with a number of additional networking signals an inputs"), 865–66 (describing why Google's IP geolocation service is better than alternatives, including because Google is able to "divid[e] groups of IPs into predicted location blocks to better geotarget ads to users in specific locations rather than to the locations of servers")).

104. Further, despite the various settings, there is nothing a user can do to prevent Google from collecting and storing the user' location through an IP address and having Google calculate the 3 km^2 (or before May 2019, 1 km^2) area containing her location. (Ex. 81 (5/8/2020 Rothfuss EUO Tr.) at 271:23–272:1; Ex. 49 (2/28/2020 Berlin EUO Tr. at 517:15–23); Ex. 3 (5/21/2020 Hennessy EUO Tr.) at 103:5–7).

105. Despite the various settings, there is nothing a user can do to prevent Google from using location information collected from IP address location for purposes of serving ads. (Ex. 3 (5/21/2020 Hennessy EUO Tr.) at 103:5–23).

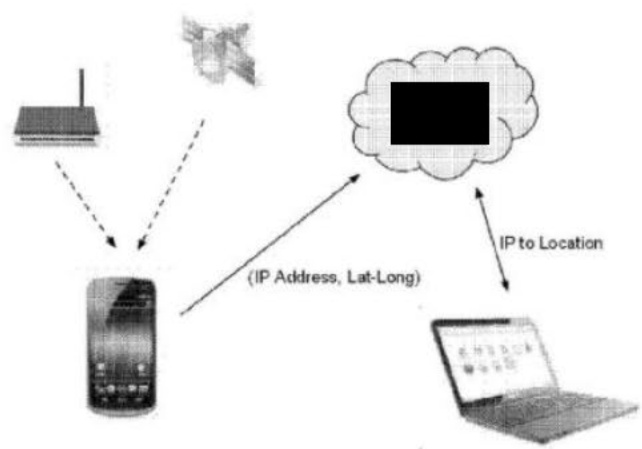
106. I understand Google's witnesses have also pointed out that Google may need to use an IP address for purposes of fulfilling certain legal obligations that are location based (*e.g.*, based on country) or filtering out spam and fraud. Be that as it may, Google's use of IP addresses does not stop there. Once Google fulfills these legal obligations, I am unaware of any legal or technical reasons as to why Google must use that information for purposes of its advertising business.

107. In addition to the use of the static IPGeo service, Google also uses what it calls [redacted] which is a separate service within Google that attempts to calculate location for users based on even more precise signals provided by other users. Like static IPGeo, Google's [redacted] attempts to calculate a location for those users who have not enabled (and in fact have disabled) the collection of their location information through the various settings.

108. Through the [redacted] Google uses Android devices to improve the accuracy of their IP-to-geographic mapping. [redacted] (Ex. 119 (9/13/2021 Eriksson Dep. Tr.) at 170:13–171:15, 194:22–196:24; Ex. 135 (GOOG-GLAZ-00226213) at 226).

109. Through its [redacted], Google can also use location information provided by users who report it to determine the location of nearby users who have not reported their location. This is illustrated by the diagram below, which comes from Google's documents:

[redacted]



(Ex. 135 (GOOG-GLAZ-00226213) at 226).

110. In this illustration, the "Reporter" represents users who are reporting their location through GLS, whereas the "User" represents users who may have not enabled their location reporting. (Ex. 146 (GOOG-GLAZ-00224647); Ex. 135 (GOOG-GLAZ-00226213) at 226; Ex. 119 (9/13/2021 Eriksson Dep. Tr.) at 176:1–177:14, 186:17–22).

111. When Google uses [redacted], "Users" (including those who have expressly declined to share their location) cannot opt out from Google's collection of their (precise) information. (Ex. 146 (GOOG-GLAZ-00224647); Ex. 119 (9/13/2021 Eriksson Dep. Tr.) at 173:12–175:3, 186:17–187:4).

112. Google then collects location information from the "Users" (including those who have expressly declined to share their location) through their actions with Google's services. (Ex. 18 (10/5/2021 Eriksson Dep. Tr.) at 234:2–12).

113. Another Google presentation explains how Google's [redacted] service can use a common WiFi access point to determine the location of "Users" (including those who have expressly declined to share their location). If the "Reporter" and "User" connect to the same WiFi access point, the [redacted] (Ex. 147 (GOOG-GLAZ-00224739) at 746; *see also* Ex. 148 (GOOG-GLAZ-00096793) at 796, 804–05, 819; Ex. 149 (GOOG-GLAZ-00225237) at 237). Google then knows that "Any queries from the same WiFi access point will be from devices nearby," even if those devices have not enabled settings that would allow Google to collect, store, or use their location information. (Ex. 147 (GOOG-GLAZ-00224739) at 746).

114. Notably, Google's use of IPGeo and [redacted] for collecting unwilling users' location information is not limited to users of Android devices. Rather, Google also uses IPGeo and [redacted] to collect, store, and exploit location information from iOS users or users on any platforms, so long as the users are interacting with Google's services. (Ex. 119 (9/13/2021 Eriksson Dep. Tr.) at 196:9–197:24).

115. As explained above, Google collects, stores, and exploits users' location information through IPGeo and [redacted] regardless of whether any particular settings are on or off. (Ex. 119 (9/13/2021 Eriksson Dep. Tr.) at 191:21–192:3; Ex. 128 (GOOG-GLAZ-00234771) at 772; Ex. 148 (GOOG-GLAZ-00096793) at 807, 823; Ex. 150 (GOOG-GLAZ-00234019) at 019–21, 023; Ex. 151 (GOOG-GLAZ-00269516) at 516).

116. A Google technical presentation confirms a "user cannot opt out" of IPGeo. (Ex. 147 (GOOG-GLAZ-00224739) at 741). The same document also confirms that Google will "Switch to [redacted], when available," and confirms that a "user cannot opt out" of "[redacted]." (*Id.* at 743).

117. For example, in a conversation with Google engineer Ingemar Eriksson, another senior software engineer at Google ([redacted])[1] explains as follows:

> [redacted]

(Ex. 128 (GOOG-GLAZ-00234771) at 772).

118. The same discussion also includes a response from Google's own engineer pushing back on Mr. Eriksson's suggestion (which he also makes his summary judgment declaration) that Google simply uses IP addresses in a manner that is necessary for communication over the internet:

> [redacted]

(Ex. 128 (GOOG-GLAZ-00234771) at 772).

119. Through IPGeo and [redacted], just about any transaction with Google (including with those users who have expressly declined to share their location) becomes an opportunity for Google to collect, store, and exploit the users' location information.

120. For example, when someone uses Google Search, Google uses IPGeo and [redacted] to triangulate the user's location—even if the user disabled the relevant location settings. (Ex. 119 (9/13/2021 Eriksson Dep. Tr.) at 174:24–175:3, 191:21–192:3). As Google's witness (Mr. Eriksson) confirms, [redacted] is "independent of settings." (*Id.* at 174:10–12).

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[1] From his Linkedin profile, I understand [redacted] is a Senior Software Engineer and has been with Google since February of 2015.

121. Google then uses this location information for "Users" (including those who have declined to share their location) to serve ads. (Ex. 18 (10/5/2021 Eriksson Dep. Tr.) at 236:7–238:8).

122. Google has not produced the witnesses, documents, or source code that would shed further light on how this technology is used.

Google's [redacted] Service

123. Google also aggregates various signals [redacted] to calculate the user's "best" location. The internal Google service that performs this aggregation is called [redacted] combines various signals—*e.g.*, [redacted]—to determine a user's current location. (Ex. 143 (GOOG-GLAZ-00171510) at 511; Ex. 119 (9/13/2021 Eriksson Dep. Tr.) at 51:11–53:8). [redacted] then transmits this location to Google's internal clients, such as various apps (like Maps), Ads, or other services.

124. The following figure illustrates various inputs used by [redacted] to compute a user's location.

[redacted]

(Ex. 135 (GOOG-GLAZ-00226213) at 219).

125. As shown in the figure above, [redacted] (*See also* Ex. 119 (9/13/2021 Eriksson Dep. Tr.) at 47:16–48:6; Ex. 152 (GOOG-GLAZ-00161951) at 956).

126. As explained above, a user cannot do anything to prevent Google from calculating his or her location from IP address; [redacted] can always report a location for the user.

127. The location calculated by [redacted] is used to inform most, if not all, of Google's products with a location. (Ex. 134 (2/27/2020 Berlin EUO Tr.) at 144:20–145:1).

128. Besides Google's Search and Ads products, the location estimated by [redacted] is used "by 250+ clients at Google." (Ex. 10 (GOOG-GLAZ-00027187) at 189; *see also* Ex. 103 (GOOG-GLAZ-00005829) at 831; Ex. 63 (7/12/2019 Monsees EUO Tr.) at 111:12–25).

129. As there are many teams and products within Google, [redacted] is "marketed" within Google as the service to use if the app should change behavior based on location. (Ex. 143 (GOOG-GLAZ-00171510) at 511). [redacted] is a backend service and exists before and independent of a user's purchase of a Google product or service.

130. [redacted] can be queried even when Google does not have current location for a user. (*Id.* at 511–12). Prior to around May 2019, [redacted] would return the most precise location it could. Since that time, [redacted] returns a "coarse" location to queries that do not already know the current location. (*Id.* at 511).

131. Various Google products and services run both on devices and in Google's servers. For example, Google Search and Google Maps have back-end servers that do most of the work and front-end clients that get user input and display results. (Ex. 119 (9/13/2021 Eriksson Dep. Tr.) at 44:16–20). The back-end servers use other Google infrastructure, such as [redacted] to process location. (*Id.*) The location-based tracking is seen by Google as crucial to the operation of ads. (Ex. 103 (GOOG-GLAZ-00005829) at 831).

132. I described above how Google stores certain location data—such as that from LH and WAA—against a user's GAIA ID when the user is signed into a Google account. However, even when a user is signed out of a Google account, Google still stores location data (from, for example, IPGeo and Maps) against something it calls a "Zwieback" ID. Zwieback IDs are used for tracking individuals on a device that are either not Google users or are Google users but are

not logged in. (Ex. 135 (GOOG-GLAZ-00226213) at 259). Both of these IDs are used by systems such as [redacted] to look up data about the user in other databases. (*Id.* at 219).

133. I understand from the testimony of Mr. Eriksson that Google has a document explaining the policies governing how signals (including those shown in the Figure reproduced above from Ex. 135) could be processed by Google and which Google internal clients have access to location information as determined by such signals. (Ex. 119 (9/13/2021 Eriksson Dep. Tr.) at 61:19–64:4). Mr. Eriksson described this document as a "text file that is also parsable by code," and the file name would end with something like .config. (*Id.* at 63:15–64:4). I expect this is also something that could be verified through a review of source code. To my knowledge, Google has not produced any of these materials.

I declare, under penalty of perjury, that the foregoing is true and correct.

DATED this 16th day of November, 2021.

Seth Nielson

APPENDIX 3

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Educational Background

- **Ph.D. Computer Science**, summer 1994, University of California, Irvine
  Dissertation: "An Object-Oriented Framework for Experimenting with Alternative Process Architectures for Parallelizing Communication Subsystems."
  Co-advisors: Dr. Tatsuya Suda and Dr. Richard W. Selby.
- **M.S. Computer Science**, summer 1990, University of California, Irvine, specializing in software engineering.
- **M.A. Sociology**, summer 1986, College of William and Mary, Williamsburg, Virginia
  Thesis: "A Statistical Analysis of University Resource Allocation Policies."
  Advisor: Dr. Michael A. Faia.
- **B.A. Sociology**, summer 1984, College of William and Mary, Williamsburg, Virginia.

Professional Experience

1. **7/1/18 – present: Associate Provost of Research Development and Technologies**
   Develop cohesive and sustainable information technology (IT) services to advance research and scholarship across Vanderbilt's ten schools and colleges; develop scalable storage and processing solutions by leveraging on-campus and cloud data storage services, as well as creating big data research cores and core-related services; and implement NIST 800-171 compliant IT services.
2. **8/1/18 – present: Co-Director of the Vanderbilt Data Science Institute**
   Facilitate highly innovative research and education initiatives that build on Vanderbilt University's current strengths, promote new collaborations, and establish a cohesive institutional framework that embraces Vanderbilt's diverse campus, while establishing the university as a leader in data science research and education.
3. **2/17 – present: Cornelius Vanderbilt Professor of Engineering**
   Received an endowed chair in recognition of my scholarship, intellect, and leadership in the field of computer science and computer engineering.
4. **1/03 – present: Full Professor with tenure**
   Conducting research on patterns, optimizations, and experimental analysis of advanced generative software techniques that facilitate the development of distributed real-time and embedded middleware and model driven architectures running over high-speed networks and interconnects in the Department of Electrical Engineering and Computer Science at Vanderbilt University.
5. **02/16 – 7/31/18: Associate Chair of Electrical Engineering and Computer Science**
   Provide intellectual leadership within the EECS department. Coordinate with EECS Chair to assist in EE, CS, and CompE curriculum development and course staffing. Assist the faculty in building industry and federal programs for EECS. Assist the Chair in mentoring junior EECS faculty. Assist the EECS Chair in improving the ranking of the EECS programs. Assist the Chair in increasing the quality and number of undergraduate and graduate student applications to the EECS programs.
6. **12/04 – 1/16: Associate Chair of Computer Science and Engineering**
   Provide intellectual leadership within the CS program. Coordinate with EECS Chair to assist in CS and CompE (CS&E) curriculum development and course staffing. Assist the faculty in building industry and federal programs centered in CS&E and IT for EECS. Assist the Chair in mentoring

junior CS&E faculty. Assist the EECS Chair in improving the ranking of the CS&E programs. Assist the Chair in increasing the quality and number of undergraduate and graduate student applications to the CS&E programs.

7. **4/13 – 2/18: Member of the Board of Directors at Real-Time Innovations (RTI)**.
Work with the CEO and other members of the Board of Directors of RTI to help assess company technical and business strategy.

8. **1/12 – present: Visiting Scientist at the Software Engineering Institute**
Assist the SEI Director's Office in formulating the SEI's technology strategy for R&D projects and external relationships by aligning the expertise of the SEI technical staff to identify and respond to the needs of sponsors, customers, and partners and help the SEI shape future innovations in complex software-reliant systems.

9. **7/11 – 7/13: Adjunct Professor of Software Engineering** in the Institute for Software Research in the School of Computer Science at Carnegie Mellon University.

10. **9/10 – 12/11: Deputy Director and Chief Technology Officer at the Software Engineering Institute (SEI)**
Lead the formulation of the SEI's technology strategy for R&D projects and external relationships by aligning the expertise of the SEI technical staff to identify and respond to the needs of sponsors, customers, and partners and help the SEI shape future innovations in complex software-reliant systems.

11. **07/05 – 8/10: Visiting Scientist at the Software Engineering Institute**
Assisted Linda Northrop and the Ultra-Large-Scale (ULS) Systems team to define the challenge problems, promising technology areas, and research roadmaps for the national R&D effort on building the software-reliant systems of the future that are likely to have billions of lines of code. This activity is defining a broad, multi-disciplinary research agenda for developing ULS systems of the future.

12. **06/09 – 8/10: Chief Technology Officer for Zircon Computing**
Assisted in the strategic direction of Zircon Computing technology development in the areas of adaptive distributed computing middleware for high-performance and real-time applications. Help to formulate the technology strategy for open-source middleware platforms, R&D partnerships, and external relationships.

13. **6/07 – 8/07: Visiting Professor at Trinity College Dublin**
Worked with Professor Vinny Cahill and the Distributed Systems Group at Trinity College on topics pertaining to service-oriented architectures and autonomic computing.

14. **10/06 – 5/09: Chief Technology Officer for PrismTechnologies**
Assisted in the strategic direction of PrismTechnologies technology development in the areas of open-source middleware platforms and model-driven tools. Help to formulate the technology strategy for open-source middleware platforms and model-driven tools, R&D partnerships, and external relationships.

15. **3/02 – 12/02: Program Manager**
Led the National effort on middleware as a Program Manager for over $60 million dollars of funding at the DARPA Information Exploitation Office (IXO). Programs include Program Composition for Embedded Systems (PCES) and National Experimentation Platform for Hybrid and Embedded Systems (NEPHEST).

16. **9/01 – 3/02: Deputy Director**
Served as the Deputy Director for the DARPA Information Technology Office (ITO), helping set and guide the National IT research and development agenda and manage programs on autonomous systems, network-centric command and control systems, combat systems, real-time avionics systems, distributed real-time and embedded systems, and augmented cognition for the U.S. Department of Defense.

17. **6/00 – 3/02: Program Manager**
Led the National effort on middleware as a Program Manager for over $60 million dollars of funding at the DARPA Information Technology Office (ITO). Programs included the Program Composition for Embedded Systems (PCES).

18. **6/01 – 6/02: Co-chair for the Software Design and Productivity (SDP) Coordinating Group**
The SDP Coordinating Group formulates the multi-agency research agenda in fundamental software design for the Federal government's Networking and Information Technology Research and Development (NITR&D) Program, which is the collaborative IT research effort of the major Federal science and technology agencies.

19. **8/99 – 2002: Associate Professor with tenure**
Conducted research on patterns, implementation, and experimental analysis of object-oriented techniques that facilitate the development of high-performance, distributed real-time and embedded computing systems on parallel processing platforms running over high-speed networks and embedded system interconnects in the Department of Computer Engineering at the University of California, Irvine.

20. **6/99 – 8/99: Associate Professor with tenure**
Conducted research on patterns, implementation, and experimental analysis of object-oriented techniques that facilitate the development of high-performance, distributed real-time and embedded computing systems on parallel processing platforms running over high-speed networks and embedded system interconnects in the Department of Computer Science and the Department of Radiology at Washington University in St. Louis.

21. **6/98 – 6/99: Associate Professor without tenure (early promotion)**
Conducted research on patterns, implementation, and experimental analysis of object-oriented techniques that facilitate the development of high-performance, distributed real-time and embedded computing systems on parallel processing platforms running over high-speed networks and embedded system interconnects in the Department of Computer Science and the Department of Radiology at Washington University in St. Louis.

22. **8/94 – 6/98: Assistant Professor**
Conducted research on object-oriented patterns and techniques for developing highly extensible, high-performance communication frameworks in the Department of Computer Science and the Department of Radiology at Washington University in St. Louis.

23. **3/91 – 8/94: Research Assistant**
Developed object-oriented frameworks for multi-processor-based communication subsystems with Professor Tatsuya Suda at the University of California, Irvine.

24. **6/90 – 11/90: Member of the Technical Staff**
Worked as a software engineer for Independence Technologies, which was one of the largest suppliers of enterprise-level TUXEDO systems, providers of professional services, and developers of management and connectivity software to support OLTP environments.

25. **8/88 – 3/91: Research Assistant**
Devised measurement-guided software development techniques for large-scale software systems with Professor Richard Selby at the University of California, Irvine.

26. **6/88 – 8/88: Research Assistant**
Studied the impact of computing on end-users in forty U.S. city governments with Dr. John King and the URBIS project at the Public Policy Research Organization, University of California, Irvine.

27. **Summer of 87: Technical Intern**
Worked with Dr. Peter G. W. Keen at the International Center for Information Technology, Washington D.C. on various projects, including software productivity, videotex, and smartcards.

28. **9/86 – 5/88: Teaching Assistant**
Developed programming assignments, grading tools, and led recitation sessions for a number of undergraduate Computer Science courses at the University of California, Irvine.

29. **Summer of 86: Statistical Programmer**
Programmed SPSS and SAS applications for the "Justice Delayed" project under the direction of Dr. Gene Flango at the National Center for State Courts, Williamsburg, Virginia.

30. **1/85 – 8/86: Research Assistant**
Examined university resource allocation policies via statistical analysis under the direction of Dr. Michael Faia at the College of William and Mary, Williamsburg, Virginia.

Publications

In Print

- **Refereed Journal Publications**

J129 Peng Zhang, Christopher Fonnesbeck, Douglas C. Schmidt, Jules White, Samantha Kleinberg, Shelagh A. Mulvaney, "Understanding Barriers to Self-Management in Type 1 Diabetes Using Machine Learning and Momentary Assessment," the JMIR *Journal of mHealth and uHealth*, 2022 (to appear).

J128 Summer Weber, Elyse Shearer, Shelagh Mulvaney, Douglas C. Schmidt, Chris Thompson, Jessica Jones, Haseeb Ahmad, Martina Coe, and Pam Hull, "Prioritization of Features for Mobile Phone Applications for Families in a Federal Nutrition Program for Low-income Women, Infants, and Children: User-Centered Design Approach," *JMIR Formative Research*, Vol 5., No 7., July 2021.

J127 Alex Roehrs, Cristiano A. da Costa, Rodrigo R. Righi, Andre H. Mayer, Valter F. da Silva, Jose R. Goldim, and Douglas C. Schmidt, "Integrating Multiple Blockchains to Support Distributed Personal Health Records," the SAGE *Health Informatics Journal*, April, 2021.

J126 Zhongwei Teng, Peng Zhang, Xiao Li, William Nock, Denis Gilmore, Marcelino Rodriguez-Cancio, Jules White, Jonathan C. Nesbitt, Douglas C. Schmidt, "Authentication and Integration Approaches for mHealth Apps from a Usability View," the journal *Advances in Electrical and Electronic Engineering*, North America, 19, March, 2021.

J125 Scott Eisele, Aron Laszka, Douglas C. Schmidt, and Abhishek Dubey, "The Role of Blockchains in Multi-Stakeholder Transactive Energy Systems," the journal *Frontiers in Blockchain: Emerging Technologies and Blockchain in Action: Applications in Supply Chain Management and Energy*, volume 3, December, 2020, pps. 1-55.

J124 Peng Zhang, Chris Downs, Nguyen Thanh Uyen Le, Cory Martin, Paul Shoemaker, Clay Wittwer, Luke Mills, Liam Kelly, Stuart Lackey, Douglas C. Schmidt, Jules White, "Towards Patient-centered Stewardship of Research Data and Research Participant Recruitment with Blockchain Technology," the *Frontiers in Blockchain special selection on Non-Financial Blockchain*, 2020, volume 3, pps. 1-32.

J123 Yao Pan, Fangzhou Sun, Jules White, Douglas C. Schmidt, Jacob Staples, Lee Krause, and Zhongwei Teng, "Detecting Web Attacks with End-to-End Deep Learning," the Springer *Journal of Internet Services and Applications*, 2019, volume 10, number 16, pps. 1-22.

J122 Shelagh Mulvaney, Lori Laffel, Korey Hood, Cindy Lybarger, Sarah Vaala, and Douglas C. Schmidt, "A Mobile App Identifies Momentary Psychosocial and Contextual Factors Related to Mealtime Self-Management in Adolescents with Type 1 Diabetes," Journal of the American Medical Informatics Association, Oxford University Press, 2019, Volume 26, Number 12, pps. 1627-1631.

J121 Maria E. Powell, Marcelino Rodriguez Cancio, David Young, William Nock, Beshoy Abdelmessih, Amy Zeller, Irvin Perez Morales, Peng Zhang, C Gaelyn Garrett, Douglas Schmidt, Jules White, and Alexander Gelbard, "Decoding Phonation with Artificial Intelligence (DEP AI): Proof of Concept," the *Laryngoscope Investigative Otolaryngology* journal, Wiley-Blackwell, Volume 4, Issue 3, 2019, pps. 328-334.

J120 Alex Roehrs, Cristiano Andre da Costa, Rodrigo da Rosa Righi, Valter Ferreira da Silva, Jose Roberto Goldim, and Douglas C. Schmidt, "Analyzing the Performance of a Blockchain-based Personal Health Record Implementation," the *Journal of Biomedical Informatics*, Elsevier, volume 92, 2019.

J119 Peng Zhang, Breck Stodghill, Cory Pitt, Cavan Briody, Douglas C. Schmidt, Jules White, Alan Pitt, and Kelly Aldrich, "OpTrak: Tracking Opioid Prescriptions via Distributed Ledger Technology," the *International Journal of Information Systems and Social Change (IJISSC)*, Special Issue On: Blockchain Technology: Platforms, Tools, and Use Cases, IGI Global, Volume 10, Number 2, 2019.

J118 Peng Zhang, Jules White, Douglas C. Schmidt, Gunther Lenz, S. Trent Rosenbloom, "FHIRChain: Applying Blockchain to Securely and Scalably Share Clinical Data," the Elsevier *Computational and Structural Biotechnology Journal* – Blockchain and Distributed Ledger Technologies in Biology, Medicine, and eHealth Special Issue, Volume 16, July 2018, pp 267–278.

J117 Shelagh A Mulvaney, Sarah Vaala, Korey K Hood, Cindy Lybarger, Rachel Carroll, Laura Williams, Douglas C Schmidt, Kevin Johnson, Mary S Dietrich, and Lori Laffel, “Mobile Momentary Assessment and Bio-Behavioral Feedback for Adolescents with Type 1 Diabetes: Feasibility, Engagement Patterns, and Relation with Blood Glucose Monitoring,” ¡EM¿Journal of Diabetes Technology and Therapeutics¡/EM¿, Vol 20, No. 7, July 2018, pp 465–474.

J116 Subhav Pradhan, Abhishek Dubey, Shweta Khare, Saideep Nannapaneni, Aniruddha Gokhale, Sankaran Mahadevan, Douglas C Schmidt, Martin Lehofer, “CHARIOT: A Holistic, Goal Driven Orchestration Solution for Resilient IoT Applications,” the ACM Transactions on Cyber-Physical Systems, Vol 2, No. 3, July 2018, pp 1-37.

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J114 Yao Pan, Jules White, Douglas C. Schmidt, Ahmed Elhabashy, Logan Sturm, Jaime Camelio, and Christopher Williams, “Taxonomies for Reasoning About Cyber-physical Attacks in IoT-based Manufacturing Systems,” Special Issue on Advances and Applications in the Internet of Things, edited by Vicente Garcia Diaz, International Journal of Interactive Multimedia and Artificial Intelligence, volume 4, number 3, 2017, pp. 45-54.

J113 Gordon Blair, Douglas C. Schmidt, and Chantal Taconet, “Middleware for Internet Distribution in the Context of Cloud Computing and the Internet of Things,” Springer Journal Annals of Telecommunications, April 2016, Volume 71, Issue 3, pp. 87-92.

J112 Yu Sun, Jules White, Sean Eade, and Douglas C. Schmidt, “ROAR: A QoS-Oriented Modeling Framework for Automated Cloud Resource Allocation and Optimization”, the Journal of Systems and Software, Elsevier, volume 116, issue C, June 2016 pp. 146.161.

J111 Nick Guertin, Brian Womble, Paul Bruhns, Douglas C. Schmidt, Adam Porter, and Bill Antypas, “Management Strategies for Software Infrastructure in Large-Scale Cyber-Physical Systems for the US Navy,” Cutter IT Journal, Vol. 28, No. 5, May 2015, pp. 14-18.

J110 Jules White, Josi A. Galindo, Tripti Saxena, Brian Dougherty, David Benavides, Douglas C. Schmidt, ”Evolving Feature Model Configurations in Software Product Lines,” Journal of Systems and Software, Volume 87, 2014, pp. 119-136.

J109 Akram Hakiri, Aniruddha S. Gokhale, Pascal Berthou, Douglas C. Schmidt, Thierry Gayraud, Software-Defined Networking: Challenges and Research Opportunities for the Future Internet,” Journal of Computer Networks, Volume 75, 2014, pp. 453-471.

J108 Hamilton Turner, Brian Dougherty, Jules White, Jonathan Preston, Russell Kegley, Douglas C. Schmidt, and Aniruddha Gokhale, ”DRE System Performance Optimization with the SMACK Cache Efficiency Metric,” Elsevier Journal of Systems and Software, Volume 98, 2014, pp. 25-43.

J107 Akram Hakiri, Pascal Berthoua, Aniruddha Gokhale, Douglas C. Schmidt, Gayraud Thierry, “Supporting SIP-based Data Distribution Service End-to-End QoS in WANs,” the Elsevier Journal of Systems and Software, Volume 95, September 2014, pp. 100-121.

J106 Jules White, Douglas C. Schmidt, and Mani Golparvar-Fard, “Applications of Augmented Reality,” IEEE Proceedings Special issue on Applications of Augmented Reality, Vol 102, No. 2., February 2014, pp. 120-123.

J105 Nickolas H. Guertin, Paul Bruhns, Douglas C. Schmidt, and Adam Porter, “Experiences Using Online War Games to Improve the Business of Naval Systems Acquisition,” Cutter Journal of Information Technology Management, Vol. 27, No. 5, May 2014, pp 13-18.

J104 Michael McLendon, Bill Scherlis, and Douglas C. Schmidt, “Addressing Software Sustainment Challenges for the DoD,” STSC CrossTalk, The Journal of Defense Software Engineering special issue on Legacy Systems Software, January, volume 27, number 1, 2014, pp. 27-32.

J103 Akram Hakiri, Pascal Berthoua, Aniruddha Gokhale, Douglas C. Schmidt, Gayraud Thierry, “Supporting End-to-end Scalability and Real-time Event Dissemination in the OMG Data Distribution Service over Wide Area Networks,” Elsevier Journal of Systems and Software, volume 86, number 10, October, 2013, pp. 2574-2593.

J102 William Otte, Aniruddha Gokhale, and Douglas C. Schmidt, “Efficient and Deterministic Application Deployment in Component-based, Enterprise Distributed, Real-time, and Embedded

Systems," Elsevier Journal of Information and Software Technology, Vol. 55, No. 2, Feb 2013, 475-488.

J101 Dr. Douglas Schmidt, Anita Carleton, Erin Harper, Mary Ann Lapham, Ipek Ozkaya, and Linda Parker Gates, 'What Will It Take to Achieve Agility-at-Scale?", Cutter IT Journal, edited by Hillel Glazer, November 2012, pp. 34-39.

J100 Brian Dougherty, Jules White, and Douglas C. Schmidt, "Model-driven Auto-scaling of Green Cloud Computing Infrastructure," the Elsevier International Journal of Future Generation Computing Systems, Special Issue on Green Computing Systems, Volume 28, Number 2, February, 2012 Pages 371-378.

J99 Joe Hoffert, Douglas C. Schmidt, and Aniruddha Gokhale, "Evaluating Timeliness and Accuracy Trade-offs of Supervised Machine Learning for Adapting Enterprise DRE Systems in Dynamic Environments," the International Journal of Computational Intelligence Systems, Volume 4, Number 5, September-October 2011, pp. 806-816.

J98 James Hill, Pooja Varshneya, and Douglas C. Schmidt, "Evaluating Distributed Real-time and Embedded System Test Correctness using System Execution Traces," Central European Journal of Computer Science, Volume 1, Number 2, August 2011, pp. 167-184.

J97 Brian Dougherty, Jules White, and Douglas C. Schmidt, "Automated Software and Hardware Evolution Analysis for Distributed Real-time and Embedded Systems," the Central European Journal of Computer Science, Volume 1, Number 1, July 2011, pp. 36-57.

J96 James Hill, Hunt Sutherland, Paul Stodinger, Thomas Silveria, Douglas C. Schmidt, John Slaby, and Nikita Visnevski, "OASIS: An Architecture for Dynamic Instrumentation of Enterprise Distributed Real-time and Embedded Systems," the International Journal of Computer Systems Science and Engineering, Special Issue on Real-time Systems, Volume 26, Number 6, November 2011, pp. 413-430.

J95 Jules White, Brian Dougherty, Chris Thompson, Douglas C. Schmidt, "ScatterD: Spatial Deployment Optimization with Hybrid Heuristic/Evolutionary Algorithms," ACM Transactions on Autonomous and Adaptive Systems Special Issue on Spatial Computing, Volume 6 Issue 3, September 2011, 18:1-8:25.

J94 Jules White, Chris Thompson, Hamilton Turner, Brian Dougherty, and Douglas C. Schmidt, WreckWatch: Automatic Traffic Accident Detection and Notification with Smartphones, Journal of Mobile Networks and Applications, Volume 16 Issue 3, July 2011, Pages 285-303.

J93 Jules White, Brian Dougherty, Richard Schantz, Douglas C. Schmidt, Adam Porter, and Angelo Corsaro, "R&D Challenges and Solutions for Highly Complex Distributed Systems: a Middleware Perspective," the Springer Journal of Internet Services and Applications special issue on the Future of Middleware, Volume 2, Number 3, December 2011, pp. 1-8.

J92 Joe Hoffert, Aniruddha Gokhale, and Douglas C. Schmidt, "Autonomic Adaptation of Publish/Subscribe Middleware in Dynamic Environments," the International Journal of Adaptive, Resilient and Autonomic Systems (IJARAS), 2(4), 1-24, October-December 2011, pp. 1-24.

J91 Joe Loyall, Matt Gillen, Aaron Paulos, Larry Bunch, Marco Carvalho, James Edmondson, Douglas C. Schmidt, Andrew Martignoni, and Asher Sinclair, "Dynamic Policy-Driven Quality of Service in Service-Oriented Information Management Systems," Wiley journal on Software: Practice and Experience, December 2011, volume 41, number 12, pp. 1459-1489.

J90 Michael Stal, Douglas C. Schmidt, and Will Otte, "Efficiently and Transparently Automating Scalable On-demand Activation and Deactivation of Services with the Activator Pattern," Software: Practice and Experience, special issue on Pattern Languages: Addressing Challenges, Edited by Mohamed Fayad and Shivanshu Singh, volume 41, number 10, October 2011, Wiley and Sons, pp. 1-16.

J89 Brian Dougherty, Jules White, Douglas C. Schmidt, Russell Kegley, and Jonathan Preston, "Deployment Optimization for Embedded Flight Avionics Systems," STSC CrossTalk, The Journal of Defense Software Engineering, November/December, volume 24, number 6, 2011, pp. 1-8.

J88 Brian Dougherty, Daniel Guymon, Douglas C. Schmidt, and Jules White, "Overcoming Cellular Connectivity Limitations with M2Blue Autonomic Distributed Data Caching," Autonomic Computing for Computer Society of India Magazine, CSI Communications, August 2011, pp. 12-15.

J87 Friedhelm Wolf, Jaiganesh Balasubramanian, Sumant Tambe, Aniruddha Gokhale, and Douglas C. Schmidt, Supporting Component-based Failover Units in Middleware for Distributed Real-time and Embedded Systems, the Elsevier Journal of System Architectures (JSA): Embedded Systems Design, Special Issue on Real-time and Embedded Systems, May, 2011 pp. 597-613.

J86 Jules White, David Benavides, Douglas C. Schmidt, Pablo Trinidad, Antonio Ruiz-Cortes, Brian Doughtery, "Automated Diagnosis of Feature Model Configurations," The Journal of Systems and Software, Special Issue on Software Product-lines, Volume 83, Issue 7, July, 2010, pp. 1094-1107.

J85 Jules White, Brian Doughtery, and Douglas C. Schmidt, "ASCENT: An Algorithmic Technique for Designing Hardware and Software in Tandem, IEEE Transactions on Software Engineering Special Issue on Search-based Software Engineering, November/December 2010 (vol. 36 no. 6), pp. 838-851.

J84 Joe Hoffert, Daniel Mack, and Douglas Schmidt, "Integrating Machine Learning Techniques to Adapt Protocols for QoS-enabled Distributed Real-time and Embedded Publish/Subscribe Middleware," International Journal of Network Protocols and Algorithms (NPA): Special Issue on Data Dissemination for Large-scale Complex Critical Infrastructures, Volume 2, Number 3, 2010, pp. 37-69.

J83 James Hill, James Edmondson, Aniruddha Gokhale, and Douglas C. Schmidt, "Tools for Continuously Evaluating Distributed System Qualities," IEEE Software, July/August, 2010, Volume 27, Number 4, pp. 65-71.

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J79 Jules White, Harrison Strowd, and Douglas C. Schmidt, "Creating Self-healing Service Compositions with Feature Modeling and Microrebooting," the International Journal of Business Process Integration and Management (IJBPIM), Special issue on Model-Driven Service-Oriented Architectures, Inderscience Publishers, pp. 35-46, Volume 4, Number 1, 2009.

J78 Nishanth Shankaran, John Kinnebrew, Xenofon Koutsoukos, Chenyang Lu, Douglas C. Schmidt, and Gautam Biswas, "An Integrated Planning and Adaptive Resource Management Architecture for Distributed Real-time Embedded Systems," IEEE Transactions on Computers, Special Issue on Autonomic Network Computing, Special Issue on Autonomic Network Computing, volume 58, number 11, pp. 1485-1498, November 2009.

J77 Jules White, Brian Doughtery, and Douglas C. Schmidt, "Selecting Highly Optimal Architectural Feature Sets with Filtered Cartesian Flattening," the Journal of Software and Systems, Special Issue on Design Decisions and Design Rationale in Software Architecture, Volume 82, Issue 8, pp. 1268-1284, August 2009.

J76 Jules White, James, Hill, Sumant Tambe, Jeff Gray, Aniruddha Gokhale, and Douglas C. Schmidt "Improving Domain-specific Language Reuse through Software Product-line Configuration Techniques, IEEE Software Special Issue: Domain-Specific Languages and Modeling, vol. 26, no. 4, pp. 47-53, July/August 2009.

J75 Jules White and Douglas C. Schmidt, "Automating Deployment Planning with an Aspect Weaver," IET Software Journal Special Issue on Domain-specific Aspect Languages, Volume 3, Issue 3 , p. 167-183, June 2009.

J74 Shanshan Jiang, Yuan Xue, and Douglas C. Schmidt, "Minimum Disruption Service Composition and Recovery in Mobile Ad Hoc Networks, Elsevier Computer Networks Journal, Special Issue on Autonomic and Self-Organizing Systems, Volume 53, Issue 10, Pages 1649-1665, 2009.

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J71 Nishanth Shankaran, Xenofon Koutsoukos, Chenyang Lu, Douglas C. Schmidt, and Yuan Xue, "Hierarchical Control of Multiple Resources in Distributed Real-time and Embedded Systems," the Springer Real-time Systems Journal, Volume 39, Numbers 1-3, August, 2008, pgs. 237-282.

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W73 Michael Walker, Abhishek Dubey, Aron Laszka, and Douglas C. Schmidt, "PlaTIBART: a Platform for Transactive IoT Blockchain Applications with Repeatable Testing," Proceedings of the ACM/IFIP/USENIX 4th Workshop on Middleware and Applications for the Internet of Things, December 2017, Las Vegas, USA.

W72 Abhishek Dubey, Subhav Pradhan, Douglas C. Schmidt, Sebnem Rusitschka, and Monika Sturm, "The Role of Context and Resilient Middleware in Next Generation Smart Grids," Proceedings of the 3rd Middleware for Context-Aware Applications in the IoT (M4IOT 2016) Workshop at the ACM/IFIP/USENIX Middleware 2016 Conference, Dec 12 - 16, 2016, Trento, Italy.

W71 Violetta Vylegzhanina, Douglas C. Schmidt, and Jules White, "Gaps and Future Directions in Mobile Security Research," Proceedings of the Third International Workshop on Mobile Development Lifecycle, Pittsburgh, PA, October 26th, 2015.

W70 Violetta Vylegzhanina, Douglas C. Schmidt, Pamela Hull, Janice S. Emerson, Meghan E. Quirk, and Shelagh Mulvaney, "Helping Children Eat Well Via Mobile Software Technologies," Proceedings of the Second International Workshop on Mobile Development Lifecycle, October 21st, 2015, Portland, OR.

W69 Jules White and Douglas C. Schmidt, ”R&D Challenges and Emering Softwares for Multicore Deployment/Configuration Optimization,” proceedings of the ACM Workshop on Future of Software Engineering Research (FoSER 2010), Santa Fe, NM, November 7-11, 2010.

W68 Will Otte, Douglas C. Schmidt, and Aniruddha Gokhale, "Towards an Adaptive Deployment and Configuration Framework for Component-based Distributed Systems," Proceedings of the 9th Workshop on Adaptive and Reflective Middleware (ARM 2010) November 27, 2010, Bangalore India, collocated with Middleware 2010.

W67 Jaiganesh Balasubramanian, Alexander Mintz, Andrew Kaplan, Grigory Vilkov, Artem Gleyzer, Antony Kaplan, Ron Guida, Pooja Varshneya and Douglas Schmidt, "Adaptive Parallel Computing for Large-scale Distributed and Parallel Applications," Proceedings of the Workshop on Data Dissemination for Large-scale Complex Critical Infrastructures (DD4LCCI), 27 April 2010, in conjunction with EDCC 2010, Valencia - Spain, April 28-30, 2010.

W66 Joe Hoffert, Douglas Schmidt, and Aniruddha Gokhale, "Adapting and Evaluating Distributed Real-time and Embedded Systems in Dynamic Environments," Proceedings of the Workshop on Data Dissemination for Large-scale Complex Critical Infrastructures (DD4LCCI), 27 April 2010, in conjunction with EDCC 2010, Valencia - Spain, April 28-30, 2010.

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W64 Chris Thompson, Jules White, Brian Dougherty, and Douglas C. Schmidt, "Optimizing Mobile Application Performance with Model-Driven Engineering," Proceedings of the 7th IFIP Workshop on Software Technologies for Future Embedded and Ubiquitous Systems (SEUS 2009), November 16-18, 2009, Newport Beach, California.

W63 Jules White and Douglas C. Schmidt, "Filtered Cartesian Flattening: An Approximation Technique for Optimally Selecting Features while Adhering to Resource Constraints," proceedings of the Workshop on Analyses of Software Product Lines (ASPL 2008) at the Software Product Lines Conference (SPLC), September 8-12, 2008, Limerick, Ireland.

W62 Joe Hoffert, Douglas C. Schmidt, Mahesh Balakrishnan, and Ken Birman, Supporting Large-scale Continuous Stream Datacenters via Pub/Sub Middleware and Adaptive Transport Protocols, Proceedings of the 2nd workshop on Large-Scale Distributed Systems and Middleware (LADIS 2008), IBM TJ Watson Research Center, Yorktown, New York, September 2008.

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W58 Douglas C. Schmidt and Hans van't Hag, "Addressing the Challenges of Tactical Information Management in Net-Centric Systems with OpenSplice DDS," Proceedings of the 16th International ACM Workshop on Parallel and Distributed Real-Time Systems (WPDRTS '08), Miami, Florida, April 2008.

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2. "Website Applications Technology Overview," Digital Technologies in Cancer Research Workshop, Vanderbilt University, Nashville, TN, May 15th 2019.
3. "Producing and Delivering a Coursera MOOC on Pattern-Oriented Software Architecture for Concurrent and Networked Software," WaveFront forum at the SPLASH 2013 conference, Indianapolis, IN, October 29th, 2013.
4. "Addressing the Challenges of Tactical Information Management in Net-Centric Systems with the OMG Data Distribution Service (DDS)," the 16th International ACM Workshop on Parallel and Distributed Real-Time Systems (WPDRTS '08), Miami, Florida, April 14, 2008.
5. "The Design and Performance of Configurable Component Middleware for End-to-End Adaptation of Distributed Real-time Embedded Systems," proceedings of the 10th IEEE International Symposium on Object/Component/Service-oriented Real-time Distributed Computing (ISORC), May 7-9, 2007, Santorini Island, Greece.
6. "A Decision-Theoretic Planner for DRE Systems," 7th OMG Real-time/Embedded CORBA workshop, Arlington, VA, July 10–13, 2006.
7. "Model-driven QoS Provisioning for Real-time CORBA and CCM DRE Systems," 6th OMG Real-time/Embedded CORBA workshop, Arlington, VA, July 11–14, 2005.
8. "Research Advances in Middleware for Distributed Systems: State of the Art," Computer Communications stream of the 17th IFIP World Computer Congress, Montreal, Canada, August 25-30, 2002.
9. "Towards Highly Configurable Real-time Object Request Brokers," the IEEE International Symposium on Object-Oriented Real-time Distributed Computing (ISORC), Washington DC, April 29 – May 1, 2002.
10. "Operating System Performance in Support of Real-time Middleware," Proceedings of the 7th IEEE Workshop on Object-oriented Real-time Dependable Systems, San Diego, CA, January, 2002.
11. "Designing an Efficient and Scalable Server-side Asynchrony Model for CORBA," Proceedings of the ACM SIGPLAN Workshop on Optimization of Middleware and Distributed Systems (OM 2001), Snowbird, Utah, June 18, 2001.
12. "DOORS: Towards High-performance Fault-Tolerant CORBA," Proceedings of the 2nd International Symposium on Distributed Objects and Applications (DOA '00), OMG, Antwerp, Belgium, September 2000.
13. "The Design and Performance of a CORBA Audio/Video Streaming Service," Proceedings of the 31st Hawaii International Conference on System Systems (HICSS), Hawaii, January, 1999, minitrack on Multimedia DBMS and the WWW, Hawaii, January 1999.
14. "Alleviating Priority Inversion and Non-determinism in Real-time CORBA ORB Core Architectures," Proceedings of the Fourth IEEE Real-Time Technology and Applications Symposium (RTAS), Denver, Colorado, June 3-5, 1998

15. "Optimizing the Performance of the CORBA Internet Inter-ORB Protocol Over ATM," Proceedings of the 31st Hawaii International Conference on System Systems (HICSS), Hawaii, January, 1998. This was selected as the best paper in the Software Technology Track (188 submitted, 77 accepted).
16. "The Double-Checked Locking Pattern," *Proceedings of the 3rd annual Pattern Languages of Programming conference* in Allerton Park, Illinois, September 4-6, 1996.
17. "Acceptor and Connector: Design Patterns for Initializing Network Services," Proceedings of the EuroPLoP '96 conference, Kloster Irsee, Germany, July 10-14, 1996.
18. "Measuring the Performance of Communication Middleware on High-Speed Networks," Proceedings of SIGCOMM '96, ACM, San Francisco, August 28-30th, 1996.
19. "Design and Performance of an Object-Oriented Framework for High-Speed Electronic Medical Imaging," Proceedings of the 2^{nd} Conference on Object-Oriented Technologies and Systems (COOTS), USENIX, Toronto, June 18-22, 1996.
20. "A Family of Design Patterns For Flexibly Configuring Network Services in Distributed Systems," Proceedings of the International Conference on Configurable Distributed Systems, IEEE, Annapolis, Maryland, May 6-8, 1996.
21. "Using Design Patterns to Develop High-Performance Object-Oriented Communication Software Frameworks," Proceedings of the 8^{th} Annual Software Technology Conference, Salt Lake City, Utah, April 21-26, 1996.
22. "An Object-Oriented Framework for High-Performance Electronic Medical Imaging," Proceedings of the *Very High Resolution and Quality Imaging* mini-conference at the Symposium on Electronic Imaging in the International Symposia Photonics West 1996, SPIE, San Jose, California USA, January 27 - February 2, 1996.
23. "Half-Sync/Half-Async: A Pattern for Efficient and Well-structured Concurrent I/O," *Proceedings of the 2^{nd} Pattern Languages of Programs Conference* Monticello, Illinois, September 6-8, 1995.
24. "Acceptor and Connector: Design Patterns for Actively and Passively Initializing Network Services." Workshop on Pattern Languages of Object-Oriented Programs at ECOOP '95, August 7 – 1, 1995, Aarhus, Denmark.
25. "Object-Oriented Components for High-speed Network Programming," *Proceedings of the Conference on Object-Oriented Technologies (COOTS)*, USENIX, June 26-29, 1995 Monterey, California, USA, pp. 21–38.
26. "Experience Using Design Patterns to Evolve Communication Software Across Diverse OS Platforms," *Proceedings of the 9^{th} European Conference on Object-Oriented Programming (ECOOP)*, ACM, Aarhus, Denmark, August, 1995,.
27. "Measuring the Performance of Parallel Message-based Process Architectures," *Proceedings of the INFOCOM Conference on Computer Communications*, IEEE, Boston, MA, April, 1995, pp. 624–633.
28. "High-Performance Event Filtering for Dynamic Multi-point Applications," Proceedings of the 1^{st} Workshop on High Performance Protocol Architectures (HIPPARCH), INRIA, Sophia Antipolis, France, December, 1994, p 1–8.
29. "Flexible Configuration of High-Performance Object-Oriented Distributed Communication Systems," 9^{th} *OOPSLA Conference, invited paper to the Workshop on Flexibility in Systems Software*, ACM, Portland, Oregon, October, 1994, pp. 1–4.
30. "Performance Experiments on Alternative Methods for Structuring Active Objects in High-Performance Parallel Communication Systems," 9^{th} *OOPSLA Conference, poster session*, ACM, Portland, Oregon, October, 1994, pp. 1–12.
31. "Measuring the Impact of Alternative Parallel Process Architectures on Communication Subsystem Performance," *Proceedings of the Proceedings of the 4^{th} International Workshop on Protocols for High-Speed Networks*, IFIP, Vancouver, British Columbia, August, 1994, pp. 103–118.
32. "Reactor: An Object Behavioral Pattern for Concurrent Event Demultiplexing and Dispatching," *Proceedings of the 1^{st} Annual Conference on the Pattern Languages of Programs*, Monticello, Illinois, August, 1994, pp. 1–10.

33. "Experiences with an Object-Oriented Architecture for Developing Dynamically Extensible Network Management Software," *Proceedings of the Globecom Conference*, IEEE, San Francisco, California, November, 1994, pp. 1–7.
34. "Configuring Function-based Communication Protocols for Distributed Applications," *Proceedings of the* 8^{th} *International Working Conference on Upper Layer Protocols, Architectures, and Applications*, IFIP, Barcelona, Spain, June 1-3, 1994, pp. 361–376.
35. "The ADAPTIVE Service Executive: An Object-Oriented Architecture for Configuring Concurrent Distributed Communication Systems," *Proceedings of the* 8^{th} *International Working Conference on Upper Layer Protocols, Architectures, and Applications*, IFIP, Barcelona, Spain, June 1-3, 1994, pp. 163–178.
36. "ASX: An Object-Oriented Framework for Developing Distributed Applications," *Proceedings of the* 6^{th} *C++ Conference*, USENIX, Cambridge, Massachusetts, April, 1994, pp. 200–220.
37. "The Service Configurator Framework: An Extensible Architecture for Dynamically Configuring Concurrent, Multi-service Network Daemons," *Proceedings of the* 2^{nd} *International Workshop on Configurable Distributed Systems*, IEEE, Pittsburgh, PA, March 21-23, 1994, pp. 190–201.
38. "Tools for Generating Application-Tailored Multimedia Protocols on Heterogeneous Multi-Processor Platforms," *Proceedings of the* 2^{nd} *Workshop on High-Performance Communications Subsystems*, IEEE, Williamsburg, Virginia, September 1-3, 1993, pp. 1–7.
39. "A Framework for Developing and Experimenting with Parallel Process Architectures to Support High-Performance Transport Systems," *Proceedings of the* 2^{nd} *Workshop on High-Performance Communications Subsystems*, IEEE, Williamsburg, Virginia, September 1-3, 1993, pp. 1–8.
40. "ADAPTIVE: a Framework for Experimenting with High-Performance Transport System Process Architectures," *Proceedings of the* 2^{nd} *International Conference on Computer Communications and Networks*, ISCA, San Diego, California, June 28-30, 1993, pp. 1–8.
41. "ADAPTIVE: A Flexible and Adaptive Transport System Architecture to Support Lightweight Protocols for Multimedia Applications on High-Speed Networks," *Proceedings of the* 1^{st} *Symposium on High Performance Distributed Computing*, IEEE, Syracuse, New York, September 9-11, 1992, pp. 174–186.
42. "GPERF: A Perfect Hash Function Generator," *Proceedings of the* 2^{nd} *C++ Conference*, USENIX, San Francisco, California, April 9-11, 1990, pp. 87–102.

Invited Talks

1. "Architecting the Systems of the Future: A Research Agenda," invited keynote talk at the Doctoral Symposium for the 22nd ACM/IFIP International Conference on Middleware, December 6th, 2021.
2. "Cyber- and Physical-Security Risks," Southern Illinois University course on Domestic Terrorism, July 22nd, 2021.
3. "Architecting the Future of Software Engineering," invited keynote talk at the 16th International Conference on Software Technologies, July 8th, 2021.
4. "Challenges of Certifying Adaptive Dynamic Computing Environments," ARLIS Workshop, January 28th, 2021.
5. "Cyber-Security and You: Practicing Safe Surfing on the Internet," the National Active and Retired Federal Employees (NARFE) chapter, Nashville TN, January 13th, 2021.
6. "Challenges of Certifying Adaptive Dynamic Computing Environments," DARPA/SEI Software Engineering Grand Challenges and Future Visions Workshop, December 1st, 2020.
7. "Survelliance Capitalism and You," invited talk at the Southeast Science Boot Camp, Nashville, TN, May 29th, 2019.
8. "Diversify Sponsorship of Your Research: Getting Funding from the Department of Defense," Office of Research Development and Support Workshop, October 22nd, 2018, Nashville, TN.
9. "Survelliance Capitalism and You," invited talk at the Memorizing the Future: Collecting in the 21st Century Conference, Nashville, TN, October 6th, 2018.
10. "Aligning Incentives to Enable More Effective Organic Software Infrastructure for the DoD," DoD Organic Software Infrastructure Workshop, Arlington VA, August 13th, 2018.

11. "The Blockchain: What It is and Why It Matters to Us," Transforming Dermatology in the Digital Era, Memorial Sloan Kettering Cancer Center, October 25, 2018, NY, NY, USA.
12. "Aligning Incentives to Enable Modular Open Software for DoD Combat Systems," Modular Open Systems Summit, May 1st, 2018, Washington DC.
13. "The Blockchain: What It is and Why It Matters to Us," Society of Women Engineers, Vanderbilt University, March 14th, 2018.
14. "The Blockchain: What It is and Why It Matters to Us," Invited keynote at the Workshop on Middleware and Applications for the Internet of Things, (co-located with the 2017 Middleware conference in Las Vegas, USA), December 11th and 12th, 2017.
15. "The Blockchain: What It is and Why It Matters," Vanderbilt University, Nashville, TN, November 28th, 2017.
16. "The Blockchain: What It is and Why It Matters," INTERFACE Nashville conference, Nashville, TN, August 24th, 2017.
17. "Applying Blockchain to Healthcare Systems," panel presentation at the Siemens Blockchain Conference, Nuremburg, Germany, May 10th, 2017.
18. "A Primer on Big Data," Vanderbilt University Board of Trust meeting, April 21st, 2017, Nashville TN.
19. "The Past, Present, and Future of MOOCs and Their Importance for Software Engineering," Distinguished Lecture, University of Illinois Chicago, Chicago, IL, November 18th, 2016.
20. "Agility-at-Scale for Safety- and Mission-Critical Industrial-Scale Systems," INFORMS Annual Conference, Nashville, TN November 13th, 2016.
21. "Product Line Architectures for Open System Architectures," Varian, Winnipeg, Canada, October 7th, 2016.
22. "Agility-at-Scale for Safety- and Mission-Critical Industrial-Scale Systems," Siemens Architecture Workshop, Tarrytown, NY, September 27th, 2016.
23. "Product Line Architectures for Oncology Treatment Services," Varian, Palo Alto, CA, September 16th, 2016.
24. "Innovation and Speed: The Rise of Open Systems," the United States Technology Leadership Council, Reston, VA, August 24th, 2016.
25. "Elastic Software Infrastructure to Support the Industrial Internet," the Siemens CPS Workshop, Munich, Germany, August 1st, 2016.
26. "Challenges of Certifying Adaptive Dynamic Computing Environments," Workshop on Safety And Control for AI, Sponsored by the White House Office of Science and Technology Policy and Carnegie Mellon University, Pittsburgh, PA, June 28th, 2016.
27. "Keeping an Unfair Advantage in a Globalized and Commoditized World," Raytheon Symposium, Tucson, AZ, May 5th, 2016.
28. "Towards Technical Reference Frameworks to Support Open System Architecture Initiatives," Office of the Secretary of Defense (OSD) System of Systems Engineering Collaborators Information Exchange, December 15th 2015.
29. "Enterprise System of Systems Engineering (SoSE) Integration and Innovation," presentation at the US Marine Corp Business Management Association meeting, Quantico, VA, December 10th, 2015.
30. "An Architecture Grand Challenge: DOD's push for Open Systems Architecture," panel presentation at the Software Solutions Conference, Crystal City, VA, November 17th, 2015.
31. "Elastic Software Infrastructure to Support the Industrial Internet," the Siemens CPS Workshop, Munich, Germany, September 29th, 2015.
32. "An Overview of Mobile and mHealth Activities at ISIS and Vandy EECS," Patient Engagement Emerging Technologies, Vanderbilt University, Nashville, TN, August 10, 2015.
33. "Mobile Cloud Computing with Android," Google I/O, Mercury Intermedia Systems, Nashville, TN, May 28th, 2015.

34. "An Architecture Grand Challenge: DOD's push for Open Systems Architecture," panel presentation at the SATURN 2015 Conference, Baltimore, MD, April 27th, 2015.
35. "'Elastic Software Infrastructure to Support Computing Clouds for Cyber-Physical Systems," Distinguish Lecture, Texas A&M, April 27th, 2015.
36. "Elastic Software Infrastructure to Support Computing Clouds for Cyber-Physical Systems", Boeing Distinguished Researcher And Scholar Seminar (B-DRASS) series, March 20th, Huntingon Beach, CA.
37. "Elastic Software Infrastructure to Support Computing Clouds for Cyber-Physical Systems," Distinguished Lecture, University of California, Irvine, February 27th, 2015.
38. "Elastic Software Infrastructure to Support Computing Clouds for Cyber-Physical Systems," Varian, Palo Alto, CA, January 15th, 2015.
39. "Keeping an Unfair Advantage in a Globalized and Commoditized World," Open Architecture Summit, Washington DC, November 4th, 2014.
40. "Proposal for a Professional Masters degree in Computer Science," invited talk at Vanderbilt University School of Engineering's Board of Visitor's meeting, October 10th, 2014.
41. "The Past, Present, and Future of Open System Architecture Initiatives," invited keynote at the Future Airborne Capabilities Environment meeting, Nashville, TN, September 24th.
42. "Future Proofing Research and Development Investments in a Globalized, Commoditized World," Boeing Technical Excellence Conference, May 20th, 2014, St. Louis, MO.
43. "Elastic Software Infrastructure to Support the Computing Clouds for Cyber-Physical Systems (CC4CPS)," Securboration Conference, November 12th, 2013, Melbourne, Florida.
44. "The Importance of Automated Testing in Open Systems Architecture Initiatives," Open Architecture Summit, November 12th, 2013, Washington DC.
45. Conference on Cloud and Mobile Computing, Siemens Corporate Research, Princeton, NJ, November 5th, 2013.
46. "Overview of the Technology Entrepreneurship Task Force," Innovation, Imagination, and Introductions: A Conversation with Entrepreneurs, Vanderbilt University, October 24th, 2013.
47. "Producing and Delivering a Coursera MOOC on Pattern-Oriented Software Architecture for Concurrent and Networked Software," Vanderbilt University's Faculty Senate committee on Strategic Planning and Academic Freedom, October 23rd, 2013.
48. "Elastic Software Infrastructure to Support the Industrial Internet," RTI Webinar series, October 23rd, 2013.
49. "The Importance of Applying Agility to DoD Software Initiatives," IEEE Computer Society Lockheed Martin webinar series, October 10th, 2013.
50. "Technology Entrepreneurship Task force: Charter and Progress Update," Vanderbilt University School of Engineering Board of Visitors meeting, October 4th, 2013.
51. "Stochastic Hybrid Systems Modeling and Middleware-enabled DDDAS for Next-generation USAF Combat Systems," AFOSR DDDAS PI meeting, Arlington, VA, October 1st, 2013.
52. "Producing and Delivering a Coursera MOOC on Pattern-Oriented Software Architecture for Concurrent and Networked Software," WithIT seminar, Vanderbilt University, September 12th, 2013.
53. "Applying Agility to the US Department of Defense Common Operating Platform Environment Initiatives," Interoperable Open Architecture conference, Washington DC, September 11th, 2013.
54. "Software Infrastructure Support of Computing Clouds for Cyber-Physical Systems," invited talk at Real-Time Innovations, July 31st, 2013, Sunnyvale, California.
55. "Introduction to the Institute for Software Integrated Systems," Nashville Entrepreneur Center, July 15th, 2013.
56. "Surviving the Coursera Digital Learning Experience," Coursera-in-TN Conference, Vanderbilt University, Nashville, TN, June 24th, 2013.
57. "Quo Vadis ISORC?," Panel presentation at ISORC 2013 Conference, June 19th, 2013, Paderborn, Germany.

58. "Software Infrastructure Support of Computing Clouds for Cyber-Physical Systems," invited keynote for ISORC 2013 Conference, June 19th, 2013, Paderborn, Germany.
59. "Towards Programming Models and Paradigms for Computing Clouds that Support Cyber-Physical Systems," NSF Workshop on Computing Clouds for Cyber-Physical Systems, March 15th, 2013, Ballston, VA.
60. "Built to Last: Planning Your Career as an Engineer," STEM contest on Securing Cyber Space, Brentwood High School, March 9th, 2013, Nashville, TN.
61. "Experience with Digital Learning and MOOCs at Vanderbilt," Nashville, TN, Feb 22nd, 2013.
62. "Software Design: Is It Really Better to Look Good Than to Feel Good?," World IA Day, Nashville, TN, Feb 9th, 2013.
63. "Pattern-Oriented Software Architectures: Patterns and Frameworks for Concurrent and Networked Software," PhreakNIC 2012, Murfreesboro, TN, November 9th, 2012.
64. "Applying Agility to the US Department of Defence Common Operating Platform Environment Initiatives," Interoperable Open Architecture 2012, 29 - 31 October, 2012, London, UK.
65. "Open System Architectures: Challenges and Success Drivers," OA Summit conference, Washington, DC, October 18th, 2012.
66. "Dependable Computing Clouds for Cyber-Physical Systems," Dependability Issues in Cloud Computing Workshop, October 11th, 2012, Irvine, CA.
67. "Computing Clouds for Cyber-Physical Systems," Reliable Cloud Infrastructure for CPS Applications Workshop, October 8th, 2012, Irvine, CA.
68. "Common Operating Platform Environments: Challenges and Success Drivers," Navy Open Systems Architecture workshop, Ballston, VA, September 27th, 2012.
69. "Meeting the Challenges of Enterprise Distributed Real-time and Embedded Systems," talk for Honeywell Aerospace, September 21, 2012.
70. "Architecture-Led Iterative and Incremental Development for Common Operating Platform Environments," NITRD Software Design and Productivity meeting, National Coordination Office, Ballston, VA, July 13th, 2012.
71. "Cyber-physical multi-core Optimization for Resource and cachE effectS," Software-Intensive Systems Producibility workshop, Arlington VA, June 5th, 2012.
72. "Applying Agility to DoD Common Operating Platform Environment Initiatives", SEI Agile Research Forum, May 22nd, 2012.
73. "Meeting the Challenges of Enterprise Distributed Real-time and Embedded Systems," keynote talk at the SATURN Conference 2012 May 7-11, 2012, St. Petersburg, FL.
74. "Reflections on 20 Years of Architecture for Distributed Real-time and Embedded Systems," SATURN Conference 2012 May 7-11, 2012, St. Petersburg, FL.
75. "US Naval Open Systems Architecture Strategy," SATURN Conference 2012 May 7-11, 2012, St. Petersburg, FL.
76. "Towards Open Systems Architectures for Distributed Real-time and Embedded Systems," The Center for Embedded Systems for Critical Applications, Annual Workshop, Virginia Tech, Blackburg, VA April 21st, 2012.
77. "Overview of the SEI Strategic Research Plan," ASD(R&E) Annual Program Review, December 7th, 2011, Pittsburgh, PA.
78. "Overview of the SEI Strategic Research Plan," Acquisition Support Program meeting, November 16th, 2011, Pittsburgh, PA.
79. "Conducting Leading-Edge Software R&D in a Globalized, Commoditized World," NITRD Software Design and Productivity meeting, National Coordination Office, Ballston, VA, November 3rd, 2011.
80. "A Technical Assessment of Open Architecture Systems for Military Use," Interoperable Open Architecture, 26th-28th October 2011, London, UK.
81. "Conducting Leading-Edge Software R&D in a Globalized, Commoditized World," Technovation 2011, Carnegie Mellon University, September 29th, 2011.

82. "CTO Report," SEI Board of Visitors Meeting, Arlington, VA, September 27th, 2011.
83. "Overview of the SEI Strategic Research Plan," Joint Advisory Committee Meeting, Arlington, VA, September 26th, 2011.
84. "Successful Development Efforts: Standards, People, & Culture: The Enterprise Perspective," Software Assurance (SwA) Forum, September 16th, 2011, Arlington, VA.
85. "Ultra-Large-Scale (ULS) Cyberphysical Systems and Their Impact on Technology and Society," University of Salzburg, June 30th, 2011, Salzburg, Austria.
86. "Ultra-Large-Scale (ULS) Cyberphysical Systems and Their Impact on Technology and Society," ARTEMIS conference, June 29th, 2011, Linz, Austria.
87. "Ultra-Large-Scale Systems and Their Impact on the DoD," Systems and Software Technology Conference Committee, keynote presentation at the 23rd Systems and Software Technology Conference, May 16-19, 2011, Salt Lake City, Utah.
88. "Ultra-Large Scale Systems and their Impact on Technology and Society," keynote presentation at the International Symposium on Object-Oriented Real-time Distributed Computing¡/A¿ (ISORC), Newport Beach, CA, March 29th, 2011.
89. "Software-reliant Systems Research at the Software Engineering Institute," Raytheon, Sudbury, MA, March 10, 2011.
90. "Review of COE Practices," US Army Senior Leadership Education Program, Pittsburgh, PA, January 20th, 2011.
91. "Software Producibility for Defense," US Army Senior Leadership Education Program, Pittsburgh, PA, January 18th, 2011.
92. "SEI Research: The Shape of Things to Come," ASP Meeting, Software Engineering Institute, Pittsburgh, PA, December 9th, 2010.
93. "R&D at ASP," ASP Air Force Training Day, Software Engineering Institute, Pittsburgh, PA, December 9th, 2010.
94. "Software-reliant Systems Research at the Software Engineering Institute," Siements Corporate Research, Princeton, NJ, November 22nd, 2010.
95. "Taming the Complexity of Software-Reliant Systems," Software Engineering Process Group conference, Colombia, South America, November 11th, 2010.
96. "SEI Technical Presentations," Joint Advisory Committee Meeting, Arlington, VA, October 26th, 2010.
97. "SEI Research: The Shape of Things to Come," ASP Meeting, Software Engineering Institute, Pittsburgh, PA, October 20th, 2010.
98. "SEI Research: The Shape of Things to Come," SEPM Meeting, Software Engineering Institute, Pittsburgh, PA, October 19th, 2010.
99. "Strategic Directions for Research at the SEI," RTSS Offsite Meeting, Pittsburgh, PA, October 12th, 2010.
100. "The World is Flat and What You Can Do About It," Family Weekend, October 9th, 2010, Vanderbilt University.
101. "SEI Research: The Shape of Things to Come," SEI Board of Visitor's Meeting, Arlington, VA, September 28th, 2010.
102. "SEI Research: The Shape of Things to Come," PD&T Meeting, Software Engineering Institute, Pittsburgh, PA, September 20th, 2010.
103. "Introduction and Initial Thoughts," RTSS Meeting, Software Engineering Institute, Pittsburgh, PA, August 19th, 2010.
104. "The Impact of Ultra-Large-Scale Systems on DoD Operations," Congressional R&D Caucus, Rayburn Building, Washington DC, January 19th, 2010.
105. "The World is Flat and What You Can Do About It," Explorers meeting, January 12th, 2010, Vanderbilt University.

106. “Expectations for University - Industry Collaborative Research in CPS,” Computing Community Consortium Workshop on New Forms of Industry-Academy Partnerships in CPS Research, George Mason University, May 19th, 2009.
107. ”How Good is Your SOA?”, Panel presentation at the AFRL QED PI meeting, April 28th, 2009, Washington DC.
108. ”The World is Flat and What You Can Do About It,” ES 140, Computer Science module, October 31st, 2008, Vanderbilt University.
109. “Meeting the Challenges of Ultra-Large-Scale Distributed Real-time and Embedded Systems with QoS-enabled Middleware and Model-Driven Engineering,” Panel on Growing and Sustaining Ultra Large Scale (ULS) Systems, OOPSLA 2008, Nashville TN, October 21-23 2008.
110. ”The World is Flat and What You Can Do About It,” Family Weekend Faculty Lecture, Vanderbilt University, October 3rd, 2008.
111. “The World is Flat and What You Can Do About It,” Senior Design Seminar, Vanderbilt University, September 17th, 2008.
112. “The World is Flat and What You Can Do About It,” CS WithIT Seminar, Vanderbilt University, September 11th, 2008.
113. ”The Managed Motorway: Real-time Vehicle Scheduling - A Research Agenda,” Qualcomm, July 28th, 2008, San Diego, CA.
114. ”Meeting the Challenges of Mission-Critical Distributed Event-Based Systems with QoS-enabled Middleware and Model-Driven Engineering,” 2nd International Conference on Distributed Event-Based Systems (DEBS), Rome Italy, July 2-4, 2008.
115. ”Meeting the Challenges of Distributed Real-time and Embedded Systems with QoS-enabled Middleware and Model-Driven Engineering,” SPAWAR, April 29th, 2008.
116. ”Meeting the Challenges of Distributed Real-time and Embedded Systems with QoS-enabled Middleware and Model-Driven Engineering,” Northrop Grumman, Boulder Colorado, April 25th, 2008.
117. “Experimentation Environment for QED,” AFRL Information Management PI Meeting, April 16 2008, Georgetown, Washington, DC.
118. “Adaptive System Infrastructure for Ultra-Large-Scale Systems,” SMART Conference, Carnegie Mellon University, March 6th, 2008.
119. ”Experimentation Environment for QED”, Air Force Research Lab, Rome, NY, March 4th, 2008.
120. ”Ultra-Large-Scale (ULS) Systems and their Impact on Technology and Society,” Clemson University, January 31st, 2008.
121. ”Meeting the Challenges of Ultra-Large-Scale Distributed Real-time and Embedded Systems with QoS-enabled Middleware and Model-Driven Engineering, invited keynote talk at Middleware 2007, Irvine, CA, November 29th, 2007.
122. ”The World is Flat and What You Can Do About It,” Senior Design Seminar, Vanderbilt University, November 14th, 2007.
123. “Technology Candidates for QED,” AFRL retreat, Minnowbrook, NY, October 23, 2007.
124. ”Overview of ISIS and Proposed IU/CRC R&D Projects,” Crystal City, VA, October 19th, 2007.
125. The Future of CORBA for Distributed Real-time and Embedded Systems, International Conference on Accelerator and Large Experimental Physics Control Systems, October 17, 2007, Knoxville, TN.
126. ”AF-TRUST: Project Overview,” Air Force Scientific Advisory Board review, Rome, NY, October 15th, 2007.
127. ”Meeting the Challenges of Distributed Real-time and Embedded Systems with Product-Line Architectures,” August 1st, 2007, Trinity College, Dublin, Ireland.
128. ”Model Driven Engineering of Product-Line Architectures for Distributed Real-time and Embedded Systems,” July 5th, 2007, University of Limerick, Ireland.
129. ”Meeting the Challenges of Mission-Critical Systems with Middleware and Model Driven Engineering”, OMG Technical Meeting, June 27, 2007, Brussels, Belgium.

130. Meeting the Challenges of Ultra-Large-Scale Distributed Real-time and Embedded Systems with Model-Driven Engineering, June 19, 2007, Trinity College, Dublin.
131. Strategic Technology Positioning, PrismTechnologies "Middleware Fest", June 14, 2007, Newcastle, UK.
132. "Hurdles for Wireless Communication Systems R&D and Some Ways to Overcome Them," OSD Workshop on Wireless Communication Systems, Rosslyn, VA, May 22nd, 2007.
133. "The World is Flat from a Computer Scientists Point of View," Vanderbilt University Commencement talk, May 10th, 2007.
134. Meeting the Challenges of Ultra-Large-Scale Distributed Real-time and Embedded Systems, invited keynote at the the 10th IEEE International Symposium on Object/Component/Service-oriented Real-time Distributed Computing, May 7-9, 2007, Santorini Island, Greece.
135. "Enhanced QoS for the GIG," AFRL JBI PI meeting, Georgetown, DC, April 24, 2007.
136. "Meeting the Challenges of Ultra-Large-Scale Distributed Real-time and Embedded Systems," Invited keynote at the 15th International Workshop on Parallel and Distributed Real-Time Systems (WDPRTS), March 26-27, 2007, Long Beach, California.
137. "The CORBA C++ Mapping: Beyond Repair?," OMG Meeting, San Diego, CA, March 27th, 2007.
138. "Meeting the Challenges of Ultra-Large-Scale Systems via Model-Driven Engineering," Distinguished Lecturer Series, Florida International University, Miami, Florida, Feb 2, 2007.
139. Model Driven Engineering and QoS-enabled Component Middleware for DRE Systems, Invited talk at the European Space Agency Operations Center, Darmstadt, Germany, Wednesday January 24, 2007.
140. "Software Wind Tunnel (SWiT) Concept of Operations and System Architecture", AFRL Software and Systems Test Track workshop, Arlington, VA, January 19, 2007.
141. "Latest Breakthroughs in SDR Software Development Using Model Driven Technologies," Rockwell Collins, Cedar Rapids, IA, December 14th, 2006.
142. "Educating the DoD Workforce in a Flat World," 2006 Raytheon Integrated Defense Systems' SW Engr. Directorate Off-Site Meeting, New Castle, New Hampshire, December 7, 2006.
143. "The Ultra Challenge: Software Systems Beyond Big," panelist at OOPSLA 2006, October, 2006, Portland, OR.
144. "Software Wind Tunnel (SWiT) Architecture," AFRL Software and Systems Test Track Workshop, Cherry Hill, NJ, October 2nd, 2006.
145. "The World is Flat and What You Can Do About it," Vanderbilt University, September 12th, 2006.
146. "The World is Flat and What You Can Do About it," Vanderbilt University, September 8th, 2006.
147. "Meeting the Challenges of Ultra-Large-Scale Systems via Model-Driven Engineering," Network-Centric Operations Industry Consortium, Reston, VA, August 2nd 2006.
148. Model Driven Architecture Roundtable, invited panelist at the Software Engineering Institute, Pittsburgh, PA, June 1st, 2006.
149. "Enhanced QoS for the GIG," AFRL JBI PI meeting, Tysons Corner, VA, April 11, 2006.
150. "Model Driven Engineering for Distributed Real-time and Embedded Systems," Distinguished Lecturer Series talk at Colorado State University, Ft. Collins, CO, April 10, 2006.
151. "Win-Win Partnership of Academia and Industry: Why Should We Care? Where Is Our Common Future?" invited panelist at the 12th IEEE Real-Time and Embedded Technology and Applications Symposium April 6, 2006, San Jose, California.
152. "Meeting the Challenges of Ultra-Large-Scale Real-time Systems," invited keynote at the IEEE Real-Time and Embedded Technology and Applications Symposium April 5, 2006, San Jose, California.
153. "Model-driven Development for Distributed Real-time and Embedded Systems," ACM Meeting at Middle Tennessee State University, March 7th, 2006.

154. "Real-time, Scalable, and Secure Information Management for the GIG," Scientific Advisory Board Meeting, Rome, NY, November 16th, 2005.
155. "Real-time, Scalable, and Secure Information Management for the GIG," Airforce Research Lab, Rome, NY, November 3rd, 2005.
156. "Model-driven Development for Distributed Real-time and Embedded Systems," Distinguished Speaker Talk at BBN Technologies, Cambridge, MA, October 27, 2005.
157. "Challenges and Research Areas for QoS-enabled Information Management in Tactical Systems of Systems," AFRL Minnowbrook Workshop, Adirondack Mountains, NY, October 21st, 2005.
158. "Model-driven Development for Distributed Real-time and Embedded Systems," Invited keynote at MODELS 2005, ACM/IEEE 8th International Conference on Model Driven Engineering Languages and Systems, Half Moon Resort, Montego Bay, Jamaica, October 5-7, 2005.
159. "The World is Flat and What You Can Do About it," CS WithIT Seminar, Vanderbilt University, September 22, 2005.
160. "Why Software Reuse has Failed and How to Make it Work for You," Motorola 2005, Symposium on Software, Systems, and Simulation, Schaumburg, IL, September 16th, 2005.
161. "Pattern-Oriented Software Architecture," 12th Pattern Language of Programming Conference, Allerton Park, Illinois, September 7-10, 2005.
162. "Model-Driven Development of Distributed Real-time and Embedded Systems," 12th Pattern Language of Programming Conference, Allerton Park, Illinois, September 7-10, 2005.
163. "Model-driven Development for Distributed Real-time and Embedded Systems," Siemens Corporate Research, Princeton, NJ, August 26th.
164. "Model-driven QoS Provisioning for Real-time CORBA and CCM DRE Systems," 6th OMG Real-time/Embedded CORBA workshop, Washington DC, July 11–14, 2005.
165. "A Proposed R&D Agenda for the Software Technology Laboratory," Lockheed Martin Advanced Technology Lab, Cherry Hill, NJ, June 28th, 2005.
166. "Model-Driven Development of Product-Line Architectures for DRE Systems," 11th Siemens Software Architecture Improvement Group (SAIG), Buffalo Grove, IL June 22, 2005.
167. "Business Drives for Platforms," panel at the 11th Siemens Software Architecture Improvement Group (SAIG), Buffalo Grove, IL June 22, 2005.
168. "Model Driven Development for Distributed Real-time and Embedded Systems," Lockheed Martin Advanced Technology Lab, Cherry Hill, NJ, June 15th, 2005.
169. "Approaches for Supporting Real-time QoS in JBI," JBI PI Meeting, Washington DC, May 24th, 2005.
170. "Overcoming Hurdles of Software Producibility," OSD, Software Producibility Workshop, Arlington, VA, May 18, 2005.
171. "Overview of Multi-Level Resource Management in ARMS," Fermilab, Chicago, IL, April 12th, 2005.
172. "Model Driven Middleware for Distributed Real-time and Embedded Systems," University of Southern Alabama, April 8, 2005.
173. "Model-Driven Development of Distributed Real-time and Embedded Systems," UAV Battlelab, Indian Springs, NV, February 10th, 2005.
174. "The Future of Software and Systems Engineering," IEEE Meeting, Vanderbilt University, February 8th, 2005.
175. Model Driven Development of Distributed Real-time and Embedded Systems, panel at the OOP conference, Munich, Germany, January 27, 2005.
176. "Product-line Architecture Technologies for Distributed Real-time and Embedded Systems, Lockheed Martin, Moorestown, NJ, November 11, 2004.
177. "Model Driven Development of Distributed Real-time and Embedded Systems," invited panelist in the "Generative Programming: Past, Present, and Future," at the 3rd ACM International Conference on Generative Programming and Component Engineering, Vancouver, CA, October 24th 2004.

178. "Developing Combat Systems with Component Middleware and Models," Lockheed Martin, Moorestown, NJ, October 22, 2004.
179. "Model Driven Development of Distributed Real-time and Embedded Systems," Lockheed Martin Advanced Technology Lab, Cherry Hill, NJ, October 21, 2004.
180. "Model Driven Development of Distributed Real-time and Embedded Systems," Lockheed Martin Missile and Fire Control, Dallas, TX, October 13, 2004.
181. "Design of ARMS MLRM Components: CCM Based Design for Dynamic Resource Management," DARPA ARMS Technical Interchange Meeting, Plymouth, RI, October 7, 2004.
182. "Model Driven Middleware for Component-based Distributed Systems," keynote for the The 8th International IEEE Enterprise Distributed Object Computing Conference, Monterey, California, September 22, 2004.
183. "Systems Science Challenge Area," TRUST NSF Science and Technology Review, UC Berkeley, September 12, 2004.
184. "Model Driven Development for Distributed Real-time and Embedded Systems," Lockheed Martin, Eagan, MN, August 31st, 2004.
185. "Model Driven Computing for Distributed Real-time and Embedded Systems," Telcordia, Piscataway, NJ, August 10th, 2004.
186. "Model Driven Computing for Distributed Real-time and Embedded Systems," Raytheon, Portsmouth, RI, August 9th, 2004.
187. "Distributed Object Computing with CORBA," Raytheon, Portsmouth, RI, August 9th, 2004.
188. "Model Driven Development of Distributed Real-time and Embedded Systems," Raytheon, Ft. Wayne, IN, July 27th, 2004.
189. "Model Driven Middleware for Distributed Real-time and Embedded Systems," panelist at the 5th OMG Real-time and Embedded Middleware Workshop, Reston, VA 2004.
190. "The Role of Open Standards,Open-Source Development, and Different Development Models and Processes on Industrializing Software," ARO Workshop on Software Reliability for FCS, Vanderbilt University, Nashville, Tennessee, May 18-19, 2004.
191. "Model Driven Middleware for Distributed Real-time and Embedded Systems," Keynote talk for the SIGS Software Engineering Today conference in Zurich, Switzerland, May 4-5, 2004.
192. "Model-Driven Development of Distributed Real-time and Embedded Systems," 10th Siemens Software Architecture Improvement Group (SAIG), Vienna, Austria, April 20-24, 2004.
193. "Adaptive and Reflective Middleware for Distributed, Real-time, and Embedded Systems," Purdue University, West Lafayette, Indiana, April 6, 2004.
194. "Model Driven Middleware for Distributed Real-time and Embedded Systems," *Technologies That Will Change the World* session at the Southeastern Software Engineering Conference, Huntsville, Alabama, March 30th, 2004.
195. "Advances in COTS Middleware for Distributed Real-time and Embedded Systems," Keynote for the International Conference on COTS-Based Software Systems (ICCBSS) 2004 in Redondo Beach, February 2-4, 2004.
196. Composable Middleware Components for High Confidence Network Embedded Systems, University of California, Berkeley, December 4th, 2003.
197. "Model Driven Middleware," TechConnect 2003, St. Louis, MO, October 1st, 2003.
198. "Advances in Model Driven Middleware for Distributed Real-time and Embedded Systems," the Model Integrated Computing PSIG meeting at the OMG Technical Meeting, September 10, 2003, Boston, MA.
199. Invited panelist for the "Research on DRE Systems" panel at the OMG Real-time Middleware Workshop, July 16, 2003, Arlington, VA.
200. "Advances in Model Driven Middleware for Distributed Real-time and Embedded Systems," the OMG Real-time Middleware Workshop, July 15, 2003, Arlington, VA.

201. Organizer and presenter for a panel on “Advances in Large-scale Distributed Real-time and Embedded Systems” at the 9th IEEE Real-time/Embedded Technology and Applications Symposium (RTAS), May 27-30, 2003, Washington, DC.
202. “Managing Project Risk for Combat Systems,” The Southeastern Software Engineering Conference, Huntsville, Alabama, April 1st, 2003.
203. “Distributed Real-time and Embedded Systems at DARPA,” OMG Workshop on Super Distributed Objects, Washington DC, Monday, November 18, 2002.
204. “Adaptive and Reflective Middleware for Distributed Real-time Systems,” Workshop on High Performance, Fault Adaptive, Large Scale Real-time Systems, Vanderbilt University, November 14, 2002.
205. Invited panelist on ”Objects and Real-time Systems” OOPSLA ’02, Seattle, WA, November 8, 2002.
206. “An Overview of ACE+TAO,” Boeing, Seattle, November 8th, 2002.
207. “Pattern-Oriented Software Architecture,” Amazon, Seattle, WA, November 6th, 2002.
208. “Using Real-time CORBA Effectively: Patterns and Principles,” CORBA Controls Workshop, Grenoble, France, October, 9th, 2002.
209. “Adaptive and Reflective Middleware for Distributed Real-time and Embedded Systems,” EMSOFT 2002: Second Workshop on Embedded Software, Grenoble, France, October, 7–9th, 2002.
210. “Designing the Future of Embedded Systems at DARPA IXO,” Keynote talk at the 6th Annual Workshop on High-Performance Embedded Computing (HPEC), September 25, Boston, MA.
211. “Open Distributed Computing Platforms,” NSF/OSTP Workshop on Information Technology Research for Critical Infrastructure Protection, Lansdowne, VA, September 20th, 2002.
212. “Real-time Object-Oriented Middleware,” Distributed Common Ground/Surface System Technical Review Group meeting, Mclean VA, September 19th, 2002.
213. “Research Advances in Middleware for Distributed, Real-time, and Embedded Systems,” Computer Communications stream of the 17th IFIP World Computer Congress, Montreal, Canada, August 25-30, 2002.
214. “DARPA Thrusts in Embedded Computing,” Mercury Computer Systems, Tyngsboro, MA, July 25th, 2002.
215. “Adaptive and Reflective Middleware for Distributed, Real-time, and Embedded Combat Systems,” Boeing Space and Missile Systems, Anaheim, CA, July 9, 2002.
216. “Annual Report on Software Design and Productivity Coordinating Group,” Interagency Working Group, ITR&D Spring Planning Meeting, NSF, Ballston, VA, May 10, 2002.
217. “Real-time CORBA Standardization: Past, Present, and Future,” panelist in the ”Standards Movements in Object-oriented Real-time Computing” panel at the ISORC 2002 Conference, Washington, DC, April 30, 2002.
218. “Towards Adaptive and Reflective Middleware for Distributed Real-time Embedded Systems,” Moderator of the *Distributed, Real-time, and Embedded Middleware for Network-Centric Combat Systems* panel at the Software Technology Conference (STC) in Salt Lake City, Utah, April 29, 2002.
219. “Applying Architectural Patterns to Address Key Challenges of Distributed Software,” Siemens Architecture Interworking Group, Chicago, IL, April 24, 2002.
220. “Towards Adaptive and Reflective Middleware for Distributed Real-time and Embedded Systems,” Space and Missile Defense Command, Huntsville, AL, April 22, 2002.
221. “How to Maintain Superiority in the Face of the Commoditization of IT,” tutorial at the UCI CEO Roundtable, Maui, Hawaii, April 12, 2002.
222. “Transformation or Transmogrification? Surviving the Commoditization of IT,” panelist at the UCI CEO Roundtable, Maui, Hawaii, April 11, 2002.
223. “Patterns and Principles of Mission-critical Middleware,” Henry Samueli School of Engineering Research Review, University of California, Irvine, March 14th, 2002.

224. “DARPA: an Agency Overview,” CRA Academic Careers Workshop, Arlington, Virginia, February 10 - 12, 2002.
225. “Towards Adaptive and Reflective Middleware for Distributed, Real-time, and Embedded Systems,” Electrical Engineering and Computer Science Department, Vanderbilt University, January 28th, 2002.
226. “Protecting Critical Cyber Infrastructure from Asymmetric Threats,” panelist at the 7th IEEE Workshop on Object-oriented Real-time Dependable Systems, San Diego, CA, January 10, 2002.
227. “The Researcher’s Dilemma: When Technology Success Causes Great Communities to Fail (at Mission-oriented R&D Agencies),” Software Design and Productivity Coordinating Group Workshop on New Visions for Software Design and Productivity: Research and Applications, Nashville, TN, December 13-14, 2001.
228. “Towards Adaptive and Reflective Middleware for Mission-Critical Systems,” Computer Science Department, College of William and Mary, September 7th, 2001.
229. “Adaptive and Reflective Middleware Systems,” Lockheed Martin, Moorestown, NJ, August 21st, 2001.
230. “Adaptive and Reflective Middleware Systems,” United Technology Research Center, Hartford, Connecticut, June 28th, 2001.
231. “Adaptive and Reflective Middleware Systems,” Raytheon Annual Processing Systems Technology Network (PSTN) Symposium, Lexington, MA, June 20th, 2001.
232. Invited presenter for the Vendors’ Panel at the OMG 2nd Workshop on Real-time and Embedded Distributed Object Computing, June 4-7, 2001.
233. ”Towards Pattern Languages and QoS-enabled Middleware for Distributed Real-time and Embedded Systems,” DARPA ITO workshop on Embedded Software, Lake Tahoe, NV, October 8-10, 2001.
234. ”TAO, CORBA, and the HLA/RTI”, Keynote talk at the Fifth IEEE International Workshop on Distributed Simulation and Real Time Applications Cincinnati, Ohio, USA August 13-15, 2001.
235. “Patterns and Principles of Middleware for Distributed Real-time and Embedded Systems,” Raytheon, Sudbury, March 29th, 2001.
236. “Adaptive and Reflective Middleware Systems,” Distinguished Lecture at Florida Atlantic University, Boca Raton, FL, March 1st, 2001.
237. “Adaptive and Reflective Middleware for Mission-Critical Distributed and Embedded Systems,” University of Alabama, Birmingham, AL, January 31st, 2001.
238. “Adaptive and Reflective Middleware for Mission-Critical Distributed and Embedded Systems,” Telcordia, Morristown, NJ, November 20th, 2000.
239. “Adaptive and Reflective Middleware for Mission-Critical Distributed and Embedded Systems,” George Mason University, Fairfax, VA, November 20th, 2000.
240. “Adaptive and Reflective Middleware for Mission-Critical Distributed and Embedded Systems,” Lucent CORBA Forum, Naperville, IL, November 17th, 2000.
241. “Putting an ORB on a Diet,” Session on *Performance and QoS of Embedded CORBA ORBs* at the OMG’s Workshop on Embedded Object-Based Systems, January 17-19, 2001.
242. “Adaptive and Reflective Middleware Systems,” Panelist in a session on “Highly Distributed Systems,” at the IEEE Symposium on Applications and the Internet, San Diego, CA, January 10, 2001.
243. “Adaptive and Reflective Middleware Systems,” Panelist at the NSF Networking PI meeting, Irvine California, November 1st, 2000.
244. “Surviving the Tornado: The Best Kept Secrets of R&D Success in the Internet Age,” Keck Observatory, Hawaii, October 9th, 2000.
245. “Adaptive and Reflective Middleware Systems,” BBN Technologies, Boston, MA, September 27th, 2000.

246. "Distributed Application Integration: Myth or Reality?" Keynote talk at 2nd International Symposium on Distributed Objects and Applications (DOA '00), OMG, Antwerp, Belgium, September 21st, 2000.
247. "Surviving the Tornado: The Best Kept Secrets of R&D Success in the Internet Age," Keynote talk at 2nd International Symposium on Distributed Objects and Applications (DOA '00), OMG, Antwerp, Belgium, September 21st, 2000.
248. "High Confidence Adaptive and Reflective Middleware: Fact or Fiction?" Keynote talk for the IFIP Fourth International Conference on Formal Methods for Open Object-Based Distributed Systems, (FMOODS 2000), Stanford University, Stanford, CA, September 7th, 2000.
249. "Adaptive and Reflective Middleware Systems," Lockheed Martin, Ft. Worth, TX, September 6th, 2000.
250. Pattern-oriented Software Architecture: Concurrent and Networked Objects, Raytheon, San Diego, August 25, 2000.
251. "Adaptive and Reflective Middleware Systems," Rockwell/Collins, Cedar Rapids, Iowa, August 22, 2000.
252. "Adaptive and Reflective Middleware Systems," Lockheed Martin, Eagan, MN, August 21, 2000.
253. "Adaptive and Reflective Middleware Systems," Honeywell Technology Center, Minneapolis, MN, August 18, 2000.
254. "Adaptive and Reflective Middleware Systems," Raytheon, Falls Church, VA, July 12, 2000.
255. "Applying Patterns to Develop High-performance and Real-time Object Request Brokers," Lockheed Martin, Eagan, Minnesota, May 19, 2000.
256. "Patterns and Principles of Real-time Object Request Brokers," Cisco, San Jose, April 12, 2000.
257. "Patterns and Principles of Real-time Object Request Brokers," BellSouth, Atlanta, Georgia, March 3, 2000.
258. "Patterns and Principles of Real-time Object Request Brokers," Distinguished Lecturer Series, Michigan State University, East Lansing, Michigan, October 21, 1999.
259. "Towards Minimum ORBs for Wireless Devices and Networks," OPENSIG '99 Workshop, Carnegie Mellon University, Pittsburgh, October, 14-15, 1999.
260. "Applying CORBA Fault Tolerant Mechanisms to Network Management," Lucent CORBA Forum, Naperville, IL, September 28th, 1999.
261. "CORBA for Real-time and Embedded Telecom Systems," Lucent CORBA Forum, Naperville, IL, September 28th, 1999.
262. "Patterns and Principles of Real-time Object Request Brokers," BEA, Munich, Germany, September 16th, 1999.
263. "Real-time CORBA – Fact or Fiction," Siemens CORBA Day, Munich, Germany, September 15th, 1999.
264. "Patterns and Principles of Real-time Object Request Brokers," Siemens MED, Erlangen, Germany, September 13th, 1999.
265. "Patterns and Principles of Real-time Object Request Brokers," RT DII COE TWG, Boeing, Seattle, WA August 25th, 1999.
266. "Patterns for Real-time Middleware," Microsoft, Redmond, WA, August 24th, 1999.
267. "Patterns and Principles of Real-time Object Request Brokers," Lockheed Martin, Eagan, Minnesota, June 22nd, 1999.
268. "Using the ACE Framework and Patterns to Develop OO Communication Software," Dreamworks SGK, Glendale, CA, May 5th, 1999.
269. "Why Telecom Reuse has Failed and how to Make it Work for You," Keynote talk at Nortel Design Forum, Ottawa, CA, April 22nd, 1999.
270. "QoS-enabled Middleware for Monitoring and Controlling High-Speed Networks and Endsystems," Lucent Bell Labs, Murray Hill, NJ, April 15th, 1999.

271. "Optimization Patterns for High-performance, Real-time Object Request Broker Middleware," University of California, Irvine, April, 2nd, 1999.
272. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," Lucent, Columbus, OH, March 18-19 and 25-26, 1999.
273. "Using Design Patterns, Frameworks, and Object-Oriented Communication Systems," Lucent, Holmdel, NJ, March 1-4, 1999.
274. Chaired a panel on "Research Directions for Middleware," NSF PI meeting, Washington, DC, January 24th, 1999.
275. "Principles and Patterns of High-performance Real-time CORBA," University of Southern California, Los Angeles, CA, December 10th, 1998.
276. "Real-time CORBA for Telecom – Fact or Fiction?," Bellcore, Morristown, NJ, December 1st, 1998.
277. "Design Patterns for Real-time Object Request Brokers," Silicon Valley Patterns Group, San Francisco, November 15, 1998.
278. "Why Reuse has Failed and how to Make it Work for You," Keynote talk at Lucent Software Symposium, October 27th, Murray Hill, NJ, 1998.
279. "Real-time CORBA – Fact or Fiction," Lucent CORBA Forum, Holmdel, NJ, September 29, 1998.
280. "Applying Software Design Patterns and Framework to Telecommunication Applications," Nortel Advanced Software Computing and Technology, Monday, April 6, 1998, Ottawa, Canada.
281. "Patterns and Performance of Real-time Object Request Brokers," University of California, Santa Barbara, February 20, 1998.
282. "Principles and Patterns of High-performance, Real-time Object Request Brokers," University of Frankfurt, Germany, February 12th, 1998.
283. "Principles and Patterns of High-performance, Real-time Object Request Brokers," University of Illinois, Urbana-Champaign November 12th, 1997.
284. "Principles and Patterns of High-performance, Real-time Object Request Brokers," University of Missouri, Kansas City, October 31st, 1997.
285. "Principles and Patterns of High-performance, Real-time Object Request Brokers," IBM T.J. Watson Research, September 15, 1997.
286. "Principles and Patterns of High-performance, Real-time Object Request Brokers," University of California, Santa Barbara, August 21st, 1997.
287. "Principles and Patterns of High-performance, Real-time Object Request Brokers," Lucent Technologies, Naperville, IL August 19th, 1997.
288. "Mastering Software Complexity with Reusable Object-Oriented Frameworks, Components, and Design Patterns," 3rd NSA Software Reuse Symposium, August 20th, 1997.
289. "Principles and Patterns of High-performance, Real-time Object Request Brokers," University of Utah, Salt Lake City, Utah, August 11th, 1997.
290. "Using the ACE Framework and Design Patterns to Develop Object-Oriented Communication Software," CERN, Switzerland, July 18th, 1997.
291. "Principles and Patterns of High-performance, Real-time Object Request Brokers," CHOOSE symposium, Zurich, Switzerland, July 17th, 1997.
292. Invited keynote speaker for 2^{nd} Component's User Conference, Munich Germany, July 1997.
293. "Principles and Patterns of High-performance, Real-time Object Request Brokers," Lucent Bell Laboratories, Murray Hill, New Jersey, July 9th, 1997.
294. "Using the ACE Framework and Design Patterns to Develop Object-Oriented Communication Software," Lockheed Martin Tactical Systems, Minneapolis, Minnesota, June 26th, 1997.
295. QoS for Distributed Object Computing Middleware – Fact or Fiction?, panel at the Fifth International Workshop on Quality of Service (IWQoS '97), May 22nd, 1997, Columbia University, NYC, USA.

296. "Design Patterns and Frameworks for Developing Object-oriented WWW Clients and Servers," Carleton University, April 11th, 1997.
297. "Principles and Patterns of High-performance, Real-time Object Request Brokers," University of Maryland, College Park, Maryland, April 2nd, 1997.
298. "A High-Performance End system Architecture for Real Time COBRA," SPARTAN Symposium sponsored by US Sprint, Lawrence Kansas, March 18th, 1997.
299. "Experience with CORBA for Communication Systems," Motorola, Chicago, January 24th, 1997.
300. "High-performance CORBA," Bay Area Object Interest Group, Stanford Linear Accelerator Center, California, December 5th, 1996.
301. "Gigabit CORBA – An Architecture for High-performance Distributed Object Computing," Numerical Aerodynamic Simulation group, NASA, Moffett Field, California, December 3rd, 1996.
302. "Towards High-performance, Real-time CORBA," Distinguished Lecturer at Kansas State University, Manhattan, Kansas, November 7th, 1996.
303. "Gigabit CORBA – An Architecture for High-performance Distributed Object Computing," University of California, Los Angeles, October 3rd, 1996.
304. "Design Patterns and Frameworks for Object-Oriented Communication Software," NSA Software Reuse Symposium, August 28th, 1996.
305. "CORBA – the Good, the Bad, and the Ugly," Lucent Bell-Labs, Naperville, IL, August 22nd, 1996.
306. "Components: the Good, the Bad, and the Ugly," keynote talk for the 1st Components Users Conference, SIEMENS, Munich, Germany, July 15th, 1996.
307. "Design Patterns for Object-Oriented Communication Software," IONA Technologies, Ltd, Dublin, Ireland, July 12th, 1996.
308. "OO Design Patterns and Frameworks for Communication Software," Siemens Corporate Research, Princeton, New Jersey, June 27, 1996.
309. "OO Design Patterns for Concurrent, Parallel, and Distributed Systems," IBM Centre for Advanced Studies, North York, Ontario, Canada, June 17, 1996.
310. "Distributed Object Computing with CORBA", Bell Laboratories, Murray Hill, New Jersey, June 11-12th, 1996.
311. "Design Patterns for Object-Oriented Communication Software," Carleton University, Ottawa, Canada, May 21st, 1996.
312. "Integrating LAN-WAN-Celestial Networks with Design Patterns," Featured technical session at the Object World East conference, Boston, MA, May 9th, 1996.
313. "Using Design Patterns to Develop Object-Oriented Communication Software Frameworks and Applications," McMaster's University, Hamilton, Canada, May 2nd, 1996.
314. "Towards Gigabit CORBA – A High-Performance Architecture for Distributed Object Computing," University of Nevada, Reno, April 25th, 1996.
315. "Domain Analysis: From Tar Pit Extraction to Object Mania?" Panelist at the 4th International Conference on Software Reuse, Orlando, Florida, April 25^{th}, 1996. (other panelists include Spencer Peterson, SEI CMU, Mark Simos, Organon Motives Inc., Will Tracz, Loral, and Nathan Zalman, BNR Inc).
316. "Concurrent Object-Oriented Network Programming with C++," Kodak Imaging Technology Center, April 19^{th}, 1996.
317. "Using OO Design Patterns and Frameworks to Develop Object-Oriented Communication Systems," INRS/NorTel Workshop on Telecommunication Software, Montreal, CA, March 14^{th}, 1996.
318. "Concurrent Object-Oriented Network Programming with ACE and C++," for Siemens Medical Engineering, Erlangen Germany, February 15^{th}, 1996.
319. "OO Componentware" Panelist at the *OOP '96 Conference*, SIGS, Munich, Germany, February 13^{st}, 1996. (other panelists included Michael Stal (Siemens AG) and Frank Buschmann (Siemens AG).

320. "Using Design Patterns to Develop High-performance Object-Oriented Communication Software Frameworks," for the Department of Information Systems, Institute of Computer Science, Johannes Kepler University of Linz, Austria, February 12^{th}, 1996.
321. "The Performance of Object-Oriented Components for High-speed Network Programming," for the Digital Libraries research group at Stanford University, Palo Alto California, February 2^{nd}, 1996.
322. "Distributed Object Computing with CORBA, ACE, and C++," for South Western Bell Telephone advanced distributed systems group, St. Louis, MO., January 26^{th}, 1996.
323. "OO Design Patterns for Large-Scale Object-Oriented Communication Software Systems," AG Communication Systems, Phoenix, Arizona, December $11 - 13^{th}$, 1995.
324. "Experience Using OO Design Patterns to Develop Large-Scale Object-Oriented Communication Software Systems," Bell Northern Research, 7th Annual Design Forum, Ottawa, Canada, December 6^{th}, 1995.
325. "Using OO Design Patterns to Develop Large-Scale Distributed Systems," Object Technology International, Ottawa, Canada, November 22^{nd}, 1995.
326. "Design Patterns for Concurrent, Parallel, and Distributed Systems," North Dallas Society for Object Technology, September 13^{th}, 1995.
327. "Using Design Patterns for Iridium Communication Services," at Motorola Iridium, Chandler, AZ, June 30^{th}, 1995.
328. "Object Technology and the World-Wide Information Infrastructure," Panelist at ECOOP '95, Aarhus, Denmark, August 9^{th}, 1995.
329. "Measuring the Performance of CORBA over ATM Networks," HP Labs, Palo Alto, CA, June 28^{th}, 1995.
330. "Measuring the Performance of Object-Oriented Components for High-speed Network Programming," The C++ and C SIG user group, New York, New York, June 5^{th}, 1995.
331. "An Overview of Design Patterns for Object-Oriented Network Programming," St. Louis Chapter of the ACM, St. Louis, MO, March 13^{th} 1995.
332. "Design Patterns for Concurrent Object-Oriented Network Programming," Distributed Systems group at Siemens Corporate Research Center, Munich, Germany, March 3^{rd}, 1995.
333. "Patterns: 'Eureka,' 'Deja-Vu,' or 'Just Say No'?" Panelist at the *OOP '95 Conference*, SIGS, Munich, Germany January 31^{st}, 1995. (other panelists included Richard Helm, (DMR), Frank Buschmann (Siemens AG), and Dave Thomas (OTI).
334. "Developing Distributed Applications with the ADAPTIVE Communication Environment," *The* 12^{th} *Annual Sun Users Group Conference*, SUG, San Francisco, California, June 17^{th}, 1994.
335. "Flexible Configuration of High-performance Distributed Communication Systems," presented at the ETH-Zentrum in the Swiss Federal Institute of Technology, Zurich, Switzerland, May 31^{st}, 1994.
336. "Object Oriented Techniques for Developing Distributed Applications," *Computer Science Department Colloquia*, California State University Northridge, December 7^{th}, 1993.
337. "Hosting the ADAPTIVE System in the *x*-Kernel and System V STREAMS," *The x-Kernel Workshop*, IEEE, Tucson, Arizona, November 10^{th}, 1992.
338. "An Environment for Controlled Experimentation on the Performance Effects of Alternative Transport System Designs and Implementations," IBM T. J. Watson Research Center, Hawthorne, New York, September 10^{th}, 1992.

Colloquia, Seminars, and Tutorials

1. "Programming with Java Lambdas and Streams," O'Reilly Live Training, December 6th, 2021.
2. "Design Patterns in Java," O'Reilly Live Training, November 15th and 16nd, 2021.
3. "Scalable Reactive Programming with Java," O'Reilly Live Training, September 9th, 2021.
4. "Design Patterns in Java," O'Reilly Live Training, September 1st and 2nd, 2021.
5. "Programming with Java Lambdas and Streams," O'Reilly Live Training, July 20th, 2021.

6. "Scalable Reactive Programming with Java," O'Reilly Live Training, May 17th, 2021.
7. "Scalable Reactive Programming with Java," O'Reilly Live Training, January 22nd, 2021.
8. "Programming with Java Lambdas and Streams," O'Reilly Live Training, January 13th, 2021.
9. "Design Patterns in Java," O'Reilly Live Training, November 12th and 13th, 2020.
10. "Design Patterns in Java," O'Reilly Live Training, September 17th and 18th, 2020.
11. "Programming with Java Lambdas and Streams," O'Reilly Live Training, September 14th, 2020.
12. "Core Java Synchronizers," O'Reilly Live Training, August 20th, 2020.
13. "Scalable Reactive Programming with Java," O'Reilly Live Training, August 19th, 2020.
14. "Programming with Java Lambdas and Streams," O'Reilly Live Training, June 1st, 2020.
15. "Design Patterns in Java," O'Reilly Live Training, May 27th and 28th, 2020.
16. "Core Java Synchronizers," O'Reilly Live Training, May 18th, 2020.
17. "Programming with Java Lambdas and Streams," O'Reilly Live Training, March 30th, 2020.
18. "Design Patterns in Java," O'Reilly Live Training, March 23rd and 24th, 2020.
19. "Scalable Concurrency with the Java Executor Framework," O'Reilly Live Training, February 24th, 2020.
20. "Core Java Synchronizers," O'Reilly Live Training, February 10th, 2020.
21. "Design Patterns in Java," O'Reilly Live Training, January 29th and 30th, 2020.
22. "Programming with Java 8 Lambdas and Streams," O'Reilly Live Training, January 22nd, 2020.
23. "Programming with Java 8 Lambdas and Streams," O'Reilly Live Training, January 22nd, 2020.
24. "Scalable Concurrency with the Java Executor Framework," O'Reilly Live Training, November 27th, 2019.
25. "Reactive Programming with Java 8 CompletableFutures," O'Reilly Live Training, November 18th, 2019.
26. "Programming with Java 8 Lambdas and Streams," O'Reilly Live Training, November 6th, 2019.
27. "Design Patterns in Java," O'Reilly Live Training, November 4th and 5th, 2019.
28. "Design Patterns in Java," O'Reilly Live Training, September 17th and 18th, 2019.
29. "Programming with Java 8 Lambdas and Streams," O'Reilly Live Training, September 3rd, 2019.
30. "Scalable Concurrency with the Java Executor Framework," O'Reilly Live Training, August 29th, 2019.
31. "Reactive Programming with Java 8 CompletableFutures," O'Reilly Live Training, August 15th, 2019.
32. "Design Patterns in Java," O'Reilly Live Training, July 29th and 30th, 2019.
33. "Reactive Programming with Java 8 CompletableFutures," O'Reilly Live Training, August 15th, 2019.
34. "Programming with Java 8 Lambdas and Streams," O'Reilly Live Training, July 2nd, 2019.
35. "Design Patterns in Java," O'Reilly Live Training, June 13th and 14th, 2019.
36. "Programming with Java 8 Lambdas and Streams," O'Reilly Live Training, May 16th, 2019.
37. "Reactive Programming with Java 8 CompletableFutures," O'Reilly Live Training, May 13th, 2019.
38. "Design Patterns in Java," O'Reilly Live Training, April 17th and 18th, 2019.
39. "Scalable Programming with Java 8 Parallel Streams," O'Reilly Live Training, March 27th, 2019.
40. "Scalable Concurrency with the Java Executor Framework," O'Reilly Live Training, March 12th, 2019.
41. "Programming with Java 8 Lambdas and Streams," O'Reilly Live Training, March 5th, 2019.
42. "Design Patterns in Java," O'Reilly Live Training, February 26th and 27th, 2019.
43. "Reactive Programming with Java 8 CompletableFutures," O'Reilly Live Training, February 19th, 2019.

44. "Scalable Concurrency with the Java Executor Framework," O'Reilly Live Training, February 5th, 2019.
45. "Programming with Java 8 Lambdas and Streams," O'Reilly Live Training, January 22nd, 2019.
46. "Design Patterns in Java," O'Reilly Live Training, January 7th and 8th, 2019.
47. "Scalable Concurrency with the Java Executor Framework," O'Reilly Live Training, December 11th, 2018.
48. "Programming with Java 8 Lambdas and Streams," O'Reilly Live Training, December 6th, 2018.
49. "Design Patterns in Java," O'Reilly Live Training, November 13th and 14th, 2018.
50. "Scalable Concurrency with the Java Executor Framework," O'Reilly Live Training, October 29th, 2018.
51. "Programming with Java 8 Lambdas and Streams," O'Reilly Live Training, October 16th, 2018.
52. "Reactive Programming with Java 8 CompletableFutures," O'Reilly Live Training, October 4th, 2018.
53. "Design Patterns in Java," O'Reilly Live Training, September 18th and 19th, 2018.
54. "Programming with Java 8 Lambdas and Streams," O'Reilly Live Training, September 4th, 2018.
55. "Reactive Programming with Java 8 CompletableFutures," O'Reilly Live Training, August 30th, 2018.
56. "Scalable Programming with Java 8 Parallel Streams," O'Reilly Live Training, August 20th, 2018.
57. "Programming with Java 8 Lambdas and Streams," O'Reilly Live Training, July 25th, 2018.
58. "Design Patterns in Java," O'Reilly Live Training, July 2nd and 3rd, 2018.
59. "Reactive Programming with Java 8 CompletableFutures," O'Reilly Live Training, June 26th, 2018.
60. "Scalable Programming with Java 8 Parallel Streams," O'Reilly Live Training, June 25th, 2018.
61. "Programming with Java 8 Lambdas and Streams," O'Reilly Live Training, June 8th, 2018.
62. "Design Patterns in Java," O'Reilly Live Training, May 24th and 25th, 2018.
63. "Reactive Programming with Java 8 CompletableFutures," O'Reilly Live Training, April 26th, 2018.
64. "Scalable Programming with Java 8 Parallel Streams," O'Reilly Live Training, April 17th, 2018.
65. "Programming with Java 8 Lambdas and Streams," O'Reilly Live Training, April 13th, 2018.
66. "Design Patterns in Java," O'Reilly Live Training, April 3rd, 2018.
67. "Reactive Programming with Java 8 CompletableFutures," O'Reilly Live Training, March 13th, 2018.
68. "Scalable Programming with Java 8 Parallel Streams: Part 2," O'Reilly Live Training, March 7th, 2018.
69. "Scalable Programming with Java 8 Parallel Streams: Part 1," O'Reilly Live Training, March 6th, 2018.
70. "Programming with Java 8 Lambdas and Streams," O'Reilly Live Training, March 1st, 2018.
71. "Reactive Programming with Java 8 CompletableFutures," O'Reilly Live Training, February 13th, 2018.
72. "Scalable Programming with Java 8 Parallel Streams," O'Reilly Live Training, February 6th, 2018.
73. "Programming with Java 8 Lambdas and Streams," O'Reilly Live Training, February 1st, 2018.
74. "Programming with Java 8 Lambdas and Streams," O'Reilly Live Training, January 12th, 2018.
75. "Scalable Programming with Java 8 Parallel Streams," O'Reilly Live Training, January 10th, 2018.
76. "Reactive Programming with Java 8 CompletableFutures," O'Reilly Live Training, January 9th, 2018.
77. "Reactive Programming with Java 8 Completable Futures," O'Reilly Live Training, October 23rd, 2017.
78. "Programming with Java 8 Lambdas and Streams," O'Reilly Live Training, October 19th, 2017.

79. "Scalable Programming with Java 8 Parallel Streams," O'Reilly Live Training, October 17th, 2017.
80. "Java 8 Concurrency," O'Reilly Live Training, September 7-8th, 2017.
81. "Java 8 Concurrency," O'Reilly Live Training, August 30-31st, 2017.
82. "Java 8 Concurrency," O'Reilly Live Training, June 28-29th, 2017.
83. "The C++ Standard Template Library," Qualcomm, San Diego, February 16-19, 2016.
84. "The C++ Standard Template Library," Qualcomm, San Diego, October 13-16, 2015.
85. "The C++ Standard Template Library," Qualcomm, San Diego, October 13-16, 2015.
86. "Pattern-Oriented Java Concurrency," InformIT Webinar, May 14th, 2015.
87. "Pattern-Oriented Concurrent Programming with Java," OOP Conference, Munich, Germany, January 30th, 2015.
88. "Concurrent Programming in Android," OOP Conference, Munich, Germany, January 29th, 2015.
89. "The C++ Standard Template Library," Qualcomm, San Diego, October 14-17, 2014.
90. "The C++ Standard Template Library," Qualcomm, San Diego, August 5-8, 2014.
91. "Pattern-Oriented Software Architecture for Concurrent and Networked Software," July 28-31, 2014.
92. "The C++ Standard Template Library," Qualcomm, San Diego, August 5-8, 2014.
93. "The C++ Standard Template Library," Qualcomm, India, March, 2014.
94. "The C++ Standard Template Library," Qualcomm, San Diego, CA, January 23-34, 2014.
95. "The C++ Standard Template Library," Qualcomm, San Diego, CA, October 16-17th, 2013.
96. "Patterns and Frameworks for Concurrent and Networked Software," 2013 International Summer School on Trends in Computing Tarragona, Spain, July 25-26, 2013.
97. "The C++ Standard Template Library," Qualcomm, San Diego, CA, January 23-24th, 2013.
98. "The C++ Standard Template Library," Qualcomm, San Diego, CA, October 4-5th, 2012.
99. "Embedded Systems Patterns for C Developers," Qualcomm, San Diego, CA, August 28th, September 11th, September 25th, October 9th, October 23rd, and November 6th, 2012.
100. "Embedded Systems Patterns for C Developers," Qualcomm, San Diego, CA, August 14-15th, 2012.
101. "The C++ Standard Template Library," Qualcomm, San Diego, CA, May 15-18th, 2012.
102. "The C++ Standard Template Library," Qualcomm, San Diego, CA, January 25-26th, 2012.
103. "Object-Oriented Software Patterns and Frameworks," Qualcomm, San Diego, CA, October 11-12th, 2011.
104. "The C++ Standard Template Library," Qualcomm, San Diego, CA, May 11-12th, 2011.
105. "The C++ Standard Template Library," Qualcomm, San Diego, CA, January 25-26, 2011.
106. "Pattern-Oriented Software Architecture: A Pattern Language for Concurrent and Networked Software," SPLASH 2010, October 17-21, 2010, Reno, Nevada.
107. "Pattern-Oriented Software Architectures - Patterns and Frameworks for Concurrent and Networked Software," ProObject, Hanover, MD, August 11th, 2010.
108. "Pattern-Oriented Software Architecture: Patterns for Concurrent and Networked Embedded Systems," Qualcomm, Bangalore, India, June 21-22, 2010.
109. "Pattern-Oriented Software Architecture: Patterns for Concurrent and Networked Embedded Systems," Qualcomm, Hyderabad, India, June 24-25, 2010.
110. "Pattern-Oriented Software Architecture: A Pattern Language for High Quality and Affordable Distributed Computing Systems," IEEE Webinar Series, June 10th, 2010.
111. "The C++ Standard Template Library," Qualcomm, San Diego, CA, May 12-13, 2010.
112. "The C++ Standard Template Library," Qualcomm, San Diego, CA, December 16-17, 2009.
113. "Pattern-Oriented Software Architecture: A Pattern Language for Distributed Computing," OOPSLA 2009, Orlando, FL, October, 2009.

114. "The C++ Standard Template Library," Qualcomm, San Diego, CA, September 15-16, 2009.
115. "Networked Embedded Systems Patterns for C Developers," Qualcomm, San Diego, CA, June 11-12, 2009.
116. "Pattern-Oriented Software Architecture: A Pattern Language for Distributed Computing," Software Architecture Technology Users' Network (SATURN) workshop May 5, 2009 in Pittsburgh, PA.
117. "The C++ Standard Template Library," Qualcomm, San Diego, CA, January 29-30, 2009.
118. "Pattern-Oriented Software Architecture: A Pattern Language for Distributed Computing," IEEE Webinar Series, January 8th, 2009.
119. "Pattern-Oriented Software Architecture: A Pattern Language for Distributed Computing," OOPSLA 2008, Nashville, TN, October 20, 2008.
120. "The Data Distribution Service for Real-time Systems," OOPSLA 2008, Nashville, TN, October 19, 2008.
121. "Object-Oriented Patterns for Concurrent and Networked Applications," Qualcomm, San Diego, CA, August 5-6th, 2008.
122. "The C++ Standard Template Library," Qualcomm, San Diego, NJ, July 29-30, 2008.
123. "Object-Oriented Patterns and Frameworks with C++," Qualcomm, San Diego, CA, June 12-13, 2008.
124. "The C++ Standard Template Library," Qualcomm, New Jersey, May 5-6, 2008.
125. "Pattern-Oriented Software Architecture: A Pattern Language for Distributed Computing," Software Architecture Technology Users' Network (SATURN) workshop April 28 - May 1, 2008 in Pittsburgh, PA.
126. Developing Distributed Computing Systems with Patterns and Middleware, UCLA Extension, February 19-21, 2008.
127. Pattern-Oriented Software Architecture: A Pattern Language for Distributed Computing, OOPSLA 2007, Montreal, CA, October 24, 2007.
128. Object-Oriented Design and Programming with Patterns, Frameworks, and Middleware, Qualcomm, New Jersey, September 27-28, 2007.
129. Object-Oriented Design and Programming with Patterns, Frameworks, and Middleware, Qualcomm, San Diego, CA, August 21-22, 2007.
130. Lightweight CORBA Component Model, 8th OMG Real-time/Embedded CORBA workshop, Washington DC, July 9–12, 2007.
131. Model-Driven Engineering for Distributed Real-time and Embedded Systems, 13th IEEE Real-Time and Embedded Technology and Applications Symposium (RTAS 2007), Bellevue, WA, United States April 3-6, 2007.
132. "Improving Product Reliability and ROI Through Effective Software Reuse," Qualcomm, San Diego, CA, March 27th, 2007.
133. "Developing Distributed Computing Systems with Patterns and Middleware," UCLA Extension, February 21-23, 2007.
134. "POSA: Patterns for Concurrent and Distributed Systems," OOP, Munich, Germany, January 22, 2007.
135. "Meeting the Challenges of Software-Intensive Embedded Systems," OOP, Munich, Germany, January 23, 2007.
136. "Object-Oriented Design and Programming with Patterns, Frameworks, and Middleware," Qualcomm, San Diego, CA, January 10-11, 2007.
137. "Model-Driven Development of Distributed Systems," OOPSLA 2006, Portland, OR, October 22-26, 2006.
138. "Pattern-Oriented Software Architecture: Patterns for Concurrent and Networked Objects," OOPSLA 2006, Portland, OR, October 22-26, 2006.

139. "Model-Driven Engineering of Distributed Systems," MODELS 2006, Genova, Italy, October 1, 2006.
140. "Distributed Real-time and Embedded Systems," Advanced Institute of Information Technology, Seoul, Korea, August 7-11 2006.
141. "Lightweight CORBA Component Model," 7th OMG Real-time/Embedded CORBA workshop, Washington DC, July 10–13, 2006.
142. "How to Use ACE Effectively," Trion World Network, Austin, TX, June 19-21, 2006.
143. "Improving Product Reliability and ROI Through Effective Software Reuse," Qualcomm, San Diego, CA, June 15, 2006.
144. "Object-Oriented Design and Programming with Patterns, Frameworks, and Middleware," Qualcomm, San Diego, CA, June 13-14, 2006.
145. "Object-Oriented Design and Programming with Patterns, Frameworks, and Middleware," Qualcomm, San Diego, CA, Feb 9-10, 2006.
146. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems, University of California, Los Angeles Extension, January 18-20st, 2006."
147. "Model Driven Development of Distributed Real-time and Embedded Systems," at the OOP conference, January 17, 2006, Munich, Germany.
148. "Pattern-Oriented Software Architecture," at the OOP conference, January 16, 2006, Munich, Germany.
149. "Model Driven Development: State of the Art," at the OOP conference, January 16, 2006, Munich, Germany.
150. "Concurrent C++ Network Programming with Patterns and Frameworks," C++ Connections: 20 Years of C++ conference, November 11, 2005, Mandalay Bay, Las Vegas, NV.
151. "Pattern-Oriented Software Architecture: Patterns for Concurrent and Distributed Systems," OOPSLA 2005, San Diego, October 17th, 2005.
152. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," BAE Systems, Greenlawn, New York, August 25, September 2-3.
153. "Lightweight CORBA Component Model," 6th OMG Real-time/Embedded CORBA workshop, Washington DC, July 11–14, 2005.
154. "Model Driven Development for Distributed Real-time and Embedded Systems," OMG Information Days: MDA - Frankfurt, Germany, June 9th, 2005
155. "Model Driven Development for Distributed Real-time and Embedded Systems," OMG Information Days: MDA - Munich, Germany, June 7th, 2005.
156. "Model Driven Development for Distributed Real-time and Embedded Systems," OMG Information Days: MDA - Zurich, Switzerland, June 1st, 2005.
157. Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," BAE Systems, Wayne, New Jersey, May 13, 16, 19, 23, 27, 2005.
158. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," BAE Systems, Wayne, New Jersey, February 18th, February 22nd, March 1, 8, and 15 2005.
159. "Pattern-Oriented Software Architectures for Distributed Systems" the OOP conference, January 28, 2005, Munich, Germany.
160. "Research on Model Driven Development of Distributed Real-time and Embedded Systems," the OOP conference, January 26, 2005, Munich, Germany.
161. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," University of California, Los Angeles Extension, January 19-21st, 2005.
162. Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems, BAE Systems, Wayne, New Jersey, October 29, November 1, 8, 15, 22, 2004.
163. "Pattern-Oriented Software Architectures for Distributed Systems," OOPSLA 2004, Vancouver, British Columbia, October 25th, 2004.

164. "Notes on the Forgotten Craft of Software Architecture", OOPSLA 2004, Vancouver, British Columbia, October 25th, 2004.
165. "Model Driven Architecture with QoS-enabled component middleware," MDE for Embedded Systems, Brest, France, September 10th 2004.
166. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," Qualcomm, San Diego, CA, Jan 7-6, 2005.
167. "Object-Oriented Design and Programming with Patterns, Frameworks, and Middleware," Qualcomm, San Diego, CA, Jan 9-10, 2005.
168. "Using the Lightweight CORBA Component Model to Develop Distributed Real-time and Embedded Applications," OMG Workshop on Distributed Object Computing for Real-time and Embedded Systems, July 12th, 2004, Reston, VA.
169. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," University of California, Los Angeles Extension, July 7-9th, 2004.
170. Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems, University of California, Los Angeles Extension, January 21st-23rd, 2004.
171. Patterns and Frameworks for Concurrent Distributed Systems, SIGS OOP Conference, Munich, Germany, January 19th, 2004.
172. Middleware for Distributed Real-time and Embedded Systems, SIGS OOP Conference, Munich, Germany, January 19th, 2004.
173. "Pattern-Oriented Software Architectures for Networked and Concurrent Applications," OOPSLA 2003, Anaheim, CA, October 27, 2003.
174. The JAOO 2003 conference, September 22-26, Aarhus, Denmark.
175. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," University of California, Los Angeles Extension, July 9-11th, 2003.
176. "Patterns, Frameworks, and Middleware: Their Synergistic Relationship," Frontiers of Software Practice, International Conference on Software Engineering, Portland, Oregon, May 7, 2003.
177. "Pattern-Oriented Distributed Systems Architecture," International Conference on Software Engineering, Portland, Oregon, May 5, 2003.
178. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," University of California, Los Angeles Extension, January 22nd-24th, 2003.
179. "Patterns and Application Experiences for Real-time Object Request Brokers," OOPSLA 2002, Seattle, Washington, November, 2002.
180. "Pattern-Oriented Software Architectures for Networked and Concurrent Applications," OOPSLA 2002, Seattle, Washington, November, 2002.
181. Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems, Raytheon, St. Petersburg, FL, September 3–5, 2003.
182. Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems, University of California, Los Angeles Extension, July 22nd-24th, 2002.
183. "Policies and Patterns for High-performance, Real-time Object Request Brokers," Mercury Computer Systems, Tysons Corner, VA, November Feb 7, 2002.
184. Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems, University of California, Los Angeles Extension, January 23rd-25th, 2002.
185. "Policies and Patterns for High-performance, Real-time Object Request Brokers," Raytheon, Rosslyn, VA, November 12th, 2001.
186. "Pattern-Oriented Software Architecture: Patterns for Concurrent and Networked Objects," OOPSLA 2001, October 15th, 2000, Minneapolis, Minnesota.
187. "Policies and Patterns for High-performance, Real-time Object Request Brokers," International Symposium on Distributed Object Applications (DOA), Rome, September 17-20, 2001.
188. "Policies and Patterns for QoS-enabled Middleware," The JAOO 2001 conference, September 10-14, Aarhus, Denmark.

189. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," University of California, Los Angeles Extension, July 23rd-25th, 2001.
190. "Policies and Patterns for High-performance, Real-time Object Request Brokers," OMG Second Workshop on Real-time and Embedded Distributed Object Computing on June 4-7, 2001 in Herndon, VA, USA.
191. "Design Patterns for Understanding Middleware and Component Infrastructures," 6th USENIX Conference on Object-Oriented Technologies and Systems, January 29, 2001, San Antonio, TX.
192. "Principles and Patterns of High-performance, Real-time Object Request Brokers," OOP conference, Munich, Germany, January 23, 2001.
193. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," University of California, Los Angeles Extension, January 3-5, 2001.
194. "Patterns for Concurrent and Distributed Objects," OOPSLA 2000, October 16th, 2000, Minneapolis, Minnesota.
195. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," University of California, Berkeley Extension, May 24-26, 2000.
196. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," Jet Propulsion Laboratory, Pasadena, CA, April, 2000.
197. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," University of California, Los Angeles Extension, March 27-31, 2000.
198. "Optimizing Middleware to Support High-Performance Real-time Distributed and Embedded Systems," OOP conference, Munich, Germany, January 27, 2000.
199. "Effective Architectures for DOC," OOP conference, Munich, Germany, January 24, 2000.
200. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," University of California, Berkeley Extension, December 13-15, 1999.
201. "Middleware Techniques and Optimizations for Real-time Embedded Systems," 12th International Symposium On System Synthesis, IEEE, San Jose, CA, USA November, 11, 1999
202. "Patterns and Principles of Real-time Object Request Brokers," OOPSLA 1999, ACM, Denver, Colorado, November 1-5, 1999.
203. "Using Design Patterns, Frameworks and CORBA to Reduce the Complexity of Developing Reusable Large-Scale Object-Oriented Concurrent Communication Components and Systems," Fifth IEEE International Conference on Engineering of Complex Computer Systems, Las Vegas, Nevada, October 18-21, 1999
204. "Distributed Technologies," Motorola, Schaumburg, IL, August 10-12, 1999.
205. "Patterns and Principles of Real-time Object Request Brokers," the 3rd Components Users Conference, SIEMENS, Munich, Germany, July 12th, 1999.
206. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," Lucent, Naperville, IL, June 23-24 and June 30 - July 1st, 1999.
207. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," Motorola Software Symposium, Ft. Lauderdale, Florida, June 21st, 1999.
208. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," University of California Los Angeles Extension, June 2-4, 1999.
209. "Concurrent Object-Oriented Network Programming and Distributed Object Computing," University of California Berkeley Extension, May 19-21, 1999.
210. "Patterns and Principles of Real-time Object Request Brokers," 5th USENIX Conference on Object-Oriented Technologies and Systems, May 4, 1999, San Diego, CA.
211. "Real-time CORBA for Telecom – Fact or Fiction?" Nortel Design Forum, Ottawa, CA, April 22, 1999.
212. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," Lucent, Columbus, OH, March 18-19 and 25-26, 1999.

213. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," Lucent, Holmdel, NJ, March 1-4, 1999.
214. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," Lucent/Octel, Milpitas, CA, December 14-16, 1998.
215. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," University of California Los Angeles Extension, December 8-10, 1998.
216. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," Motorola, Schaumburg, IL, December 2-4, 1998.
217. "Concurrent Object-Oriented Network Programming and Distributed Object Computing," University of California Berkeley Extension, November 16-18, 1998.
218. "Using Design Patterns and Frameworks to Develop Object-Oriented Communication Software," OOPSLA 1998, October 19th, 1998, Vancouver, British Columbia.
219. "High-Performance CORBA," Lucent CORBA Forum, Holmdel, NJ, September 29, 1998.
220. "Writing Efficient Multi-Thread CORBA Applications," the 3rd Components Users Conference, SIEMENS, Munich, Germany, July 10, 1998.
221. "Using Design Patterns and Frameworks to Develop Object-Oriented Communication Software," UCLA extension course, Milan, Italy, June 29 - July 1, 1998.
222. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," Lucent, Naperville, IL, June 8-11, 1998.
223. "Patterns and Performance of Real-time Object Request Brokers," Fourth IEEE Real-Time Technology and Applications Symposium (RTAS), Denver, Colorado, June 5, 1998.
224. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," University of California Los Angeles Extension, June 1-3, 1998.
225. "Patterns and Principles of Real-time Object Request Brokers," NSA, Ft. Meade, MD, March 22, 1998.
226. Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems, Crosskeys, Ottawa Canada, March 19-21, 1998.
227. "Concurrent Object-Oriented Network Programming and Distributed Object Computing," University of California Berkeley Extension, March 4-6, 1998.
228. "Building Distributed Communication Software with CORBA," the Motorola Systems Symposium, February, 1998, Austin, Texas, USA.
229. "Introduction to Distributed Objects with CORBA," SIGS OOP '98, February 9-13, 1998, Munich, Germany.
230. "Design Patterns for Developing and Using CORBA Object Request Brokers," SIGS OOP '98, February 9-13, 1998, Munich, Germany.
231. Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems, Lucent Technologies, Whippany, NJ, January 5-6, 1998.
232. "Using Design Patterns, Frameworks, and CORBA to Develop Object-Oriented Communication Systems," University of California Los Angeles Extension, December 10-12, 1997.
233. "Concurrent Object-Oriented Network Programming and Distributed Object Computing," University of California Berkeley Extension, December 10-12, 1997.
234. "Using Design Patterns and Frameworks to Develop Object-Oriented Communication Systems," Motorola Cellular Infrastructure Group, Arlington Heights, Illinois, December 1 - 3, 1997.
235. "Using Design Patterns and Frameworks to Develop Object-Oriented Communication Systems," TOOLS Pacific '97, Melbourne, Australia November 24 - 27, 1997.
236. "Using Design Patterns and Frameworks to Develop Object-Oriented Communication Systems" for the IEEE GLOBECOM '97 conference, Phoenix, AZ, November 4-8, 1997.
237. "High-performance Distributed Object Computing with CORBA," IEEE International Conference on Network Protocols, Atlanta, GA, October 28th, 1997.

238. "Using Design Patterns and Frameworks to Develop Object-Oriented Communication Systems," OOPSLA 1997, ACM, Atlanta, GA, October 6-7th, 1997.
239. "Using Design Patterns and Frameworks to Develop Object-oriented Communication Systems," 24th International Conference on Technology of Object-Oriented Languages and Systems (TOOLS Asia '97). Beijing, China, September 22, 1997.
240. "Principles and Patterns of Distributed Object Computing Systems," for the ACM Principles of Distributed Computing Conference (PODC), Santa Barbara, CA, August 21st, 1997.
241. "Distributed Object Computing with CORBA and ACE," Alta Software, Jacksonville, FL, June 4-5th, 1997.
242. "Distributed Object Computing with CORBA", Object Expo, NY, NY, June 2nd, 1997.
243. "Concurrent Object-Oriented Network Programming and Distributed Object Computing," University of California Berkeley Extension, May 28-30, 1997.
244. "Patterns and Principles of Real-time Object Request Brokers," National Security Agency, Ft. Meade, MD, May 13th, 1997.
245. "Building Distributed Communication Software with CORBA," the Motorola Systems Symposium, March, 1997, Chandler, AZ, USA.
246. "Evaluating Concurrency Models for CORBA Servers," the 2nd Components Users Conference, SIEMENS, Munich, Germany, July 14th, 1997.
247. "Design Patterns for Evolving System Software Components from UNIX to Windows NT," the 2st Components Users Conference, SIEMENS, Munich, Germany, July 14th, 1997.
248. "Techniques and Patterns for Distributed Object Computing with CORBA and C++," University of California Berkeley Extension, December 4-6, 1996.
249. "Design Patterns for Concurrent Object-Oriented Programming with ACE and C++," C++ World, Dallas, TX, November 11th, 1996.
250. "Implementing Concurrent CORBA Applications with Multi-Threaded Orbix and ACE," C++ World, Dallas, TX, November 12th, 1996.
251. "Why Reuse has Failed, and How You Can Make it Work for You," Berne Technology Forum 1996, Berne, Switzerland, October 18, 1996.
252. "Introduction to Distributed Object Programming with CORBA," the Local Computer Networks '96 conference, IEEE, Minneapolis, Minnesota, October 13, 1996.
253. "Object-Oriented Design Patterns for Concurrent, Parallel, and Distributed Systems," the OOPSLA 1996 conference, ACM, San Jose, California, October, 1996.
254. "OO Design Patterns Network Programming in C++," Object Expo Europe, London, England, September 23rd, 1996.
255. "Effective Multithreaded CORBA Programming," Object Expo Europe, London, England, September 24th, 1996.
256. "Workshop on Object Oriented Technologies," Mitsubishi, July 22nd to July 26th, 1996, Kobe, Japan.
257. "Evaluating Concurrency Models for CORBA Servers," the 1st Components Users Conference, SIEMENS, Munich, Germany, July 15th, 1996.
258. "Design Patterns for Evolving System Software Components from UNIX to Windows NT," the 1st Components Users Conference, SIEMENS, Munich, Germany, July 15th, 1996.
259. "OO Design Patterns for Concurrent, Parallel, and Distributed Systems," the 2^{nd} *Conference on Object-Oriented Technology*, USENIX, Toronto, Canada, June 17, 1996.
260. "OO Design Patterns for Concurrent, Parallel, and Distributed Systems," the 3^{rd} *Conference on Object-Oriented Technology*, USENIX, Portland, Oregon, June 16th, 1996.
261. "OO Design Patterns for Network Programming in C++," the *Object Expo '96 Conference*, SIGS, Sydney, Australia, June 3^{rd}, 1996.
262. "Effective Multi-threaded CORBA Programming Programming," the *Object Expo '96 Conference*, SIGS, Sydney, Australia, June 5^{th}, 1996.

263. "Concurrent Object-oriented Network Programming with C++," University Of California Berkeley Extension, Berkeley, California, May $22^{nd} - -24^{th}$, 1996.
264. "Experience Developing Reusable Software Using Object-Oriented Design Patterns and Frameworks," the 4^{th} *International Conference on Software Reuse*, Orlando, Florida, USA April 23-26, 1996.
265. "Techniques for Object-Oriented Network Programming," the *OOP Conference*, SIGS, Munich, Germany, Feb 14th, 1996.
266. "Using Object-Oriented Design Patterns to Develop Large-Scale Distributed Systems," the *OOP Conference*, SIGS, Munich, Germany, Feb 13^{th}, 1996.
267. "Concurrent Object-oriented Network Programming with C++," University Of California Berkeley Extension, Berkeley, California, November 30th-December 1st, 1995.
268. "Using Object-Oriented Design Patterns to Develop Large-Scale Distributed Systems," the 4^{th} *C++ World Conference*, SIGS, Chicago, Illinois, October 31st, 1995.
269. "Techniques for Object-Oriented Network Programming," the 4^{th} *C++ World Conference*, SIGS, Chicago, Illinois, October 31st, 1995.
270. "Experience using OO Design Patterns to Develop Large-scale Distributed Communication Systems," *OOPSLA 1995 Conference* in Austin, Texas, October 1995.
271. "Concurrent Object-oriented Network Programming with C++," the 9^{th} *European Conference on Object-Oriented Programming (ECOOP)*, Aarhus, Denmark, August, 1995.
272. "Concurrent Object-Oriented Network Programming with C++," the 1^{st} *Conference on Object-Oriented Technology*, USENIX, Monterey, California, June 23, 1995.
273. "Design Patterns for Concurrent and Distributed Systems," the *Object Expo '95 Conference*, SIGS, New York, NY, June 5^{th} 1995.
274. "Object Oriented Network Programming," the *Object Expo '95 Conference*, SIGS, New York, NY, June 5^{th}, 1995.
275. "Software Construction with Active Objects in C++," the *OOP '95 Conference*, SIGS, Munich, Germany January 31, 1995.
276. "Object-Oriented Concurrent Programming with C++," the *OOP '95 Conference*, SIGS, Munich, Germany January 31, 1995.
277. "Concurrent Object-Oriented Programming," the *Winter USENIX Conference*, USENIX, New Orleans, Louisiana, January, 1995.
278. "Object-Oriented Network Programming with C++," the 3^{rd} *C++ World Conference*, SIGS, Austin, Texas, November 14, 1994.
279. "Object-Oriented Techniques for Dynamically Configuring Concurrent Distributed Applications," the 9^{th} *OOPSLA 1994*, ACM, Portland, Oregon, October 23, 1994.
280. "Object-Oriented Network Programming," the 6^{th} *C++ Conference*, USENIX, Cambridge, Massachusetts, April 11, 1994.
281. "Object-Oriented Techniques for Developing Extensible Network Servers," the 2^{nd} *C++ World Conference*, SIGS, Dallas, Texas, October 19, 1993.

Professional Activities

Editorial Activities

1. Guest co-editor for a special issue of the Springer Journal Annals of Telecommunications on "Middleware for Internet distribution in the context of Cloud Computing and the Internet of Things," 2016, with Gordon Blair and Chantal Taconet.
2. Guest co-editor of the Proceedings of the IEEE special issue on Applications of Augmented Reality Environments, 2014.
3. Guest co-editor of the International Journal of Network Protocols and Algorithms (NPA) Special Issue on Data Dissemination for Large scale Complex Critical Infrastructures, 2010.

4. Wrote the foreword to the book *Patterns of Parallel Software Design* by Jorge Luis Ortega Arjona, Wiley, 2010.
5. Editorial board member of the Springer Journal of Internet Services and Applications (JISA).
6. Editorial board member of the Transactions on Pattern Languages of Programming (TPLoP) published by Springer-Verlag.
7. Wrote the foreword to the book *Practical Software Factories in .NET*, by Gunther Lenz and Christoph Wienands, Apress, 2006.
8. Guest editor of the IEEE Computer Special Issue on Model Driven Development, February 2006.
9. Guest co-editor of IEEE Network special issue on "Middleware Technologies for Future Communication Networks," February 2004 (co-editors with Gordon Blair and Andrew Campbell).
10. Editorial board member of the Springer Journal of Aspect-Oriented Software Development.
11. Wrote the foreword to the book *Fundamentals of Distributed Object Systems: The CORBA Perspective*, by Zahir Tari and Omran Bukhres, Wiley and Sons, 2001.
12. Wrote the foreword to the book *Design Patterns in Communication Software*, edited by Linda Rising, Cambridge University Press, 2000.
13. Guest editor of the Special Issue on Components and Patterns for *The Journal of Theory and Practice of Object Systems*, Wiley & Sons, to appear 2002.
14. Invited editorial on "Trends in Distributed Object Computing" for the special issue on Distributed Object-Oriented Systems appearing in the Parallel and Distributed Computing Practices journal, edited by Maria Cobb and Kevine Shaw, Vol. 3, No. 1, March 2000.
15. Co-editor of "Building Application Frameworks: Object-Oriented Foundations of Framework Design," John Wiley & Sons, 1999 (co-editors are Mohamed Fayad and Ralph Johnson), ISBN 0-471-24875-4.
16. Co-editor of "Implementing Application Frameworks: Object-Oriented Frameworks at Work," John Wiley & Sons, 1999 (co-editors are Mohamed Fayad and Ralph Johnson), ISBN 0-471-25201-8.
17. Guest editor of the Special Issue on OO Application Frameworks for the Communications of the ACM, (co-editor Mohamed Fayad), ACM, October, 1997.
18. Guest editor of the special issue on Distributed Object Computing for USENIX Computing Systems Journal, November/December, 1996.
19. Guest editor of a feature topic on Distributed Object Computing for IEEE Communications Magazine, February, 1997.
20. Wrote the foreward for Dr. Nayeem Islam's book on *Distributed Objects: Methodologies for Customizing Operating Systems* (IEEE Computer Society Press, 1996).
21. Guest editor of the Special Issue on Patterns and Pattern Languages for Communications of the ACM, (co-editors Ralph Johnson and Mohamed Fayad), ACM, October, 1996.
22. Co-editor of a book entitled "Pattern Languages of Program Design," Addison-Wesley, 1995 (co-editor is Jim Coplien, Bell Labs).
23. Editor of the Patterns++ section of the C++ Report Magazine, April 1997 - March 1998.
24. Editor-in-chief of the C++ Report Magazine, January 1996 - February 1997.
25. Editorial board member of the IEEE Computer Society - Computer Science & Engineering Practice Board.

Program Chairmenships and Conference Organization

1. Chair of the DoD Organic Software Infrastructure Workshop, Arlington VA, August 13th, 2018.
2. General Chair of the Software Product Line Conference, Nashville TN, July/August, 2015.
3. Program Chair of the Interoperable Open Architecture 2013 conference, September 10-11, 2013, Washington, DC.
4. Program Chair of the NSF Workshop on Computing Clouds for Cyber-Physical Systems, March 15th, 2013, Ballston, VA.

5. Program Chair of the Interoperable Open Architecture 2012 conference, October 29-31, 2012, London, UK.
6. Program co-chair for the 1st International Symposium on Secure Virtual Infrastructures (DOA-SVI'11), 17-19 Oct 2011, Crete, Greece.
7. Program co-chair for the COMmunication System softWAre and middleware (Comsware) conference, Helsinki, Finland, August 2010.
8. Doctoral symposium chair for OOPSLA 2009, Orlando Floria, October 25-29, 2009.
9. General co-chair for the 3rd ACM International Conference on Distributed Event-Based Systems (DEBS 2009), July 6-9, 2009 - Nashville, TN, USA.
10. Member of the ISORC 2009 advisory and publicity committee for ISORC 2009, March 17-20, 2009, Toyko, Japan.
11. Area Coordinator for the Integrating Systems of Systems using Services topic at the 6th International Conference on Service Oriented Computing, Sydney (Australia), December 1st - 5th, 2008.
12. Member of the Advisory and Publicity Committee for ISORC 2008, Orlando, Florida, May 5 -7, 2008.
13. Co-chair of the Middleware for Network Eccentric and Mobile Applications (MiNEMA.08) Workshop co-located with ACM EuroSys Conference, March 31 - April 1, 2008, Glasgow, Scotland.
14. General chair of the ACM/IEEE 10th International Conference on Model Driven Engineering Languages and Systems (MODELS 2007), Nashville TN, September 30-October 5, 2007.
15. Area co-coordinator for the Quality of Service research track at the The Fifth International Conference on Service-Oriented Computing, September 17-20, 2007, Vienna, Austria.
16. Program co-chair of the NSF workshop on New Research Directions in Composition and Systems Technology for High Confidence Cyber Physical Systems, July 9, 2007.
17. Program co-chair for the Science of Design Principal Investigators workshop, February 28 to March 2, 2007.
18. Program co-coordinator for SOA Runtime area of the 4th International Conference on Service Oriented Computing Chicago, USA, December 4-7, 2006.
19. Program co-chair of the NSF/NCO Workshop on High-Confidence Software Platforms for Cyber-Physical Systems (HCSP-CPS) Workshop systems, November 30th to December 1st, 2006, Alexandria, VA.
20. Panels chair for the MoDELS 2006 conference, Genova Italy, Oct. 2-6, 2006.
21. Program Co-Chair of the Generative Programming and Component Engineering (GPCE) Conference, Portland, OR, October 2006 (collocated with OOPSLA '06).
22. Program Chair of the NSF/NCO Workshop on New Research Directions in High Confidence Software Infrastructure for Distributed Real-time and Embedded (DRE) systems, July 10th, 2006, Fairfax VA.
23. Program Co-Chair of the NSF/NCO High Confidence Medical Device Software and Systems (HCMDSS) Workshop, May 2005, University of Pennsylvania, Philadelphia, Pennsylvania.
24. Track Vice Chair for Real-time Middleware and Software Engineering for the Real-time Systems Symposium, Lisbon, Portugal, December, 2004.
25. Program Co-chair for the NSF/NCO Planning Meeting for the High Confidence Medical Device Software and Systems (HCMDSS) Workshop, November 16-17, 2004, Arlington, VA.
26. Program chair for 19th Annual ACM SIGPLAN Conference on Object-Oriented Programming, Systems, Languages, and Applications (OOSPLA), October 24-28, 2004, Vancouver, British Columbia, Canada.
27. General co-chair of the IEEE Real-Time and Embedded Technology and Applications Symposium, May 25 – 28, 2004, Toronto, Canada.
28. Program chair of the CCM Workshop, December 10th, 2003, Nashville, TN.
29. General co-chair for the 5th International Symposium on Distributed Objects and Applications, November 3–7 2003, Catania, Sicily.

30. Program co-chair of the 3rd TAO Workshop, July 18, 2002, Arlington, VA.
31. Program co-chair for Middleware 2003, 4th IFIP/ACM/USENIX International Conference on Distributed Systems Platforms, June 16-20, 2003, Rio de Janeiro, Brazil.
32. Program co-chair for the 9th IEEE Real-time/Embedded Technology and Applications Symposium (RTAS), May 27-30, 2003, Washington, DC.
33. Area vice-chair and session chair for Middleware at the 23rd IEEE International Conference on Distributed Computing Systems (ICDCS), May 19-22nd, 2003, Providence, RI.
34. Program co-chair of the IEEE Workshop on LargeScale Real-Time and Embedded Systems, December 2, 2002, Austin, TX.
35. Program co-chair for the 4th International Symposium on Distributed Objects and Applications, October 28–November 1, 2002, Irvine, CA.
36. Co-organizer of the cross-agency Software Design and Productivity Coordinating Group Workshop on New Visions for Software Design and Productivity: Research and Applications, December 13-14, Nashville, TN.
37. Program co-chair for the 3rd International Symposium on Distributed Objects and Applications, September 18-20, 2001, Rome, Italy.
38. Co-organizer of the cross-agency Workshop on New Visions for Software Design and Productivity, April 18-19, 2000, Ballston, VA.
39. Area vice-chair and session chair for Middleware at the IEEE International Conference on Distributed Computing Systems, April 16-19, Phoenix, AZ, 2001.
40. Tutorial chair for the 6th USENIX Conference on Object-Oriented Technologies and Systems, January 27 - February 3, 2001, San Antonio, TX.
41. Co-chair of the OMG Workshop on Real-time and Embedded CORBA, in Reston, VA, July 24-27, 2000.
42. General chair of the IFIP/ACM International Conference Middleware 2000 in New York, April, 2000.
43. Tutorial chair for the 5^{th} USENIX Conference on Object-Oriented Technologies and Systems, May 3-7, 1999, San Diego, CA.
44. Treasurer for the Fourth International Workshop on Object-oriented Real-time Dependable Systems (WORDS'99) January 27-29, 1999, Radisson Hotel, Santa Barbara, California, USA.
45. Tutorial chair for the 4^{th} USENIX Conference on Object-Oriented Technologies and Systems, April 27-30, 1998, Santa Fe, New Mexico.
46. Co-chair of the mini-track on Engineering Client-Server Systems for the HICSS-31 conference, the Big Island of Hawaii - January 6-9, 1998.
47. Tutorial chair for the 3^{rd} USENIX Conference on Object-Oriented Technologies and Systems, Portland, OR, June 1997.
48. Publicity chair for the 5^{th} IEEE International Workshop on Object-Orientation in Operating Systems, IEEE TCOS and USENIX, Seattle, Washington, October 27-28, 1996.
49. Program chair for 3^{rd} conference on Programming Languages of Programming, Allerton, IL, USA, September, 1996.
50. Program chair for the 2^{nd} USENIX Conference on Object-Oriented Technologies, June 1996.

Professional Service and Advisory Positions

1. Member of the Fraunhofer Advisory Board for the University of Maryland, College Park.
2. Member of the steering committee for the Software Product-Line Conference series.
3. Member of the Future Airborne Capabilities Environment (FACE) Advisory Board.
4. Vice-Chair of the Cyber Situation Awareness study for the Air Force Scientific Advisory Board.
5. Member of the Joint Tactical Radio System (JTRS) Tiger Team in support of the Assistant Secretary of the Army, Acquisition, Logistics, and Technology.

6. Member of the Air Force Scientific Advisory Board.
7. Member of the advisory board for the NSF-sponsored Repository for Model-Driven Development (ReMoDD) project at Colorado State University.
8. Member of the National Academics Committee on Advancing Software-Intensive Systems Producibility, chaired by Bill Scherlis from Carnegie Mellon University (CMU).
9. Member of the Engineering and Methods Technical Advisory Group (TAG) for the Software Engineering Institute at Carnegie Mellon University (CMU) from 2006 to 2009.
10. Member of the Ultra-Large-Scale (ULS) Systems study commissioned by the US Army and conducted at the Software Engineering Institute at Carnegie Mellon University (CMU).
11. Member of the Joshua group, which is an advisory board for the Air Force Research Lab (AFRL) in Rome, NY.
12. Member of the steering committee for the Distributed Objects and Applications conference series.
13. Member of the steering committee for the ACM/USENIX/IFIP Middleware conference series.
14. Member of the steering committee for EMSOFT 2002: Second Workshop on Embedded Software, Grenoble, France, October, 7–9th, 2002.
15. Member of the steering committee for EMSOFT 2001: First Workshop on Embedded Software, Lake Tahoe, California, October, 8th–10th, 2001.
16. Member of the Board of Directors for the Embedded Systems Consortium for Hybrid and Embedded Research (ESCHER).
17. Member of the NASA/JPL Mars Science Laboratory Mission Concept Review Board.
18. Chair of the subcommittee on Embedded and Hybrid Systems program for the National Science Foundation's 2003 Committee of Visitors in the Computer and Communications Research (C-CR) Division.
19. Co-chair of the Software Design and Productivity (SDP) Coordinating Group of the Federal government's multi-agency Information Technology Research and Development (IT R&D) Program, the collaborative IT research effort of the major Federal science and technology agencies. The SDP Coordinating Group formulates the multi-agency research agenda in fundamental software design.
20. One of the three founding members of the Scientific Advisory Board for the *International Symposium of Distributed Objects and Applications* conference series.
21. Member of the advisory board for Entera, which provides Internet content delivery systems based on ACE.
22. Invited to participate in the OO Working Group of the "Strategic Directions in Computing Research" workshop sponsored by ACM at MIT in June 1996.

Technical Program Committees

1. The 3rd IEEE International Conference on Autonomic Computing and Self-Organizing Systems (ACSOS 2022) held virtually from 19th to 23rd September 2022.
2. The 16th ACM International Conference on Distributed and Event-Based Systems, June 27 to July 1, 2022, Copenaghen, Denmark.
3. 8th International Workshop on Middleware and Applications for the Internet of Things (M4IoT), held in December 2021 in conjunction with the ACM/IFIP International Middleware Conference.
4. Middleware 2021 Doctoral Symposium, Dec. 6-10, 2021 in Quebec Canada.
5. The 2nd IEEE International Conference on Autonomic Computing and Self-Organizing Systems (ACSOS 2021), September 27 to October 1, 2021, Washington DC, USA.
6. "Web of Things, Ubiquitous and Mobile Computing" Track for the Web Conference 2021, Ljubljana, Slovenia, from April 19-23, 2021.
7. 7th International Workshop on Middleware and Applications for the Internet of Things (M4IoT), December 2020 in conjunction with the ACM/IFIP International Middleware Conference.
8. 14th ACM International Conference on Distributed and Event-based Systems, July 13 to July 17, 2020, in Montreal, Quebec, Canada.

9. The Web Conference 2020: Web of Things, Ubiquitous, and Mobile Computing Track, April 20-24th, 2020, Taipei, Taiwan.
10. 6th Middleware for Context-Aware Applications in the IoT (M4IOT) workshop collocated with the ACM/IFIP/USENIX Middleware 2019 Conference, UC Davis, California, USA, December 9-13th 2019.
11. IEEE Workshop on IoT Big Data and Blockchain, at the 2019 IEEE International Conference on Big Data (IEEE Big Data 2019), December 9-12, 2019, Los Angeles, CA, USA.
12. The Second International Workshop on Blockchain Dependability, in conjunction with SRDS2019, Lyon, France, October 1, 2019.
13. The 13th ACM International Conference on Distributed and Event-based Systems, 4th-28th June, 2019, Darmstadt, Germany.
14. The "Web of Things, Ubiquitous, and Mobile Computing" track of The Web Conference 2019, San Francisco, CA, USA, May 13–17, 2019.
15. 17th Workshop on Adaptive and Reflexive Middleware (ARM), collocated with ACM/IFIP/Usenix Middleware 2018, December 10-14th, 2018, Rennes, France.
16. 25th International Conference on Pattern Languages of Programs (PLoP 2018), October 23 – 26th, Portland, OR, USA.
17. First International Workshop on Blockchain Dependability (WBD2018), held in conjunction with the 14th European Dependable Computing Conference, 10-14 September 2018, Iasi, Romania.
18. Workshop on Designing Resilient Intelligent Systems for Testability and Reliability, April 30 – May 4, 2018 in Seattle, USA (co-located with ICSA 2018).
19. 15th IEEE International Conference on Autonomic Computing (ICAC 2018), Sept 3-7, 2018, Trento, Italy.
20. International Conference on Information Society and Smart Cities (ISC 2018), Oxford city, United Kingdom 06-07 June, 2018.
21. 16th Workshop on Adaptive and Reflective Middleware workshop collocated with the ACM/IFIP/USENIX Middleware 2017 Conference, Las Vegas, Nevada, Dec 11-15, 2017.
22. 4th Middleware for Context-Aware Applications in the IoT (M4IOT) workshop collocated with the ACM/IFIP/USENIX Middleware 2017 Conference, Las Vegas, Nevada, Dec 11-15, 2017.
23. 10th International Workshop on Dynamic Software Product Lines - Adaptive Systems through Runtime Variability (DSPL '17), Sept 25-29, 2017, Sevilla, Spain.
24. 11th ACM International Conference on Distributed and Event-Based Systems (DEBS 2017), June 19 - 23, 2017, Barcelona, Spain.
25. 3rd Middleware for Context-Aware Applications in the IoT (M4IOT) workshop collocated with the ACM/IFIP/USENIX Middleware 2016 Conference, December 12-16, 2016 - Trento, Italy.
26. 7th International Symposium On Leveraging Applications of Formal Methods, Verification and Validation, October 5th – 14th, 2016, Corfu, Greece.
27. 10th ACM International Conference on Distributed and Event-based Systems, June 20 to June 24, 2016 in Irvine, CA.
28. First International Workshop on Science of Smart City Operations and Platforms Engineering (SCOPE), April 11, 2016, Vienna, Austria (Co-located with CPS Week).
29. 9th Dynamic Software Product Lines (DSLP) 2015 (held as part of SASO 2015) at MIT on September 21, 2015.
30. 13th International Conference on Advances in Mobile Computing and Multimedia (MoMM2015), Brussels, Belgium from 10-12 December 2015.
31. 13th IEEE/IFIP International Conference on Embedded and Ubiquitous Computing (EUC 2015, track on Cyber Physical Systems, Porto Portugal, October 21-23, 2015.
32. 35th IEEE International Conference on Distributed Computing Systems (ICDCS), June29 - July 2, 2015 in Columbus, Ohio, USA.

33. Fourth International Conference on Emerging Applications of Information Technology (EAIT) at Indian Statistical Institute, Kolkata, India, December 19-21, 2014.
34. The 20th IEEE Real-Time and Embedded Technology and Applications Symposium (RTAS 2014), Berlin, Germany, April 2014.
35. International Conference on Model-Driven Engineering and Software Development (MODELSWARD 2014), Lisbon, Portugal, 7-9 January, 2014.
36. 14th ACM/IFIP/USENIX International Middleware Conference (Middleware 2013), December 9-13, Beijing, China.
37. 32nd International Symposium on Reliable Distributed Systems (SRDS 2013), September 30-October 3, 2013 at Braga, Portugal.
38. 17th International Software Product Line Conference SPLC, Tokyo, Japan, 26-30 August 2013.
39. First International Workshop on Engineering Mobile-Enabled Systems, in conjunction with ICSE 2013, May 18-26th, 2013, San Francisco, CA.
40. International Conference on Model-Driven Engineering and Software Development (MODELSWARD 2013), Barcelona, Spain, 19-21 February, 2013.
41. ACM/USENIX/IFIP International Middleware conference, Montreal, Quebec, Canada, December 3-7, 2012.
42. 11th Workshop on Adaptive and Reflective Middleware, in conjunction with Middleware 2012 in Montreal, Quebec, Canada, December 3-7, 2012.
43. International Workshop on Real-Time and Distributed Computing in Emerging Applications (RE-ACTION) 2012, San Juan, Puerto Rico, December 4, 2012, in co-location with the 33rd IEEE Real-Time Systems Symposium.
44. Third International Conference on Emerging Applications of Information Technology (EAIT) November 29 - December 01, 2012, Kolkata, India.
45. IASTED International Conference on Parallel and Distributed Computing and Systems (PDCS), Las Vegas, USA, November 12 - 14, 2012.
46. 31st International Symposium on Reliable Distributed Systems (SRDS), 8th-11th October 2012. Irvine, California.
47. Sixth International Workshop on Dynamic Software Product Lines (DSPL), September 2 - 7, 2012, Salvador, Brazil.
48. 16th International Software Product Line Conference (SPLC 2012), Salvador, Brazil on 02-07 September 2012.
49. 5th International workshop UML and Formal Methods (UML&FM 2012), Paris, France, August 27-31, 2012.
50. UML&AADL 2012, July 18-20,2012, Ecole Normale Superieure, Paris, France.
51. 17th IEEE International Conference on Engineering of Complex Computer Systems (ICECCS 2012), July 18-20,2012, Ecole Normale Superieure, Paris, France.
52. COMPSAC 2012 - Trustworthy Software Systems for the Digital Society, July 16-20, 2012, Izmir, Turkey.
53. Foundations Track of the 8th European Conference on Modelling Foundations and Applications (ECMFA 2012), Copenhagen, Denmark, 2-6th of July, 2012.
54. 24th International Conference on Software Engineering and Knowledge Engineering, Redwood City, California, USA, July 1-3, 2012.
55. 12th IFIP International Conference on Distributed Applications and Interoperable Systems (DAIS'12), Stockholm, Sweden, 13-16 June 2012.
56. 15th IEEE International Symposium on Object and component-oriented Real-time distributed Computing (ISORC), April 11-13, 2012, Shenzhen, China.
57. 23rd IASTED International Conference on Parallel and Distributed Computing and Systems (PDCS 2011), Dallas, USA, December 14 to 16, 2011.

58. Fourth IEEE International Workshop on Real-Time Service-Oriented Architecture and Applications (RTSOAA 2011), December 12th–14th 2011, University of California, Irvine, CA.
59. ACM/IFIP/USENIX International Middleware Conference, Lisbon, Portugal, December 12th to 16th, 2011.
60. 9th International Conference on Advances in Mobile Computing and Multimedia (MoMM2011), Hue City, Vietnam, 05-07 December 2011.
61. Control Systems, Automation and Robotics track of the 3rd International Congress on Ultra Modern Telecommunications and Control Systems (ICUMT 2011), Hungary on October 5-7, 2011.
62. 15th IEEE International Enterprise Distributed Object Computing Conference (EDOC 2011), August 29th - September 2nd, 2011, Helsinki, Finland.
63. 15th International Software Product Line Conference (SPLC 2011), Research/Experience Track, Munich, Germany, August, 22-26, 2011.
64. 15th International Software Product Line Conference (SPLC 2011), Industry Track, Munich, Germany, August, 22-26, 2011.
65. 2nd Workshop on Formal Methods in Software Product Line Engineering - Munich (Germany), August 2011.
66. 23rd International Conference on Software Engineering and Knowledge Engineering (SEKE2011), Miami Beach, USA, July 7-9, 2011.
67. 2nd International Workshop on Analysis Tools and Methodologies for Embedded and Real-time Systems, July, 5th 2011, Porto, Portugal.
68. Fourth IEEE International workshop UML and Formal Methods, co-located with FM 2011, June 20th, 2011, Lero, Limerick, Ireland.
69. The Software Engineering and Data Engineering (SEDE 2011) conference, Las Vegas, Nevada, June 20-22, 2011.
70. 3rd International Workshop on Model-Driven Architecture and Modeling-Driven Software Development (MDA&MDSD 2011) in conjunction with the 6th International Conference on Evaluation of Novel Approaches to Software Engineering - ENASE 2011, Beijing Jiaotong University, 8-11, June 2011.
71. 11th International IFIP Conference on Distributed Applications and Interoperable Systems (DAIS 2011), Reykjavik, Iceland, June 6-9 2011.
72. Second Product LinE Approaches in Software Engineering (PLEASE) workshop, collocated with 33rd International Conference on Software Engineering, Waikiki, Honolulu, Hawaii, May 21-28, 2011.
73. 16th Annual IEEE International Conference on the Engineering of Complex Computer Systems (ICECCS), April 27th-29th, 2011 Las Vegas, NV, USA.
74. Sixth IEEE International workshop UML and AADL, in conjunction with ICECCS 2011, April 27th, 2011, Las Vegas, USA.
75. First International Workshop on Cyber-Physical Networking Systems (CPNS'2011), in conjunction with INFOCOM 2011, April 15, 2011, Shanghai, China.
76. 2nd Workshop on Model Based Engineering for Embedded System Design (M-BED 2011), colocated with the Design, Automation, and Test in Europe (DATE) conference, 14-18, March, 2011, Grenoble, France.
77. Second International Conference on Emerging Applications of Information Technology (EAIT 2011), February, 2011 at Kolkata, India.
78. Fifth International Workshop on "Variability Modeling of Software-intensive Systems" (VaMoS '11), January 27-29 2011 in Namur, Belgium.
79. 9th Workshop on Adaptive and Reflective Middleware (ARM 2010) November 27, 2010, Bangalore India, collocated with Middleware 2010.
80. The 22nd IASTED International Conference on Parallel and Distributed Computing and Systems (PDCS 2010), November 8-10, 2010, Marina Del Ray, California.

81. International Conference on Software Engineering, Management, and Application (ICSEMA 2010) Kathmandu, Nepal, October 29th and 30th, 2010.
82. The MobiCPS 2010 workshop, held in conjunction with the 7th International Conference on Ubiquitous Intelligence and Computing (UIC2010), October 26-29, 2010 Xian, China.
83. Fourteenth IEEE International Enterprise Computing Conference (EDOC 2010), 25-29 October 2010, Vitoria, ES, Brazil.
84. Advances in Business ICT (ABICT) 2010 Workshop Wisla, Poland, October 18-20, 2010.
85. 3rd Workshop on Model Based Architecting and Construction of Embedded Systems (ACES-MB), held in conjunction with MoDELS 2010, Oslo, Norway, October 3-8, 2010.
86. 4th Dynamic Software Product Line Workshop held in conjunction with the 14th International Software Product Line Conference 2010, Jeju Island, South Korea, September 13-17, 2010.
87. TOOLS Europe 2010, Malaga, Spain, June 28 to July 2, 2010.
88. 22nd International Conference on Software Engineering and Knowledge Engineering (SEKE'2010), to be held July 1-3, 2010, Redwood City, California.
89. 13th International Symposium on Component Based Software Engineering (CBSE 2010), June 23-25 2010 in Prague, Czech Republic.
90. Sixth European Conference on Modelling Foundations and Applications (ECMFA), University of Pierre & Marie Curie, Paris, France. June 15-18, 2010.
91. 10th IFIP WG 6.1 International Conference on Distributed Applications and Interoperable Systems (DAIS), Amsterdam, The Netherlands, June 7-9, 2010.
92. The 11th OMG Real-time/Embedded CORBA workshop, Washington DC, May 24-26, 2010.
93. Industrial track at the 32nd International Conference on Software Engineering (ICSE 2010), Cape Town (South Africa), May 2-8, 2010.
94. Thirteeth International Conference on Business Information Systems (BIS 2010), Berlin, Germany, May 3-5 2010.
95. 1st International Workshop on Product LinE Approaches in Software Engineering, May 2nd, 2010, Cape Town, South Africa, held in conjunction with the 32nd International Conference on Software Engineering (ICSE 2010).
96. Workshop on Effective Multicasting for Future Critical Networked Systems (EMFINES 2010), at the Eighth European Dependable Computing Conference (EDCC), Valencia, Spain, April 28-30, 2010.
97. 1st Workshop on Model-Based Engineering for Embedded Systems Design, co-located with DATE 2010, March 12, 2010 in Dresden, Germany.
98. IEEE International Conference on Engineering of Complex Computer Systems (ICECCS 2010), Oxford 22-26, March 2010.
99. Special session on "Advanced Peer-to-Peer Protocols and Applications" at the Ninth IASTED International Conference on Parallel and Distributed Computing and Networks (PDCN 2010) February 16-18, 2010 Innsbruck, Austria.
100. Fourth Variability Modelling of Software-intensive Systems (VaMoS '10) workshop, Linz, Austria - January 27-29, 2010.
101. 8th Workshop on Adaptive and Reflective Middleware (ARM'09), in collocation with the 10th ACM/IFIP/USENIX Middleware Conference, in Urbana Champaign, Illinois, November 30th, 2009.
102. Workshop committee for OOPSLA 2009, Orlando Floria, October 25-29, 2009.
103. The ARTIST 2nd International Workshop on Model Based Architecting and Construction of Embedded Systems (ACESMB 2009), in conjunction with the 12th ACM/IEEE International Conference on Model Driven Engineering Languages and Systems (MODELS 2009), October 6th, 2009, Denver, Colorado.
104. The Thirteenth IEEE International EDOC Conference (EDOC 2009), 31 August - 4 September 2009, Auckland, New Zealand.

105. The 10th OMG Real-time/Embedded CORBA workshop, Washington DC, July 13–15, 2009.
106. The Software Engineering and Knowledge Engineering (SEKE'2009) conference, July 1-3, 2009, Boston, MA.
107. 12th International Symposium on Component-Based Software Engineering (CBSE 2009), East Stroudsburg University, Pennsylvania, USA, June 22-25, 2009.
108. The Second International Workshop on Cyber-Physical Systems (WCPS2009), held in conjunction with IEEE ICDCS 2009 in Montreal, Canada, June 22, 2009.
109. The Fifth European Conference on Model Driven Architecture Foundations and Applications (ECMDA), Gdansk, Poland, summer of 2009.
110. The 9th IFIP International Conference on Distributed Applications and Interoperable Systems (DAIS 2009) conference, Lisbon, Portugal, June 9-11, 2009.
111. The Fourth International Conference on COMmunication System softWAre and middlewaRE (COMSWARE), 15th - 19th June 2009, Trinity College Dublin, Ireland.
112. The UML&AADL Workshop, held in conjunction with ICECCS 2009 The fourteenth IEEE International Conference on Engineering of Complex Computer Systems June 02, 2009, Potsdam, Germany.
113. The 15th Real-time and Embedded Applications Symposium (RTAS) 2009, Track B, Real-time and Embedded Applications, Benchmarks and Tools, San Francisco, CA, United States, April 13 - 16, 2009.
114. Member of the ISORC 2009 advisory and publicity committee for ISORC 2009, March 17-20, 2009, Toyko, Japan.
115. the 13th International Software Product Line Conference (SPLC), August 24-28, 2009, San Francisco, CA.
116. the European Conference on Model Driven Architecture - Foundations and Applications 2009, University of Twente, Netherlands, June 2009.
117. The third workshop on "Variability Modelling of Software-intensive systems" (VaMoS'09), January 28-30 2009 in Sevilla, Spain.
118. the 1st Workshop on Software Reuse Efforts, November 27-29, 2008 Brazil.
119. the 7th Workshop on Adaptive and Reflective Middleware (ARM'08) in collocation with the 9th ACM/IFIP/USENIX Middleware Conference, Leuven, Belgium, December 1st 2008.
120. the Middleware 2008 9th International Middleware Conference, December 1-6, 2008, Leuven, Belgium.
121. the 11th Component-Based Software Engineering conference, Karlsruhe, Germany, October 14-17, 2008.
122. the ARTIST International Workshop on Model Based Architecting and Construction of Embedded Systems (ACESMB 2008), in conjunction with the 11th ACM/IEEE International Conference on Model Driven Engineering Languages and Systems (MODELS 2008), Toulouse, September 29th, 2008.
123. the 6th Java Technology for Real-Time and Embedded Systems (JTRES) conference, Santa Clara, California, USA, 24-26 September, 2008.
124. the 12th IEEE International Enterprise Distributed Computing Conference (EDOC) (EDOC 2008), 15-19 September 2008, Munich, Germany.
125. the First Workshop on Analyses of Software Product Lines (ASPL'08), September 12, 2008 in Limerick, Ireland in conjunction with SPLC'08.
126. the 9th OMG Real-time/Embedded CORBA workshop, Washington DC, July 14–17, 2008
127. the 3rd International Conference on Software and Data Technologies, July 5-8, 2008, Porto, Portugal.
128. the 20th International Conference on Software Engineering and Knowledge Engineering (SEKE'08), Redwood City, California, USA, July 1-3, 2008.
129. the TOOLS EUROPE 2008 conference, June 30 to July 4, 2008 at ETH Zurich.

130. National Conference on Research & Development in Hardware & Systems (CSI-RDHS 2008), Computer Society of India Kolkata Chapter & CSI Division I (Hardware & Systems), June 20-21, 2008, Kolkata, India.
131. the First International Workshop on Cyber-Physical Systems, Beijing, China, June 17 - 20, 2008.
132. the ECMDA 2008 (Fourth European Conference on Model Driven Architecture Foundations and Applications) in Berlin, June 09 - 12, 2008.
133. the Distributed Applications and Interoperable Systems (DAIS), Oslo, Norway, June 4, 2008.
134. the 2nd International Workshop on Ultra-Large-Scale Software-Intensive Systems (ULSSIS 2008), May 10-11, 2008 Leipzig, Germany.
135. the Automotive Systems Track at the 30th International Conference on Software Engineering (ICSE), Leipzig, Germany, 10-18 May 2008.
136. the Real-Time and embedded Applications / Benchmarks track at the 14th IEEE Real-Time and Embedded Technology and Applications Symposium (RTAS 2008), St. Louis, MO, April 22-24, 2008.
137. the 3rd UML and AADL Workshop held in conjunction with the 13th IEEE International Conference on Engineering of Complex Computer Systems, Belfast, Northern Ireland, 31 March - 4 April 2008.
138. the ACM Programming for Separation of Concern track at SAC 2008, Fortaleza, Brazil, March 16 - 20, 2008.
139. the 6th edition of the International Workshop on Adaptive and Reflective Middleware, held in conjunction with Middleware 2007 in Newport Beach, California.
140. the IEEE/ACM/USENIX Middleware conference, November 2007.
141. the IASTED International Conference on Parallel and Distributed Computing and Systems, PDCS 2007, Cambridge, MA, USA from Nov 19-21, 2007.
142. the 9th International Symposium on Distributed Objects, Middleware, and Applications (DOA), Iberian peninsula and islands, Oct 28 - Nov 2, 2007.
143. Member of the Doctoral Symposium committee at OOPSLA 2007, Portland, OR October 21-25, 2007.
144. the International Symposium on Ambient Intelligence and Computing, October 2007, Korea.
145. the IEEE conference on Enterprise Distributed Object Computing (EDOC), Annapolis, MD, October 15-19, 2007.
146. the 5th Java Technology for Real-Time and Embedded Systems (JTRES), Vienna, Austria, 26-28 September, 2007.
147. the Workshop on Trade-Off analysis of Software Quality Attributes (TOSQA), collocated with the sixth joint meeting of the European Software Engineering Conference and the ACM SIGSOFT Symposium on the Foundations of Software Engineering, Dubrovnik, Croatia, September 3-7, 2007.
148. the 2nd International Conference on Software and Data Technologies, July 22-25th 2007, Barcelona, Spain.
149. the Fourth IEEE International Conference on Web Services, Salt Lake City, UT, July 9-13, 2007.
150. the 10th International Component-Based Software Engineering (CBSE) Symposium, Boston, MA, July 9-11 2007.
151. the 8th OMG Real-time/Embedded CORBA workshop, Washington DC, July 9–12, 2007.
152. the International Conference TOOLS EUROPE 2007, Zurich, Switzerland on June, 24-28 2007.
153. the track on "Real-Time and Embedded Applications and Benchmarks" for the 13th IEEE Real-Time and Embedded Technology and Applications Symposium, Bellevue, WA, April 3 - April 6, 2007.
154. the Workshop on the Foundations of Interactive Computation (FInCo 2007), Braga, Portugal, March 24 - April 1, 2007.
155. the 15th International Workshop on Parallel and Distributed Real-Time Systems (WPDRTS), Long Beach, California, 26-27 March, 2007.

156. the ACM Symposium on Applied Computing, Programming for Separation of Concerns track, Seoul, Korea, March 11 - 15, 2007.
157. the Workshop on Pervasive Computing Environments and Services (PCES 07), Naples, Italy, Feb 7-9, 2007.
158. the Minitrack on Components for Embedded and Real-time Systems at the 40th Hawaiian International Conference on System Sciences, January 3-6, 2007 at Waikoloa, Big Island, Hawaii.
159. the 13th Asia Pacific Software Engineering Conference (APSEC06), Bangalore, India, Dec 6-8, 2006.
160. the Real-time Middleware and Software Engineering track of the The 27th IEEE Real-Time Systems Symposium, December 5-8, 2006 Rio de Janeiro, Brazil.
161. the 2nd International Conference on Trends in Enterprise Application Architecture, November 29th to December 1st, 2006, Berlin, Germany.
162. the workshop on MOdel Driven Development for Middleware (MODDM), November 27, 2006, Melbourne, Australia.
163. the International Symposium on Distributed Objects and Applications (DOA), Montpellier, France, Oct 29 - Nov 3, 2006.
164. the "Library-Centric Software Design" (LCSD'06) workshop at the OOPSLA'06 conference in Portland, Oregon, October 22-26, 2006.
165. Judge for the Student Research Competition at OOPSLA 2006, Portland, OR, October 23-24, 2006.
166. the NSF Workshop On Cyber-Physical Systems, October 16 - 17, 2006, Austin, Texas.
167. the Models at Run-Time MaRT-06 workshop held at the MoDELS 2006 conference, Genova Italy, Oct. 2-6, 2006.
168. the MoDELS 2006 conference, Genova Italy, Oct. 2-6, 2006.
169. the 7th OMG Real-time/Embedded CORBA workshop, Washington DC, July 11–14, 2006.
170. the European Conference on Object-Oriented Programming, Nantes, France, July 3-7, 2006.
171. the 9th International Symposium on Component-Based Software Engineering (CBSE 2006), Malardalen University, Sweden, June 29th-1st July 2006.
172. the 28th International Conference on Software Engineering (ICSE 28), May 24-26, 2006, Shanghai, China.
173. the 14th International Workshop on Parallel and Distributed Real-Time Systems, April 25-26, 2006, Island of Rhodes, Greece.
174. the 9th IEEE International Symposium on Object-oriented Real-time Distributed Computing, April 24-26, 2006, Gyeongju, Korea.
175. the Automotive Software Workshop San Diego (ASWSD 2006), University of California, San Diego, March 15-17, 2006.
176. the C++ Connections: 20 Years of C++ conference, Nov 7-11, 2005, Mandalay Bay, Las Vegas, NV.
177. the Conference on Distributed Objects and Applications (DOA 2005), Oct 31 - Nov 4, 2005, Agia Napa, Cyprus.
178. the 20th Annual ACM SIGPLAN Conference on Object-Oriented Programming, Systems, Languages, and Applications (OOSPLA), October 16-20, 2005, San Diego, CA, USA.
179. the 6th International Conference on Middleware (Middleware'2005), October, 2005, Grenoble, France.
180. the 2005 Monterey Workshop on Networked Systems, Laguna Beach, California, September 22-24, 2005.
181. The 12th Pattern Language of Programs (PLoP 2005), September 7-10, 2005, Allerton Park, Monticello, Illinois, USA.
182. the 14th IEEE International Symposium on High-Performance Distributed Computing (HPDC-14), Research Triangle Park, North Carolina, July 27, 2005.

183. the 5th International Workshop on Software and Performance (WOSP 2005), Palma de Mallorca, Spain, July 11-15, 2005.
184. the 6th OMG Real-time/Embedded CORBA workshop, Washington DC, July 11–14, 2005.
185. the 5th IFIP WG 6.1 International Conference on Distributed Applications and Interoperable Systems (DAIS 2005), June 15-17, 2005, Athens, Greece.
186. the International Conference on Autonomic Computing (ICAC 2005), Seattle, WA, June 2005.
187. the International Symposium on Component-Based Software Engineering (CBSE), co-located with the International Conference on Software Engineering (ICSE), May 14-15, 2005, St. Louis, MO.
188. the Foundations of Interactive Computation (FINCO'05) Workshop, Saturday, 9 April 2005, in Edinburgh, Scotland.
189. the Embedded Applications track of the IEEE Real-Time and Embedded Technology and Applications Symposium (RTAS) 2005, San Francisco, California, March 2005.
190. the "Programming for Separation of Concerns" track at Symposium on Applied Computing (SAC 2005), Santa Fe, New Mexico, March 2005.
191. the 12th International Symposium on the Foundations of Software Engineering, November 6th, 2004, Newport Beach, California.
192. the Conference on Distributed Objects and Applications (DOA 2004), October 25-29, 2004 in Cyprus, Greece.
193. the 2nd International Workshop on Java Technologies for Real-Time and Embedded Systems (JTRES), October 25-29, 2004, Larnaca, Cyprus.
194. the 3rd Workshop on Reflective and Adaptive Middleware (RM2004), October 19, 2004, Toronto, Ontario, Canada.
195. the Middleware 2004 5th IFIP/ACM/USENIX International Conference on Distributed Systems Platforms, October 18-22, 2004, Toronto, Canada.
196. the 4th TAO+CIAO Workshop, Arlington, VA, July 16, 2004.
197. the DARPA Workshop on Java in Real-Time and Embedded Defense Applications, Arlington, VA, July 13, 2004.
198. the OMG Real-time/Embedded CORBA workshop, Crystal City, VA, July 12–15, 2004.
199. the ECOOP 2004 conference, June 14-18, 2004, Oslo, Norway.
200. the Middleware track of the 24th IEEE International Conference on Distributed Computing Systems (ICDCS), May 23-26, 2004, Tokyo, Japan.
201. the 2nd International Workshop on Remote Analysis and Measurement of Software Systems (RAMSS), Edinburgh, Scotland, UK, May 24, 2004.
202. Aspect-Oriented Software Development conference, Lancaster, England, March 22-26, 2004.
203. the SPIE/ACM Conference on Multimedia Computing and Networking, January 21-22, 2004 Santa Clara, California.
204. the Real-time Systems Symposium (RTSS), Cancun, Mexico, December 3-5, 2003.
205. the 4th IFIP International Conference on Distributed Applications and Interoperable Systems (DAIS), Paris - France November 17-21, 2003.
206. the International Workshop on Java Technologies for Real-Time and Embedded Systems (JTRES), November 3-7, 2003, Catania, Sicily, Italy.
207. the Domain Driven Development track at the OOPSLA 2003 18th Annual ACM SIGPLAN Conference on Object-Oriented Programming, Systems, Languages, and Applications, October 26-30, 2003, Anaheim, California, USA.
208. the OOPSLA 2003 18th Annual ACM SIGPLAN Conference on Object-Oriented Programming, Systems, Languages, and Applications, October 26-30, 2003, Anaheim, California, USA.
209. External reviewer for the 2nd Generative Programming and Component Engineering (GPCE '03) conference, Erfurt, Germany, September 22-25, 2003.
210. the OMG Real-time/Embedded CORBA workshop, Crystal City, VA, July 14–17, 2003.

211. the The 2nd Workshop on Reflective and Adaptive Middleware, Rio de Janeiro, Brazil, June 17, 2003.
212. the ACM SIGPLAN 2003 Conference on Programming Language Design and Implementation (PLDI), San Diego, California, June 9 - 11, 2003.
213. the 1st International Workshop on Remote Analysis and Measurement of Software Systems (RAMSS), Portland, Oregon, May 9, 2003.
214. External reviewer for the 17th International Parallel and Distributed Processing Symposium, April 22–26, 2003, Nice, France.
215. the ACM International Conference on Aspect-Oriented Software Development, March 17 - 21, 2003, Boston, MA.
216. the SPIE/ACM Conference on Multimedia Computing and Networking, Santa Clara, California, January 29–31, 2003.
217. the International Workshop on Product Line Engineering The Early Steps: Planning, Modeling, and Managing (PLEES '02), Seattle, WA, November 5, 2002.
218. the 8th IEEE Real-Time and Embedded Technology and Application Symposium (RTAS), San Jose, CA, September 24-27, 2002.
219. the 9th Conference on Pattern Language of Programs, Allerton Park, IL, September 8-12, 2002.
220. the Workshop on Dependable Middleware-Based Systems, held as a part of DSN 2002, Washington, D.C., June 23-36, 2002.
221. the 2nd TAO Workshop, Arlington, VA, July 19, 2002.
222. the OMG Real-time/Embedded CORBA workshop, Crystal City, VA, July 15–18, 2002.
223. the 16th European Conference on Object-Oriented Programming, University of Malaga, Spain June 10-14, 2002.
224. the Tenth International Workshop on Quality of Service (IWQoS), May 15-17, 2002, Miami Beach, Florida.
225. the International Symposium on Object-Oriented Real-time Distributed Computing (ISORC), Washington DC, April 29 – May 1, 2002.
226. the Seventh IEEE International Workshop on Object-oriented Real-time Dependable Systems (WORDS 2002), January 7-9, 2002, San Diego, CA.
227. the International Workshop on Multimedia Middleware October 5th, 2001, Ottawa, Canada.
228. the OMG Workshop on Real-time and Embedded CORBA, in Reston, VA, June 4-6, 2001.
229. the USENIX 2001 conference, Boston, MA, June 25-30, 2001.
230. the International Symposium on Object-oriented Real-time Distributed Computing (ISORC), May 2-4, Magdenburg, Germany, 2001.
231. the 6th USENIX Conference on Object-Oriented Technologies and Systems, January 27 - February 3, 2001, San Antonio, TX.
232. External reviewer for OOPSLA 2000, Minneapolis, MN, October 2000.
233. the 3rd IFIP International Conference on Trends towards a Universal Service Market (USM'2000), September 12-14, 2000.
234. the International Symposium on Distributed Objects and Applications (DOA '00), OMG, Antwerp, Belgium, September 2000.
235. the ACM SIGCOMM 2000, Stockholm, Sweden, August 30 to September 1st, 2000.
236. the Pattern Languages of Programming (PLoP) conference, Monticello, Illinois, August, 2000.
237. the 9th IEEE International Conference on High-Performance Distributed Computing, August, 2000.
238. the "International Workshop on Software Engineering for Parallel and Distributed Systems" (PDSE 2000), at the 22nd International Conference on Software Engineering (ICSE-2000), in Limerick, Ireland in June, 2000.
239. the 6th IEEE Real-Time Technology and Application Symposium (RTAS), May 17-19, 2000, Washington DC, USA.

240. the 1999 ACM OOPSLA conference, Denver, Colorado, November 1-5, 1999.
241. the IFIP Sixth International Workshop on Protocols For High-Speed Networks (PfHSN '99), Wednesday August 25 – Friday August 27, 1999 Salem, MA.
242. the 1999 IEEE Real-Time Technology and Applications Symposium (RTAS99), Vancouver, British Columbia, Canada, June 2-4, 1999.
243. the 5th USENIX Conference on Object-Oriented Technologies and Systems, May 3-7, 1999, San Diego, CA.
244. Technical workshop committee for the International Software Architecture workshop, ACM SIGSOFT's FSE9 conference in Orlando FL, November 1-5, 1998.
245. the workshop on Software and Performance (WOSP98), Santa Fe, New Mexico, Oct 12-16 1998.
246. the IFIP International Conference on Distributed Systems Platforms and Open Distributed Processing: Middleware '98. September 15-18 1998, The Lake District, England.
247. the TOOLS USA'98 conference. Santa Barbara, California, August 3 - 7, 1998.
248. the IEEE High Performance Distributed Computing conference, Chicago, IL, July 28-31, 1998.
249. 12^{th} European Conference on Object-Oriented Programming, Brussels, Belgium, July 20 - 24, 1998.
250. the 3rd EuroPLoP conference, Kloster Irsee, Germany, July 9-11, 1998.
251. the IEEE International Conference on Configurable Distributed Systems (ICCDS '98), Annapolis, MD, May 4-6, 1998.
252. the IEEE IWQoS '98 in Napa Valley, CA, May 18-20, 1998.
253. the 4th USENIX Conference on Object-Oriented Technologies and Systems, April 26-29, 1998, Santa Fe, New Mexico.
254. the 3^{rd} International Workshop on Software Engineering for Parallel and Distributed Systems, at the 20th International Conference on Software Engineering (ICSE-20), in April 20-21, Kyoto, Japan.
255. the IEEE Conference on Open Architectures and Network Programming, April 3-4, 1998, San Francisco, CA.
256. the Workshop on Middleware for Real-Time Systems and Services, held in conjunction with IEEE Real-time Systems Symposium, December 2nd, San Francisco, California.
257. the Open Signaling for ATM, Internet and Mobile Networks. October 6th and 7th, 1997, Columbia University, New York, NY.
258. the 24^{th} International Conference on Technology of Object-Oriented Languages and Systems (TOOLS Asia '97). Beijing, China, September 22 - 25, 1997.
259. the 4^{th} Pattern Languages of Programming conference, Allerton Park, Illinois, September 3-5, 1997.
260. the 3^{rd} USENIX Conference on Object-Oriented Technologies and Systems, Portland, June 16-19th 1997.
261. Session chair of the Patterns technical paper session at ECOOP '97, June 13th, 1997.
262. the 1997 European Conference on Object-Oriented Programming (ECOOP), June 9-13, 1997, Jyvskyl, Finland.
263. Chair of the technical session on "Distributed Object Computing" for the IFIP/IEEE Fifth International Workshop on Quality of Service (IWQoS '97).
264. the 2^{nd} International Workshop on Software Engineering for Parallel and Distributed Systems, at the 19^{th} International Conference on Software Engineering (ICSE-19) Sheraton Boston Hotel and Towers, Boston, Massachusetts, USA, May 19 and 20, 1997.
265. the 3^{rd} USENIX Conference on Object-Oriented Technologies and Systems, Portland, 1997.
266. the 5^{th} IEEE International Workshop on Object-Orientation in Operating Systems, IEEE TCOS and USENIX, Seattle, Washington, October 27-28, 1996.
267. the 1997 ACM SIGCOMM conference, Cannes, French Riviera, France, September 1997.
268. the 1997 IEEE INFOCOM conference, Kobe, Japan, April 1997.

269. the 1996 IEEE INFOCOM conference, San Francisco, CA, USA, March 24-28, 1996.
270. the 1995 IEEE INFOCOM conference, Boston, Massachusetts, USA, April, 1995.
271. the 3^{rd} IEEE workshop on Architecture and Implementation of High Speed Communication Subsystems (HPCS '95), held in Mystic, Connecticut, August 1995.
272. the 8^{th} IFIP International Working Conference on Upper Layer Protocols, Architectures, and Applications, held in Barcelona, Spain, June 1 to 3, 1994.

Workshops and Panels Organized

1. Co-organized the 1st International Workshop on Data Dissemination for Large scale Complex Critical Infrastructures (DD4LCCI 2010), at the Eighth European Dependable Computing Conference, Valencia, Spain, April 28-30, 2010.
2. Co-organized the OOPSLA Jeopardy panel at OOPSLA 2009, Orlando Floria, October 25-29, 2009.
3. Co-organized a workshop entitled First International Workshop on Software Technologies for Ultra-Large-Scale (ULS) Systems at 29th Int. Conference on Software Engineering, May 20-29th, Minneapolis, MN, 2007.
4. Co-organized a session on architectures, platforms, and standards for QoS-enabled dissemination at the Systems and Information Interoperability Meeting, Oct 25-27, 2006 at the Minnowbrook Conference Center, Blue Mountain Lake, NY.
5. Co-organized a workshop entitled "Breathturn: Ultra Large Scale Systems" at OOPSLA 2006, October 26, 2006, Portland, OR.
6. Co-chair of the NSF workshop on open-source Middleware for Distributed Real-time and Embedded Systems, 7th OMG Real-time/Embedded CORBA workshop, Arlington, VA, July 10–13, 2006.
7. Organized and led a session on architectures, platforms, and standards for real-time tactical information management at the Systems and Information Interoperability Meeting, Oct 18-21, 2005 at the Minnowbrook Conference Center, Blue Mountain Lake, NY.
8. Co-organizer of the technical workshops program at OOPSLA 2005, San Diego, October 16th-20, 2005.
9. Co-organizer for the MODELS 2005 workshop on "MDD for Software Product-lines: Fact or Fiction?," October 2, 2005, Jamaica.
10. Co-organizer of the OOPSLA '02 workshop on "Patterns in Distributed Real-Time and Embedded Systems", Seattle, WA, November, 2002.
11. Co-organizer of the OOPSLA '01 workshop on "Towards Patterns and Pattern Languages for OO Distributed Real-time and Embedded Systems" Tampa Bay, FL, October 14, 2001.
12. Organizer and chair of a panel on real-time extensions to OO middleware, OPENSIG Fall '97 workshop on Open Signaling for ATM, Internet and Mobile Networks Columbia University, October 6-7 1997, New York, NY.
13. Co-organizer of a workshop for the 1997 European Conference on Object-Oriented Programming entitled CORBA: Implementation, Use, and Evaluation, Jyvaskyla, Finland, June 10th, 1997.
14. Organizer and chair of a panel on "QoS and Distributed Systems Platforms" for the IFIP Fifth International Workshop on Quality of Service (IWQoS '97), May 22-24th, 1997, Columbia University, New York.
15. Co-organizer of the OOPSLA '95 workshop on "Patterns for Concurrent, Parallel, and Distributed OO Systems."
16. Co-facilitator of the ECOOP '95 workshop workshop on Pattern Languages of Object-Oriented Programs, Aarhus, Denmark, August 1995.

Reviewer for Professional Submittals

Reviewed papers for the following journals, conferences, books, and grant review processes:

1. Reviewer for COVID-19 proposals to the C3.ai Digital Transformation Institute.
2. *The 21st IEEE International Symposium on Real-time Computing (ISORC)*, Nanyang Technological University, Singapore, 29th - 31st May 2018.

3. *Future Generation Computer Systems*, Elsevier, edited by Aniruddha Gokhale et al., 2016.
4. *IEEE Software*, Special Issue on Next Generation Mobile Computing, edited by James Edmondson et al., 2013.
5. *Software Testing in the Cloud*, edited by Scott Tilley, 2012.
6. Elsevier Information & Software Technology special issue on Software Reuse and Product Lines, 2012.
7. The 2010 Military Communications Conference, Cyber Security and Network Management, San Jose, CA, October 31-November 3, 2010.
8. *Model-Driven Domain Analysis and Software Development: Architectures and Functions*, edited by Janis Osis and Erika Asnina, 2010.
9. Reviewer for the book "Patterns for Parallel Software Design," by Jorge L. Ortega Arjona, Wiley, 2010.
10. Special Issue on Industrial Applications of Aspect Technology for the journal Transactions on Aspect-Oriented Software Development (TAOSD), 2009.
11. *Software Engineering for Self-Adaptive Systems*, edited by Betty H. C. Cheng, Rogerio de Lemos, Holger Giese, Paola Inverardi, and Jeff Magee, Springer, 2009.
12. Special issue on Service Oriented Computing for the ACM Transactions on the Web journal, 2008.
13. Special Issue in Software Reuse: Methods, Processes, Tools and Experiences for the Journal of the Brazilian Computer Society (JBCS), 2007
14. Designing Software-Intensive Systems: Methods and Principles book, 2008
15. Special issue on Patterns for the IEEE Software, 2007
16. IEEE Internet Computing Magazine, 2006.
17. IEEE Transactions on Parallel and Distributed Systems, 2004
18. International Journal of Software Process: Improvement and Practice Special issue - Software Variability: Process and Management
19. IEEE Internet Computing Magazine
20. 2004 NSF NSG panel
21. IEEE Transactions on Parallel and Distributed Computing special issue on Middleware, 2003
22. 2003 NSF ITR panel
23. 2002 NSF CAREER panel
24. IEEE Internet Computing Magazine, 2002
25. NIST Competence Proposals, May 2002
26. DARPA MoBIES program, May 2002
27. DARPA NEST program, May 2002
28. DARPA DASADA program, April 2002
29. Elsevier Journal of Systems and Software Special Issue on Software Architecture: Engineering Quality Attributes, 2002
30. IEEE Communications Magazine, Evolving Communications Software: Techniques and Technologies, 2001
31. DARPA Network Embedded Software Technology (NEST) program, 2001
32. DARPA Software Enabled Control (SEC) program, 2000
33. IEEE Concurrency magazine, Object-Oriented Systems Track, 1999
34. IEEE Journal on Selected Areas in Communications special issue on "Service Enabling Platforms for Networked Multimedia Systems," 1999
35. IEEE Journal of Communications and Networks, 1999
36. Reviewer for the 4^{th} Pattern Languages of Programming Design book published by Addison Wesley

37. The International Journal of Time-Critical Computing Systems, special issue on Real-time Middleware, edited by Wei Zhao
38. Next Generation Internet (NGR) networking research review panel, October 1998
39. IEE Transactions on Software Engineering, special issue on Configurable Distributed Systems
40. Theme issue on Symbolic Modeling in Practice for the Communications of the ACM
41. "Multimedia DBMS and the WWW" Minitrack at the 32nd Hawaii International Conference on System Sciences, 1999
42. "Dependable Distributed Systems" Minitrack at the 32nd Hawaii International Conference on System Sciences, 1999
43. IEEE Computer special issue on "Design Challenges for High-Performance Network Interfaces," 1998
44. 1998 NSF Experimental Software Systems review panel.
45. ACM SIGMetrics Conference, 1998
46. ACM Transactions on Software Engineering Methods
47. Special Issue on Patterns and Pattern Languages for the journal of Theory and Practice of Object Systems, (Stephen P. Berczuk, Editor), John Wiley and Sons, 1995
48. Special Issue of Computer Communications on Building Quality of Service into Distributed Systems
49. IEEE Communications Magazine
50. IEEE/ACM Journal of Transactions on Networking
51. Communications of the ACM
52. IEE/BCS Distributed Systems Engineering Journal
53. Software Practice and Experience, John Wiley and Sons
54. 1998, 1997, and 1996 NSF networking program
55. 1996 NSF software engineering and programming languages CAREER panel
56. 1994 California MICRO (Microelectronics Innovation Computer Research Opportunity) engineering computer network grant review process
57. IEEE Conference on Parallel and Distributed Computing Systems, 1994
58. IEEE International Conference on Computer Communications and Networks, 1994
59. IEEE INFOCOM conference, 1994
60. 1993 NASA Applied Information Systems Research grant review process
61. 1992 California MICRO (Microelectronics Innovation Computer Research Opportunity) engineering computer network grant review process
62. 7^{th} *IFIP International Conference on Upper Layer Protocols, Architectures, and Applications*, 1992
63. The 1992 Special Issue on Measurement for IEEE Journal Transactions on Software Engineering

Memberships: IEEE, ACM, and USENIX

Patents

1. US patent 7,523,471 – "Interpretive network daemon implemented by generic main object," in conjunction with Karlheinz Dorn, Dieter Quehl, Detlef Becker, and Christian Scharf of SIEMENS Medical Engineering, Erlangen, Germany, 2009.

Theses Supervised

- *Doctoral and Masters Committees Chaired*

  1. Chaired the masters thesis committee for Cici Wang, November 2021.
  2. Chaired the masters thesis committee for Evan Segaul, March 2021.
  3. Co-chair of the doctoral dissertation defense for Peng Zhang, August 2018.
  4. Co-chair of the doctoral dissertation defense for James Edmondson, March 2012.
  5. Co-chair of the doctoral topic defense for James Edmondson, December 2011.
  6. Co-chair of the doctoral dissertation defense for Will Otte, November 2011.
  7. Chair of the doctoral dissertation defense for Brian Dougherty, March 2011.
  8. Chair of the doctoral topic defense for Brian Dougherty, June 2010.
  9. Chair of the masters defense for Pooja Varshneya, May 2010.
  10. Chair of the doctoral topic defense for Nilabja Roy, March 2010.
  11. Chair of doctoral topic defense for Joe Hoffert, November 2009.
  12. Chair of the doctoral dissertation defense for Jai Balasubramanian, September 2009.
  13. Chair of masters defense for Friedhelm Wolf, March 2009.
  14. Chair of the doctoral dissertation defense for Nishanth Shankaran, October 2008.
  15. Chair of the doctoral dissertation defense for Jules White, October 2008.
  16. Chair of doctoral dissertation defense for Gan Deng, December 2007.
  17. Chair of doctoral dissertation defense for Krishnakumar Balasubramanian, September 2007.
  18. Chair of the doctoral topic defense for Nishanth Shankaran, April 2007.
  19. Chair of doctoral topic defense for Krishnakumar Balasubramanian, March 2006.
  20. Chair of doctoral topic defense for Gan Deng, March 2006.
  21. Chair of final doctoral dissertation defense for Arvind Krishna, December 2005.
  22. Chair of masters thesis committee for Emre Turkay, summer 2005.
  23. Chair of doctoral topic defense for Arvind Krishna, summer 2005.
  24. Chair of masters thesis committee for Ossama Othman, December, 2002.
  25. Chair of doctoral dissertation committee for Carlos O'Ryan, May, 2002.
  26. Chair of dissertation topic defense committee for Carlos O'Ryan, September, 2001.
  27. Chair of masters committee for Nagarajan Surendran, August, 1999.
  28. Chair of masters committee for Alexander Babu Arulanthu, July, 1999.
  29. Chair of oral exam committee for Chris Gill, June, 1999.
  30. Chair of doctoral exam committee for Andy Gokhale, May, 1998.
  31. Chair of masters exam committee for Sumedh Mungee, May, 1998.
  32. Chair of masters exam committee for Sergio Flores, May, 1998.
  33. Chair of masters committee for Prashant Jain, June 1997.
  34. Chair of doctoral topic defense for James Hu, February 1997.
  35. Chair of masters committee for Tim Harrison, February 1997.
  36. Chair of doctoral topic defense committee for Andy Gokhale, October, 1996.

- *Doctoral and Masters Committees Member*

  1. Served on the doctoral topic defense for Zhongwei Teng, April 2021.
  2. Served on the masters thesis committee for Gabriela Gresenz, March 2021.
  3. Served on the masters thesis committee for Xiaoxing Qiu, March 2021.
  4. Served on the doctoral dissertation defense for Anirban Bhattacharjee, January 2020.
  5. Served on the doctoral topic defense for Anirban Bhattacharjee, April 2019.
  6. Served on the doctoral dissertation defense for Shunxing Bao, September 2018.
  7. Served on the doctoral dissertation defense for Shashank Shekhar, May 2018.
  8. Served on the doctoral dissertation defense for Fangzhou Sun, March 2018.
  9. Served on the doctoral topic defense for Shunxing Bao, March 2018.

10. Served on the doctoral topic defense for Peng Zhang, January 2018.
11. Served on the doctoral dissertation defense for Marcelino Rodriguez-Cancio, December 2017.
12. Served on the doctoral dissertation defense for Yao Pan, November 2017.
13. Served on the doctoral topic defense for Fangzhou Sun, September 2017.
14. Served on the doctoral topic defense for Shashank Shekhar, May 2017.
15. Served on the doctoral topic defense for Yao Pan, February 2017.
16. Served on the doctoral dissertation defense for Faruk Caglar, July 2015
17. Served on the doctoral dissertation defense for Wei Yan, May 2015.
18. Served on the doctoral dissertation defense for Kyoungho An, March 2015.
19. Served on the masters thesis committee for Songtao Hei, March 2015.
20. Served on the masters thesis committee for Meng Wang, March 2015.
21. Served on the doctoral dissertation defense for Sean Hayes, January 2015.
22. Served on the doctoral dissertation defense for Hamilton Turner, November 2014.
23. Served on the doctoral topic defense for Faruk Caglar, November 2014.
24. Served on the doctoral topic defense for Hamilton Turner, February 2014.
25. Served on the doctoral dissertation defense for Fan Qui, February 2014.
26. Served on the doctoral dissertation defense for Xiaowei Li, May 2013.
27. Served on the doctoral topic defense for Fan Qiu, April 2013.
28. Served on the doctoral dissertation defense for Janos Mathe, August 2012.
29. Served on the doctoral dissertation defense for Tripti Saxena, July 2012.
30. Served on the doctoral dissertation defense for Akshay Dabholkar, April 2012.
31. Served on the doctoral topic defense for Xiawei Li, March 2012.
32. Served on the doctoral topic defense for Janos Mathe, August 2011.
33. Served on the doctoral dissertation defense for Liang Dai, April 2011.
34. Served on the doctoral dissertation defense for Daniel Balasubramanian, March 2011.
35. Served on the doctoral topic defense for Will Otte, February 2011.
36. Served on the doctoral topic defense for Akshay Dabholkar, February 2011.
37. Served on the doctoral dissertation defense for Joe Hoffert, February 2011.
38. Served on the doctoral topic defense for Tripti Saxena, January 2011.
39. Served on the doctoral dissertatin defense for Nilabja Roy, November 2010
40. Served on the doctoral topic defense for Daniel Balasubramanian, October 2010.
41. Served on the doctoral dissertation defense for Sumant Tambe, September 2010.
42. Served on the doctoral topic defense for Sumant Tambe, April 2010.
43. Served on the doctoral dissertation defense for John Kinnebrew, March 2010.
44. Served on the doctoral dissertation defense for Shanshan Jiang, November 2009.
45. Served on the doctoral dissertation defense for James Hill, March 2009.
46. Served on the doctoral topic defense for James Hill, October 2008.
47. Served on the doctoral topic defense for Jai Balasubramanian, August 2008.
48. Served on the doctoral topic defense for Liang Dai, December 2008.
49. Served on the doctoral topic defense for Shanshan Jiang, November 2008.
50. Served on the doctoral topic defense for Jules White, April 2008.
51. Served on the doctoral topic defense for Amogh Kavimandan, February 2008.
52. Served on the doctoral dissertation defense for Amogh Kavimandan, November 2008.
53. Served on the doctoral topic defense for Amogh Kavimandan, February 2008.
54. Served on the doctoral dissertation defense for Michael Stal, University of Groningen, March 2007.
55. Served on the doctoral topic defense for Karlkim Suwanmongkol, fall 2004.
56. Served on the doctoral dissertation topic defense committee for Aditya Agrawal, July, 2004.
57. Served on the doctoral dissertation defense for Angelo Corsaro, July 2004.
58. Served on the doctoral dissertation defense for Nanbor Wang, April 2004.

59. Served on the doctoral topic defense for Angelo Corsaro, October 2003.
60. Served on the doctoral dissertation defense committee for Jonathan Sprinkle, July, 2003.
61. Served on the doctoral dissertation topic defense committee for Aditya Agrawal, June, 2003.
62. Served on masters committee for Kirk Kelsey, March 2003.
63. Served on the dissertation topic defense committee for Jonathan Sprinkle, February, 2003.
64. Served as external examiner for Bob Jolliffe's masters thesis Department of Computer Science, University of South Africa, March, 2003.
65. Served on the doctoral dissertation committee for Irfan Pyarali, December, 2001.
66. Served on the doctoral dissertation committee for Chris Gill, December, 2001.
67. Served as external examiner for Daniel Heggander's Ph.D. dissertation in the Department of Software Engineering and Computer Science at Blekinge Institute of Technology, Sweden, September, 2001.
68. Served as external examiner for Mohammad Radaideh's masters thesis in the Electrical Engineering department at McMaster's University, Canada, Winter 2000.
69. Served as external examiner for David Holmes' Ph.D. dissertation in the information and computer sciences department at Macquarie University, Sydney, Fall 1999.
70. Served on final doctoral dissertation committee for Priya Narasimhan, August, 1999.
71. Served on the doctoral final dissertation defense for Christo Papadopoulos, August, 1999.
72. Served on dissertation topic defense for Michael Plezbert, February, 1999.
73. Served on masters committee for Craig Nauman, February, 1999.
74. Served on the doctoral exam committee for Chuck Cranor, July, 1998.
75. Served on masters exam committee for Mihai Tutunaru, April, 1998.
76. Served on the doctoral exam committee for Michael Plezbert, June, 1997.
77. Served on masters committee for Todd Rogers, June 1997.
78. Served on masters committee for Robert Engel, January 1997.
79. Served on committee for final doctoral dissertation defense of R. Gopalakrishnan, November, 1996.
80. Served on committee for final doctoral dissertation defense of Lorrie Cranor, September, 1996.
81. Served on the doctoral dissertation topic proposal committee for Christos Papadopoulos July, 1995.
82. Served on the doctoral dissertation topic proposal committee for Charles Cranor December, 1994.
83. Served on oral exam committee for Andy Gokhale December, 1994.
84. Served on the doctoral dissertation proposal committee for Lorrie Cranor, December, 1994.
85. Served on the doctoral final dissertation defense committee for Donald Wilcox, November, 1994.
86. Served on masters committee for Madhavapeddi Shreedhar, September, 1994
87. Served on the doctoral dissertation topic proposal committee for R. Gopalakrishnan, September, 1994.

- *Doctoral Student Advisees and Co-Advisees*

  1. Mike Walker (USA)

- *Graduated PhD Students*

  1. Jaiganesh Balasubramanian, Ph.D., 2009, currently works for Citigroup, New York, NY.
  2. Krishnakumar Balasubramanian, Ph.D., 2007, Mathworks, Boston, MA.
  3. Angelo Corsaro, Ph.D. 2004, PrismTechnologies, Parise France.
  4. Gan Deng, Ph.D., 2007, Citigroup, Charleston, SC.
  5. Brian Dougherty, Ph.D. 2011, Optio Labs, Nashville, TN.
  6. James Edmondson, Ph.D., 2012, Member of the Technical Staff, Software Engineering Institute, Pittsburgh, PA.
  7. Chris Gill, Ph.D. 2001, Professor, Washington University, St. Louis, MO.

8. Andy Gokhale, Ph.D. 1998, Associate Professor, Vanderbilt University, Nashville, TN.
9. James Hill, Ph.D., 2009, Assistant Professor, Indiana University, Purdue University, Indianapolis.
10. Joe Hoffert, Ph.D. 2011, Assistant Professor, University of Edmonton, Canada.
11. John Kinnebrew, Ph.D., 2010, ISIS, Nashville, TN.
12. Arvind Krishna, Ph.D. 2005, Qualcomm, San Diego, CA.
13. Irfan Pyarali, Ph.D. 2001, CitiGroup, New Jersey.
14. Nilabja Roy, Ph.D. 2011, Research Scientist, Institute for Software Integrated Systems, Nashville, TN.
15. Carlos O'Ryan, Ph.D., 2002, CitiGroup, Charleston, SC.
16. Nishanth Shankaran, Ph.D., 2008, Amazon, Seattle, WA.
17. Nanbor Wang, Ph.D. 2004, Research Scientist, Tech-X, Boulder, Colorado.
18. Jules White, Ph.D. 2008, Assistant Professor, Virginia Tech, Blackburg, VA.

- *Graduated Masters and Ugrad Students*

1. Alexander Babu Arulanthu, MS 1999, Sylantro, Campbell, CA.
2. Everett Anderson, BS 1998, Sun, Mountain View, CA.
3. Shawn Atkins, BS 1998, Lucent, Columbus, OH.
4. Matt Braun, BS 1998.
5. Darrell Brunsch, BS 1999, Microsoft, Redmond, WA.
6. George Edwards, BS 2004, Ph.D. student at University of Southern California.
7. Sergio Flores-Gaitan, MS 1998, Microsoft, Redmond, WA.
8. Priyanka Gontla, MS 2000, UBS, Irvine, CA.
9. Pradeep Gore, MS 2000, OOMWorks, New Jersey.
10. Tim Harrison, MS 1997, Mayasoft, Palo Alto, CA.
11. Prashant Jain, MS 1997, IBM Research, India.
12. Vishal Kachroo, MS 1999, Stentorsoft, CA.
13. Michael Kircher, BS 1998, Siemens CT, Munich, Germany.
14. Yamuna Krishnamurthy, MS 2000, OOMWorks, New Jersey.
15. Tao Lu, MS 2003, Trading Technologies, Chicago, IL.
16. Sumedh Mungee, MS 1998, Fujitsu, Santa Clara, CA.
17. Bala Natarajan, MS 2000, Veritas, India.
18. Kirthika Parameswaran, MS 2000, Telcordia, Piscataway, NJ.
19. Stoyan Paunov, MS 2006, working at Bloomberg, NYC.
20. Ossama Othman, MS 2002, independent consultant, Portland, OR.
21. Marina Spivak, MS 2000, AT Desk, Charleston, SC.
22. Nagarajan Surendran, MS 1999, Sylantro, Campbell, CA.
23. Emre Turkay, MS 2005, Turkey.
24. Pooja Varshneya, May 2010, Zircon Computing, Wayne, NJ.
25. Seth Widoff, BS 1998, independent consultant, San Francisco, CA.
26. Ming Xiong, MS 2007, currently working at AT Desk, Charleston, SC.

- *Former Staff*

1. Chris Cleeland, OCI, St. Louis, MO.
2. Ray Klefstad, Research Assistant Professor, University of California, Irvine.
3. Boris Kolpackov, Independent Consultant, South Africa.
4. Fred Kuhns, Research Associate, Washington University, St. Louis, MO.
5. David Levine, Director of Engineering, CombineNet, Inc, Pittsburgh, PA.
6. Will Otte, Institute for Software Integrated Systems, Nashville, TN
7. Jeff Parsons, Optio Labs, Nashville, TN
8. Jules White, Ph.D. 2008, Vanderbilt University, Nashville, TN

Research Support

Total research funding since June 1995: $41,899,342

- Sole PI: $12,030,403
- Co-PI: $29,868,939

Grants and Contracts Received

1. "Automated Clothing Simulation and Human Avatar Generation Engine" NSF, 9/15/2019 to 2/29/2020, $50,000.
2. "Digital Thread Modelling Environment (DTME)," AFRL (subcontract through Securboration), 8/20/2019 to 8/20/2021, $250,000, with Jules White.
3. "Creating an Evidence-based Professional Development Support Tool for Pre-K Coaches and Teachers," Department of Education (IES), $1,399,992, 7/1/18 to 6/30/22, Co-PI with Caroline Christopher.
4. "Blockchain as Middleware Services for Transactive Energy Applications," Siemens, 4/1/2017 to 9/30/2018, $274,397, co-PI Abhishek Dubey.
5. "Children Eating Well (CHEW) Smartphone Application for WIC Families," USDA 4/15/2017 to 4/14/2022, , co-PI with Pam Hull.
6. "Industrial Internet Architecture," Varian Medical Systems, Inc., 10/1/14 to 12/31/18, $288,808, co-PI Jules White.
7. Securboration, "Virtualize Combat System Environment (ViCE)," $15,000, 1/1/18-3/26/18, Co-PI with Jules White.
8. "Container Hopping at Random Intervals or Targeted-Attacked (CHARIOT)," OSD SBIR with Securboration, 1/19/17 to 1/19/18, $35,000.
9. "A Digital Platform for Social and Emotional Learning," NSF, 7/1/2018 to 12/31/2018, $50,000.
10. "Blockchains Data Exchange via FHIR," Solaster, 9/1/18 to 8/31/19, $30,000, co-PI with Jules White.
11. "Advancing Data-Driven mHealth Technologies for Long-term Health and Health Behavior Change," Trans-Institutional Program (TIPs), Vanderbilt University, 9/1/2016 to 8/31/2018, $100,000, Co-PIs Jules White, Trent Rosenbloom, and Heidi Silver.
12. "IMMoRTALS," DARPA (through subcontract with Raytheon), 12/1/15 to 12/1/19, $1,235,567, Co-PI Jules White.
13. "The Robust Software Modeling Tool (RSMT)," ONR, 7/1/14 to 6/30/17, $749,904, Co-PI Jules White.
14. "Building Resilient Distributed Systems for Next Generation Mobile Adhoc Cyber Physical Systems," Siemens 9/1/14 to 8/31/17, $438,188, co-PI Abhishek Dubey.
15. "Capability-Based Technical Reference Frameworks for Open System Architecture Implementations," OSD ASDR&E, 7/3/14 to 9/11/14, $29,690.
16. "Progressive Model Generation for Adaptive Resilient System Software," ONR STTR, 8/6/13 to 1/31/14, $49,406, co-PI Jules White.
17. "Systems and Software PRodUcibility Collaboration and Experimentation Environment (S2PRUCE2)," AFRL (subcontract through Lockheed Martin Advanced Technology Lab), 1/4/13 to 9/30/13, $108,645, with A. Gokhale.
18. "Stochastic Hybrid Systems Modeling and Middleware-enabled DDDAS for Next-generation US Air Force Systems," AFOSR, 10/1/13 to 9/30/16, $935,402, Co-PI(s) Aniruddha Gokhale and Xenofon Koutsoukous.
19. "Workshop on Computing Clouds for Cyber Physical Systems," NSF, 9/15/12 to 12/31/2013, $73,738.
20. "Using Social Learning to Improve Adolescent Diabetes Protocol Adherence," NIH, $1,798,029, 9/1/12-8/31/16, PI Shelagh Mulvaney.

21. "Systems and Software PRodUcibility Collaboration and Experimentation Environment (S2PRUCE2)," AFRL (subcontract through Lockheed Martin Advanced Technology Lab), 4/3/08 to 9/30/12, $381,708, with A. Gokhale.
22. "Team for Research in Ubiquitous Secure Technology (TRUST)," NSF (subcontract through UC Berkeley), 6/1/05 to 10/31/15, $5,970,900, co-PI(s) J. Sztipanovits and G. Karsai.
23. "Android Mobile Military Middleware Objects (AMMO)," DARPA, 9/30/10 to 5/02/12, $1,074,093, with S. Neema.
24. "Cyber-physical multi-Core Optimization for Resource and cachE effectS (C2ORES)", AFRL, 8/1/12 to 7/31/13, $300,000, with A. Gokhale.
25. "Model-Driven Tools for Distributed- and Multi-Core Middleware," AFRL, 4/10/12 to 10/2/12, $30,000, with A. Gokhale.
26. "Cloud Environmental Analysis and Relief," NSF, 8/1/10 to 7/31/12, $66,000, with A. Gokhale.
27. "Environment-Specific Inter-ORB Protocols," SAIC, 8/1/09 to 5/23/12, $348,350, with A. Gokhale.
28. "CoSMIC and CIAO Enhancements," Northrop Grumman, 7/1/09 to 9/30/10, $878,661
29. "Integrating DDS and CCM," Northrop Grumman, 7/1/09 to 2/15/10, $85,000
30. "Early Integration and Performance Testing of Heterogeneous Computing Environments," Australian Defence Science and Technology Organization (DSTO), 1/9/09 to 7/30/09, $180,000.
31. "Predictive Cache Modeling and Analysis," AFRL (subcontract through Lockheed Martin Aeronautics), 3/1/10 to 9/30/11, $100,000.
32. "Applications of Reliable, Fast Event Notification," Raytheon, 6/1/2008 to 5/30/2009, $60,000.
33. "Open Modular Embedded Architectures," General Electric Global Research, 8/1/2008 to 1/31/2009, $35,000.
34. "Analysis and Simulation Techniques for Next-generation Motion Control Systems," Aagard, 8/1/2008 to 1/31/2009, $13,850 with Akos Ledeczi.
35. "Open Modular Embedded Architectures," Raytheon, 8/1/2008 to 3/31/2009, $74,276.
36. "NAOMI," LMCO Advanced Technology Lab, 9/1/2007 to 11/30/2009, $290,000.
37. "IU/CRC Membership," Siemens, 1/1/2009 to 12/31/2009, $40,000.
38. "Enterprise Application Configuration in the Context of Model Driven Software Development and Software Factories," Siemens Corporate Research, 10/1/07 to 9/31/08 $91,798.
39. "Modular Extendable Demonstration of an Upgradeable Space Architecture (MEDUSA)," DARPA (subcontract through Lockheed Martin Advanced Technology Center), 2/1/2008 to 1/31/2011, $600,000.
40. "CCM Middleware Implementation and Integration," PrismTech, 6/8/2007 to 3/31/2007, $33,778.
41. "The Smart Sensor Web Architecture," NASA (subcontract through Lockheed Martin Advanced Technology Center), 12/15/06 to 11/14/09, $467,728, co-PI G. Biswas.
42. "I/UCRC Membership," General motors, 1/1/2008 to 12/31/2008, $100,000, co-PI G. Karsai.
43. "Pollux: Enhanding the Real-time QoS of the Global Information Grid," AFRL, 2/24/06 to 7/24/08, $1,242,718, co-PI M. Reiter.
44. "Intelligent Middleware for Next Generation Petascale Scientific Computing," Vanderbilt Discover Grant, 5/1/05 to 6/30/07, $100,000, co-PI(s) A. Gokhale and P. Sheldon.
45. "Air Force Center for Research on GIG/NCES Challenges," AFOSR (subcontract through UC Berkeley), 3/1/06 to 2/28/08, $600,000, co-PI J. Sztipanovits.
46. "Quality of Service Enabled Dissemination," AFRL (subcontract through BBN Technologies), 12/31/2007 to 9/30/2009, $320,000.
47. "A Fault-Tolerant Real-Time CORBA Naming Service," US Navy (subcontract through Tech-X Corp), 11/1/2007 to 4/30/2010, $175,000, co-PI A. Gokhale.
48. "System Execution Modeling Technologies for Large-scale Net-centric Systems," AFRL, 1/1/2008 to 12/31/2010, $244,000.

49. "Model-Driven Computing for Distributed Real-time Embedded Systems," Raytheon, 8/31/04 to 8/31/08, $500,000.
50. "NAOMI," LMCO Advanced Technology Lab, 9/1/2007 to 11/30/2007, $50,000.
51. "ACE/TAO Improvement Techniques and Solutions, Veritas/Symantec, 3/31/05 to 4/31/08, $198,500.
52. "Adaptive Resource Control for Certificable Systems," DARPA (subcontract through LMCO Advanced Technology Lab), 3/30/2007 to 12/31/2007, $50,000.
53. "Survivable Internet-scale Distributed Systems," IDA, 3/30/2007 to 12/31/2007, $60,000.
54. "QUality of service pICKER (QUICKER)," LMCO Advanced Technology Lab, 3/30/2007 to 12/31/2007, $60,000.
55. "Thimble," LMCO Advanced Technology Lab, 3/30/2007 to 12/31/2007, $60,000.
56. "CADynCE Experimentation Operations (CEO)," DARPA (subcontract through LMCO Advanced Technology Lab), 8/31/2007 to 12/31/2007, $25,000.
57. "Real-time Discovery for Pub/Sub Middleware in WANs," US Navy (subcontract through Tech-X Corp), 6/16/2007 to 9/31/2007, $15,000.
58. "GEMS Utilization Test Suite," LMCO Advanced Technology Lab, 9/1/07 to 11/30/07, $50,000.
59. "Advanced Information Systems and Technology Program," NASA (subcontract through LMCO Advanced Technology Center), 11/13/2007 to 12/1/2007, $22,000, co-PI G. Biswas.
60. "Design for Adaptivity and Reliable Operation of Software Intensive Systems," NSF CNS-0613971, 9/1/06 to 8/31/08, $199,867, co-PI(s) S. Abdelwahed and G. Karsai.
61. "Software Technologies Targeting Interoperability for Systems of Systems," Army Research Lab, 1/15/07 1/14/10, $851,567, co-PI(s) G. Karsai and J. Sztpanovits.
62. "Software Wind Tunnel (SWiT) Capabilities," Lockheed Martin Advanced Technology Lab, 8/1/06 to 12/31/06, $60,000.
63. "High-Confidence Software Platforms for Cyber-Physical Systems," NSF, 5/1/06 to 7/30/08, $129,179.
64. "Applying AOP to Develop of Component Synthesis with MDD," Siemens, 3/1/03 to 2/28/07, $400,005.
65. "Addressing Domain Evolution Challenges in Model-Driven Software Product-lines," Siemens Corporate Research, 10/1/05 9/31/07, $100,000.
66. "A Fault Tolerant Real-time CORBA Naming Service," US Navy (subcontract through Tech-X Corp), 11/1/05 to 8/31/06, $15,000.
67. "The SYstem DEployment and Configuration AssisteR (SYDECAR)," Lockheed Martin Advanced Technology Lab, 8/1/05 to 8/1/08, $500,000.
68. "Future Combat Systems: Software Architecture Engineering," DARPA (subcontract through Boeing), 1/28/05 to 12/31/07, $2,764,226, co-PI(s) J. Sztipanovits and G. Karsai.
69. "Development of an Eclipse Plug-in," PrismTech, 4/28/05 to 9/30/05, $25,000.
70. "Prometheus: Enhancing the QoS of the JBI," AFRL, 3/25/05 to 12/31/05, $500,000, co-PI(s) K. Birman and Mike Reiter.
71. "A Testbed for Assuring Quality of Software for DRE Systems," ONR, 2/15/05 to 1/31/06, $200,000, co-PI(s) A. Gokhale and A. Porter.
72. "Enhancing the QoS of SOAs Using Eclipse-based MDD," IBM, 2/15/05 to 1/31/06, $29,515, co-PI A. Gokhale.
73. "Model-Driven Development of BEEP Application Protocols," Cisco, 12/15/04 to 12/14/05, $57,976, co-PI A. Gokhale.
74. "Evaluating CORBA Middleware for Space Systems," NASA (subcontract through Lockheed Martin Advanced Technology Center), 9/23/04 to 11/30/06, $186,180, co-PI G. Biswas.
75. "Refactoring Techniques to Reduce Middleware Resource Utilization," Qualcomm, 10/31/04 to 10/31/05, $104,000, co-P B. Natarajan.
76. "Model-Driven Development for Software Defined Radios," BAE Systems, 12/1/04 to 3/31/05, $32,000.

77. "Enhancing the Robustness and Performance of TENA," DISA (subcontract through SAIC and OSC), 7/1/04 to 12/31/04, $75,000.
78. "QoS-enabled Fault Tolerant Middleware and MDA Tools," Lockheed Martin MSS, 4/1/03 to 12/31/04, $516,434.
79. "Trustworthiness in Embedded Systems," NSF ITR CCR-032574, 9/31/03 to 8/31/06, $210,454.
80. "ACE+TAO Enhancements," OCI, gift $20,000.
81. "Acquiring Accurate Dynamic Field Data Using Lightweight Instrumentation," NSF ITR CCR-0312859, 10/1/02 to 9/31/07, $1,850,000, co-PI(s) A. Porter, D. Notkin, and A. Karr.
82. "Intergovernmental Personnel Act," DARPA, 6/1/00 to 5/31/02, $198,934.
83. "Optimizing Component Models," DARPA, 4/1/01 to 6/31/02, $210,000.
84. "HLA RTI Next-generation," DMSO (subcontract through SAIC), 6/1/01 to 12/31/01, $70,895.
85. "ACE Enhancements for Windows NT and Windows CE," Siemens Medical Engineering, 2/1/00 9/19/01, $112,000.
86. "Scalable and Fault Tolerant Middleware," AFRL MURI, 12/1/99 to 3/31/02, $253,701.
87. "Protocol Engineering Research Center," AFOSR MURI, 6/15/00 to 6/14/03, $264,720, co-PI Tatsuya Suda.
88. "Optimizing ORBs for Network Management," Cisco Systems, 1/1/00 to 12/31/00, $100,000.
89. "TAO Optimizations," Raytheon, 10/1/99 to 6/01/01, $50,000.
90. "ACE+TAO on pSoS," Motorola, 8/15/99 to 12/31/99, $30,000.
91. "Real-time Distributed Object Computing," Sprint, 8/15/99 8/14/00, $133,068.
92. "TAO Enhancements," Krones, 8/1/99 to 9/1/99, $5,000.
93. "ACE Enhancements," ICOMVERSE, gift, $20,000.
94. "Weapon Systems Open Architecture," Boeing, 7/15/99 to 1/31/00, $51,491.
95. "Fault Tolerant CORBA," Motorola Labs, 7/15/99 to 7/14/00, $139,000.
96. "TAO Enhancements," Global MAINTECH, 7/1/99 to 8/1/99, $5,000.
97. "ACE QoS Extensions," Motorola Trunking, 6/1/99 to 8/1/99, $5,000.
98. "CORBA Interceptors," Experian, 5/15/99 7/14/99, $10,000.
99. "DCOM performance evaluation," Microsoft, gift, $30,000.
100. "TAO Improvements," OCI, 4/1/99 to 9/31/00, $27,000.
101. "Middleware Optimizations," Telcordia, 2/1/99 to 1/31/00, $52,700.
102. "Minimum CORBA," Hughes Data Networking, 4/1/99 to 3/31/00, $50,000, co-PI David Levine.
103. "Framework Usage Patterns," Siemens Corporate Research, 4/1/99 to 3/31/00, $35,000.
104. "Dynamic Scheduling and Real-time ORB Optimizations," Boeing, 10/1/98 9/30/99, $184,860.
105. "Distributed Object Computing Middleware," Nortel, 11/1/98 10/31/99, $75,000.
106. "ACE subsetting," "ACE subsetting,," Nokia, 10/8/98 4/8/99, $30,000.
107. "Boeing Research Fellowship," Boeing, 9/1/98 8/31/00, $81,486.
108. "Patterns and Frameworks Reuse Curriculum," Lucent Bell Labs, 9/1/98 12/31/98, $31,200.
109. "Patterns, Frameworks, and Components," Siemens ZT, 12/1/98 5/31/00, $175,000.
110. "High availability frameworks," Lucent, 9/1/98 8/31/99, $39,400.
111. "Real-time Distributed Object Computing," Sprint, 8/1/98 7/31/99, $288,194.
112. "Distributed Object Integration for the Quorum Project," DARPA S30602-98-C-0187 (subcontract through BBN), 9/1/98 8/31/01, $448,643, co-PI(s) R. Schantz and J. Loyall.
113. "Evaluating a Framework for Dynamic Distributed Real-Time Scheduling,," USENIX, gift, $18,000.
114. "Distributed Object Computing," Microsoft, gift, $20,000.
115. "Distributed Object Visualization Environment," Lockheed Martin, 5/1/98 to 11/31/99, $54,000.

116. "Distributed Object Computing with Adaptive End-to-end QoS Guarantees," DARPA 9701561, 8/1/97 to 7/31/00, $873,625.
117. "Real-time CORBA for Telecommunications," Lucent, 12/1/97 to 11/31/98, $100,000.
118. "Developing an HLA-compliant RTI with ACE," SAIC, 12/15/97 to 1/31/00, $228,075.
119. "Real-time CORBA for Wireless," Motorola LMPS, 10/15/97 to 10/14/98, $200,000.
120. "Real-time CORBA for Avionics," Computing Devices International, 10/15/97 to 10/14/98, $39,050.
121. "Dynamic Scheduling of Real-time OFPs," Boeing, 9/1/97 to 8/31/98, $224,604.
122. "Distributed Object Visualization," Siemens MED, 10/1/97 to 9/1/98, $40,000.
123. "The ADAPTIVE Communication Environment," Siemens MED, 10/1/97 to 9/1/98, $70,000.
124. "The Architect's Assistant," Siemens Corporate Research, 9/1/97 to 8/1/98, $35,000.
125. "Monitoring, Visualization, and Control of High Speed Networks," NSF NCR-97-14698, 9/1/97 to 8/31/01, $1,200,000, co-PI(s) G. Parulkar, E. Kraemer, J. Turner, and R. Cytron .
126. "Adaptive Software Technology Demonstration (ASTD)," AFRL (subcontract through Boeing), 9/1/98 to 8/31/02, $1,200,000, co-PI(s) B. Doerr, D. Allen, and R. Jha.
127. "Patterns, Frameworks, and Components for Multimedia Systems," Siemens Research, 1/97 to 6/98, $150,000.
128. "Adaptive Servers for High-Performance Imaging," Kodak Networked Imaging Tech. Center, 11/96 to 11/97, $40,000.
129. "Real-time CORBA," Sprint, 9/96 to 12/97, $345,000, co-PI G. Parulkar.
130. "OpenMAP – Object-Oriented Components for Real-time Avionics," McDonnell Douglas, 9/96 to 9/97, $241,591.
131. "Compilation and Automatic Optimization of Network Protocol Implementations," NSF NCR-9628218, 8/96 to 8/99, $411,025, co-PI(s) G. Varghese and R. Cytron (PI).
132. "Medical Imaging with Java and the WWW," SIEMENS Medical Engineering, 8/96 to 7/97, $125,000.
133. "The ADAPTIVE Communication Environment," SIEMENS Medical Engineering, 8/96 to 7/97, $90,000.
134. "High-performance Distributed Medical Imaging," Kodak Imaging, 12/94 to 8/96, $55,152, co-PI J. Blaine.
135. "Design Patterns for Concurrent Object-Oriented Networking," Object Technologies International, 4/96 to 4/97, $25,000.
136. "Distributed Object Computing with CORBA and DCE," Bellcore, 5/96 to 12/96, $32,978.
137. "The ADAPTIVE Communication Environment," SIEMENS Medical Engineering, 6/95 to 6/96, $170,000.

Courses Taught

Courses at Vanderbilt University

1. CS 215 – Intermediate Software Design, Spring 2006
2. CS 251 – Intermediate Software Design, Spring 2007, Spring 2008, Spring 2009, Fall 2009, Spring 2010, Spring 2012, Spring 2013, Spring 2014, Spring 2015, Spring 2016, Summer 2020, Summer 2021
3. CS 253 – Parallel Functional Programming with Java and Android, Fall 2020, Fall 2021
4. CS 254 – Concurrent Object-Oriented Programming with Java and Android Spring 2021
5. CS 291/242 – Software Design Studio, Fall 2004
6. CS 291/242 – Software Design Studio, Fall 2003
7. CS 292 – Beyond the Oneway Web, Fall 2008
8. CS 278 – Software Engineering, Fall 2008

9. CS 279 – Software Engineering Projects, Spring 2010
10. CS 282 – Principles of Operating Systems II, Spring 2003, Spring 2004, Fall 2005, Fall 2007, Fall 2012, Fall 2013, Fall 2014, Fall 2015, Fall 2016, Spring 2017
11. UNIV 278 – Tackling Big Questions with Mobile Cloud Computing, Fall 2016, Spring 2017, Fall 2017
12. CS 395 – Advanced Network Software Design, Fall 2006
13. CS 395 – QoS-enabled Middleware, Fall 2008
14. CS 395 – Reactive Microservices, Summer 2021
15. CS 396 – QoS-enabled Component Middleware, Spring 2005
16. CS 891 – Introduction to Concurrent and Parallel Java Programming with Android, Fall 2017
17. CS 891 – Advanced Concurrent Java Programming in Android, Spring 2018, Spring 2019, Spring 2020
18. CS 891 – Introduction to Parallel Java Programming, Fall 2018, Fall 2019
19. CS 892 – Concurrent Java Programming in Android, Spring 2017

Courses at Coursera

1. Android App Development (Android for Java; Android App Components - Intents, Activities, and Broadcast Receivers; Android App Components - Services, Local IPC, and Content Providers), 2016 to present
2. Mobile Cloud Computing with Android (Pattern-Oriented Software Architecture: Communication; Pattern-Oriented Software Architecture: Concurrency), 2014 to 2016
3. Pattern-Oriented Software Architectures for Concurrent and Networked Software, 2013

Courses at University of California, Irvine

1. ECE 011 – Computational Methods in ECE, Winter 2000
2. ECE 255 – Distributed Software Architecture Design, Spring 2000
3. ICS 142 – Compiler Theory, Summer 1989
4. ICS 23 – Data Structures, Summer 1988

Courses at Washington University, St. Louis

1. CS 562 – Advanced Object-Oriented Software Development with Patterns and Frameworks, Spring 1999
2. CS 242 – Introduction to Software Design, Spring 1998
3. CS 673 – Distributed Systems research seminar, Fall 1997
4. CS 422 – Operating Systems Organization, Fall 1997
5. CS 242 – Introduction to Software Design, Spring 1997
6. CS 544 – Distributed System Design, Fall 1996
7. Ada tasking course for McDonnell Douglas, Fall 1996
8. OO design course for McDonnell Douglas, Spring 1996
9. CS 523 – Distributed Operating Systems Organization, Spring 1995
10. CS 242 – Introduction to Software Design, Fall 1995
11. CS 673 – Distributed Systems research seminar, Spring 1995
12. CS 422 – Operating Systems Organization, Fall 1994

Other Teaching Experience

In addition to the academic teaching experience above, I have also taught numerous short-courses and tutorials on object-oriented design patterns and programming techniques, UNIX and Windows NT systems programming and network programming, C++ and C programming languages, and various distributed/networked system, compiler construction, algorithm, data structure, mobile app, and web-based cloud computing courses for the following universities and professional organizations:

- O'Reilly Live-Training
- Pearson LiveLessons
- University Extension Program, University of California, Berkeley, CA
- University Extension Program, University of California, Irvine, CA
- University Extension Program, University of California, Los Angeles, CA
- Oregon Graduate Institute of Science and Technology, Beaverton, OR
- USENIX association
- Association of Computing Machinery (ACM)
- Addison-Wesley's Technology Exchange Program, Reading, MA
- SIGS Conferences
- Object Computing Institute, St. Louis, MO
- National University, Irvine, CA

Department/School/Community Service

Service at Vanderbilt University

1. Faculty advisor for the "DataBrains" AI and Data Science student club.
2. Faculty advisor for the "Vandy Apps" student club.
3. Faculty advisor for the "BizTech" student club.
4. Led the effort to create an online Professional Masters in CS
5. Led the effort to create a continuing education program in Web Development
6. Interview panel for the Director of Professional Programs in VUSE
7. Served on the Digital Literacy committee
8. Chair of two year review committee for Taylor Johnson
9. Chair of the CS search committee in 2003, 2005, 2013, 2016, 2018
10. Chair of the committee on Big Data for the VUSE Strategic Plan
11. Member of the Provost's Special Task Force of the Data Science Visions Working Group: Trans-institutional Masters in Data Science.
12. Member of the Provost's Data Science Visions working group
13. VUSE representative for the Research IT committee
14. VUSE representative on the Provost's Digital Literacy committee
15. Reviewer for University Course proposals
16. Faculty mentor for "Accenture Garage Program"
17. VUSE representative for the Research IT committee.
18. Member of the search committee for the first Director of the Innovation Center
19. Member of the Provost's Study Group on Cross College Teaching
20. Member of the Advisory Committee for the Vanderbilt Institute for Digital Learning (VIDL)
21. Chair of the Provost's Committee on the Innovation Center
22. Member of the VUSE Career Committee
23. VUSE point of contact for VUIT
24. Committee member for Eugene Vorobeychik's promotion case to associate professor
25. Committee member for Bobby Bodenheimer's promotion case to full professor
26. Committee member for Julie Adams's promotion case to full professor
27. Committee member for Akos Ledeczi's promotion case to full professor
28. Chair of the tenure committee for Yuan Xue
29. Chair of the four year review committee for Yuan Xue

30. Member of the two year committee for Yuan Xue
31. Member of the promotion committee for Ted Bapty
32. Member of review committee for Xenofon Koutsoukos
33. Chair of promotion committee for Gabor Karsai
34. Member of promotion committee for Gautam Biswas
35. Chair of the VUSE Technology Entrepreneurship Task Force
36. Member of the VUIT faculty advisory committee
37. Owen-VUSE joint committee for 2014-2015
38. Chair of the Schmidt Family Annual Educational Technologies Lectureship
39. Member of the Provost's Study Group on Cross College Teaching
40. Chair of two year review committee for Eugene Vorobeychik
41. Member of the Chancellor's Social Media and the Internet committee
42. Member of the VU Online Education Task Force
43. Member of the ad hoc committee on EECS Industrial Advisory Board
44. Ex-officio member of the ad hoc committee on the CS graduate program
45. Ex-officio member of the ad hoc committee on the CS undergraduate program
46. Faculty facilitator for the Vanderbilt Visions program
47. Chair of the Information Technology committee for the Vanderbilt School of Engineering
48. Chair of the tenure committee for Bobby Bodenheimer
49. EECS Corporate/Internship Liaison for Computer Science and Engineering
50. Ex-officio Member of the Ad Hoc Committee on Computer Engineering
51. Faculty sponsor of the new EECS Graduate Student Organization
52. Member of the VUSE Research Institutes and Centers Council
53. Associate Chair of Computer Science and Engineering
54. Member of the Vanderbilt University Faculty Senate
55. Chair of the faculty committee on Academic Computing and Information Technology (ACIT)
56. Member of the Research Advisory Committee on Information Technology (RACIT)
57. Chair of the Systems Engineering concentration committee
58. Member of the Plan Integration and Communication Group (PICG)
59. Member of the CS graduate curriculum committee

Service at Washington University, St. Louis

1. Member of the Faculty recruiting committee
2. Member of the CS committee on recruiting industrial graduate students (RIGS)
3. Member of the CS Experimental Infrastructure for Teaching and Research (CEITR)
4. Member of the Introductory course committee
5. Member of the Graduate admission committee
6. Member of the CS representative to the CEC advisory board
7. Member of CS departmental chair search committee

Awards and Honors

1. Received the Cornelius Vanderbilt Professor of Engineering endowed chair in February 2017.
2. Received the 2015 Award for Excellence in Teaching by the Vanderbilt University School of Engineering.
3. Interviewed for Software Engineering Radio (www.se-radio.net/).
4. Vice-chair of the IEEE Chapter in middle Tennessee.
5. Elected to three year term as member of the Vanderbilt University Faculty Senate.
6. Invited speaker at the dedication of the Henry Samueli School of Engineering, along with UC Irvine Chancellor, Ralph Cicerone; Dean of the School of Engineering, Nicolaos Alexopoulos; Chairperson of the Regents of the University of California, S. Sue Johnson; President of the University of California, Dick Atkinson; and CTO and co-founder of Broadcom Henry Samueli.
7. Interviewed for Dr. Dobb's journal TechNetCast, October 24, 2000.
8. Interviewed for **iX** magazine, October, 2000.
9. Received early promotion to tenure as an Associated Professor at Washington University, St. Louis, five years after joining the faculty as an Assistant Professor in 1994.
10. Director of the "Center for Distributed Object Computing" at Washington University, St. Louis since spring of 1999.
11. Listed in Marquis' "Who's Who in Media and Communications," 1997.
12. Received joint appointment to the Mallinckrodt Institute Department of Radiology, Washington University School of Medicine, February 1996.
13. Selected to participate in the ACM OOPSLA '94 Doctoral Symposium.
14. Invited by Dr. Martina Zitterbart to participate in a 4-week international exchange program at the Universität Karlsruhe Institut für Telematik in Karlsruhe, Germany, April 1993.
15. Served as elected representative to the Associated Graduate Student organization at the University of California, Irvine from May 1991 to June 1992.
16. Served as elected graduate student representative to the Computer Science Computing Resource Committee at the University of California, Irvine from August 1988 to August 1990.

Consulting Work

1. ARINC, Fountain Valley, CA
2. ACM, NY, NY
3. Advanced Institute of Information Technology, Seoul, Korea
4. AG Communication Systems, Phoenix, AZ
5. Anderson Consulting, Chicago, IL
6. Apple, Cupertino, CA
7. AT&T Research, Murray Hill, NJ
8. BAE Systems, Greenlawn, NY
9. BAE Systems, Wayne, NJ
10. BEA, San Jose, CA
11. Bellcore, Morristown, NJ
12. BellSouth, Atlanta, GA
13. Boeing, St. Louis, MO
14. Boies, Schiller, & Flexner, Santa Monica, CA
15. Bridges & Mavrakakis, Palo Alto, CA
16. Cooley LLP, San Francisco, CA

17. Correct Care Solutions, Nashville, TN
18. Credit Suisse, Zurich, Switzerland
19. Crosskeys, Ottawa, Canada
20. DARPA, Arlington, VA
21. Desmarais, NY, NY
22. Duane Morris, Atlanta, GA
23. Edward D. Jones, St. Louis, MO
24. Envision Inc. St. Louis, MO
25. Ericsson, Cypress, CA
26. Fitzpatrick, Cella, Harper & Scinto, NY, NY
27. GaN Corporation, Huntsville, AL
28. Gibson, Dunn, & Crutcher, NY, NY
29. Goldman, Ismail, Tomaselli, Brennan, & Baum, Chicago, IL
30. Jet Propulsion Lab, Pasadena, CA
31. Kasowitz, Benson, & Torres, Redwood Shores, CA
32. Keystone Strategy, Boston, MA
33. Kilpatrick Stockton, Atlanta, GA
34. Kirkland & Ellis, San Francisco, CA
35. Kodak Imaging, Rochester, NY
36. Laureate University, Baltimore, MD
37. Lockheed Martin Tactical Systems, Minneapolis, MN
38. Lockheed Martin Mission Systems, Boulder, CO
39. Lockheed Martin Advanced Technology Lab, Cherry Hill, NJ
40. Lucent Bell Labs, Naperville, IL
41. Lucent Bell Labs, Murray Hill, NJ
42. Lucent, Whippany, NJ
43. McDonnell Douglas, St. Louis, MO
44. Microsoft, Redmond, WA
45. Morrison & Foerster, Washington DC
46. Morgan Stanley, New York, NY
47. Motorola Cellular Infrastructure Group, Arlington Heights, IL
48. Motorola Iridium, Chandler, AZ
49. Motorola Land Mobile Products, Chicago, IL
50. National Security Agency, Ft. Meade, MD
51. Naval Air Weapons Stations, China Lake, CA
52. Nortel, Ottawa, Canada
53. Object Computing Institute, St. Louis, MO
54. Object Technologies International, Ottawa, CA
55. Odetics Broadcasting, Anaheim, CA
56. Oracle, Redwood Shores, CA
57. Park, Vaughan, & Fleming, Boise, ID
58. Pearson Education, London, UK
59. Pragmatus, Alexandria VA
60. PrismTechnologies, Newcastle, UK

61. Qualcomm, San Diego, CA
62. Quinn Emanuel, NY, NY
63. Raytheon, San Diego, CA
64. Reichman Jorgensen, CA
65. Riverace, Boston, MA
66. Rubin Anders Scientific, Boston, MA
67. SAIC, Washington D.C.
68. Schwegman, Lundbert, & Woessner, Minneapolis, MN
69. Siemens Medical Engineering, Erlangen, Germany
70. Siemens Corporate Research, Princeton, NJ
71. SIGS, New York, NY
72. Software Engineering Institute, Pittsburgh, PA
73. Teradyne, Chicago, IL
74. Teledyne, Thousand Oaks, CA
75. UC Berkeley Extension, Palo Alto, CA
76. UCLA Extension, Los Angeles, CA
77. USENIX, Lake Forest, CA
78. Venable, NY, NY
79. Wong, Cabello, Lutsch, Rutherford & Brucculeri, Houston, TX
80. WMS Gaming, Chicago, IL
81. Zircon Computing, Wayne, NJ

Expert Testimony in the Past Five Years

1. March 2016, Deposed in support of Oracle in the Oracle vs. Google Fair Use trial in the United States District Court for the Northern District of California, San Francisco division. Case No. Civ. A. No. 10-03561 WHA.

2. May 2016, Testified in support of Oracle in the Oracle vs. Google Fair Use trial in the United States District Court for the Northern District of California, San Francisco division. Case No. Civ. A. No. 10-03561 WHA.

3. February 2017, Deposed in support of IBM in the IBM vs. Priceline Group case. Case No. Civ. A. N. 15-cv-137-LPS-CJB.

4. February 2018, Deposed in support of IBM in the IBM vs. Groupon case. Case No. Civ A. N. 16-122-LPS-CJB.

5. July 2018, Testified in support of IBM in the IBM vs. Groupon case. Case No. Civ A. N. 16-122-LPS-CJB.

6. August 2018, Deposed in support of Palo Alto Networks in the Palo Alto Networks vs. Implicit case. Case No. Civ 6:17-CV-182-JRG.

7. January 2019, Deposed in support of C3IoT in the E2.0 vs. C3IoT case. Case No. 1:15-cv-00530-GMS.

8. February 2019, Testified in support of C3IoT in the E2.0 vs. C3IoT case. Case No. 1:15-cv-00530-GMS.

9. June 2019, Deposed in support of IBM in the IBM vs. Expedia Inc. case. Civil Action No. IPR2018-01136.

10. July 2019, Deposed in support of Philips in the Philips vs. Microsoft case. Civil Action No. 4:18-cv-01885-HSG.
11. August 2019, Deposed in support of Philips in the Philips vs. HTC case. Civil Action No. 4:18-cv-01885-HSG.
12. August 2019, Deposed in support of Philips in the Philips vs. ASUS case. Civil Action No. 4:18-cv-01885-HSG.
13. September 2019, Deposed in support of Kroy in the Kroy vs. Groupon case. Civil Action No. IPR2019-00044.
14. September 2019, Deposed in support of Kroy in the Kroy vs. Groupon case. Civil Action No. IPR2019-00061.
15. March 2020, Deposed in support of Cisco in the Centriptal vs. Cisco case. Civil Action No. 2:18-cv-00094-HCM-LRL.
16. May 2020, Testified in support of Cisco in the Centriptal vs. Cisco case. Civil Action No. 2:18-cv-00094-HCM-LRL.
17. Jan 2021, Deposed in support of Droplets in the Droplets vs. Yahoo case. Civil Action No. 12-CV-03733-JST.
18. Jan 2021, Deposed in support of Droplets in the Droplets vs. Nordstrom case. Civil Action No. 12-CV-04049.
19. June 2021, Deposed in support of Sonos in the Sonos vs. Google case. Civil Action No. 6:20-cv-00881-ADA.
20. September 2021, Deposed in support of IBM in the IBM vs. Zillow case. Civil Action No. IPR2020-01655.
21. November 2021, Deposed in support of Apple in the Apple vs. Identity Security case. Civil Action No. 6:21-CV-460-ADA
22. January 2022, Deposed in support of IBM in the IBM vs. Chewy case. Civil Action No. 1:21-cv-01319-JSR.
23. February 2022, Deposed in support of Droplets in the Droplets vs. Yahoo case. Civil Action No. 12-CV-03733-JST
24. March 2022, Deposed in support of Sonos in the Sonos vs. Google case. Civil Action No. 3:21-cv-7559.
25. March 2022, Testified in support of Droplets in the Droplets vs. Yahoo case. Civil Action No. 12-CV-03733-JST

Summary of Research Contributions

At Vanderbilt University I direct the Distributed Object Computing (DOC) Group at the Institute for Software Integrated Systems (ISIS), which is one of the leading research groups in the world on middleware platforms and MDE tools for DRE systems and mobile cloud computing platforms. Over the past several decades I have conducted and managed research projects on a range of topics, including patterns, optimization techniques, and empirical analyses of software frameworks that facilitate the development of quality of service (QoS)-enabled middleware and model-driven engineering (MDE) techniques/tools for distributed real-time and embedded (DRE) systems and mobile cloud computing apps running over wired/wireless networks and embedded system interconnects. The research methodology throughout my career has involved:

- *Creating* innovative middleware and MDE technologies technologies, such as design formalisms, QoS specification/enforcement techniques, end-to-end and cross-layer middleware optimizations, and automated tools for specifying, analyzing, and synthesizing dependable DRE software from higher-level domain-specific models.

- *Applying* these technologies in conjunction with colleagues in academia and industry to demonstrate and mature middleware and MDE technologies and tools in the context of production mission-critical DRE systems.
- *Amplifying* the adoption and transition of these technologies in both academia and industry via 625+ technical papers, 575+ tutorials and invited talks, millions of lines of popular open-source software, and scores of innovative face-to-face and online courses published and delivered to more than 300,000 students around the world.

The R&D efforts I have led have had a significant impact on academic research and commercial practice. For example, dozens of universities throughout the world use the middleware and MDE tools my DOC Group has developed as the basis for their research and teaching efforts. Moreover, the open-source middleware frameworks and MDE tools generated from projects I've led constitute some of the most successful examples of software R&D ever transitioned from research to industry, being widely used by thousands of companies and agencies worldwide in many domains for three decades. For example, the ACE and TAO middleware frameworks developed by the DOC Group are used by developers in thousands of companies (such as Boeing, Cisco, Ericsson, Kodak, Lockheed Martin, Lucent, Motorola, NASA/JPL, Nokia, Nortel, Raytheon, SAIC, Siemens, Sprint, and Telcordia) in a wide range of domains (such as telecom/datacom, healthcare, process automation, avionics, homeland security and defense, financial services, online gaming, social media, and distributed interactive simulation).

Teaching Contributions and Impact

I have taught scores of cutting-edge courses on topics relating to object-oriented design and programming, software patterns, middleware for distributed real-time and embedded systems, concurrent and networked programming with C++ and Java, and mobile cloud computing with Android. I received the 2015 Award for Excellence in Teaching by the Vanderbilt University School of Engineering. In addition, I've taught 10 popular MOOCs at Vanderbilt on topics related to pattern-oriented mobile cloud computing with Android to over 200,000 learners from around the world.

I recently created and co-taught one of the first cross-college University Courses at Vanderbilt on "Tackling Big Problems with Mobile Cloud Computing," where ten highly diverse teams consisting of 11 arts and science students and 44 computer science students were mentored by 11 faculty from the College of Arts and Sciences, the School of Nursing, the School of Law, the School of Medicine, the School of Engineering and Vanderbilt University Medical Center. The projects in this course addressed relevant, real-world problems involving mobile cloud computing technologies, including:

- Effectively engaging young people with chronic diseases and medical conditions, such as diabetes, asthma and obesity
- Creating "smarter" cities and sustainable energy platforms via an app-based transportation hub for Nashville, and remotely monitoring the safety and operations of novel sources of power, including solar, wind and natural gas, and
- Helping economically disadvantaged individuals bridge the digital divide to obtain better guidance on medical and legal matters.

Summary of Career Accomplishments

My career accomplishments include the following:

Publications and presentations. I have published 650+ works (127 journal papers, 195 conference papers, 5 books, 4 book-length reports, 3 edited book collections, 64 book chapters, 74 workshop papers, 13 short papers and posters, 75 trade magazine columns/articles, and 101 editorials and book forewords). My papers have appeared in the most selective journals (*e.g.*, ACM Transactions in Embedded Computing Systems, IEEE Transactions on Parallel and Distributed Systems, IEEE Transactions on Software Engineering, IEEE Transactions on Computing, IEEE Journal of Selected Areas of Communications, and ACM Transactions on Autonomous and Adaptive Systems) and conferences (*e.g.*, ACM SIGCOMM, ACM OOPSLA, IEEE INFOCOM, IEEE ICDCS, IEEE RTAS, ACM/IEEE Middleware, and the ACM/IEEE ICSE) in my field. I have also given 600+ invited lectures and tutorials world-wide.

Measures of scholarly impact. My publications have been cited 45,000+ times across a comprehensive spectrum of high-impact venues. My h-index is 87 and my i10 index is 401. These bibliometrics indicate the significant impact of my publications as a researcher in the field of Computing.

Funding. Since June 1995 I have been a PI or co-PI for grants, contracts, and gifts totaling more than $41 million dollars. I have been the sole PI for over $11.5 million dollars of this amount.

Graduate advising and training. During my academic career I have (co-)advised and graduated 19 doctoral students and over 25 masters students.

Professional service and leadership. I have engaged in the following professional service and leadership capacities during my career:

- Served as guest editor of 12 ACM, IEEE, and USENIX journals, and served as editor-in-chief of the C++ Report magazine.
- Served as general chair or program (co)-chair for 35 conferences, tutorial chair for 4 conferences, co-organized 14 workshops, and served on the program committees for over 245 ACM, IEEE, IFIP, USENIX, and OMG conferences.
- From 2013 to 2015 I served on the Advisory Board for the joint US Navy/Army Future Airborne Capability Environment (FACE).
- From 2013 to 2015 I served as co-lead of a task area on "Published Open Interfaces and Standards" for the US Navy's Open Systems Architecture initiative.
- From 2010 to 2014 I served a member of the Air Force Scientific Advisory Board, where I was the Vice Chair of a study on Cyber Situational Awareness for Air Force mission operations.
- From 2006 to 2011 I served as the Chief Technology Officer for the Software Engineering Institute at Carnegie Mellon University (2010 to 2011), Zircon Computing (2009 to 2010), and Prism Technologies (2006-2008), where I was responsible for directing the technical vision and strategic R&D investments.
- From 2000 to 2003 I served as a Program Manager at the DARPA Information Technology Office (ITO) and Information eXploitation Office (IXO) the Deputy Director for DARPA ITO, where I lead the national R&D effort on QoS-enabled middleware for DRE systems.
- From 2001 to 2003 I served as Co-chair for the Software Design and Productivity (SDP) Coordinating Group, which formulates the multi-agency research agenda in fundamental software design for the Federal government's Information Technology Research and Development (IT R&D) Program, which is the collaborative IT research effort of the major Federal science and technology agencies.

University service and leadership. I have engaged in the following service and leadership capacities at Vanderbilt University during the past two decades:

- **Associate Provost of Research**. I became the Associate Provost for Research at Vanderbilt University in July of 2018. In this capacity I am responsible for developing cohesive and sustainable information technology (IT) services to advance research and scholarship across Vanderbilt's ten schools and colleges, including scalable and secure storage, processing, and communication solutions; big data research cores and corerelated services, and NIST 800-171 compliant IT services. I am also responsible for overseeing Vanderbilt's new "liquid workforce" service that provides researchers with on-demand access to shared technology expertise to help them develop research IT solutions, especially with data-intensive workflows, while also enabling shared software developers to add value to multiple research programs throughout the university.
- **Data Sciences Initiatives**. I am deeply involved in Vanderbilt's initiatives on Data Science. Starting in August 2018, I became a founding Co-Director of the Data Science Institute at Vanderbilt. During the past year I also chaired the ad hoc committee on Big Data for the Vanderbilt University School of Engineering (VUSE) strategic planning process, as well as served on the Provost's Special Task Force on a trans-institutional Masters in Data Science and the Provost's Working Group on Data Science Visions, which sets the direction for trans-institutional Data Science research. I also created and led a presentation on "Big Data" for the Vanderbilt University Board of Trust in the spring of 2017 that helped initiate Vanderbilt's investment in the Data Science Institute.
- **Cross-College Teaching**. I am a leader in Vanderbilt University's forays into Cross-College teaching. For example, I served as a member of the Provost's Study Group on Cross College Teaching, which formulated the concept of "University Courses" that brings faculty together from multiple schools to actively engage students of diverse backgrounds and promote new and creative trans-institutional learning. I also created/taught one of the first University Courses on "Tackling Big Problems with Mobile Cloud Computing." Each semester since the fall of 2016 I've taught this

course in a multidisciplinary environment where undergraduate and graduate students from multiple schools team with computer science students to address big questions, such as how mobile cloud computing technologies can engage young people with chronic diseases; change political discourse in the United States and around the world; and help economically disadvantaged individuals bridge the digital divide to obtain better guidance on nutrition and legal matters. I also spearheaded the effort to create a CS 1000 course on "the beauty and joy of computing" that is intended for non-CS majors at Vanderbilt University.

- **Digital Learning**. I play a significant role in Vanderbilt's digital learning initiatives, including teaching (1) the first Massive Open Online Course (MOOC) at Vanderbilt in 2013 on "Pattern-Oriented Software Architecture for Concurrent and Networked Systems," (2) the first trans-institutional MOOC Specialization (together with the University of Maryland, College Park) in 2014 on "Mobile Cloud Computing with Android," (3) a Coursera Specialization on "Android App Development" since the spring of 2016, and (4) the forthcoming online Computer Science professional master's degree being created in conjunction with 2U. I have also played a key role in formulating the Vanderbilt digital learning strategy as a member of the Advisory Committee for the Vanderbilt Institute for Digital Learning (VIDL), a member of the Vanderbilt Online Education Task Force, a member of the Chancellor's Social Media and the Internet committee, chair of the Schmidt Family Annual Educational Technologies Lectureship, and a member of the Provost's committee on Digital Literacy whose charter is to ensure that all Vanderbilt students learn computational thinking in their undergraduate experience.
- **Technology Entrepreneurship**. I have been highly engaged in entrepreneurship leadership at Vanderbilt over the past five years. In particular, I chaired the VUSE Technology Entrepreneurship Task Force and the Provost's Committee on the Vanderbilt Innovation Center, known as the Wond'ry (I also served as a member of the search committee for the first Director of the Wond'ry Innovation Center). I am one of the inaugural faculty mentors for the "Garage Program at the Wond'ry, where I mentor multi-disciplinary teams of undergraduate and graduate students to help companies (such as Accenture and RGP) establish new lines of business, e.g., liquid workforce services for the oil and gas domain, supply chain risk management using blockchain technologies, etc. I also serve as the faculty advisor for the VandyApp, DataBrains, and BizTech student organizations, which teach software development skills, prepare students for technical job interviews, and foster a welcoming and diverse environment for high-tech entrepreneurship collaboration across campus.
- **EECS Department Leadership**. I served as the Associate Chair of the Electrical Engineering and Computer Science (EECS) department at Vanderbilt University from 2004 to July 2018. In this capacity I worked with the EECS Chair to provide intellectual leadership and assist in EE, CS, and CompE faculty hiring, curricular development, and course staffing. I also represented Vanderbilt at the bi-annual CRA "CS Chairs" meeting at Snowbird Utah since 2008. In the past several years I focused on innovative digital learning techniques (such as pre-recording material and/or recording lectures in class so students can listen/watch to them at their leisure to ensure they master the course material) to handle the surge in undergraduate CS enrollment without adversely affecting Vanderbilt's commitment to high quality education. I also spearheaded several initiatives to create a continuing education program focused on web development in partnership with Trilogy Education Services and a professional masters degree program in CS in conjunction with 2U.
- **Information Technology Infrastructure for Research**. Over the past two decades I've played a leadership role in the Vanderbilt University Information Technology (VUIT) planning and governance processes. In addition to my latest role as the Associate Provost for Research, I've also chaired the faculty committee on Academic Computing and Information Technology (ACIT), served as the VUSE point of contact for VUIT, the VUSE representative for the Research IT committee as a member of the VUIT faculty advisory committee, as well as served as a member of the Research Advisory Committee on Information Technology (RACIT), and a member of the Provost's Research IT Special Project Working Group, which focuses on supporting the research needs of all schools at Vanderbilt.