IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MARYLAND

WIKIMEDIA FOUNDATION, Plaintiff, v. NATIONAL SECURITY AGENCY, *et al.*, Defendants.	))))))))))	Civil Action No. 1:15-cv-00662-TSE

Attachment C

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MARYLAND

WIKIMEDIA FOUNDATION,	)	
Plaintiff,	)	
v.	)	Civil Action No. 1:15-cv-00662-TSE
	)	~~FILED UNDER SEAL~~
NATIONAL SECURITY AGENCY, *et al.*,	)	
Defendants.	)	

<u>EXHIBIT 1</u>

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MARYLAND

WIKIMEDIA FOUNDATION, Plaintiff, v. NATIONAL SECURITY AGENCY, *et al.*, Defendants.	No. 1:15-cv-0662 (TSE)

DECLARATION OF DR. HENNING SCHULZRINNE

Dr. Henning Schulzrinne, for his declaration pursuant to 28 U.S.C. § 1746, deposes and says as follows:

INTRODUCTION

1. I am the Julian Clarence Levi Professor of Computer Science at Columbia University in New York, New York. I submit this declaration at the request of the United States Department of Justice to address technical issues surrounding, and to render opinions concerning, the assertion of plaintiff Wikimedia Foundation ("Wikimedia") that the National Security Agency ("NSA"), in the course of conducting electronic surveillance known as "Upstream" collection, must as a matter of technological necessity be intercepting, copying, and reviewing at least some of Wikimedia's electronic communications that traverse the Internet. For the reasons I detail herein, that assertion is incorrect. Based on what is publicly known about the NSA's Upstream collection technique, the NSA in theory could be conducting this activity, at least as Wikimedia conceives of it, in a number of ways that would not involve NSA interaction with Wikimedia's online communications.

2. A complete statement of my conclusions in this matter and the bases for them are set forth below, as are my background and qualifications in the fields of computer science, electrical engineering, and digital communications technology, and the sources of information I considered in arriving at the conclusions stated herein. I am being compensated for my services in this matter at the rate of $350 per hour. I have not previously testified as an expert whether by declaration, at trial, or by deposition.

QUALIFICATIONS

3. I received my Ph.D. in Electrical Engineering in 1992 from the University of Massachusetts at Amherst, a Master's Degree in Electrical Engineering as a Fulbright scholar at the University of Cincinnati, Ohio, in 1987, and undergraduate degrees in Electrical Engineering and Economics from the Darmstadt University of Technology (Technische Hochschule) in Darmstadt, Germany, in 1984.

4. Prior to joining the faculty at Columbia University, I was an associate department head, from 1994 to 1996, at the Fraunhofer Institute for Open Communication Systems in Berlin, Germany (FOKUS), formerly an institute of the Society for Mathematics and Data Processing (GMD). From 1992 to 1994 I was a member of the technical staff at AT&T Bell Laboratories in Murray Hill, New Jersey.

5. I joined the faculty at Columbia University as a Professor of Computer Science and Electrical Engineering (a dual appointment) in 1996, and was named as Julian Clarence Levi Professor of Computer Science in 2009. I chaired the Department of Computer Science from 2004 to 2009. I teach courses in Computer Networks; Advanced Internet Services; and Internet Technology, Economics, and Policy and have in the past taught courses on network security and advanced programming. Concurrent with my position on the faculty at Columbia, from 2010 to 2012 I was an Engineering Fellow and Technical Advisor at the Federal Communications Commission (FCC), and Chief Technology Officer of the FCC from 2012 to 2017. In that role I guided the FCC's work on technology and engineering issues to ensure that FCC policies promoted technological innovation in the telecommunications industry.

6. In addition to my teaching responsibilities, I also head Columbia University's Internet Real-Time Laboratory, which under my supervision conducts research in the areas of real-time Internet multimedia services and Internet telephony; wireless and mobile networks; streaming; quality of service; resource reservation; dynamic pricing for the Internet; network measurement and reliability; service location; network security; media on demand; content distribution networks; multicast networks and ubiquitous and context-aware computing and communication; and designs, analyses and prototypes for next-generation "radio," "TV," and "telephone" networks. Additional research interests of mine include Internet signaling, packet scheduling, multicast, the use and development of security algorithms and protocols for prevention of denial-of-service attacks, secure multimedia services, and resource reservations.

7. Over the course of my career in the field of digital communications technology I have co-developed a number of Internet protocols (or supervised their development at the Internet Real-Time Lab). Broadly speaking, Internet protocols are generally accepted sets of rules governing how different types of Internet communications are to be structured so that they may be efficiently transported on, and intelligibly sent and received by devices connected to, the Internet. A number of the protocols that I have developed are now used by almost all Internet telephony and multimedia applications. Among the most prominent are:

- Real-time Transport Protocol (RTP): a network protocol for transmitting audio and video services over Internet Protocol networks, used extensively in communication and entertainment systems that involve streaming media, such as telephony, video teleconferencing and television services.
- Real-Time Streaming Protocol (RTSP): a network control protocol designed for use in entertainment and communications systems to control (rather than transmit) streaming media services, allowing end users to issue VCR-style commands, such as *play*, *record* and *pause*, to facilitate real-time control of the media streaming
- Session Initiation Protocol (SIP): a signaling protocol used for initiating, maintaining, and terminating real-time multimedia communication sessions in applications of Internet telephony for voice and video calls, in private IP telephone systems, in instant messaging over Internet Protocol networks as well as mobile phone calling.

8. My current professional associations include the Institute of Electrical and Electronics Engineers (IEEE), of which I was named a Fellow in 2006 in recognition of my contributions to the design of protocols, applications, and algorithms for Internet multimedia. I have been a member of the Board of Governors of the IEEE Communications Society, past Chair of the IEEE Communications Society Technical Committee on Computer Communications, and past Co-Chair of the IEEE Communications Society Internet Technical Committee. I am also a member of the Association for Computing Machinery (ACM), and served as Vice Chair of ACM's Special Interest Group on Data Communications and the Internet (SIGCOMM).

9. I have also been a member of the Internet Architecture Board (IAB), a committee of the Internet Engineering Task Force (IETF) with responsibility for, among other matters, providing architectural oversight of Internet protocols and procedures, managing Internet standards documents (the "RFC" series) and protocol parameter value assignment. The IAB also acts as an advisory board to the Internet Society (ISOC), the internationally recognized body committed to the open development of Internet standards, protocols, and technical and administrative infrastructure. I also served on the Internet2 Applications, Middleware and Services Advisory Council and have led a working group in the National Science Foundation's GENI (Global Environment for Network Innovations) project, which provides a virtual laboratory for networking and distributed systems research and education.

10. I also serve on a number of conference and journal steering committees, including for the IEEE/ACM journal Transactions on Networking, a bi-monthly publication of high-quality papers that advance the state of the art in communication network research, including theoretical research presenting new techniques, concepts, or analyses, as well as applied contributions reporting on experiences and experiments with actual systems. In the past, I have chaired or co-chaired various IEEE and ACM annual global conferences in the field digital communications technology.

11. I have published more than 250 journal and conference papers, and more than 70 Internet RFCs. (RFCs are publications documenting Internet specifications, communications

protocols and procedures adopted as standards by the IETF, but from time to time are also informative in nature, describing research or innovations applicable to the working of the Internet and Internet-connected systems.) A list of my publications, including all publications I have authored in the previous 10 years, may be found in my curriculum vitae, a copy of which is attached to this declaration as Exhibit A. I have also been editor of several periodicals in the field of computer science, including "Computer Communications Journal," "ACM Transactions on Multimedia Computing," and "ComSoc Surveys & Tutorials," "IEEE Transactions on Image Processing," the "Journal of Communications and Networks," "IEEE/ACM Transactions on Networking," and "IEEE Internet Computing Magazine."

12. In 2013, I was inducted into ISOC's Internet Hall of Fame, in recognition of my contributions to the development of key Internet protocols, including the RTP, RTSP, and SIP protocols noted above. Among other awards, I received the New York City Mayor's Award for Excellence in Science and Technology, the VON Pioneer Award by the Voice-over-Net Conference, the IEEE Technical Committee on Computer Communications Outstanding Service Award, and the IEEE Region 1 William Terry Award for Lifetime Distinguished Service to the IEEE.

FACTS AND INFORMATION CONSIDERED

13. For purposes of preparing this declaration, I have relied on (and cite herein) various types of sources, including: (i) Internet standards documents adopted and published by the IETF, known as RFCs, *see* paragraph 11, above, available at https://www.rfc-editor.org/search/rfc_search.php; (ii) public registries and other websites where information concerning assigned protocol and port numbers, IP addresses, and the like, may be found; (iii) various publicly available statistics and technical information concerning Internet infrastructure; (iv) information obtained from manufacturer websites; (v) standard college textbooks, written by well-established leaders in the field, that have become the accepted teaching materials for engineering and computer science students entering the field of computer networks; and (vi) my own knowledge of and familiarity with the technology and operation of global communications networks.

14. As appropriate, I also refer to documents and information produced by Wikimedia in discovery proceedings in this case, and to official U.S. Government documents publicly describing, in unclassified terms, the operation of NSA Upstream surveillance. A list of the documents provided to me by Justice Department counsel, and which I have also reviewed, is attached as Exhibit B. In reaching the conclusions stated herein I have not considered nor have I been provided with any classified or other non-public information concerning the Upstream program.

SUMMARY OF CONCLUSIONS

15. Principally, I have been asked to evaluate Wikimedia's assertion that the NSA, in the course of conducting Upstream surveillance, must as a matter of technological necessity be intercepting, copying, and reviewing at least some of Wikimedia's electronic communications that traverse any Internet backbone "link" monitored by the NSA. For the reasons I explain at length below, I conclude that Wikimedia's assertion is incorrect. Based on what is publicly known about the NSA's Upstream collection technique, the NSA could be conducting Upstream-type surveillance, at least as envisioned by Wikimedia, in a number of technically feasible, readily implemented ways that would not involve NSA interaction with Wikimedia's online communications.

INTERNET INFRASTRUCTURE

16. Technically speaking, the Internet is a global collection of networks, large and small, "interconnected by a set of routers which allow them to function as a single, large virtual network." (RFC 1208, 1991) In other words, it is a network of networks, owned and operated by thousands of private and public entities across the world, including telecommunications service providers, governments, and non-profit organizations. There is no precise count of the number of networks that together make up the Internet, but currently there are approximately 62,000 autonomous systems (networks or collections of networks managed and supervised by large entities or organizations) with their own identifiers (Autonomous System Numbers) assigned by the global Internet Assigned Numbers Authority (IANA). These include networks operated by

Columbia University (AS 14), the Wikimedia Foundation (AS 14907), Google (AS 15169) and large carriers such as Verizon (AS 702 and others). Consisting of servers, communication links, and intermediate devices that route information from one network to another ("routers"), this infrastructure allows any device connected to this network of networks to send information to any other connected device (subject to restrictions imposed by the sender or recipient). These network devices, even though manufactured by many different companies, can communicate with one another since they use a common set of agreed-upon technical standards.

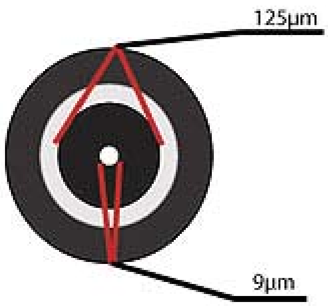
17. To communicate over the Internet an individual user must obtain a connection from an Internet Service Provider ("ISP"), either directly or indirectly through an organization such as an employer, or an Internet café (for example, a Starbucks). Typically, an ISP is a private company that provides subscribers access to the Internet for a periodic fee. Subscribers to an ISP's services can be individuals, businesses, educational institutions, government agencies, or other organizations. An ISP maintains one or more local facilities, referred to as points of presence (POPs), at which subscribers can connect with the ISP's network and thereby gain access to the rest of the Internet. Access can be provided via the twisted-pair copper cables originally installed for telephone service, coaxial cable also used to provide cable television service, fiber-optic cable, or wireless satellite signal.

18. In a residential setting the connection is ordinarily made through a device located at the subscriber's home (and often supplied by the ISP) called a router or modem. (Increasingly, however, some individual Internet users have "cut the cord" and only use services provided by cellular telephone networks.) In a business, government agency, or other large organization, the device used by an individual will be part of a local area network (LAN) operated by the organization. The local area network is then connected to the network of a local or regional ISP with which the organization has contracted. The networks of local and regional ISPs in turn connect, at locations known as regional points of presence, to the networks of still larger ISPs, the largest of which are so-called "Tier 1" telecommunication service providers such as AT&T, CenturyLink, Cogent, Verizon or their international equivalents such as NTT or Deutsche Telekom.

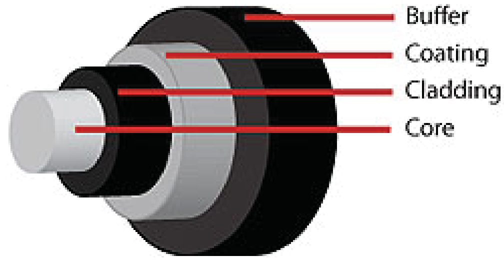
19. Tier 1 and other large carriers maintain high-capacity terrestrial fiber-optic networks, generally known as Internet "backbone" networks, which use long-haul terrestrial cables to link large metropolitan areas across entire nations or regions. (Shown below are the North American parts of Cogent's fiber-optic network.) Data travel across these fiber-optic cables in the form of optical signals, or pulses of light. Each fiber-optic cable contains between 4 and 432 glass fibers, with strand counts of around 144 common.

Cogent US domestic fiber network

Each fiber has at its core a thin, flexible strand of glass, about 9 micrometers thin, surrounded by another glass strand of 125 micrometers. (A micrometer is one-millionth (10^{-6}) of a meter. A human hair has a diameter of between 17 and 181 micrometers.) Data is transmitted by lasers, carried long distances through the insertion of optical amplifiers, and received by photo detectors.



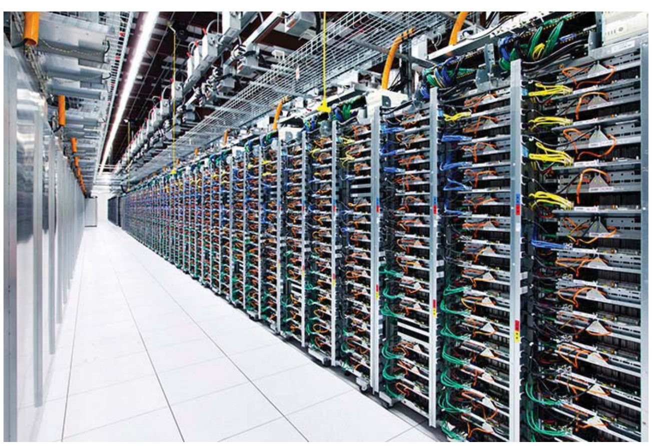
Fiber-optic strand



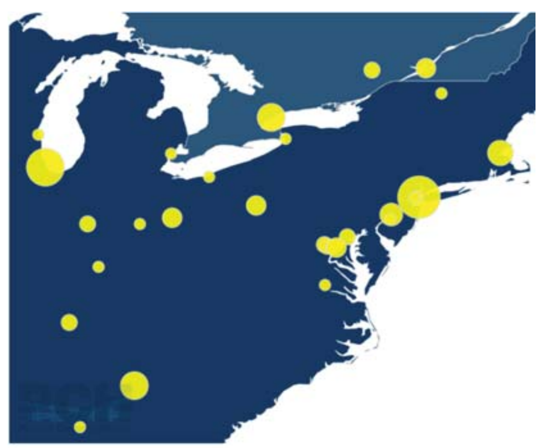
Fiber-optic cable

Buried fiber cable

20. To make possible communications between users linked to one provider's network with users linked to another's, Tier 1 providers typically interconnect (link) their networks either directly, at facilities known as private peering points, or through public Internet exchange points (IXPs). In an Internet exchange, many different telecommunication carriers can link with each other, exchanging traffic. For example, the Amsterdam Internet Exchange (AMS-IX) (shown below) connects 824 different networks, using 1,423 ports (connections), and carries about 5 terabits (5 billion bits) per second of traffic during the peak hour of the day.[1] A public directory[2] lists 905 such IXPs, differing greatly in the number of carriers that interconnect at each and the total volume of traffic carried.



AMS-IX Internet exchange (Amsterdam)[3]



Map of IXPs in eastern United States (source: PCH)

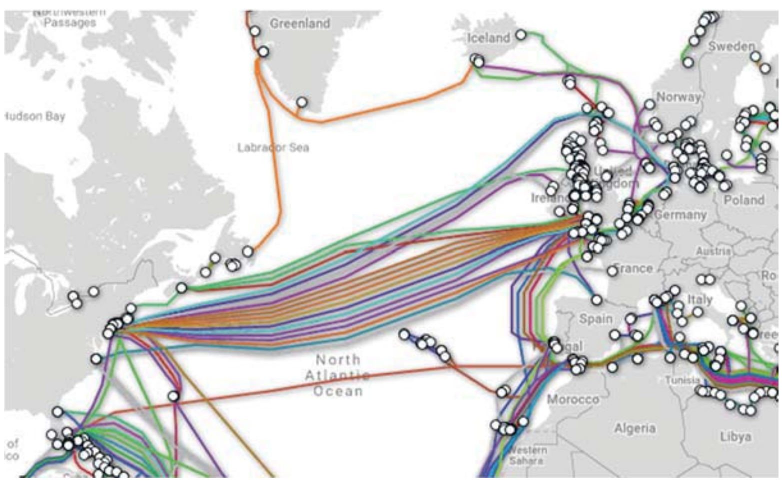
[1] https://ams-ix.net/technical/statistics

[2] https://www.pch.net/ixp/dir

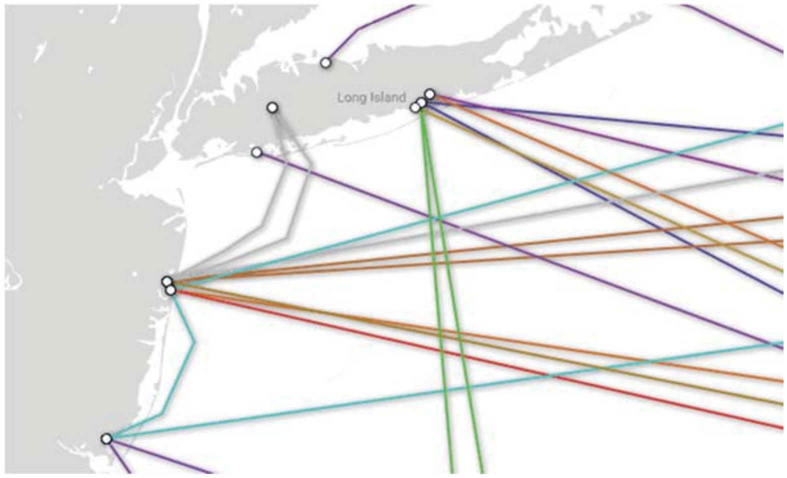
[3] https://pcmweb.nl/artikelen/internet/zo-werkt-ams-ix-alles-over-het-grootste-internetknooppunt-ter-wereld/

21. In addition to long-haul terrestrial cables, the Internet backbone also includes transoceanic cables linking North and South America with each other and with Europe, Asia, the Middle East, and Africa. These undersea cables are laid directly on the ocean floor, and make landfall at points known as cable landing stations. Technologically speaking, there is no fundamental difference between long-haul terrestrial and transoceanic links. Both types use buried fiber cable with optical amplifiers placed at regular intervals, although the hostile environment of the oceans and the difficulty of providing power to amplifiers far from shore influence design details. As an example, the recently-completed MAREA cable has landing points in Virginia Beach, Virginia and Bilbao, Spain, and is composed of eight fibers delivering a total of 160 terabits per second (160,000 billion bits per second). The fiber bundle, encased in heavy-duty metal shielding, has a diameter similar to a garden hose and is placed directly on the ocean floor, except for the shallow stretches near the landing stations, where it is buried to protect it against ship anchors and other disturbances.

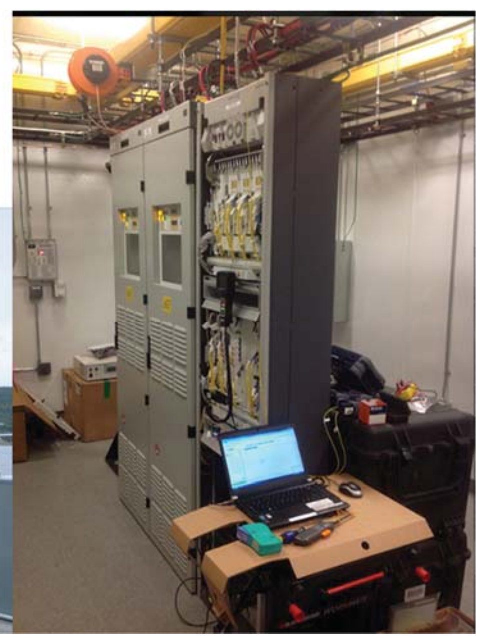
22. The map below, provided by TeleGeography, illustrates some of the Internet-carrying fiber-optic cables linking the east coast of the United States to Europe.



The map enlargement below, from the same source, shows that most east coast transatlantic fibers originate from a few landing sites in New Jersey and on Long Island.



23. At each shore location, cable landing stations connect the transoceanic cable to terrestrial cable networks. An example of a cable landing station (Cape Broyle, Canada) is shown below, drawn from the manufacturer's web site.[4] It contains fiber amplifiers, management systems, and possibly Internet routers. The adjacent picture shows the inside of the same facility, showing fiber racks and ceiling cable trays. A terrestrial cable then connects the landing station to the nearest Internet exchange point (IXP), where multiple service providers then link to the terrestrial cable.



[4] http://americanmanufacturedsystemsandservices.com/products-services/products/cable-landing-stations/new-cable-landing-project.html

24. Using this infrastructure, every device connected to the Internet can communicate with every other device, no matter where located or to which providers it is connected. While the process is usually not apparent to the individual user, a communication (such as an email) being sent from one device to another across the country, or across the globe, can travel through numerous other networks en route to its destination. If the communication is traveling to a destination outside of the network of the user's ISP, it will flow onto the networks of Tier 1 or other larger providers, typically reached via an Internet exchange point, before reaching its destination via regional and local networks on the receiving end. If an international communication, it may also be carried on one or more transoceanic undersea cables, traversing cable landing stations as it exits one continent and makes landfall on the next. Such communications may traverse the networks of anywhere from one to maybe a dozen different carriers. Usually, the path is roughly similar to the shortest geographic route, but business relationships and the availability of interconnection points and transoceanic links may lead to detours, similar to how airlines may use hub airports to connect smaller or more far-flung cities.

TRANSMISSION OF COMMUNICATIONS ON THE INTERNET

25. Generally speaking, to send a communication on the Internet, the transmitting device (e.g., a personal computer, a cell phone, or the computer—a.k.a. "server"—on which a website is physically stored) first converts the communication into one or more "packets." Packets are relatively small chunks of digital information that can be transported more efficiently than transporting communications (such as entire webpages, or large documents) whole. Packets are typically between a few tens of bytes and 1,500 bytes long, where each byte, roughly speaking, can carry one text character of information. A brief discussion of network protocols and "layers" is helpful to understanding how the packets comprising a communication travel across the Internet.

26. In all communications networks, including the Internet, communicating entities need to agree on a set of technical conventions concerning how to exchange information. These conventions are generally called protocols. "A protocol defines the format and order of messages

exchanged between two or more communicating entities, as well as the actions taken on the transmission and/or receipt of a message or other event."[5] Most telecommunications protocols are defined in engineering specifications, drawn up by international bodies and revised periodically. For the Internet, protocols are primarily defined by the Internet Engineering Task Force (IETF), discussed above, in documents known for historical reasons as RFCs. Each protocol operates and serves its function within a "layer" of the communications network architecture. The concept of layering is a way of functionally sub-dividing a communications system into subsystems, or "layers," of similar functions that provide services to the layer "above" and receive services from the layer "below."

27. In the most widely used network model, the Internet protocol suite, the layers from the "bottom" to "top" of the "stack" are the physical, data link, network, transport, and application layers. For purposes here, the primary layers of interest are the physical, network, transport, and application layers. The physical layer transports electrons or photons between routers and switches, e.g., via fiber-optic or copper cable. The network layer allows two devices on the Internet to communicate with each other by making it possible for packets to travel and be exchanged across many links and networks of different providers using differing technologies. The Internet Protocol, now in two different versions, is the only widely used network-layer protocol at the moment. The transport layer ensures that the receiver can detect whether the information has arrived without error, with the Transmission Control Protocol (TCP) as the dominant protocol. TCP also retransmits any packets that may have been lost by the network and makes a sequence of packets appear as a stream of data and thus hides the packet nature of the Internet from applications using the protocol. UDP, the other transport protocol, does not provide reliability and in-order delivery. Finally, the application layer makes possible the transmission of various communications applications, such as email, or web pages, using protocols specific to each application, such as the Simple Mail Transfer Protocol (SMTP) and the

[5] J. Kurose and K. Ross, "Computer Networking: A Top-Down Approach," p. 5 (Pearson, 2017).

Internet Messaged Access Protocol (IMAP) (both for email), and the Hyper Text Transfer Protocol HTTP (for web pages). As a rough analogy to road networks, the asphalt is the physical layer, the trucks and cars offer network services, a shipping company offers a transport service, and an e-commerce company provides the application service.

28. When a communication is broken into separate packets, each packet includes (i) a "header," that is, the routing, addressing, and other technical information required by the transport protocol to facilitate the travel of the packets from their source to their intended destination, and (ii) a "payload," that is, a portion of the contents of the communication being transmitted. A rough analogy can be drawn between the transmission of packets and delivery of mail by the postal service. A business letter has a "header" containing the sender address, a date ("time stamp") and the recipient address, in addition to various processing indications, such as confidentiality markings or signatures. The letter is then placed in an envelope for delivery that displays this "header" information, but contents of the letter remain invisible to the postal service. The manner and timing of the letter's delivery is unaffected by such factors as the contents, language, or format of the letter.

29. Each layer of the communication stack uses a different header, corresponding to that layer's purpose. For our purposes here, I mainly focus on the network and transport layers. The packet headers for the network and transport layers contain three relevant pieces of address and routing information: (i) the packet's source and destination Internet Protocol (IP) addresses and (ii) protocol numbers, in the network layer header; and (iii) the source and destination ports, in the transport protocol header.

30. <u>IP Addresses</u>: IP addresses are unique numeric identifiers assigned to particular computers, devices, or systems connected to the Internet, and which, as the name suggests, are used by the Internet Protocol at the network layer to send data from one computer or other online device to one or more other devices, and back. IP addresses may be analogized, as in the example above, to the destination and return addresses on an envelope sent through the mail, or to telephone numbers identifying the source and destination of a call. On the telephone

network, telephone switches rely on telephone numbers, area codes, and country codes to route calls locally, within the same local exchange, and long distance. On the Internet, IP addresses fulfill a similar function.

31. Currently there are two versions of IP addresses in use. Since the 1980s the Internet has used so-called IP version 4 addresses (RFC 791, 1981), abbreviated as IPv4. There are approximately four billion such addresses. For example, the web server hosting Wikipedia (Wikimedia's largest website) has an IPv4 address written as 208.80.154.224 in the US. (It may use other addresses elsewhere.[6]) The growth of the Internet, primarily through mobile devices, has outstripped the supply of IPv4 addresses, so a new version, IP version 6 (IPv6) has been adopted that uses a greater number of characters, thus allowing for as many as 340 undecillion (10^{36}) addresses. That is sufficient to assign as many addresses as the current IPv4 provides to every star in the universe. In the United States, the Wikipedia server currently uses the IPv6 address 2620:0:861:ed1a::1. Many computers "speak" both protocols; web servers, including the Wikipedia servers, may deliver content using either Internet protocol, depending on the computer connecting to the server.

32. Each ISP or other large enterprise with a fixed presence on the Internet acquires blocks of IP addresses from the appropriate regional Internet registry affiliated with the IANA. For example, the American Registry for Internet Numbers (ARIN) allocates blocks of IP addresses to large enterprises in the United States and Canada. Columbia University has been assigned the 65,536 IP addresses from 128.59.0.0 to 128.59.255.255. Comcast uses, among many other IPv4 address blocks, the roughly eight million addresses starting at 50.128.0.0. There are public databases that record, with very high accuracy, which address blocks are used by what entities, at least at the granularity of ISPs or other large organizations that have assigned autonomous system (AS) numbers, like the Wikimedia Foundation (ASN 14907).

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[6] Sites such as https://www.whatsmydns.net/ can be used to determine the IP addresses of a domain (e.g., a website) as they would appear from various geographic locations.

33. IP addresses can be assigned on a permanent or temporary basis, referred to respectively as "static" and "dynamic" addresses. Static IP addresses can be assigned directly to a "self-hosting" organization by the regional Internet registry (as in Wikimedia's case), or indirectly to businesses or other organizations that obtain Internet access via ISPs. (ISPs, after obtaining their allocations of IP address blocks from the registry, in turn assign smaller blocks of fixed addresses to their business customers.) Static IP addresses almost never change. Fixed IP addresses are necessary to run servers, as a server's IP address needs to be disseminated to client (user) computers and mobile devices that want to connect to it. For example, the IP addresses of the servers that host Amazon.com, or Wikipedia.org, must remain unchanging if online shoppers, or Wikipedia's readers and contributors, are to reach them over the Internet. As a rough analogy, static IP addresses are like business phone numbers, which typically do not change for years since they are advertised on business cards and painted on delivery vans. So that Internet users are not required to ascertain, or memorize, the IP addresses of every website they visit, a database service called the domain name service (DNS) translates the names that users type into their browsers, e.g., Wikipedia.org, into Internet addresses, e.g., 208.80.154.224.

34. While the business customers of ISPs may be allotted a fixed block of IP addresses, assigned permanently, ordinarily residential customers get exactly one "dynamic" IPv4 address at a time, assigned on a temporary basis. Dynamic IP addresses may be assigned for a day, an hour, or some other period of time, depending on the needs, resources, and business practices of a particular ISP, after which they are assigned to other customers. An ISP may even assign a particular IP address to a home customer only for the specific length of time (session) that the customer is connected to the Internet, after which the IP address may be released and assigned for temporary use by another customer. (Consumers may be assigned a block of IPv6 addresses, but again without any claim to keep that particular block.)

35. Ports: IP addresses alone are not sufficient to operate networks having multiple functions. For example, the same server may host a web service, an email service and a voice-over-IP (Internet telephony, a.k.a. VoIP) service. The operating system on the server, such as

Windows or Linux, uses *port numbers*, carried in the transport layer protocol (typically TCP or UDP), and included in the header of each communication packet, to distinguish packets destined for the web service from those meant for the email or VoIP services. Likewise, on the user's end, a client computer (a home or office computer, or mobile phone) may run multiple applications for various online activities, such as web-browsing, sending and receiving email, or voice communications using VoIP technology. The user's device also uses port numbers contained in packet headers to ensure, for example, that pages downloaded from a website are routed to the user's browser, not his or her email application, and vice versa.

36. While IP addresses used to route a communication to a particular destination device can be analogized to the street address on a letter, or to a telephone number, port numbers are roughly analogous to the apartment numbers at a multi-unit dwelling, or individual extensions to a business telephone number. Port numbers for common applications like web-browsing and email, each with its own application-layer protocol, are maintained in a common industry registry maintained by the IANA. Some common port number assignments are in the table below; they are generally numbers between 1 and 49,151.

Port number	Protocol	Application
20	ftp	File transfer
22	ssh	Remote login
25	SMTP	Mail delivery between servers
53	DNS	Domain name system (host name lookup)
80	HTTP	Web pages, unencrypted
123	NTP	Network time (clock) synchronization
143	IMAP	Remote email message access
443	HTTPS	Encrypted web pages, using SSL/TLS

587	SMTP	Email submission protocol, from client to server
993	IMAP	Email access, encrypted using TLS
5060	SIP	VoIP session setup

37. It is possible to run network applications on non-standard ports, but then users on both ends of the communication have to be aware that this is being done. For example, http://portquiz.net:8080/ is a website that uses port 8080, but needs to indicate that fact by including the port number in the web address (URL). Some applications, such as the media (voice or video) components of voice-over-IP, do not have fixed port numbers; rather, devices on each end of the conversation agree on suitable port numbers on a call-by-call basis.

38. Protocol Numbers: Protocols associated with various layers of the network architecture are also assigned numbers maintained in a registry by the IANA. Protocol numbers are also included in packet headers and used by receiving devices to determine the appropriate protocols to apply for interpreting and acting on each packet upon arrival.

39. Once a communication has been broken into constituent packets by the transmitting device, the job of ensuring that the packets travel an appropriate path across the Internet from their source to their destination IP address is performed by devices known as routers and switches. Routers and switches are specialized computers, located at strategic network points, that take on a similar role for the Internet as switches on the telephone network. That is, their basic function is to determine where on the Internet to send packets next. Packets constituting a single communication can travel through several to as many as dozens of routers and switches to reach their destination. Typically, so-called carrier- or enterprise-grade routers are located at ISP points of presence (POPs), peering stations, or Internet exchanges, routing packets from one network to another. A large router commonly found in such Internet exchanges is shown below. Carrier- or enterprise-grade switches are typically located at points of presence where different legs of the same carrier backbone network interconnect, and forward packets from one leg of the network to another.

Juniper router ((c) Juniper Networks)

40. To perform its function, each router or switch along a packet's path "decodes" the incoming light pulses from the connected fiber-optic cable and reconstitutes the individual packets for processing. The router or switch then scans each packet's header information, including its destination IP address, and matches the address against an internal routing table. The routing table contains rules (updated by a routing protocol) determining the direction in which packets with addresses falling in particular IP ranges should be forwarded. This exercise may leave the router or switch with a choice of anywhere between three and hundreds of possible next-leg destinations for the packet. The routing protocol can also be used to convey performance-based rules for determining which of the available paths to choose. This allows the router or switch to find a connection with good performance, avoid congested connections, detour packets around failed network links, and use newly available connections, somewhat similar to the manner in which Google Maps updates the fastest route to take between a user's starting point and his/her destination. The largest routers and switches, those used to handle exchanges of communications data at major intersections on the Internet, handle millions of data packets every second.

41. While, in theory, each packet in a single communication could take a different path across the Internet, in practice packets traveling between two points on the Internet generally follow the same path for long distances, just like most motorists traveling between New York City and Washington, D.C., take Interstate 95, following different possible paths (like different county

roads, or neighborhood streets) only when nearing their destinations, or to avoid traffic jams. In particular, since transoceanic connections are only added and removed infrequently, and since most carriers only have a few links that they use, any traffic between international destinations is likely to keep using the same fiber links for months, if not years, except for routing around any outages. Generally, traffic takes the shortest route, subject to business arrangements between carriers. For example, packets comprising an email sent from New York to Amsterdam will traverse the Atlantic Ocean via undersea cable to a landing site in northern Europe, rather than take a circuitous route via the Pacific Ocean, or even a southern route across the Atlantic via Africa.

42. To protect the privacy and integrity of information, users sending data across the Internet may choose to encrypt their traffic, i.e., convert the data into code by a mathematical transformation, so that it can only be read by parties who have the encryption key. Generally, modern encryption techniques are considered to be unbreakable by any third party that does not have access to the key, even if the encryption mechanism is known. The most common encryption mechanism is the Transport Layer Security (TLS) protocol, which operates at the transport layer, one below the web HTTP protocol. The combined use of TLS and HTTP is commonly referred to as HTTPS, even though it is not a single protocol and TLS can also be used for other applications. Use of the encrypted HTTPS protocol is designed to ensure that information sent to or from a web site can only be read by the user's web browser and the host web server, but not third parties, including entities capable of copying packets en route between the browser and the web server. HTTPS offers the exact same functionality of retrieving web pages, but ensures that the web browser connects to the correct web server, and that no third party can read the content of the communications. Despite its relation to HTTP, HTTP-over-TLS (HTTPS) has been assigned a different port, port 443 (the unencrypted HTTP protocol is assigned port 80), allowing web browsers and web servers to distinguish encrypted from unencrypted information by the port number.

43. Increasingly, most popular websites, including those of the Wikimedia Foundation, use HTTPS or at least offer their content via both HTTP or HTTPS. In fact, given the commonality of encryption today, most entities with an Internet presence offer an encrypted version of their content, and the temporary use of unencrypted content to, for example, support legacy applications that have not yet made the transition, is increasingly rare.

44. Once the packets making up a communication arrive at the receiving computer or smartphone, the operating system of the receiver reassembles the packets into the original communication, such as a web page or email, even if the network between the sender and receiver discards, corrupts or reorders some of the packets. As noted earlier, TCP, a transport layer protocol, performs this service, by retransmitting missing or corrupted packets.

PUBLICLY AVAILABLE INFORMATION ABOUT NSA "UPSTREAM" COLLECTION

45. NSA "Upstream" collection of communications is described, in general terms, in a number of official public reports issued by the Government, albeit not all of them authored or released by the NSA. Because such reports are relied on by Wikimedia in its Amended Complaint to inform its view of how Upstream collection might work, I rely on them as well.

46. According to these reports, once the necessary approvals are obtained from the Foreign Intelligence Surveillance Court, NSA analysts identify non-U.S. persons located outside the United States who are reasonably believed to possess or receive, or are likely to communicate, designated foreign-intelligence information. NSA Civil Liberties and Privacy Office Report, NSA's Implementation of FISA Section 702 at 4 (Apr. 16, 2014) ("NSA Civil Liberties Report), available at https://www.nsa.gov/Portals/70/documents/about/civil-liberties/reports/nsa_report_on_section_702_program.pdf. Once the NSA has designated such persons as targets, it then tries to identify specific means by which the targets communicate, such as email addresses or telephone numbers, which are referred to as "selectors." See NSA Civil Liberties Report at 4; Privacy & Civil Liberties Oversight Board Report on the Surveillance Program Operated Pursuant to Section 702 of the FISA at 32-33, 36 ("PCLOB Section 702 Report") available at https://www.pclob.gov/library/702-Report.pdf. A telecommunications service

provider may then be compelled to provide the Government all information or assistance necessary to acquire communications associated with the selector, a process referred to as "tasking." NSA Civil Liberties Report at 4-5; PCLOB Section 702 Report at 32-33.

47. Upstream collection is one of the methods through which the NSA receives information concerning tasked selectors. Upstream collection occurs as communications transit the Internet backbone within the United States. PCLOB Section 702 Report at 36-37. Under Upstream collection, tasked selectors are sent to a U.S. electronic-communications-service provider to acquire communications that are transiting the Internet backbone. PCLOB Section 702 Report 36-37. Internet communications are first filtered to eliminate potential domestic communications, and are then scanned to capture only communications containing the tasked selector. PCLOB Section 702 Report at 37. Unless communications pass both these screens, they are not ingested into NSA databases. PCLOB Section 702 Report at 37.

WIKIMEDIA'S CONTENTIONS

48. Wikimedia alleges in its First Amended Complaint that "[t]he NSA conducts Upstream surveillance by connecting surveillance devices to multiple major internet cables, switches, and routers on the internet backbone inside the United States," for the purpose of "enabl[ing] the comprehensive monitoring of international internet traffic." (Amended Complaint ¶¶ 47, 48). Wikimedia envisions Upstream surveillance as encompassing four processes, some implemented by telecommunications service providers at the NSA's direction:

- **Copying:** the use of surveillance devices, installed at key access points along the internet backbone, to make a copy of substantially all international text-based communications, and many domestic ones, flowing across certain high-capacity cables, switches, and routers.
- **Filtering:** the attempted exclusion of wholly domestic communications from the copied stream of internet data, perhaps using IP filters, while preserving the international communications.
- **Content review:** review of the full content of copied communications for the NSA's search terms, called selectors, including email addresses, phone numbers, IP addresses, and other identifiers believed by the NSA to be associated with foreign intelligence targets.

- **Retention and Use:** the retention of communications containing selectors associated with NSA targets for querying and review by NSA analysts, and sharing of the results with the Federal Bureau of Investigation.

(Amended Complaint ¶ 49)

49. I reiterate that I have not been given access to classified or other non-public information about Upstream surveillance, and so have no knowledge or information concerning the accuracy of Wikimedia's description of the Upstream collection process.

50. Wikimedia maintains that it is "virtually certain" that the NSA "has intercepted, copied, and reviewed" at least some of its communications in the course of conducting Upstream surveillance (Amended Complaint ¶ 60), based on several assumptions. First, Wikimedia asserts that given "the geographic distribution of [its] contacts and communications across the globe," with "individuals in virtually every country on earth," its communications "almost certainly traverse every international backbone link connecting the United States with the rest of the world." (Amended Complaint ¶¶ 60, 61) Second, and critically for purposes of this declaration, Wikimedia posits that "as a technical matter" the NSA "must be" copying and reviewing all international text-based communications transiting any link it is monitoring, in order to "reliably" obtain communications to or from its targets. (Amended Complaint ¶ 62) This is so, according to Wikimedia, because (i) the NSA cannot know beforehand which communications will contain selectors associated with its targets, and so must copy and review them all in order to identify those of interest, and (ii) in order to review the contents of a communication for the presence of a targeted selector, the NSA must first copy and reassemble all the packets making up that communication, requiring that it copy all packets traversing a given backbone link in order to reassemble and review communications in the manner Wikimedia describes. (Amended Complaint ¶¶ 62, 63)

51. On these premises, Wikimedia concludes that "even if the NSA conducts Upstream surveillance on only a single internet backbone link, it must be intercepting, copying, and reviewing at least those communications of [Wikimedia] traversing that link." (Amended Complaint ¶¶ 64) For the reasons I discuss in the following two sections, Wikimedia's conclusion

is incorrect. Even assuming, hypothetically, that the NSA conducts Upstream collection in the manner Wikimedia posits, by connecting collection equipment to routers and switches at links on the Internet backbone, there are a number of methods by which the NSA could be conducting Upstream surveillance without intercepting (much less copying or reviewing) all communications transiting any Internet backbone link it (hypothetically) monitors. Using these methods, the NSA could conduct Upstream surveillance without intercepting, copying, reviewing, or otherwise interacting with communications of Wikimedia. This would be true regardless of where on the Internet, or at how many locations, the NSA conducts Upstream collection.

WHETHER THE NSA "MUST BE" INTERCEPTING, COPYING, AND REVIEWING ALL COMMUNICATIONS THAT TRAVERSE A GIVEN INTERNET BACKBONE LINK

52. Wikimedia bases its belief that the NSA, in the course of Upstream collection, "must be" intercepting, copying, reviewing, or otherwise interacting with Wikimedia's online communications on the premises (i) that the NSA must be conducting Upstream surveillance at one or more Internet backbone links, such as peering points, Internet exchanges, points of presence, or cable landing stations, and (ii) that the NSA, at any given link where Upstream collection is conducted, must, as a matter of technical necessity, be intercepting, copying, and reviewing all communications crossing that link (including, therefore, Wikimedia's). I have no information concerning the actual number or location(s) of the site(s) at which the NSA conducts Upstream surveillance, so for purposes of my analysis I accept the first of these premises as given, that Upstream surveillance must be conducted at one or more links constituting the Internet backbone.

53. The second premise, however, is incorrect. As I explain below, there are a number of technically feasible, readily implemented means of conducting Upstream-type surveillance that would not require interception, copying, reviewing, or otherwise interacting with all communications that traverse any Internet backbone link the NSA allegedly monitors. I do not mean to suggest that the NSA is, in fact, conducting its surveillance by any of these means, or that these are the only possible methods by which the NSA could be conducting Upstream

surveillance. As I have stated elsewhere in this declaration, I have no knowledge or information concerning how Upstream surveillance is actually conducted. What I am saying is that, regardless of the number or types of locations on the Internet backbone at which the NSA might be conducting Upstream surveillance, there are at least several practical means for conducting that surveillance, in a manner akin to that posited by Wikimedia, that would not involve intercepting, copying, reviewing, or otherwise interacting with, all communications transiting the links the NSA allegedly monitors, thus disproving Wikimedia's hypothesis that such interception, copying, review, or other interaction with all communications "must be" occurring.

54. There are at least two well-known approaches to obtaining copies of Internet communications at locations other than the sources or destinations of the communications (or an ISP's server), which is to say, while the communications are still in transit. Locations where either of these approaches could be implemented include, but are not necessarily limited to, peering points, Internet exchanges, cable landing stations, and Internet points of presence.

55. Under the first approach, an entity desiring to obtain copies of communications for purposes of surveillance (or otherwise) could intercept the pulses of light carried on an optical fiber through the use of a device called a fiber-optic splitter (also referred to as an optical splitter). As its name suggests, a splitter, when attached to an optical fiber, "splits" the light signals on the fiber, making an identical copy of the communications stream. Through the use of one or more splitters, an exact duplicate of the communications stream flowing over each fiber-optic cable at an Internet exchange point, cable landing station, or other location could be made. The original communications could continue to travel uninterrupted to their intended destinations on the Internet, while copies of all the communications in each stream could be diverted elsewhere for processing to identify communications of interest.

56. Fiber-optic splitters are passive devices that are incapable of copying selectively, that is, they are incapable of copying only certain communications, but not others, according to specified criteria. Hence, the use of fiber-optic splitters to obtain copies of online

communications for surveillance purposes would entail, as alleged by Wikimedia, the copying of all communications flowing across a given fiber-optic link. (Amended Complaint ¶¶ 49, 62)

57. In contrast, the second approach to obtaining copies of Internet communications while in transit would allow for selectively copying only those communications that are deemed more likely to include communications of interest, without copying or otherwise handling those that are not. This approach would be desirable from the perspective of reducing the volume of communications that must be processed (electronically scanned) to identify the communications of interest, which would in turn reduce the associated time and expense. This selective copying of communications can be accomplished through the use of intelligent devices such as routers and switches (specialized computers, as discussed above), operated by carriers, to "mirror" selected communications carried in a given communications stream.

58. "Mirroring" is the technical term for a process which may be described as follows. As discussed in paragraph 40, above, when the light pulses on a fiber-optic cable enter a router, or a switch, the device "decodes" the stream into individual packets, and examines the address and routing information contained in the header of each packet, to determine where on the Internet each packet should be forwarded next. In the course of this process, the router, or the switch, can also "mirror" some or all of the traffic by making copies of selected packets, and diverting the designated copies off-network for separate processing. Almost all carrier-grade routers and switches, of the kind found at Internet exchanges and regional points of presence, are capable of traffic mirroring, as this functionality is required in order to conduct routine operational monitoring of a carrier's network. For example, traffic mirroring is used as a means of detecting denial-of-service attacks (intentionally flooding a device or network with traffic to force a shutdown and render it inaccessible to its intended users), or of ensuring that a carrier's traffic-routing policies are being properly implemented. Traffic mirroring does not interfere with the delivery of packets and is invisible to both the source and destination of the traffic.

59. Cisco Systems, the largest vendor of carrier-grade routers (based on market-share data from Dell'Oro and IDC[7]), describes the traffic-mirroring process as follows:

> "Traffic mirroring, which is sometimes called port mirroring, or Switched Port Analyzer (SPAN) … enables you to monitor Layer 3 network traffic passing in, or out of, a set of Ethernet interfaces. You can then pass this traffic to a network analyzer for analysis. Traffic mirroring copies traffic from one or more Layer 3 interfaces or sub-interfaces and sends the copied traffic to one or more destinations for analysis by a network analyzer or other monitoring device. Traffic mirroring does not affect the switching of traffic on the source interfaces or sub-interfaces, and allows the mirrored traffic to be sent to a destination next-hop address."[8]

60. Traffic mirroring can be employed to provide a collecting entity with access to select copies of communications transiting a particular Internet link, using fine-grained controls known as access control lists (ACLs). Routers are programmed using ACLs to determine whether packets are forwarded or blocked at a given router interface, that is, a given link between the router and another device.[9] Each of a router's interfaces has an associated ACL with criteria defining which types of packets may pass through the interface, and which not. The criteria used include a packet's source or destination IP address, the port number, protocol numbers, or other information contained in a packet header. The router examines the header information of each packet it processes, and compares it to the criteria established by the ACLs corresponding to each interface, to determine which interfaces the packet may or may not pass through. The router then allows separate copies of the packet to pass, in other words, to be mirrored, through each of the interfaces whose criteria it satisfies, as specified in the associated ACL.

61. Carrier-grade switches, too, can be programmed with access control lists, and, in the same fashion as a router, a switch uses the criteria in the ACLs associated with each of its

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[7] https://www.telecomlead.com/telecom-statistics/cisco-leads-service-provider-router-and-carrier-ethernet-switch-market-84577

[8] Cisco, "Configuring Traffic Mirroring on the Cisco IOS XR Software," Manual; available at https://www.cisco.com/c/en/us/td/docs/routers/crs/software/crs_r5-1/interfaces/configuration/guide/hc51xcrsbook/hc51span.pdf.

[9] RFC 4949 (2007) defines ACL: "A mechanism that implements access control for a system resource by enumerating the system entities that are permitted to access the resource and stating, either implicitly or explicitly, the access modes granted to each entity."

interfaces to determine which packets processed by the switch can pass (be mirrored) through each interface.

62. Carriers routinely use access control lists for a variety of reasons, one of the most important being network security. ACLs prevent packets coming from other carriers' or providers' networks, or from less secure areas of a carrier's own network, from entering more sensitive areas of the carrier's network. The use of access control lists to control the flow of network traffic is sometimes referred to as filtering. Publicly available documentation from Cisco explains the filtering capabilities of its carrier-grade routers using access control lists.[10] The skills required to configure ACLs and load them into a router are part of the repertoire of any trained network technician.

63. Cisco produces two commonly used models of router, the Cisco CRS and ASR, that support traffic mirroring.[11] The figure below, drawn from related Cisco documentation[12] shows a simplified schematic representation of a network topology wherein the network analyzer (i.e., the collecting entity's equipment) receives some or all of the packets sent between transmitting device A and receiving device B. The access control lists (ACLs) supported by Cisco devices can restrict or allow packets' passage based on either source or destination characteristics, including the interface (*e.g.*, a particular fiber), Internet (IP) address, the Internet protocol version (IPv4 or IPv6), the next-layer protocol (*e.g.*, IPsec or TCP), or the port number.[13] The number of ACL entries varies depending on the hardware. For example, the Cisco ASR 9000 router supports up to 4,095 unique access control lists. The practical limits of the number of white list or black list

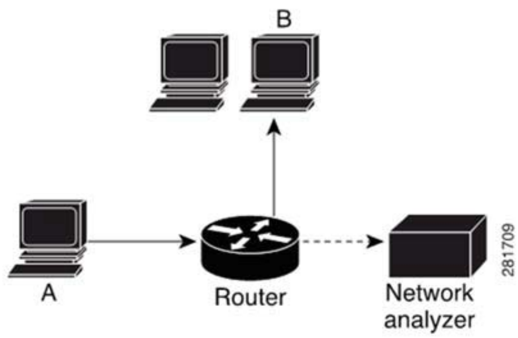
[10] https://www.cisco.com/c/en/us/td/docs/routers/asr9000/software/asr9k_r4-0/addr_serv/command/reference/ir40asrbook_chapter1.html is one example of this capability.

[11] https://www.cisco.com/c/en/us/td/docs/routers/crs/software/crs_r5-1/interfaces/configuration/guide/hc51xcrsbook/hc51span.pdf and https://www.cisco.com/c/en/us/td/docs/routers/asr9000/software/asr9k_r5-1/interfaces/configuration/guide/hc51xasr9kbook/hc51span.html#96505

[12] https://www.cisco.com/c/en/us/td/docs/routers/asr9000/software/asr9k_r4-1/interfaces/configuration/guide/hc41asr9kbook/hc41span.pdf

[13] https://www.cisco.com/c/en/us/td/docs/routers/asr9000/software/asr9k_r4-0/addr_serv/command/reference/ir40asrbook_chapter1.html#wp49507452

entries depends on the router model and may vary. Other router vendors support similar functionality.



64. Traffic mirroring through the use of access control lists could likewise be used in a surveillance context to make only certain packets available for inspection by the collecting entity at any given link on the Internet where surveillance may be conducted. There are several ways in which this could be accomplished. Initially, it would be necessary to establish a link between the router, or switch, directing traffic at that location, and the separate set of equipment used by the collecting entity (wherever situated) to electronically scan the packets to which it is given access for communications of interest.

65. Once the link is established, traffic passing through the carrier's router, or switch, to the collector's equipment could be filtered by various "whitelisting" or "blacklisting" techniques, defined below, that involve configuration of an access control list that allows only packets meeting the ACL's criteria to be copied and passed through the interface to the collector's equipment. For example, if the collecting entity possesses information that communications of interest to it are associated with a particular IP address, or set of IP addresses, then it could request that the carrier provide it only with packets whose source or destination IP addresses match the IP addresses of interest. (I assume for purposes of this discussion that the "tasking" described earlier can go beyond simply enumerating targeted email addresses or phone numbers to the carrier, i.e., include limitations on the protocols, sources and destinations of Internet traffic to be made available for NSA examination.) The carrier, in turn, could configure the ACL of the appropriate interface with a "whitelist" of the specified IP addresses. As a result,

when the router (or switch, as the case may be) examines the header information of each packet it processes, it would, as usual, forward a copy of the packet (as determined by its routing tables) toward the packet's intended destination, possibly create and forward additional copies of the packet through other interfaces, depending on the routine policies and practices of the carrier, and if, but only if, the packet header contains a source or destination IP address on the designated whitelist, create an additional copy of the packet and forward it through the interface with the collector's equipment to the collector's possession and control.

66. Packets not meeting the whitelist criteria would not be copied for, or made available to, the collector's equipment for reassembly, review, retention, or any other purpose, and would not be handled or processed in any way other than would ordinarily occur under the carrier's routine practices.

67. Blacklisting, as the name suggests, is the converse of whitelisting. Tipton and Krause define them as follows in a more general information security context: "Blacklisting consists of banning a list of resources from access. … Whitelisting is listing entities that are granted a set of privileges (access, services, validity, etc.) within an environment. A whitelist is solely used to define what is allowed to be executed, whereas anything that is not included in the whitelist cannot be executed."[14] Blacklisting involves the configuration of an access control list that allows all packets to pass through the interface with the collector's equipment except those meeting the ACL's criteria. For example, the collecting entity might conclude that communications traffic to and from certain IP addresses, perhaps by virtue of the geographic locations or the organizations they are associated with, are of little interest for the collector's purposes, and that these communications burden the processing capacity of its equipment without yielding information of significant value. In that situation, the collector may advise the carrier that it does not wish to receive traffic to and from these "low-yield" IP addresses. In that case, the carrier could configure the ACL corresponding to the interface with the collector's

[14] Harold Tipton and Micki Krause, "Information Security Management Handbook," CRC, 2007.

equipment with a "blacklist" of the specified IP addresses. Once so programmed, the router, or switch, would as usual examine the header of each packet it processes, forward each packet toward its destination on the Internet, create and forward copies of each packet through various interfaces as dictated by the carrier's business practices, and create an additional copy of each packet, and forward it through the interface with the collector's equipment to the collector's possession and control, *except* for those packets with source or destination IP addresses on the designated blacklist.

68. If on examination a packet is found to contain a source or destination IP address on the blacklist, an additional copy of that packet is not created or forwarded through the interface to the control of the collecting entity, and would not be handled or processed in any way other than would ordinarily occur under the carrier's routine practices.

69. Whitelisting and blacklisting techniques can also be used to limit mirroring to particular sources of traffic. For example, if a router at an exchange, landing station, or point of presence is linked to multiple fiber-optic cables used respectively by different carriers, or linked to particular countries, mirroring can be restricted to traffic only from certain carriers' networks, or certain global regions.

70. In addition, whitelisting and blacklisting can be used to mirror only particular kinds of communications based on their protocols. As discussed above, communications of different types, having different protocols, are assigned different port numbers to ensure that user communications, or requests for information, are directed to the appropriate service hosted on the recipient server, and that the response to the user is directed to the appropriate application on the user's computer, cellphone, or other device. The access control list associated with the interface between a router or switch and a collecting entity's equipment can also be configured to whitelist or blacklist distinct types of communications based on their assigned port numbers. Suppose, for example, that the collecting entity is interested only in examining email. Email communications use the SMTP and IMAP protocols, the default ports for which are port 25 and port 143, respectively. If advised by the collecting entity that it only wishes to examine email

communications, the carrier could configure the ACL corresponding to the router interface with the collector's equipment to create additional copies of packets, and forward them to the collector's control, only if the port number contained in the packets' headers is port 25 or 143.

71. On the other hand, the collecting entity may determine that certain types of communications yield little information of value, and simply burden the capacities of its processing equipment. In that event, the collecting entity may inform the carrier that it does not wish to receive communications of that type. The carrier could then configure the appropriate ACL so that packets containing port numbers corresponding to those undesired types of communications are not copied and passed through the interface to the collecting entity's control. For example, as discussed above, the encrypted HTTPS protocol, used to communicate with sites on the World Wide Web, provides a high degree of assurance that communications sent to or from a website can only be read by the user's web browser and the host web server, but not third parties who intercept them in transit. A collecting entity, if it lacks the capability of decrypting HTTPS communications, and therefore can glean no useful information from them, might advise an assisting carrier that it does not wish access to such communications. Because HTTPS communications are assigned port number 443, the carrier could simply configure the access control list for the interface with the collecting entity's equipment so that no packets containing port number 443 are copied and passed to the collecting entity's possession and control.

72. Wikimedia, in fact, posits a highly similar type of scenario in its Amended Complaint. Wikimedia states:

> By some estimates . . . two-thirds of internet traffic consists of video traffic. The NSA could readily configure its surveillance equipment to ignore that traffic, or at least the significant portions of it (e.g., Netflix traffic) that are almost certainly of no interest. Because of the substantial efficiency gains to be had, it is extremely likely that the government engages in this kind of filtering . . . .

Amended Complaint ¶ 59. To achieve the result hypothesized by Wikimedia, the carrier at any Internet link where the NSA might theoretically be conducting Upstream surveillance could "readily," as Wikimedia says, configure the access control list associated with the interface between the carrier's router or switch and the NSA's surveillance equipment to block transmission of any packets whose source IP addresses correspond to the streaming video services whose traffic the NSA did not wish to have access to.

73. As mentioned above, Wikimedia gives two specific reasons why it believes the NSA nevertheless "must be" copying all the international text-based communications that travel across any given Internet link where it conducts Upstream surveillance. I address both here. First, Wikimedia maintains that because the NSA cannot know beforehand which international, text-based communications traversing a link will contain selectors associated with its targets, it must copy and review them all in order to "reliably" identify those of interest. (Amended Complaint ¶ 62) The foregoing discussion of traffic mirroring demonstrates that this is not necessarily the case. If a collecting entity, by whatever means, were to ascertain to an acceptable degree of confidence that the communications of interest to it are associated with particular IP addresses, then by whitelisting packets containing those IP addresses in their headers, it can reliably obtain the packets of all communications to and from those IP addresses crossing that link, without obtaining access to any other communications crossing that link. Conversely, if the collecting entity ascertained to an acceptable degree of confidence that communications to and from certain IP addresses do not include communications of interest to it, then by blacklisting communications to and from those "low-interest" IP addresses, it could reliably obtain all communications of interest that are crossing that link without obtaining access to any of the blacklisted communications. And in either scenario, the packets not accessed would undergo no handling or processing other than would ordinarily occur under the carrier's routine practices.

74. The question remains, of course, how confident would a collecting entity have to be that it could "reliably" acquire its targets' communications using these more selective approaches, based on IP addresses (or port or protocol numbers), before it would deem them acceptable. Speaking as someone who has studied the economics as well as the technology underlying large-scale network engineering, I would say that the answer to that question

depends on the collector's objectives, capabilities, resources, and competing organizational priorities. So far as this case is concerned, these are all matters known only to the NSA.

75. Second, Wikimedia maintains that the NSA cannot "reliably" obtain its targets' communications without copying and reviewing all international text-based communications traveling across a link because, according to Wikimedia, to review a communication for the presence of a targeted selector, the NSA must first copy and reassemble all the packets making up that communication. (Amended Complaint ¶ 63) This reasoning is flawed.

76. It is not the case that all the packets on a communication link must be collected before the communication of interest can be reassembled. Each set of communication relationships and protocols is independent. For example, an email communication between two parties does not depend on a web transfer, either between those two parties or any other party, and reassembling the web communication is neither necessary nor helpful to obtain or analyze the email communications. Thus, it is sufficient to reassemble only the email-related packets, identifiable by protocol number and port, if email is of interest. All of the packets in a communication to or from an individual target will have a common destination or source IP address, respectively. If the target can be identified by IP address or range of addresses, and if the collecting entity obtains access to all packets crossing the link that contain that address (or an address falling in that range), it will have all the packets making up that communication, and can reconstruct it. Through traffic mirroring, this objective can readily be achieved either by whitelisting packets containing IP addresses associated with communications of interest, or blacklisting communications to and from IP addresses that are likely of no interest. In either case, it would not be necessary, as a technical matter, to copy all packets crossing the link in order to "reliably" reassemble and identify communications of interest, so long as the collecting entity itself were sufficiently confident in its ability to identify the IP addresses of high-interest communications, or communications (and their IP addresses) that are of low interest.

WHETHER THE NSA "MUST BE" INTERCEPTING, COPYING, AND REVIEWING WIKIMEDIA'S ONLINE COMMUNICATIONS

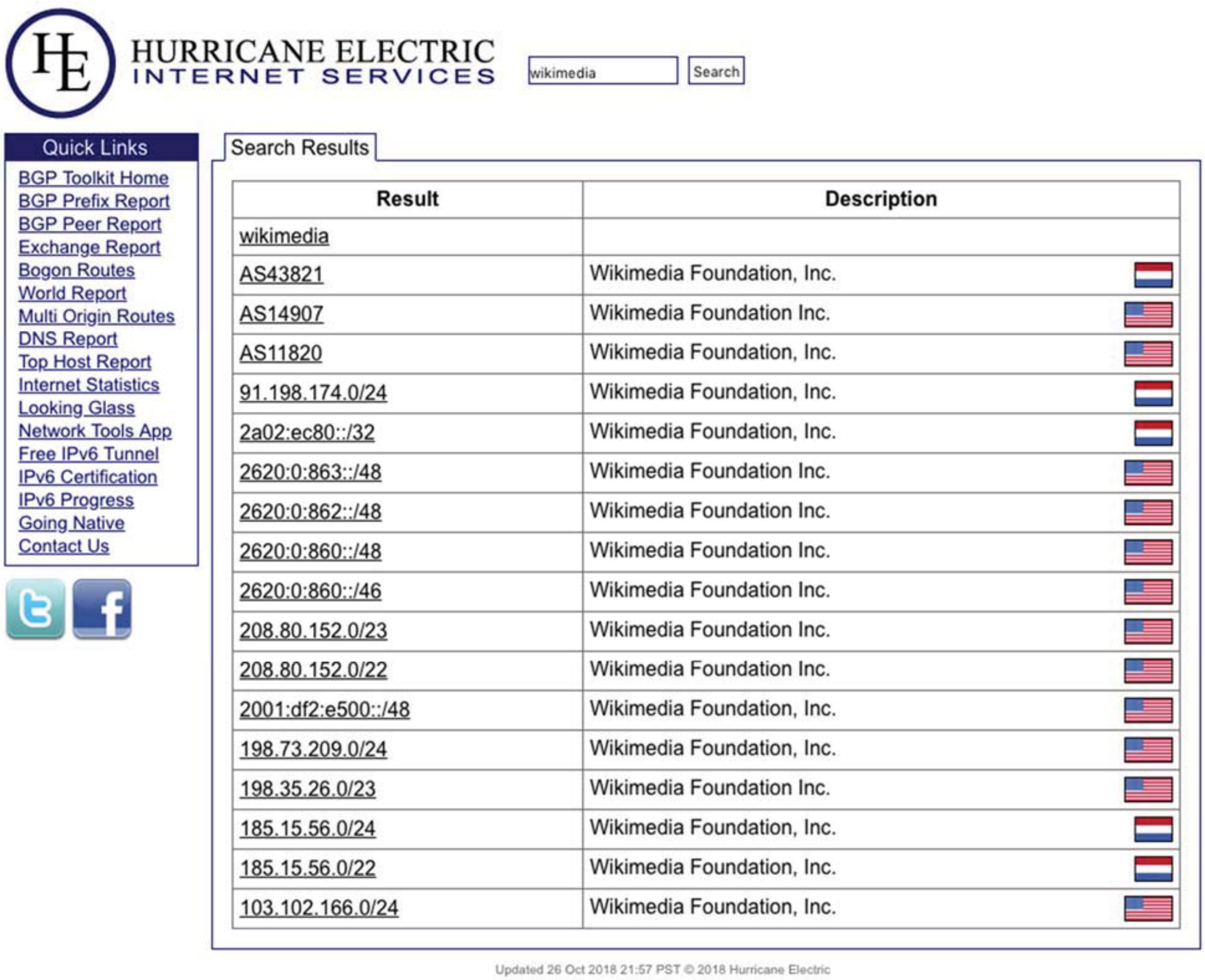
77. In this section I explain how the NSA, through the use of traffic-mirroring techniques such as those discussed in the preceding section, could conduct Upstream-type surveillance in a manner similar to that posited by Wikimedia without intercepting, copying, reviewing, or otherwise interacting with communications of Wikimedia. I emphasize, again, that I do not mean to suggest that the NSA in fact employs any of these techniques in conducting Upstream collection, only that they are technically feasible, readily implemented means by which it could do so without intercepting, copying, reviewing, or otherwise interacting with Wikimedia's communications. I am advised by Justice Department counsel that Wikimedia has identified three categories of its communications that it believes are subjected to Upstream collection processes: (1) communications with and among its "community members," that is to say, individuals who read or contribute to its websites; (2) its server log communications; and (3) communications to and from its staff. I discuss each category below in turn.

78. Category 1 (communications with and among "community members"): In a chart entitled "Technical Statistics for 2017 to 2018 Responsive to ODNI Interrogatory No. 19," Wikimedia describes the first category of its allegedly intercepted communications as "Wikimedia communications with its community members, who read and contribute to Wikimedia's Projects and webpages, and who use the Projects and webpages to interact with each other." It specifies three types of communications as falling within this first category, HTTP and HTTPS requests from foreign users to Wikimedia servers in the United States (presumably requests to view or download content from Wikimedia websites); HTTP and HTTPS requests from users in the United States to foreign Wikimedia servers (presumably the same), and SMTP communications from foreign users to Wikimedia servers in the United States (presumably email). In brief, then, Category 1 communications consist of traffic using the HTTPS protocol (i.e., encrypted web traffic), the HTTP protocol (unencrypted web traffic) and the SMTP protocol (email traffic), all destined to a limited number of IP addresses used by Wikimedia, that are also listed in the chart.

79. To my knowledge, the Government has publicly acknowledged that the NSA uses email addresses and telephone numbers as "selectors" to identify communications involving its Upstream targets, but has not publicly confirmed whether or not it uses any other kind of identifier for that purpose. It is therefore unknown (at least publicly) what types of communications other than email or telephone calls, if any, that the NSA acquires via Upstream collection. If, hypothetically, the NSA does not collect web communications, whether due to their volume, because they may be of insufficient interest, or both, then it would stand to reason that the NSA, at any link where Upstream surveillance may be conducted, might not seek access to traffic using either of the current web protocols, HTTP and HTTPS. (If the NSA does not possess the capability to decipher encrypted HTTPS communications—whether it does or does not I do not know—then that is an additional reason it might regard such unreadable communications to be of low interest.) Using a blacklisting approach such as I describe above, the assisting carrier could block any HTTP and HTTPS traffic transiting that link (*i.e.*, packets with port numbers 80 and 443, respectively) from being forwarded to the NSA's collection equipment. Under such a scenario, none of Wikimedia's HTTP or HTTPS communications crossing that link would be intercepted or copied (other than for the carrier's own purposes, if any) and would not be made available to the NSA. If the NSA, for whatever reason, were not interested in collecting web communications, including Wikimedia's, there is no technical reason why it would nevertheless be compelled to intercept, copy, or review them, as Wikimedia suggests.

80. Even if HTTP and HTTPS communications are not excluded, as a general matter, from those the NSA obtains access to for Upstream purposes, Wikimedia's web communications could still be subject to exclusion from the communications provided to the NSA at any given link, through whitelisting or blacklisting. As reflected in Wikimedia's technical statistics chart, Wikimedia has been allocated a number of static (permanent) IP addresses, as is essential for users around the world to access and contribute to its public websites. For the same reason, these addresses are publicly disseminated, and are available from online directories that track organizations' IP addresses according to their assigned AS (autonomous system) numbers.

(Shown below is an example from Hurricane Electric, a well-known Internet backbone carrier.) Additionally, for global routing of international traffic, each router or switch located at a link on a major carrier's network contains an accessible registry, also organized by AS number, of the IP addresses that can be reached via that link. Anyone knowledgeable in the realm of network traffic management would have the skill needed to access these registries and compile a list of all IP addresses associated with any organization, such as Wikimedia, that has been assigned its own AS number. That list could be used, in turn, to exclude communications associated with such an organization, including Wikimedia.



Result	Description
wikimedia	
AS43821	Wikimedia Foundation, Inc.
AS14907	Wikimedia Foundation Inc.
AS11820	Wikimedia Foundation, Inc.
91.198.174.0/24	Wikimedia Foundation, Inc.
2a02:ec80::/32	Wikimedia Foundation, Inc.
2620:0:863::/48	Wikimedia Foundation Inc.
2620:0:862::/48	Wikimedia Foundation Inc.
2620:0:860::/48	Wikimedia Foundation Inc.
2620:0:860::/46	Wikimedia Foundation Inc.
208.80.152.0/23	Wikimedia Foundation Inc.
208.80.152.0/22	Wikimedia Foundation Inc.
2001:df2:e500::/48	Wikimedia Foundation, Inc.
198.73.209.0/24	Wikimedia Foundation, Inc.
198.35.26.0/23	Wikimedia Foundation Inc.
185.15.56.0/24	Wikimedia Foundation, Inc.
185.15.56.0/22	Wikimedia Foundation, Inc.
103.102.166.0/24	Wikimedia Foundation, Inc.

81. Therefore if, at a given link, the NSA was being given access only to communications to or from specified IP addresses (whitelisting), and Wikimedia's addresses were

not among them, then the NSA would not obtain access to any Wikimedia HTTP or HTTPS communications (or communications of any kind), unless users communicating with its websites had been assigned a targeted (whitelisted) IP address. Conversely, if at a given link the NSA were, at its request, not being given access to traffic to or from the IP addresses of certain high-volume but perhaps low-interest sites (blacklisting), such as, hypothetically, Amazon.com, and Wikimedia's sites, then under this scenario, as well, the NSA would receive no access to Wikimedia HTTP or HTTPS communications (or, for that matter, Wikimedia communications of any kind).

82. Regarding the email (SMTP) communications in Category 1, the chart of technical statistics provided by Wikimedia states that the volume of these email communications and the countries from which they are received are unknown. There is no basis, then, on which to assert that these communications with Wikimedia "almost certainly traverse every international backbone link connecting the United States with the rest of the world," the first of the assumptions on which Wikimedia bases its belief that its communications are intercepted by the NSA. (Paragraph 50, above; Amended Complaint ¶ 60) Because the SMTP communications do not satisfy this condition for interception under Wikimedia's own theory, further discussion of these communications is unnecessary for present purposes. Nevertheless, I observe that because all of these communications are received at a sub-set of the same IP addresses as the HTTP and HTTPS communications in Category 1 (as shown in Wikimedia's technical statistics chart), then whitelisting or blacklisting by IP address, as discussed in paragraphs 80-81, above, would also block NSA access to these Wikimedia SMTP email communications as well.

83. <u>Category 2 (server log communications)</u>: Wikimedia's technical statistics chart describes the second category of its allegedly intercepted communications, "Wikimedia's internal log communications," as "Apache Kafka log communications" transmitted from Wikimedia servers in the Netherlands to Wikimedia servers in the United States. (Apache Kafka is a commercial data-streaming software application.) These are communications containing server logs, files automatically created and maintained by servers of the activities they perform. A

common example are logs maintained by web servers of user requests to view or download information from a website. These logs typically contain such information as the user's IP address, the time and date of the request, the webpage requested, and the amount of data transmitted. Server logs may be analyzed in aggregate to study traffic patterns, ensure adequate site resources, maintain efficient site administration, and for other purposes. When, as is common, server logs are transmitted elsewhere (to another server) for the performance of such analyses, they are typically encrypted, for security. According to the Amended Complaint, the log communications at issue here are of server logs created by Wikimedia web servers when they receive requests from users seeking to access Wikimedia websites. (Amended Complaint ¶ 93) Wikimedia's technical statistics chart indicates that it encrypts its log communications using an encryption protocol known as IPSec.

84. If the NSA did not wish in the course of Upstream collection to have access to Wikimedia's server log communications, or those of the many other entities that generate such logs, due to their aggregate volume and the relatively limited amount of information they offer (especially if indecipherably encrypted), then it would be a simple matter to block NSA access to those communications, in either of two ways. First, packets encrypted using the IPSec protocol are easily recognized by the corresponding protocol number, protocol 50, contained in their header information. It would be a simple matter at any given link for an assisting carrier to configure the access control list to the interface between its router or switch and a (hypothetical) set of NSA collection equipment to blacklist, that is, to block transmission of, all packets containing protocol 50 in their headers. Second, as shown in Wikimedia's technical statistics chart, its log communications are received at one of the same public IP address ranges as its HTTP, HTTPS, and SMTP communications in Category 1. Like those communications, NSA access to Wikimedia's log communications could be blocked by whitelisting or blacklisting by IP address, as discussed in paragraphs 80-81, above.

85. <u>Category 3 (staff communications)</u>: The third and final category of Wikimedia's allegedly intercepted communications, "Communications by Wikimedia staff," are described in

the technical statistics chart as "[l]ogged international" TCP, UDP, and ICMP "connections" using Wikimedia's Office Network or its Virtual Private Network (VPN). "TCP" refers to the Transmission Control Protocol, discussed in paragraph 27, which operates at the transport layer, just beneath the application layer, and allows two devices on the Internet (such as a web server and a user's computer) to establish a connection with one another and exchange streams of data. "UDP" stands for the User Datagram Protocol, another transport layer protocol typically used with applications for which speed is more critical than reliability, such as Internet telephony and video streaming. "ICMP" is the Internet Control Message Protocol, a network layer protocol used by network devices such as routers and servers to send error messages (such as "host unreachable") to other devices when problems are encountered delivering packets.

86. Wikimedia's technical statistics chart does not identify the applications (email, web browsing, VoIP, etc.) used in connection with the TCP and UDP communications identified in Category 3, and so it is unclear whether they are identifiable by port or protocol number. Although the chart specifies that communications conducted over Wikimedia's Virtual Private Network are encrypted using the SSL/TLS protocol described in paragraph 42, it indicates further that not all of its staff communications are sent or received over the encrypted VPN.

87. Nevertheless, the technical statistics chart indicates that Wikimedia's encrypted and unencrypted staff communications are sent from and received at IP addresses that are readily ascertainable from publicly available sources. The IP address range stated for Wikimedia's unencrypted Office Network, 198.73.209.0/24, is discoverable from such sources as the Hurricane Electric directory (see paragraph 80, above, and referenced search results for Wikimedia). (The notation 198.73.209.0/24 in the Hurricane Electric table encompasses the addresses from 198.73.209.0 through 198.73.209.255, and thus includes the address 198.73.209.25 listed as the VPN address in Exhibit 1.) In other words, Wikimedia's staff communications, like its HTTP, HTTPS, and SMTP communications in Category 1, and its log communications in Category 2, could be blocked by whitelisting or blacklisting by IP address, as discussed in paragraphs 80-81, above.

88. In short, at any given Internet backbone link where the NSA might hypothetically be conducting Upstream-type surveillance in a manner posited by Wikimedia, it would be technically feasible for the assisting carrier, through one or more of the traffic-mirroring techniques I have discussed, to configure its routing or switching equipment so that Wikimedia's communications transiting that link are not intercepted, copied, or forwarded to surveillance equipment under the NSA's control.

RELEVANCE OF THE NUMBER OF SITES AT WHICH UPSTREAM SURVEILLANCE OCCURS

89. Finally, I briefly address the import of Wikimedia's assertion that the NSA "must conduct Upstream surveillance at many different backbone chokepoints" if it is to "comprehensively and reliably obtain" communications involving its targets. (Amended Complaint ¶ 66) Wikimedia says this must be true because communications to and from individual targets "may take multiple paths when entering or leaving the United States," even "in the course of a single exchange." (*Id.*) Wikimedia's allegation overstates the extent to which communications between the same two endpoints are likely to take different paths across the Internet, and in particular on Internet backbone networks. As I explained above (paragraph 41), barring network outages or other atypical events, in practice packets transiting between two points on the Internet will follow the same path for the great majority of the distance traveled. The path followed from one communication to the next will differ, if at all, only when the constituent packets first make their way toward the Internet backbone, or as they near their destination.

90. The point is a moot one, though. As I have set out above, at any given backbone link where the NSA might hypothetically be conducting Upstream surveillance in a manner envisioned by Wikimedia, there are various traffic-mirroring techniques available that would allow the NSA, as a technical matter, to obtain access to communications of its targets without intercepting, copying, reviewing, or otherwise interacting with communications of Wikimedia. This would remain the case, therefore, regardless of the number of such locations, whether one, or dozens, at which Upstream surveillance might in theory be conducted.

Case 1:15-cv-00662-TSE Document 164-4 Filed 12/07/18 Page 44 of 99

I declare of penalty of perjury that the foregoing is true and correct to the best of my knowledge and belief.

Executed in New York, New York, on November 12, 2018.

Henning Schulzrinne

HENNING G. SCHULZRINNE

DECLARATION OF DR. HENNING G. SCHULZRINNE
***WIKIMEDIA FOUND. V. NSA*, NO. 1:15-CV-00662-TSE (D. MD)**

EXHIBIT A

Henning Schulzrinne

Julian Clarence Levi Professor	work phone:	+1 212 939 7042
Dept. of Computer Science	fax:	+1 212 666 0140
Columbia University	email:	hgs@cs.columbia.edu
New York, NY 10027	WWW:	http://www.cs.columbia.edu/˜hgs
USA	SIP:	sip:hgs@cs.columbia.edu

INTERESTS

Internet multimedia, policy, services, architecture, computer networks and performance evaluation. Telecommunication policy; Internet telephony, collaboration and media-on-demand; Internet of things; emergency services; signaling and session control; mobile applications; ubiquitous and pervasive computing; network measurements; quality of service; Internet protocols and services; congestion control and adaptive multimedia services; implementations of multi-media and real-time networks; operating system support for high-bandwidth services with real-time constraints; performance analysis of computer networks and systems.

WORK EXPERIENCE

Chief Technology Officer, Federal Communications Commission (FCC), January 2017–August 2017.

Senior Advisor for Technology, Federal Communications Commission (FCC), September 2016–December 2016.

Technology Advisor, Federal Communications Commission (FCC), September 2014–August 2016.

Chief Technology Officer, Federal Communications Commission (FCC), January 2012–August 2014.

Engineering Fellow, Federal Communications Commission (FCC), Sept. 2010–May 2011.

Professor (tenured), Dept. of Computer Science and Dept. of Electrical Engineering (joint appointment), Columbia University. August 1996–. Department vice chair, 2002–2003; Department chair, 2004–2009.

Researcher, GMD Fokus[1], Berlin, Germany. March 1994 - July 1996. Multimedia systems, ATM performance issues. Deputy department head; project leader TOMQAT, Multicube, MMTng. Lecturer at Technical University Berlin.

Consultant, 1994-1996: design and implementation of an Internet packet audio tool for a WWW-based "Virtual Places" shared environment (Ubique, Israel). Consultant on real-time packet audio (Vocaltec, Israel).

Postdoc, Distributed Systems Research Department, AT&T Bell Laboratories, Murray Hill, New Jersey. September 1992 – February 1994: designed and implemented BENE network emulator, research in real-time multimedia and electronic publishing.

Teaching Assistant, Dept. of Computer Science, University of Massachusetts, January 1992 – June 1992: co-taught senior-level computer networking course.

Research Assistant, Dept. of Computer Science, University of Massachusetts, July 1988 – September 1992: research in congestion control and performance evaluation related

[1] GMD - Forschungszentrum Informationstechnik (German National Research Center for Information Technology), Research Institute for Open Communication Systems

to high-speed computer networks. Also assisted in teaching performance evaluation course.

Research Assistant, Dept. of Electrical and Computer Engineering, University of Massachusetts at Amherst, January 1988 – July 1988: collaboration with Dr. Wei-Bo Gong in the area of perturbation analysis.

Teaching Assistant, Dept. of Electrical and Computer Engineering, University of Massachusetts at Amherst, September 1987 – July 1988: taught discussion section of introductory programming class for engineers (Pascal and Fortran).

Research Assistant, Dept. of Electrical and Computer Engineering, University of Cincinnati, March 1985 – August 1987: planning and implementation of speech processing laboratory and networking, tool development, vector quantization research, system administration.

EDUCATION

PhD Electrical Engineering, Department of Electrical and Computer Engineering at the University of Massachusetts, Amherst, September 1992.

PhD Thesis: *Congestion Control and Packet Loss for Real-Time Traffic in High-Speed Networks*. Principal advisors: Jim Kurose, Don Towsley and Christos Cassandras.

Master of Science, Department of Electrical and Computer Engineering at the University of Cincinnati, Cincinnati, Ohio; with emphasis on digital signal processing (voice coding, software models). August 1987.

Master's thesis: *Multi-Stage Vector Quantization for Speech and Image Coding; The DSP Workbench: Distributed Multiprocess System Simulation*. Experimental and theoretical results for a new method of vector quantization and development of a distributed high-level simulator for signal processing applications. Principal advisor: P. A. Ramamoorthy.

B.S. Electrical Engineering, (combined with B.S. Industrial Engineering), Technical University of Darmstadt, Federal Republic of Germany, June 1984.

HONORS AND AWARDS

- IEEE Infocom 2018 *Test of Time Paper Award* for "An Analysis of the Skype Peer-to-Peer Internet Telephony Protocol" (with Salman Baset).
- IEEE Internet award, 2016.
- ACM Fellow, 2015.
- WCNC 2015, "Intelligent Content Delivery over Wireless via SDN", best paper award.
- IEEE Communications Society Internet Technical Committee Distinguished Service Award, 2014.
- Internet Hall of Fame, 2013
- GREE 2013 best paper award ("Wimax in the classroom: Designing a cellular networking hands-on lab")
- 2011 Internet2 IDEA Award winner for "Do You See What I See" tool (Kyung Hwa Kim, PhD Student)
- Region 1 William Terry Award for Lifetime Distinguished Service to IEEE Region 1 (2010)

- IPTComm 2010 best paper award ("Reliability and Relay Selection in Peer-to-Peer Communication Systems")
- IMSAA-08 3rd best paper award for *A New SIP Event Package For Group Membership Management in Advanced Communications* (co-authored with Vishal Singh and Piotr Boni)
- VDE ITG Preis 2008 for *Ubiquitous Device Personalization and Use: The Next Generation of IP Multimedia Communications* (co-authored with Ron Shacham, Srisakul Thakolsri and Wolfgang Kellerer)
- IPTCOMM 2008 Best Student Paper Award for *SIP Server Overload Control: Design and Evaluation* (co-authored with Charles Shen)
- CATT lifetime innovation award (Brooklyn Polytech University) (2007)
- Sputnik Innovator Award (2005)
- IEEE Fellow (2006)
- IEEE ComSoc Technical Committee on Computer Communications (TCCC) Outstanding Service Award 2005
- IEEE Senior Member (2004)
- Internet Telephony 2004 Product of the Year
- Mayor's Award for Excellence in Science and Technology (2004)
- VON Pioneer Award, 2000
- *IEEE Communication Society* Lecturer, 1997
- nominated for ACM Best Dissertation award
- University of Massachusetts Graduate School Fellowship, 1990-1991
- University Summer Research Fellowship 1987
- University Summer Research Fellowship 1985
- German Fulbright Scholarship 1984
- President Electrical Engineering Graduate Student Association 1985/86
  Graduate Outstanding Service award 1986
- German National Scholarship Foundation ("Studienstiftung des deutschen Volkes")
- Regional finalist German Young Scientists Competition (Jugend forscht)

Professional Activities

Editorial positions:

- Associate Editor, *Computer Communications*, 2009–
- Editor, *Foundations and Trends in Networking*, 2005–.
- Editor, *ACM Transactions on Multimedia Computing, Communications and Applications*, 2005–
- Associate Editor, *ACM/IEEE Transactions on Networking*, 2000–2008
- Associate Editor, *IEEE Transactions on Image Processing*, 1999–2000
- Guest editor for *IEEE Network Magazine* and *IEEE Internet Computing* on Internet Telephony, May/June 1999
- *Journal of Communications and Networks*, editor (1998–2001), division editor (2001–2004)

- *IEEE Communication Surveys*, member editorial board, 1996–2000, 2002–
- *Internet Computing*, Communications Society liaison editor, 1996–1999, editor, 2008–
- *IEEE Communications Magazine*, Internet Technology feature series editor (1996–1998)
- Guest editor for *IEEE Journal on Selected Areas in Communications* on the Global Internet

Technical program committees:

- *P2P* 2008
- *ANCS (Architectures for Networking and Communication Systems)* 2005
- *ACM Multimedia* 2005
- *SIP 2000–2008*
- *Feature Interaction Workshop (FIW)* 2003, 2005
- *International Conference on Distributed Computing Systems (ICDCS)* 2005
- *IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks* (WoWMoM) 2005, 2006
- ACM *Mobihoc* 2002, 2005
- IEEE *INFOCOM* 1994–1996, 1998, 2000–2004, 2006–2019
- *Network and Operating System Support for Digital Audio and Video* (NOSSDAV), 1997–2010, 2012–2014
- *IEEE Global Internet* 1996–2000, 2005, 2007
- *Packet Video Workshop*, 1999, 2000
- *ACM/SPIE Multimedia Computing and Networking*, 1998
- *Open Architectures and Network Programming (OPENARCH)* 1998, 1999
- NSF review panel, 1999, 2002, 2003, 2004, 2006, 2007, 2008, 2010, 2011, 2015
- *IEEE Global Internet*, November 1996 (conference technical program vice chair)
- W3C *Real-Time Multimedia Workshop* (RTMW), October 1996
- *International Conference on Network Protocols (ICNP)*, 1996, 2008
- *Workshop on Integration of IP and ATM*, 1996

Advisory boards and committees:

- North American Numbering Council (NANC), a federal advisory committee (FCC, 2017–2018)
- Computing Community Consortium, Intelligent Infrastructure Task Force (2017–2018)
- Applied Technology Council (ATC) - ATC-126 (*Community Resilience of Lifeline Systems*) project technical committee (2016)
- Steering Committee (member, current chair), *IEEE/ACM Transactions on Networking* (2007–2017)
- ACM publication board technology committee (2015)
- ACM SIGCOMM vice chair (2007–2013)
- Member of the Board, Armstrong Memorial Research Foundation (2009–)

- Internet2 Applications, Middleware and Services Advisory Council (AMSAC) (2008–2012)
- GENI OptIn working group co-chair (2008–2009)
- board of directors, *SIP Forum* (1998–2002)
- Member of Internet Architecture Board (IAB), the technical advisory group of the Internet Society and the architectural oversight body of the IETF (1999–2001)
- Co-chair, *Internet Technical Committee* of the IEEE Communications Society (1994-2000)
- Chair, *IEEE Communications Society Technical Committee on Computer Communications* (1999–2001)
- SIP Bake-Offs, Columbia University (April 1999, August 1999, December 1999)
- IEEE *Infocom* Executive Committee (1995–2000)
- Internet2 Applications, Middleware and Services Advisory Council (AMSAC) 2008–2010
- GENI OptIn working group co-chair, 2008–2009
- IEEE Travel Reduction Task Force, 2009
- member-at-large, Board of Governors, IEEE *Communications Society*, 2002
- board of directors, *SIP Forum*, 1998–2002
- past co-Chair, *Internet Technical Committee* of the IEEE Communications Society
- Chair, *IEEE Communications Society Technical Committee on Computer Communications* (1999–2001)
- member IEEE Electronic Processes Steering Group, 2000

Conference leadership:

- *Mobiquitous 2018* general co-chair
- *e-Energy 2011* technical program co-chair
- *IEEE COMSNETS 2010* general co-chair
- *IEEE P2P 2009* general co-chair
- *IEEE ICNP 2009* general co-chair
- *IFIP Networking 2009* technical program co-chair
- *IEEE IM 2009* technical program co-chair
- *ACM IPTCOMM 2008* technical program co-chair
- *ACM IPTCOMM 2007* general co-chair
- *CoNext 2007* general co-chair
- *ACM Multimedia* 2004 general co-chair
- technical program co-chair Internet Telephony Workshop 2001
- IEEE *Infocom* 2000 technical program co-chair
- *NOSSDAV* technical program co-chair 2001
- IEEE *Infocom* 1998 vice general chair
- Organizer, SIP Bake-Offs, Columbia University (April 1999, August 1999, December 1999)

- IEEE *Infocom* Executive Committee 1995–2000
- *NOSSDAV*, *MobiArch* and *IPTComm* steering committees (current)

Referee for *IEEE Transactions on Networking*, *Springer/ACM Multimedia Systems Journal*, *IEEE Transactions on Communications*, *Computer Networks and ISDN Systems*, *Internetworking*, IEEE Infocom, ACM Sigcomm, IC^{3}N, National Science Foundation, and others.

Maintainer and editor of the web-based Network Bibliography.

PATENTS

US patent 5,509,074: *Method of protecting electronically published materials using cryptographic protocols* (issued April 1996)

US patent 6,141,788: *Method And Apparatus For Forward Error Correction In Connection In Packet Networks* (October 2000)

US patent 6,446,108: *Method For Network Address Translation* (September 2002)

US patent 6,538,416: *Border Gateway Reservation Protocol for Tree-Based Aggregation of Inter-Domain Reservations* (March 2003)

US patent 6,771,644: *Program insertion in real time IP multicast* (August 2004)

US patent 6,937,597: *Signaling Method For Internet Telephony* (August 2005)

US patent 6,970,909: *Multi-protocol data communication systems supporting wireless telephony and content delivery* (November 2005)

US patent 7,257,201: *System and method for unified messaging in inter/intranet telephony* (August 2007)

US patent 7,266,091: *System and method for conferencing in inter/intranet telephony* (September 2007)

US patent 7,296,091: *System and method for receiving over a network a broadcast from a broadcast source* (November 2007)

US patent 7,319,689: *Method for handling the simultaneous mobility of mobile hosts in infrastructure-based networks* (January 2008)

US patent 7,610,384: *Network telephony appliance and system for inter/intranet telephony* (October 2009)

US patent 7,610,384: *Network telephony appliance and system for inter/intranet telephony* (October 2009)

US patent 7,636,336 *Methods and systems for reducing MAC layer handoff latency in wireless networks* (December 2009)

US patent 8,027,251 *Systems and methods for implementing protocol-aware network firewall* (September 2011)

US patent 8,166,102 *Signaling method for internet telephony* (April 2012)

US patent 8,302,186 *System and method for testing network firewall for denial-of-service (DOS) detection and prevention in signaling channel* (October 2012)

US patent 8,522,344 *Theft of service architectural integrity validation tools for session initiation protocol (SIP)-based systems* (August 2013)

US patent 8,565,384 *Systems, methods, and media for connecting emergency communications* (October 2013)

US patent 8,689,328 *Malicious user agent detection and denial of service (DOS) detection and prevention using fingerprinting* (March 2014)

US patent 8,719,926 *Denial of service detection and prevention using dialog level filtering* (April 2014)

US patent 8,737,220 *Systems for providing feedback to sending entities* (May 2014)

US patent 8,737,351 *Methods and systems for reducing MAC layer handoff latency in wireless networks* (May 2014)

US patent 8,750,242 *Methods, media, and devices for moving a connection from one point of access to another point of access* (June 2014)

US patent 8,804,513 *Methods and systems for controlling SIP overload* (August 2014)

US patent 8,966,619 *Prevention of denial of service (DoS) attacks on session initiation protocol (SIP)-based systems using return routability check filtering* (February 2015)

US patent 8,995,742 *Methods and systems for controlling traffic on a communication network* (March 2015)

US patent 9,036,605 *Methods, media, and devices for moving a connection from one point of access to another point of access* (May 2015)

US patent 9,118,814 *Set-top box peer-assisted video-on-demand* (August 2015)

US patent 9,374,342 *System and method for testing network firewall using fine granularity measurements* (June 2016)

US patent 8,750,242 *Methods, media, and devices for moving a connection from one point of access to another point of access* (July 2016)

US patent 9,473,529 *Prevention of denial of service (DoS) attacks on Session Initiation Protocol (SIP)-based systems using method vulnerability filtering* (October 2016)

US patent 10,039,033 *Systems, methods, and media for implementing call handoff between networks* (July 2018)

TUTORIALS

Partial listing:

- *IDMS/PROMS*, Coimbra, November 2002;
- *Mobicom* tutorial, Atlanta, September 2002;
- *Sigcomm* tutorial, Stockholm, August 2000;
- *International Conference on Multimedia (ICME)*, July 2000;
- *Networking 2000* tutorial, Paris, May 2000;
- *IEEE Real Time Applications Symposium*, May 2000;
- *VON Developers Conference*, semi-annually since 1999;
- BellSouth (Atlanta), February and March 1998, November 1999;
- *IEEE International Conference on Network Protocols* (ICNP), October 1999;
- ASSET conference (Dallas, Texas), March 1999;
- CEFRIEL (Milan), May 1999;
- MCI Corp. (Colorado Springs), August 1998;
- EPFL summer school (Lausanne, Switzerland), June 1998;

- 16th Brazilian Symposium on Computer Networks, May 1998;
- IEEE Infocom, March 1998;

SOFTWARE

MICE: Web-based information management for departmental personnel, student, space and financial data;

CINEMA: Columbia InterNet Extensible Multimedia Architecture (with Jonathan Lennox, Kundan Singh, and others);

EDAS: editor's assistant; conference paper management software used for IEEE ICC, IEEE Globecom, Mobicom, IEEE Infocom, ICNP, NOSSDAV, Packet Video (about 8,000 total), with roughly 770,000 users;

e*phone: Ethernet packet audio device; the first SIP-speaking embedded Internet phone (with Jianqi Yin).

graph++: graphing tool with matrix manipulation facilities.

NeVoT: network voice terminal, first RTP-capable Internet voice application.

rtptools: set of tools for analyzing, recording and playing back RTP packets; used in a number of media-on-demand projects.

RTP library: library implementing RTP (with Jonathan Lennox, Jonathan Rosenberg and Dan Rubenstein);

rtspd: RTSP multimedia server (with Jonathan Lennox and Kundan Singh).

sipc: SIP user agent (Internet telephony agent) (with Xiaotao Wu).

sipconf: SIP-based software conferencing server (with Kundan Singh);

sipd: First publically available SIP proxy and redirect server (with Jonathan Lennox);

sipum: SIP-based unified messaging system (with Kundan Singh);

simul: discrete-event simulator emulating SIMAN.

JOURNAL PUBLICATIONS

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CURRENT PHD STUDENTS

Jan Janak.

NON-US THESIS COMMITTEES

Ralf Ackermann (Technische Universität Darmstadt, July 2003), Paulo Mendes (University of Coimbra, Portugal, January 2004), Cristian Hesselman (University of Twente, Holland, May 2005), Martin Krebs (RWTH Aachen University, May 2010), Ian Marsh (KTH, Sweden, June 2009), Tommy Ou (University of Oulu, Finland, August 2010), Antti Mäkelä (Aalto University, Finland, August 2012), Erkki Harjula (University of Oulu, Finland, June 2016).

DECLARATION OF DR. HENNING G. SCHULZRINNE
***WIKIMEDIA FOUND. V. NSA*, NO. 1:15-CV-00662-TSE (D. MD.)**

EXHIBIT B

DOCUMENTS PROVIDED BY DEPARTMENT OF JUSTICE
FOR CONSIDERATION IN PREPARATION OF DECLARATION

1. NSA Director of Civil Liberties and Privacy Office Report, NSA's Implementation of FISA Section 702 (Apr. 16, 2014), https://www.nsa.gov/Portals/70/documents/about/civil-liberties/reports/nsa_report_on_section_702_program.pdf.

2. Privacy & Civil Liberties Oversight Board Report on the Surveillance Program Operated Pursuant to Section 702 of the FISA (July 2, 2014), https://www.pclob.gov/library/702-Report.pdf

3. Office of the Director of National Intelligence, Facts on the Collection of Intelligence Pursuant to Section 702 of the Foreign Intelligence Surveillance Act (June 8, 2013), https://www.dni.gov/index.php/newsroom/press-releases/press-releases-2013/item/871-facts-on-the-collection-of-intelligence-pursuant-to-section-702-of-the-foreign-intelligence-surveillance-act

4. The National Security Agency: Missions, Authorities, Oversight and Partnerships (Aug. 9, 2013), https://fas.org/irp/nsa/nsa-story.pdf

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6. *Wikimedia Found. v. NSA*, 143 F. Supp. 3d 344 (D. Md. 2015)

7. *Wikimedia Found. v. NSA*, 857 F.3d 193 (4th Cir. 2017)

8. Declaration of Robert T. Lee, ECF No. 77-3, *Wikimedia Found. v. NSA*, No. 1:15-cv-00662-TSE (D. Md.)

9. [*Redacted Caption*], Memorandum Opinion and Order (F.I.S.C. Apr. 26, 2017) (public redacted version), https://www.dni.gov/files/documents/icotr/51117/2016_Cert_FISC_Memo_Opin_Order_Apr_2017.pdf

10. [*Redacted Caption*], 2011 WL 10945618 (F.I.S.C. Oct. 3, 2011) (public redacted version)

11. Wikimedia Foundation Inc.'s Responses and Objections to National Security Agency's First Set of Interrogatories (Jan. 11, 2018)

12. Wikimedia Foundation Inc.'s Responses and Objections to United States Department of Justice's First Set of Interrogatories (Jan. 11, 2018)

13. Wikimedia Foundation Inc.'s Responses and Objections to the Office of the Director of National Intelligence's First Set of Interrogatories (Jan. 11, 2018)

14. Documents produced in discovery by Plaintiff Wikimedia Foundation, beginning with Bates-stamp nos.: WIKI0001412, 1458, 1474, 1545, 1950, 1956, 1957, 1960, 2097, 2301, 2316, 2344, 2358, 2429, 2459, 2479, 2483, 5174, 5466, 5500, 5577, 5693, 5832, 5978, 6363, 6505, 6508, 6536, 6543, 6564, 6662, 6700, 6836, 6872, 7093, 7108, 7115, 7347, 7351, 7382, 8108, 9269

15. Exhibit 1 to Wikimedia Foundation, Inc.'s Amended Responses and Objections to Office of the Director of National Intelligence's Interrogatory No. 19 (Apr. 6, 2018), and Exhibits A-G thereto

16. Deposition of Michelle S. Paulson (Apr. 13, 2018)