The Evolution of SRSnet

Andrew J. Johnson

Abstract

Beginning in 1982 the site computer network, currently called SRSnet, has evolved over the past 17 years to support the tremendous increase in computing and information technologies at the Savannah River Site (SRS). The growth of this network coincided with the explosion in the number of personal computers for office, laboratory, and process operations use and with the introduction of electronic mail and other office automation tools for site employees. SRSnet expanded throughout the 1980s to cover all site operations areas over the 300-square-mile SRS reservation and has undergone (and still is undergoing) major upgrades in technologies. SRSnet was one of the first large-scale computer networks in the country and remains one of the largest examples of a local area computer network. Because of the distribution of computers and computer-based processing across the Site, SRSnet is now considered essential to Site operations. Current upgrades to the network are focusing on eliminating single points of failure and upgrading the capacity of the network to transport the continually increasing load generated by Site operations.

The Early Years—Savannah River Laboratory and Laboratory Data Automation

The genesis of SRSnet goes back to 1981. At that time, the Computer Systems Division (CSD) of the Savannah River Laboratory (SRL) conducted a study of the automation needs of the Laboratory researchers. In 1981, general purpose computing at the Savannah River Plant consisted of three components. An International Business Machines (IBM) "mainframe computer" processed all major computations, business-oriented as well as most scientific and engineering calculations. A few dozen "minicomputers", primarily Digital Equipment Corporation (DEC) PDP systems, were dedicated to laboratory data automation and process data monitoring. A small number of microprocessor-based, or Personal Computer (PC), systems were also in use. Although introduced by this time frame, the now familiar pairing of Intel microprocessor hardware and Microsoft operating system software had not yet become the industry *de facto* standard. Personal computers in individual offices were rare, and most site microprocessors were located in laboratories to collect data and manage laboratory instrumentation.

The state of art of computer networking at the Site at this time consisted of a network of a few hundred "dumb" terminal workstations. ("Dumb" being the industry term for a workstation with no independent processing capability.) These terminals were attached through slow-speed phone lines and modems to the mainframe computer. A much smaller number of equally dumb terminals attached via separate phone lines, and modems to a few of the Site minicomputers were also in use.

As part of recommendations to Laboratory management on how to improve the use of computers to support the role of the laboratory researcher, the CSD study recommended establishing a local area network (LAN) based on Ethernet. Ethernet was a networking technology developed in the mid 1970s at the Xerox Palo Alto Research Facility, and, in 1981, it was just beginning to be available commercially. Ethernet defines a set of hardware and software protocols for establishing a communications "bus", linking distributed computers together to pass information and to share peripheral devices such as printers. The basic data transmission rate of Ethernet is ten million bits of information per second (mbps), a rate that was considered extremely fast at the time. In 1982, SRL management authorized the acquisition of a demonstration-scale local area network and supporting computers. The LAN components were purchased from Ungermann-Bass, Inc., and the resulting SRL network represented one of the earliest commercial implementations of an Ethernet network.

For the initial network, the network medium consisted of a 500-meter long coaxial cable that was installed in or near the ceiling throughout key locations in Building 773-A, the principal SRL facility. Network "taps" and "drop" cables connected microprocessor-based "Network Interface Units (NIU)" to the coaxial cable. Computers and terminals were attached via low speed serial cables (RS-232) to the NIUs, also called terminal servers. The Ethernet protocols made it possible for many devices to share a network, each capable of communicating with any other device on the network.

In 1983 the initial SRL network was expanded with the addition of coaxial cable segments, extending the reach of the network to the main laboratory locations of SRL. At the same time a fiber-optic cable and Ethernet repeaters were installed between SRL and the Site Central Computer Facility (CCF), which was located across from SRL. This was the first Site use of fiber optics in a computer networking application, and it provided the capability for micro and minicomputers attached to the network to send data to a minicomputer attached to the IBM mainframe computer. The minicomputer provided a store-and-forward mechanism between the laboratory computers and the IBM mainframe, which contained databases and computer programs for data storage and analysis. Additions of terminal emulation software for personal computers and a "protocol converter" enabled PCs attached to the LAN to emulate either a minicomputer terminal or a mainframe terminal for the purpose of logging into and using one of these "host" computers. By this point, fewer than 100 SRL employees were using the network. However, the network was demonstrating the three primary uses of any computer network:

- Allowing people to access distributed computing resources
- Supporting data transfers between individual computers on the network
- Allowing computers to share peripherals such as printers

Office Automation and the Expansion to All Site Areas

In 1985, Savannah River Plant (SRP) executive management, as the result of a comprehensive study of the computer and communications needs of the Site, formed the Computer Projects Department (CPD). CPD's mission was to establish and support office automation productivity tools for Site "information workers". At that time, the Site population consisted of over 10,000 employees of which 4000 were judged to be information workers by virtue of their job assignments as managers, supervisors, professional, or clerical employees. CPD acquired the office automation system, "ALL-IN-1", a product of Digital Equipment Corporation, which became the basis for the first introduction of electronic mail to the Site. ALL-IN-1 was a complex piece of software that ran on several DEC VAX minicomputers. It required a terminal connection between a user and the host computer. Therefore, CPD had the collateral mission of extending the original SRL LAN throughout the Site so employees at all 12 of the major operating areas would have connectivity to an ALL-IN-1 computer.

At that time, the size of the Site presented a technical challenge to the network implementers. Ethernet remained the state-of-the-art technology for computing network, but Ethernet protocols limited networks to no more than 2500 meters between devices. Since the distances between SRS areas extend up to several miles, simply extending the Ethernet between areas was not possible. Moreover, the state of data connections over existing phone systems at the Site limited transmission speeds on the order of 10,000 bits per second, which was woefully inadequate for linking area LANs together. Using an existing site cable TV (CATV) plant that connected all Site areas for video surveillance and information dissemination applications solved this problem. Specialized broadband/Ethernet interconnect devices, called bridges, were acquired from a small networking company, Applitek. The Applitek bridges transferred data packets between intra-area Ethernet LANs using a 6-megahertz TV channel over the CATV cable system to provide a 10-million-bit-per-second inter-area data network. Also, by this time Ethernet interconnection "bridges" were commercially available. These allowed the construction of complex Ethernet topologies so that the largest site areas could be interconnected via a single bridged Ethernet.

During 1986 and 1987, Ethernet LANs were implemented in each Site area, using Ethernet repeaters and bridges to extend the LANs within each area. These LANs were interconnected using the Site CATV system and the broadband/Ethernet bridges. At this time, SRSnet became one of the largest (in terms of geographical coverage) "campus" networks in the country. Figure 1 is a highly simplified schematic that shows the state of the network in 1987 after it had become a site-wide computer network using extended Ethernet LANs in each Site area and the CATV cable plant to connect the areas together.

Besides the very large area of Site territory, a major factor that hampered widespread deployment of the site network was the network

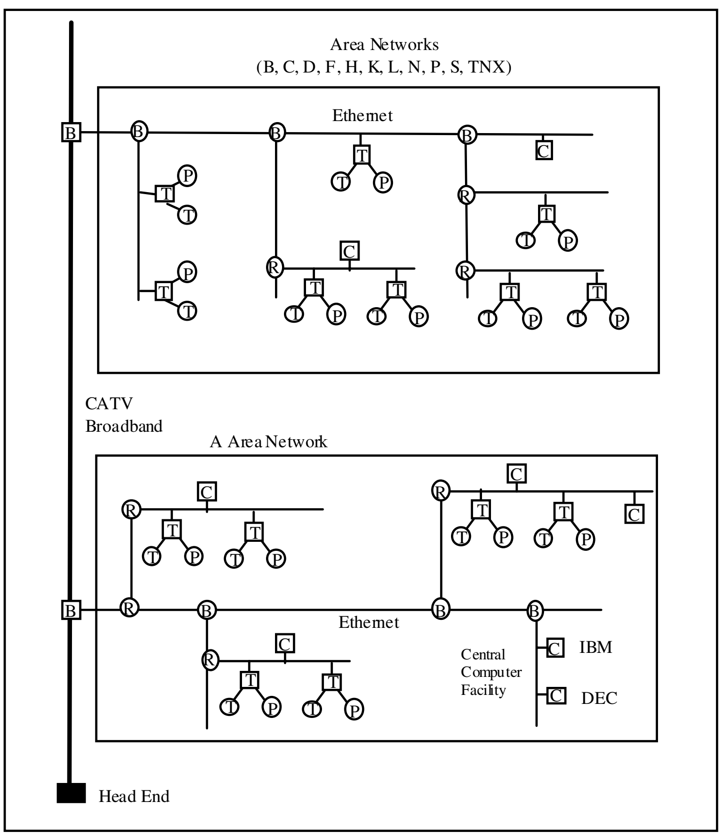

Figure 1. SRSnet - 1987

media itself. Initially, Ethernet required expensive and difficult-to-install coaxial cables. By the mid 1980s, the rapidly growing local area networking industry developed and standardized on a way to use inexpensive wiring consisting of pairs of wires twisted together to improve data communications characteristics. This type of wiring and its installation are common to the telephone industry. A site-structured wiring standard based on the industry standard (10BaseT) was defined, and projects were initiated that eventually resulted in the rewiring of virtually all Site locations so that every office or laboratory has at least one telephone connection and at least two data connection ports. Site rewiring started in 1989 and was not substantially completed until 1996 because of funding limitations.

The first-generation network based on terminal servers providing terminal access to host computers was transformed as the terminal servers were replaced with twisted pair wiring Ethernet "hubs", and terminals were replaced with personal computers containing Ethernet adapters. This meant that user connections were upgraded from a 9600-bits-per-second terminal port to a shared 10-million-bits-per-second Ethernet. Each Ethernet segment typically supported several hundred users. The 10BaseT hubs, Multi Media Access Centers (MMAC) from Cabletron Systems, were joined together by Ethernet coaxial cable or Ethernet extensions over fiber optic links.

By the end of 1989, the Site network had grown to near unmanageable proportions. The network topology consisted of highly complex area networks bridged together over the Site cable TV system. New interconnect devices, called network routers, were introduced to add more reliability and manageability to the Site network. Also by this time the Site telephone system had been upgraded to support high-speed digital data circuits, called T1. A network of routers and T1 circuits replaced the broadband cable system and Applitek bridges. Implementation of the network routers, acquired from Cisco Systems, required that the network be divided into multiple "subnets" with each subnet supporting no more than 255 attached devices. Each subnet was connected to the Site network via a dedicated Ethernet port on a network router. The routers were interconnected to each other via Ethernet segments (within an area) and T1 circuits between areas using a "hub ("A" Area) and spoke" arrangement.

By 1990, a large increase in the Site employee population that occurred after the Site contract transition from the Du Pont Company to the Westinghouse Savannah River Company (WSRC) required the location of several thousand WSRC employees into offsite office buildings. These buildings were located in the nearby cities of Aiken, South Carolina; North Augusta, South Carolina; and Augusta, Georgia. Each of these buildings was wired according to Site standards and equipped with a local area network based on 10BaseT technology. T1 data circuits and Cisco Systems routers were used to connect these facilities to the onsite SRSnet. Figure 2 shows the state of SRSnet after the implementation of routers, subnets, T1 circuits, connection to the Internet, and connections to offsite facilities.

The PC Revolution and WISDOM

As SRSnet was expanding from a few dozen interconnected laboratory computers to several thousand computers and workstations across the entire Site, advances in microprocessor technology made the personal computer ubiquitous with ever increasing capabilities at ever lower costs. This led to the acquisition of large numbers of personal computers at SRS. By the end of the 1980s, thousands of personal computers were attached to SRSnet, yet SRSnet could not really be considered a personal computer local area network. This was because the vast majority of PCs were attached via slow speed serial communications ports (RS-232) and terminal servers to SRSnet. These PCs ran special software that allowed them to emulate a

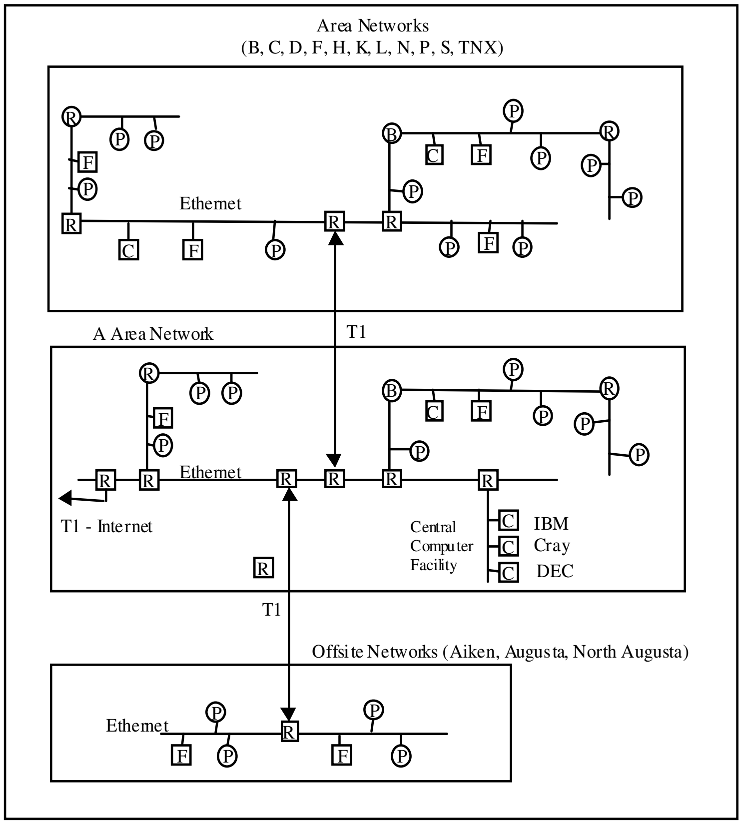

Figure 2. SRSnet - 1992

"dumb" terminal. Computer users employed this terminal emulation software to log onto and use a variety of computers across the Site, including the ALL-IN-1 office automation VAX computers, the Cray scientific supercomputer, and the IBM mainframe.

A true PC LAN consists of personal computers linked at high speeds directly to each other and supporting "servers", computers dedicated to the functions of supplying data storage and printing services for the attached PCs. In 1991, the Site, led by the Information Resource Management Department (IRM), published the first comprehensive computer architecture, to "serve as a unifying plan or blueprint for the implementation of computer-based systems and the computing, communications, and data management infrastructure required to support these systems." The computing architecture document recommended the transformation of SRSnet to a true PC LAN.

In 1992, the WISDOM project became the implementation of this recommendation. WISDOM stood for **W**orkstation **I**ntegration **S**ystem for **D**esktop **O**ffice **M**achines. The WISDOM system consisted of standard personal computers (IBM PS/2 computers with the Microsoft Corporation's Windows operating system and Apple Computer's Macintosh computers) with Ethernet (10BaseT) adapters for high-speed attachment to SRSnet. Local (i.e., nearby) file and print servers provided network file storage and access to network attached printers for all users. Netware, a software product of Novell, Inc., was the basis for providing networked-based file and print services. A standard set of business productivity applications was available for download on demand from the local file server.

The real significance of the WISDOM system was the standardization it brought to Site PCs. Prior to WISDOM, each Site personal computer was set up individually based on the desires of the user or under the direction of some local PC support specialist. This heterogeneous environment made it virtually impossible to deploy modern client/server applications in which the speed and graphical user interface of the personal computer is used cooperatively with the speed and data storage capabilities of larger "server" computers. It also meant that per system PC support costs were very high relative to industry best practices.

In 1996, IRM began to implement standardized PC configurations based on Microsoft's two newest operating systems, Windows 95 and Windows NT. The original WISDOM configurations, based on Microsoft Windows and the Apple Macintosh, were gradually retired. With the introduction of WISDOM and its replacements, the number of personal computers attached to SRSnet grew rapidly from some 4000 in 1991 to over 12,000 by 1996. IRM was able to deploy several client/server applications, and the cost to support individual personal computers rapidly fell to the point that the Site has received industry recognition as "best in class" in its ability to support PCs at a low cost.

The Replacement Telephone System and Fiber Optic Technologies

In 1988, the Department of Energy authorized a major project to completely replace the Site telephone system. This project included replacing all Site telephone switches (PBXs) as well as installing a fiber optic backbone connecting all Site areas together. In addition, the project included fiber optic-based connections to the fiber backbone from all Site permanent facilities (buildings). The "Replacement Telephone System" (RTS) project was completed in 1995. The project was quite an undertaking, consisting of 2 AT&T 5ESS switches with 10 optical remote modules, 18,000 telephone lines, 117 miles of installed copper cable installed, and 184 miles of installed fiber cable.

From a data network perspective, the completion of the RTS project was timely. The rapid growth in the use of information technology, in general, and personal computers, in particular, at the Site had greatly increased the demands for bandwidth (i.e., network capacity) being put on SRSnet. Both the inter-area T1 data circuits and the Ethernet-based trunks in each Site area were being used at near-capacity rates. The new fiber optic facilities opened the door to a newer, faster, and more reliable data networking technology upon which to build the inter-area and intra-area network trunks. This technology is called Fiber Distributed Data Interface (FDDI). FDDI networks are fiber optic based and consisted of rings of systems connected together at transmission speeds of 100 million bits per second. This represents a factor of 10 improvement in bandwidth over Ethernet and a factor of 64 improvement over a T1 circuit.

During the period 1994-1996, a major upgrade of SRSnet was accomplished. Dual inter-area FDDI trunks were used to redundantly interconnect the major site areas. New, much faster routers (Cisco Systems 7000) with FDDI interfaces were the key components of the inter-area network. Each individual area network consisted of several FDDI rings interconnected via a FDDI switch (Digital Equipment Corporation Gigaswitch). The network within each building consisted of several Ethernet (10BaseT) networks connected via a FDDI/Ethernet bridge (Cabletron Systems ESXmim) to the area FDDI ring. Each Ethernet network was limited to no more than 24 connected computers to increase the resulting bandwidth available to any one user. (Previously each Ethernet LAN typically supported 100 to 200 connected computers each). The configurations of the routers were changed to support large subnets, one per SRS

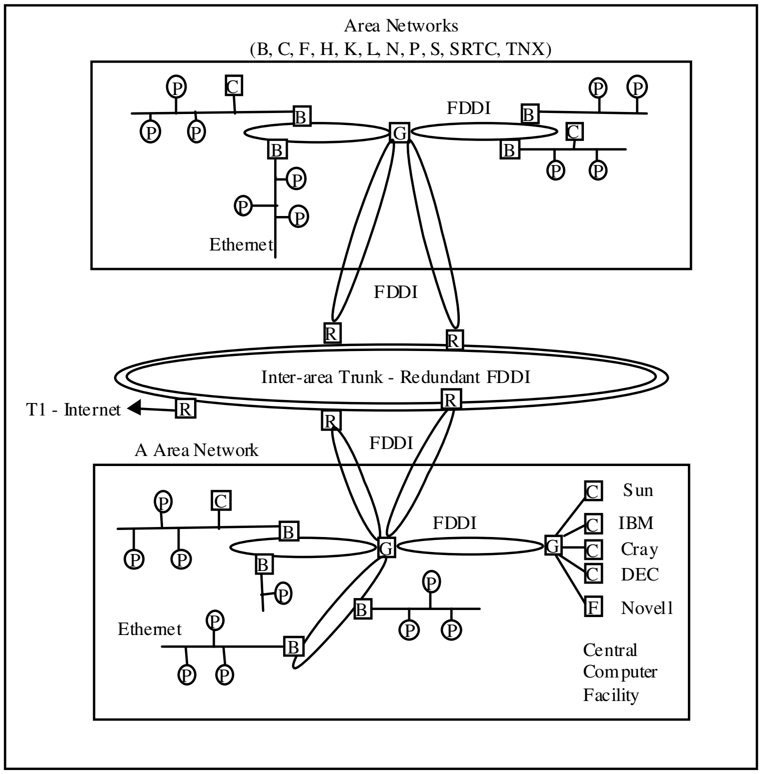

Figure 3. SRSnet - 1997

area. Figure 3 shows the state of SRSnet by the beginning of 1997 after implementing FDDI inter-area trunks, FDDI area networks, large subnets, centralizing the file servers in the Central Computer Facility, and closing the offsite facilities.

This upgrade greatly improved both the capacity and the reliability of SRSnet. The reliability of FDDI technology and the network switches and routers along with the redundant trunk design provided this increase in robustness. Use of the network continued to grow nearly exponentially, and increasingly applications deemed critical to successful Site operations were implemented that depended on the availability and responsiveness of SRSnet services.

The Introduction of the Internet and the World Wide Web

The worldwide computer network now known as the Internet developed out of a Department of Defense research network, ARPAnet, started over 30 years ago. In the early years the Internet demonstrated the utility of electronic mail and the ability to transfer computer files between computers systems across the country (and later the world). In the early 1990s, the development of a new way to present information on a network led to the World Wide Web (WWW, or simply “the Web”) and explosive growth in the size and amount of use of the Internet. Simply put, Web technologies define standard methods of encoding textual and graphical information in a collection of computer files on "Web servers" located across the Internet. These standards enable users on any personal computer attached to the Internet the ability to locate and display for viewing specific information using a PC program called a "browser".

In 1992, SRSnet was connected to the Internet. A secure gateway computer, called a firewall, provided the interface between SRSnet and the Internet. The firewall prevented outside access to SRSnet from the Internet while allowing SRSnet users access to the WWW, external electronic mail addresses, and other Internet services. The initial connection to the Internet was at T1 data rates, but increased usage led to an upgrade to T3 (45 million bits per second) in 1999. The Internet has proven to be indispensable to Site researchers, engineers, and information workers for locating and obtaining information necessary to support Site missions and in communicating with Site overseers, partners, suppliers, and stakeholders.

In 1996, the use of Web technology internally at Savannah River Site was put to use with the **S**avanna**h** **R**iver **I**nformation **N**etwork **E**nvironment (ShRINE). ShRINE is the Savannah River Site's "Intranet" and consists of a system of Web servers containing a wide variety of Site information such as organization charts, telephone directories, newsletters, and electronic versions of common site manuals. A standard browser was installed on every Site personal computer to facilitate employee access to this information and the information found on the WWW.

Since 1996, ShRINE has grown in size and importance to Site operations. Today there are millions of pages of information stored on several ShRINE servers on SRSnet. Over 10,000 users collectively access 2-4 million ShRINE pages in any given week. ShRINE has been extended from the display of static information to include interactive applications in such areas as Material Safety Data Sheets (MSDS), training course registration, personal equipment inventory, and conference room scheduling.

Summary

From humble beginning in the early eighties as a laboratory research tool, SRSnet has grown to become indispensable to Savannah River Site operations. The scope and impact of SRSnet can be seen from the following numbers:

- Area networks - 12
- Buildings served – 600
- FDDI ports – 200
- Ethernet ports – 30,000
- ATM ports - 300
- Fiber cable miles, inter-area - 75
- Fiber cable miles, intra-area - 100
- Connected devices – 15,000
- Number of bytes of data transmitted daily – 8,000,000,000,000 (8 terabytes)

In order to meet the growing volume requirements placed on SRSnet by its users, the next generation SRSnet is currently under development. This is based on new and faster Ethernet protocols supporting transmission speeds up to a billion bits per second.

Acknowledgments

As in any large undertaking, there have been many contributors to the development of SRSnet. I would like to recognize the following individuals (in chronological order) for their major contributions to the birth and growth of the network:

Dr. Randall N. Sims first introduced the concept of local area computer networks to the Site and implemented the first LAN in SRL.

James W. Wade was the Savannah River Plant General Superintendent for Information Systems who sponsored the development of the network during its formative years of 1982-1989.

Frank C. Fortune was responsible for developing office wiring standards that made universal access to SRSnet possible.

James R. Pennington led the SRSnet design and implementation team that took SRSnet from a small demonstration project to total site coverage.

S. Mark Johnson promoted the establishment of an Internet link to the Site and introduced the usage of the TCP/IP network protocols.

David W. Eckert conceived the WISDOM system for supporting personal computers in a distributed LAN environment.

Thomas J. Kennedy designed the major technology upgrade to use fiber optics and FDDI technology.

Philip L. Ames led the efforts to establish ShRINE and use it as a tool to speed the flow of information to site employees.

Henry L. Longley is the current SRSnet engineering lead who was responsible for implementing the 1995-1996 fiber upgrades to SRSnet and who is currently leading the migration of SRSnet to ATM.

Paul N. Sand has been the SRSnet operations lead for the last five years and has been instrumental in implementing past and on-going major network upgrades.

Biography

Andrew (Andy) J. Johnson has a BA degree in mathematics from Rhodes College and an MS in meteorology from the University of Michigan. Following a stint in the U. S. Air Force as a meteorologist and computer programmer responsible for global weather forecast models, Mr. Johnson went to work for the Du Pont Company at the Savannah River Laboratory in the Computer Applications Department in 1977. In his career at Savannah River, Mr. Johnson has been involved in numerous projects, most notably being responsible for the introduction of E-mail across the Site, the early development of SRSnet, the Site computer network, and the formulation of the Site's first strategic computing architecture. He is currently the Manager for Information Delivery Services in the Information Technology Department of the Westinghouse Savannah River Company.

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