11-16-94

SANDIA REPORT

SAND93-0002 • Revised • UC-906

Unlimited Release

Printed November 1994

Intra-Building Telecommunications Cabling Standard for Sandia National Laboratories

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Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
under Contract DE-AC04-94AL85000

Supersedes SAND93-0002 dated August 1993

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Supersedes SAND93-0002 Printed August 1993

Intra-Building Telecommunications Cabling Standard for Sandia National Laboratories

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Abstract

This revision is an update to the Sandia National Laboratories' standard for intra-building telecommunications cabling. It is based on current national cabling standards and modified, where appropriate, to meet Sandia's specific high-technology business needs. The telecommunication components described within this document comprise Sandia's intra-building distribution systems for twisted-pair and optical-fiber cable for both Secure and Open/Restricted Access environments. This document will continually be revised with updates to incorporate technology advances and to accommodate Sandia's changing business requirements.

Acknowledgment

I would like to thank all the members of the recabling project team for their continuous support. Their unprecedented teaming efforts over the past year have staged Sandia for a “new day” in telecommunication capabilities.

Special thanks to Orlando Trujillo, Dept. 7906, for his exceptional coordination of all construction design tasks; to Don Gould, Dept. 7911, for his tireless performance coordinating the construction work force; to Frank Martin, Dept. 13917, for his “get the job done” attitude over the past year; and especially Ray Gonzales, Dept. 7904, for his diligent efforts with construction project management.

Special thanks to the “dynamic duo” of Jon Eberhart and Tim Francis, both with Holmes and Narver Inc. Their on-site support activities ranged from conceptual design to coordination of ribbon cutting ceremonies and everything in between. Their energy, enthusiasm, and embodiment of quality has greatly facilitated the lab-wide recabling project.

I would like to express a sincere thanks to Bob Dougherty, Dept. 13902, for being the recabling project’s “essential enabler.” Bob’s wisdom and vision allowed him to identify the modernization of Sandia’s entire telecommunications infrastructure as a critical survival task facing Sandia National Laboratories. Bob possesses a truly remarkable suite of personal skills and inner motivation. It is a true joy to work with an individual of Bob’s caliber. Keep it up, Bob!

Lastly, I would like to thank Mary Elizabeth Stevenson-Adams for her continuous support and love. Mary’s gifts of grace and compassion have allowed me to experience fulfillment at work and more importantly, at home.

Preface

In the early 1980s, prompted by the need to distribute classified computing capabilities, the Communications Design and Services Departments initiated the installation of a lab-wide Secure computer data distribution system. Several buildings were chosen as concentration points for the communication equipment required by this distribution system. These concentration points, referred to as Technical Control Centers (TCCs), were selected to serve geographic areas within Sandia. Originally, the Secure distribution system included copper wiring only. It now includes an optical fiber backbone that interconnects the TCCs and all other major buildings. Sandia's entire Secure distribution system conforms to the security requirements of the Department of Energy's Protected Distribution System.

In the recent past, technology and world relations have undergone enormous change. That change has created numerous challenges for Sandia National Laboratories. One of the most important challenges faced by the Communications Department at Sandia is to provide two separate cabling distribution systems capable of supporting state-of-the-art technologies for all telecommunication needs. One cabling distribution system will be dedicated to Secure telecommunication needs and the other dedicated to Open/Restricted Access telecommunication needs.

A mandatory prerequisite to the creation of two separate maintainable cabling distribution systems with identical state-of-the-art capabilities is establishing a single lab-wide intra-building cabling standard. This document is intended for that purpose.

This document defines Sandia National Laboratories' intra-building cabling standard for transmission media and termination hardware. It is based on current national standards and modified, where appropriate, to meet specific Sandia high-technology business needs. Implementation of this standard during the recabling of existing buildings and cabling of new buildings is required by Sandia National Laboratories. The resultant standard infrastructure for intra-building cabling will be the foundation of Sandia National Laboratories' entire information infrastructure. As such, the intra-building cabling infrastructure is an essential enabler allowing Sandia to continue functioning as a premiere high-technology research and development center in the world.

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Contents

Introduction	1
Sole-Make Justification	2
Unique Features.....	2
Compatibility.....	3
Standardization.....	3
Summary	4
Telecommunication Cabling Components	4
Cables	4
Unshielded Twisted Pair Cable	5
Optical Fiber.....	6
Termination Components	8
User Outlet	9
Optical Fiber Connector/Coupler/Attenuator	9
EUTP RJ45 Modular Jack	10
EUTP Mass-Termination Frames	11
Optical Fiber Distribution Panels	12
Cross-Connect Jumpers.....	13
Physical and Logical Topologies.....	14

Figures

1 Optical Waveguide	6
2 Multimode Optical Waveguide.....	7
3 Singlemode Optical Waveguide	7
4 Sandia Standard User Outlet	9
5 EIA/TIA T568A Eight-Position Jack Pin/Pair Assignments	11
6 Sandia Standard EUTP Mass-Termination Frame	11
7 Sandia Standard EUTP Mass-Termination Frame with Protectors	12
8 Sandia Standard IDR Optical Fiber Distribution Panel	12
9 IDR LIU Wall-Mounted Optical Fiber Distribution Panel Array.....	13
10 Sandia Standard TCC Optical Fiber Distribution Panel.....	13
11 Physical Topologies.....	14

Tables

1 UTP Cable Labeling, Bit Rates, and Common Cable Type - Applications.....	15
2 Sandia Standard 4-pair EUTP Cable Specifications.....	15
3 Sandia Standard 4-pair EUTP Color Code.....	16
4 Sandia Standard 25-pair EUTP Cable Specifications.....	16
5 Sandia Standard 25-pair EUTP Color Code.....	17
6 Sandia Standard 4-fiber Multimode Cable Specifications.....	17
7 Sandia Standard Optical Fiber Color Code	18
8 Sandia Standard 4-fiber Singlemode Cable Specifications	18
9 Sandia Standard User Outlet Specifications.....	19
10 Sandia Standard Optical Fiber Connector/Coupler/Attenuator Specifications	19
11 Sandia Standard EUTP RJ45 Modular Jack Specifications	20
12 Sandia Standard EUTP Mass-Termination Frames Specifications	20
13 Sandia Standard IDR Optical Fiber Distribution Panel Specifications	20
14 Sandia Standard TCC Optical Fiber Distribution Panel Specifications	21

Acronyms

10BASE-F	10Mbps baseband optical fiber media
ADSL	Asymmetrical Digital Subscriber Line
ANSI	American National Standards Institute
ATM	asynchronous transfer mode
AT&T	American Telephone and Telegraph
CAP	carrierless amplitude and phase
CSMA/CD	carrier sense, multiple access/collision detect
dB	decibel
DOE	Department of Energy
EIA/TIA	Electronic Industries Association/Telecommunications Industry Association
EMF	electromagnetic field
EUTP	enhanced unshielded twisted pair
FDDI	fiber distributed data interface
FOIRL	fiber optic inter-repeater link
ft	feet
Hz	Hertz, frequency in cycles per second
IC	intermediate cross-connect
IDR	intermediate distribution room
IEC	International Electrotechnical Committee
IEEE	Institute of Electrical and Electronic Engineers
ISDN	Integrated Services Digital Network
km	kilometer, one thousand meters
LAN	local area network
LASER	optoelectronic device that emits coherent light
LED	light-emitting diode, incoherent light
LIU	lightguide interconnection unit
LST	lightguide shelf termination
MAN	metropolitan area network
MAP	Manufacturing Automation Protocol
MC	main cross-connect
MHz	megahertz
MMF-PMD	Multimode Fiber - Physical Media Dependent
NEMA	National Electrical Manufacturers Association
NEXT	near-end crosstalk
NFPA	National Fire Protection Agency
nm	nanometer, one billionth of a meter
PBX	private business exchange
NYLATCH®	registered trademark of Hartwell Corporation
PC	physical contact
PDS	Protected Distribution System
POF	plastic optical fiber
ps	picosecond, one 10 ⁻¹² of a second
RGB	Red/Green/Blue video format
SCR	Sandia contracting representatives
SCS	structured cabling systems
SCSI	small computer system interface

SMF-PMD	Singlemode Fiber - Physical Media Dependent
SOF	silicon optical fiber
SONET	Synchronous Optical Network
ST®	registered trademark of AT&T, straight tip optical connector
ST®II	registered trademark of AT&T, straight tip version 2 optical connector
TC	telecommunication closet
TP-DDI	unshielded twisted pair - distributed data interface
TCC	technical control center
UTP	unshielded twisted pair
WAN	wide area network

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Intra-Building Telecommunications Cabling Standard for Sandia National Laboratories

Introduction

Advancements in telecommunication capabilities over the past ten years have exploded. National and international telecommunication standardization efforts have struggled to keep pace. The obvious advantages witnessed as a result of local area network (LAN), metropolitan area network (MAN), and wide area network (WAN) protocol standards focused the need for similar cabling standardization efforts. In July 1991, ANSI (American National Standards Institute) EIA/TIA (Electronic Industries Association/Telecommunications Industry Association) published EIA/TIA 568 *Commercial Building Telecommunications Wiring Standard* to "define a generic telecommunications wiring system --- that will support a multiproduct, multivendor environment." Before the publication of that document, generic cabling standards did not exist.

Cables were frequently selected to complement specific equipment requirements, usually at the request of the vendor. Little, if any, consideration was given to future telecommunication needs including flexibility, capability, compatibility, maintainability, or cost. Cable types ranged from twisted pair to coaxial to optical fiber, with literally hundreds of each type.

At Sandia, each unique telecommunication cabling solution ultimately became a "throw-away" for two reasons. First, the annual churn rate (relocation of staff) has risen as high as 30 percent in recent years. The chance of relocating staff to an area with cabling equivalent to that of the vacated area was extremely small.

Second, computer vendors (for the most part) were only interested in endorsing cabling products that satisfied immediate customer needs. Future capabilities of cables and the life of the building were rarely considered. Hundreds of "throwaway" cable systems at Sandia resulted in uncontrolled recabling costs, reduced staff productivity and efficiency, and continual business disruptions. These undesirable results will be stopped by implementing a lab-wide cabling standard.

The cable infrastructure that results from implementing this intra-building cabling standard will serve as the foundation of Sandia National Laboratories' entire information infrastructure. It is a prerequisite, "essential enabler" for corporate reengineering, which Sandia has embraced. Every Sandia business unit will be positively affected with regard to cost, schedule, and performance. Successful implementation of a standard will allow the Laboratories to continue functioning as one of the premiere high-technology research and development centers in the world.

An October 1993 study by Infonetics Corp. (San Jose, CA) found that network downtime costs Fortune 1000 companies an average of \$62K per hour! This cost is undoubtedly much higher at research and development facilities such as Sandia National Laboratories. Furthermore, unreliable cable infrastructures are estimated to account for 70 percent of all current LAN problems. The time and energy dedicated to establishing Sandia's high-quality intra-building telecommunications cabling standard are well worth it.

This document and its future revisions will serve as Sandia National Laboratories' intra-building cabling standard. It is based on current national and international cabling standards and modified, where appropriate, to meet Sandia's specific high-technology business needs. Modifications address Sandia requirements in areas such as media types, quantities, and the security requirements of the Department of Energy (DOE).

This intra-building cabling standard must be implemented as part of every remodeling project, existing building recabling project, and conceptual designs for new construction.

The resultant information infrastructure will easily satisfy all generic requirements posed by intended Information Superhighway applications including: full-duplex/2-way simultaneous communications, extremely high data rates (into the gigabits) and nonproprietary, open system protocols.

Some telecommunication networks that will be supported include; circuit and packet switched networks (PBX/5ESS Voice and Low-Speed Data), LANs (Ethernet, Token Ring, Fiber and Copper Distributed Data Interface), and WANs (Frame Relay, Switched Multi-megabit Data Service, and Asynchronous Transfer Mode). These networks will transport all of Sandia's applications including; voice, text, graphics, still images, and full-motion video. These networks will allow Sandia to deploy future commercial applications such as: movies on demand, interactive video, distance learning or tele-education, and world libraries access. They will allow Sandia to participate in new-age corporate advertising and marketing.

Sandia's intra-building cable infrastructure must be capable of delivering these technologies, and more, to every user.

Sole-Make Justification

Sandia National Laboratories is the DOE's prime research and development contractor and therefore must comply with all established DOE directives.

The DOE is Sandia's primary funding source. Sandia must embrace and implement appropriately stringent specified purchasing

practices of the DOE.

Sole-make justification must be based on fact, not competing manufacturers' claims. Sandia contracting representatives (SCRs) in the Procurement Department team with and rely on Sandia technical staff for all information required for sole-make endorsement.

Sandia's technical staff is well equipped and encouraged to survey any and all technical data pertaining to their area of expertise. World-wide associations with other research and development laboratories, technical professional societies, national and international standards bodies, world-class technical libraries, and higher-level educational institutions afford Sandia staff members the opportunity to constantly continue their education and stay abreast of state-of-the-art technological advances. These sources of knowledge, along with technical data requested directly from competing manufacturers, allow Sandia to develop, publish, and support sole-make justifications.

Sandia's sole-make justification for the telecommunication cable and termination components contained in this document are based on 1) Unique Features, 2) Compatibility, and 3) Standardization. These three areas are consistent with information requested on Sandia's Sole-Source/Sole-Make Justification form SF 6430-JJ.

Unique Features

Unique features of individual telecommunication components are exceedingly important, but the installed composite configuration is paramount. For example, a typical end-to-end telecommunication link is composed of transmission media (cable), connectors, couplers, attenuators, cross-connect cables, and termination frames and blocks. Inferior performance of any single component in the link will limit the performance of the entire link.

To further illustrate this point, an investment in the highest quality cable would be lost if it were terminated with inferior components, or vice versa. Restated, as important as the individual unique component features are, they are superseded by the combined links' capabilities throughout the installed telecommunica-

tion infrastructure.

Each Sandia-specified component has been thoroughly investigated and deemed necessary to complement every other associated component. The resultant telecommunication cabling infrastructure will enable Sandia to develop a lab-wide state-of-the-art information infrastructure. Sandia's businesses are becoming highly competitive, and the successful implementation of a telecommunication cabling infrastructure is absolutely necessary for Sandia's survival.

The detailed information contained in the Cables and Termination Components sections of this document will enumerate the many unique features incorporated in each telecommunication component.

Compatibility

Compatibility must be maintained with Sandia's existing inter-building distribution systems.

Sandia's inter-building optical fiber distribution system represents over 10 years of design and installation efforts and contains more than 8,000,000 installed fiber feet. The total dollar investment is in the tens of millions.

Other manufacturers' optical fibers have been tested at Sandia for interoperability. Testing revealed dimensional inconsistencies such as core diameter, eccentricity, and concentricity. Dimensional inconsistencies between dissimilar optical fibers induce unpredictable system performance, such as wide-ranging, coupling loss. Unpredictable system performance would severely degrade the capabilities of the entire cable distribution system.

The tests also revealed critical transmission compatibility problems, including intolerable reflectivity between dissimilar optical fibers. Slight differences in optical fiber indices of refraction and mode field qualities such as diameter and photonic energy patterns result in unacceptable reflectivity levels.

Again, the use of dissimilar optical fibers would cause unpredictable characteristics of the optical transmission throughout the entire optical-distribution system and render it unmaintainable and severely degraded in its capabilities.

Standardization

In the recent past, Sandia's Corporate management conceived and created an unprecedented Information Architecture Department. Staffed with some of Sandia's best visionaries, the Information Architecture Department established fundamental requirements that were to be implemented lab-wide. One fundamental requirement was to embrace and deploy standards at every opportunity.

Published standards have contributed to recent advancements in world-wide telecommunications by encouraging and even forcing equipment manufacturers to offer interoperability capabilities instead of proprietary solutions. Some exceptional standards documents that have been recently published are listed below:

Institute of Electrical and Electronic Engineers (IEEE) 802 LAN standards including 802.3 CSMA/CD (commonly referred to as Ethernet), 802.4 Token Bus (Manufacturing Automation Protocol - MAP), 802.5 Token Ring (IBM 4/16 Mbps), 802.6 metropolitan area network (MAN), and 802.7 through 802.12 which include wireless and other network standards.

EIA/TIA standards including 568A (commercial cable and termination components), 569 (cable pathways and spaces), 570 (residential and light commercial cabling), 606 (cable administration and documentation), and 607 (cable grounding and bonding).

ANSI standards including small computer systems interface (SCSI), X3T9.5 fiber distributed data interface (FDDI), and X3T9.3 Fibre Channel.

International Telegraph and Telephone Consultative Committee (CCITT) Integrated Services Digital Network (ISDN) standard.

Products meeting these standards are afforded an uncommon high level of interoperability. The proper installation of the telecommunications cable and termination components described in this document will result in an infrastructure for telecommunication cable that will easily meet and exceed all current published cabling standards.

More importantly, the information networks populating Sandia's cable infrastructure will be afforded unlimited potential for internal (and

external) multiprotocol interoperability. Internal network interoperability at Sandia will be wide spread, limited only by the cable infrastructure. Ultimately, every user at Sandia will be allowed to connect to every Sandia information resource regardless of his/her location or the resources location. Obviously, actual connectivity will be provided on a need-to-know basis.

Summary

In summary, the sole-make telecommunication cable and termination components specified in this document are the most advanced products available today. When properly installed, they will function as integrated end-to-end telecommunication links. The cable and termination components meet and exceed current national and international cabling standards. Sandia's unique high-technology business needs and the security requirements of the DOE can only be satisfied by the specified components listed in this document.

Telecommunication Cabling Components

Sandia National Laboratories' ability to continue as a premier high-technology research and development center depends greatly on the capabilities of the telecommunication cable infrastructure. Therefore, all cabling components must be of the highest quality available, installed with utmost care, and thoroughly tested and documented.

This document describes and specifies all cabling components. Sandia Facilities Engineering documents and manufacturer installation guideline documents describe and specify all cabling installations. A companion document, SAND93-1076, Revised, titled *Standard Testing Procedures for Optical Fiber and Unshielded Twisted Pair at Sandia National Laboratories*, describes and specifies all intra-building telecommunications cable testing procedures.

Telecommunication cabling components are critical to the overall transmission capabilities of the installed infrastructure. The

components specified in this document exceed the highest levels of performance currently stated in national standards. For instance, the transmission capabilities of Sandia-specified, enhanced unshielded twisted pair (UTP) components and Singlemode optical fiber components greatly exceed the EIA/TIA 568A standard. The Laboratories' traditional usage of state-of-the-art technologies mandates the deployment of these advanced cabling components.

Sandia's research and development activities require two separate telecommunication networks. These networks are 1) the Secure network and 2) the Open/Restricted Access network. They are physically separated per DOE directives, and must incorporate identical capabilities, flexibilities, survivabilities, and maintainabilities to satisfy all of Sandia's telecommunication needs.

The two networks will differ only in size. The Open/Restricted Access (or BLACK) network will be enormous. The BLACK network is required to be truly ubiquitous, as it includes voice distribution. The size of the Secure (or RED) network will be based on actual customer needs and Sandia corporate plans to establish reduced core Secure tech areas. RED network requirements have been shrinking as a result of changes in current world politics and Sandia's associated business direction changes.

This document sets forth a standard for intra-building cables and termination components that will ensure all of the aforementioned network requirements.

Cables

The two basic cable types included in Sandia's intra-building telecommunications cable infrastructure are 1) UTP and 2) optical fiber. These two types of cables will replace all other cable types such as coax. The Sandia standard cable suite distributed to each user outlet is composed of three 4-pair enhanced unshielded twisted pair (EUTP) cables, one 4-fiber multimode cable, and one 4-fiber singlemode cable.

At Sandia, the predominant cable jacket rating is riser. The National Electric Code (NEC) published by the National Fire Protection Agency (NFPA) allows riser-rated cables to be

installed in metal conduit and sealed metal pull boxes as they pass through plenum-type spaces. If other cable pathway conveyances such as ladders or trays are used, plenum-rated cables must be used. These other cable pathway conveyances could only be used in Sandia's BLACK network because all RED distribution network cables are required to be installed in conduit per DOE PDS documents.

Unshielded Twisted Pair Cable

In the past, UTP cable was traditionally used for voice communication. UTP was relatively low-cost and simple to install and maintain.

Today, new high-quality UTP cable has resulted from recent technology advances including innovative construction techniques and newly manufactured materials. This high-quality UTP cable is capable of high-speed data rates and is commonly referred to as enhanced unshielded twisted-pair cable.

EUTP link performance is established by proper installation of all the individual link components including cable, jacks, and mass-termination blocks and their individual capabilities. Sandia requires EUTP cable designed to offer the highest quality performance available.

Sandia's Standard EUTP cables are manufactured by AT&T. AT&T's Bell Laboratories led world research and development in the expansion of UTP cable capabilities. AT&T's exceptional engineering and manufacturing has yielded the most capable EUTP products on the market today.

AT&T designates this high-quality EUTP product line as HIGH-5™. These HIGH-5™ components were specifically designed to be installed as a complete integrated system. Installed as such, they can deliver unparalleled end-to-end (or link) performance capabilities.

4-Pair EUTP Cable. AT&T HIGH-5™ cable and termination components were recently demonstrated (May 1994, at AT&T's Global Private Network Seminar, Pine Isle, Georgia) supporting 622Mbps on a 95-ft HIGH-5™ link. This would equate to 23,000 pages of text per second! This unprecedented

demonstration required sophisticated, one-of-a-kind transmission equipment incorporating a state-of-the-art encoding technology known as CAP 64 (carrierless amplitude and phase modulation). CAP 64 encoding uses sophisticated digital signal processing and adaptive equalization. All four pairs of conductors in the cable were used. The information transported over the link was digitized red, green, blue (RGB) video, commonly referred to as studio quality video.

The AT&T HIGH-5™ product line will easily support the new and exciting Asymmetrical Digital Subscriber Line (ADSL) technology. ADSL was designed primarily to provide 2-way video communications over voice grade UTP cable.

AT&T's HIGH-5™ components easily support 100Mbps LAN bit rates. The ANSI X3T9.5 fiber distributed data interface (FDDI) working group has officially identified the UTP version of the 100Mbps LAN as twisted pair-data distributed interface (TP-DDI).

Asynchronous transfer mode (ATM) equipment manufacturers are currently designing and manufacturing EUTP transmission equipment with 155Mbps data rates. AT&T's HIGH-5™ product line warranty includes 155Mbps customer applications when properly installed by an AT&T certified SYSTIMAX® structured cabling systems (SCS) reseller.

AT&T HIGH-5™ EUTP cable far exceeds the EIA/TIA 568A Category 5 UTP cable. Table 1 lists EIA/TIA Categories, Underwriter Laboratories levels, bit rates, and common cable types and applications.

Sandia Standard 4-pair EUTP cable specifications are contained in Table 2. Sandia Standard 4-pair EUTP color code is contained in Table 3.

25-Pair EUTP. A recent addition to Sandia's intra-building cabling standard is AT&T's 25-pair HIGH-5™ EUTP cable. Currently, this cable will only be used in intermediate distribution rooms (IDRs) to connect wall-mounted AT&T 110 mass-termination blocks to free-standing 19-in. equipment racks. The 19-in. equipment racks will house customer specific LAN/WAN electronics. These multipair cables

will facilitate cable management, documentation, and maintenance.

Developing a 25-pair HIGH-5™ EUTP cable presented several new challenges to AT&T. One challenge was physical cable assembly, i.e., creating unique twist ratios for each pair in the cable and for bundles of pairs. The physical positioning of electrical conductors in near-proximity causes many detrimental electrical phenomena, the most significant of which is near-end crosstalk (NEXT). Cable construction and materials are crucial.

Another challenge faced by AT&T was to develop a new performance parameter and test procedure that would allow standardization of multipair cable NEXT parameters. AT&T's research in multipair cable led to a new "power sum" NEXT quantifier, which has been included in EIA/TIA 568A.

Sandia Standard 25-pair EUTP cable specifications are contained in Table 4. Sandia Standard 25-pair EUTP color code is contained in Table 5.

Optical Fiber

In the past 20 years, a tremendous amount of research and design effort has been directed toward developing lightwave transmission. Lightwave transmission offers many superior communication capabilities such as: high immunity to external electromagnetic fields (EMF), minimization of signal coupling between adjacent conductors, caustic atmospheric environment tolerances, and most importantly, very high transmission bit-rates across long distances. (Singlemode optical fiber is capable of propagating extremely high frequencies of light, in the thousands of TeraHz!)

The conductor or light guide used for lightwave transmission is commonly referred to as an "optical fiber." An optical fiber is a cylindrically shaped, light waveguide. Today, high bit-rate transmission optical fibers are typically composed of silicon cladding and doped silicon core. They are referred to as silicon optical fibers (SOFs). Plastic optical fibers (POFs) are being researched; however, excessive internal optical attenuation has limited their deployment in

telecommunications.

Lightwave transmission is based on the physical principle of total internal reflection of light. Optical fibers are internally structured in two concentric regions, the core and the cladding. (Figure 1.) The core material, having a slightly higher index of refraction than the cladding material, channels the light by total internal reflection. Total internal reflection occurs when light rays in the core region strike the core/cladding interface at less than a critical angle and propagate the length of the optical fiber.

Optical fibers have evolved into two basic types, Multimode and Singlemode. These types of optical fibers have been incorporated within many national and international standards such as FOIRL (fiber optic inter-reactor link), 10BASE-F, FDDI MMF-PMD (Multimode Fiber-Physical Media Dependent), and SMF-PMD (Singlemode Fiber-Physical Media Dependent). Newly developing international standards such as Fibre Channel, SONET (Synchronous Optical Network), and ATM will also incorporate them.

Figure 1. Optical Waveguide (commonly referred to as an optical fiber)

Multimode. Multimode optical fiber is constructed to accept and propagate multiple modes (or paths) of light concurrently. (Figure 2.)

Up to 1,000 separate modes may propagate a Multimode optical fiber. Mode propagation depends on physical parameters of the core, such as diameter and numerical aperture, and on the light wavelength of the transmitter. Ideal light wavelengths for Multimode optical fiber are 850 and 1300 nanometers (nm). These wavelengths correspond to intrinsic low loss "windows" in Multimode optical fiber.

Figure 2. Multimode Optical Waveguide
(allows many paths of light to propagate)

Typically, non-coherent light sources (light-emitting diodes, LEDs) are used as transmitters for Multimode optical fiber. They are relatively cheap and very reliable. LEDs emit light in thousands of directions simultaneously. Light injected into a Multimode optical fiber from an LED can and does travel in hundreds of separate paths. The shortest path is the axial path while the longest path is one of repeated core/cladding boundary reflections at just less than a critical angle. The critical angle results from the difference in indices of refraction between the core material and the cladding material.

A single pulse of light from an LED (perhaps representing a digital bit) will actually travel through the Multimode optical fiber core in many paths. The further the pulse travels, the greater the difference between the shortest and the longest path distance. Light transitions, at the beginning and end of the transmitted pulse, will appear to "spread" at the receiver as a result of the delay between different light paths. This pulse "spreading," primarily caused by modal dispersion, increases proportionately with cable length.

Modal dispersion is the primary bandwidth limiting factor for Multimode optical fiber. Multimode optical fiber bandwidth is expressed as cycles per second for a given distance megahertz-kilometer (MHz-km) at optimal wavelengths.

Sandia's Standard Multimode optical fiber cables are manufactured by AT&T. AT&T is the world leader in optical fiber technology and produces the highest quality optical fiber cables available today.

AT&T's Multimode optical fiber cables

have been endorsed by all national and international standards committees including: EIA/TIA, IEEE, ANSI and International Electrotechnical Committee (IEC). AT&T has continuously supplied vital scientific documentation to these standards groups to facilitate their efforts. AT&T's documentation originates primarily from Bell Laboratories, world renowned as the preeminent telecommunications research and development facility.

AT&T's Multimode optical fiber cables lead the industry in transmission capabilities. Sandia's standard Multimode optical fiber cables have minimum transmission capabilities of 500 MHz-km at the 1300 nm wavelength window and 200 MHz-km at the 850 nm wavelength window. AT&T's Multimode core/cladding dimensions of 62.5/125 μm have been adopted as the de facto industry standard.

Sandia Standard 4-fiber Multimode cable specifications are contained in Table 6. The Sandia Standard optical fiber color code is contained in Table 7.

Singlemode. Singlemode optical fiber is constructed to accept and propagate a single mode of light, the axial mode. (Figure 3.)

Light propagating through a Singlemode optical fiber actually travels in a mode field that is slightly larger than the core diameter. This becomes a critical parameter if optimal transmission between two Singlemode optical fibers is desired through splices or connectors.

Figure 3. Singlemode Optical Waveguide
(allows one path of light to propagate)

Ideal light wavelengths for Singlemode optical fiber are 1310 and 1550 nm. These wavelengths correspond to intrinsic low-loss "windows" in Singlemode optical fiber.

With one mode field of light propagating, there is virtually no modal dispersion as described in the Multimode optical fiber section above. However, a different form of dispersion called chromatic dispersion ultimately limits the band-width of Singlemode optical fiber.

In Singlemode optical fiber, the pulse "spreading" phenomenon is primarily due to the delay between different light frequencies. This pulse "spreading," primarily caused by chromatic dispersion, is directly related to the spectral width of the optical transmitter.

Typically, coherent light sources (LASERs) are used as optical transmitters for Singlemode optical fiber. LASERs are relatively expensive but capable of extremely high-frequency operation. LASERs emit light in a single coherent direction, eliminating the possibility of modal dispersion. However, LASERs typically emit tens of different light frequencies at various power levels.

These different frequencies of light (more commonly referred to as wavelengths) typically exist in a bell distribution around a central wavelength. This distribution is used to establish a LASER's publishable spectral width. The quantity and power of each wavelength present in this distribution directly contribute to pulse "spreading". Increased cable length also contributes pulse "spreading".

Chromatic dispersion occurs in both Multimode and Singlemode optical fiber. However, modal dispersion in Multimode optical fiber is several orders of magnitude larger than chromatic dispersion. Therefore, chromatic dispersion is considered an insignificant contributor to the bandwidth limitation of Multimode optical fiber and is not measured or published by Multimode optical fiber manufacturers.

Chromatic dispersion is the primary contributor to the bandwidth limitation of Singlemode optical fiber. Singlemode optical fiber dispersion is expressed as picoseconds per nanometer for a given distance (ps/nm-km) at optimal wavelengths.

Sandia's Standard Singlemode optical fiber cables are manufactured by AT&T. AT&T is the world leader in optical fiber technology and produces the highest quality optical fiber cables available today.

AT&T's Singlemode optical fiber cables

have been endorsed by all national and international standards committees including: EIA/TIA, IEEE, ANSI, and IEC. AT&T has continuously supplied vital scientific documentation to these standards groups to facilitate their efforts. AT&T's documentation originates primarily from Bell Laboratories, world renowned as the preeminent telecommunications research and development facility.

AT&T's Singlemode optical fiber cables lead the industry in transmission capabilities. Sandia's Standard Singlemode optical fiber cables have minimum transmission dispersions of 2.8 ps/nm-km at 1310 nm and 18 ps/nm-km at 1550 nm. AT&T's Singlemode core/cladding dimensions are 8.3/125 μm . The mode field diameter is 8.8 μm .

Sandia Standard 4-fiber Singlemode cable specifications are contained in Table 8. Sandia Standard optical fiber color code is contained in Table 7.

Termination Components

Standard termination components at Sandia include; user outlets, optical fiber connectors/couplers/attenuators and distribution panels, EUTP modular jacks and mass-termination frames, and cross-connect jumpers.

All intra-building cabling at Sandia will be "home run" between the user outlet and the intermediate distribution room (IDR). "Home run" cables are continuous, having no interconnections or splices.

In the user location, the surface-mounted multimedia outlet(s) will house both terminated EUTP and optical fiber cables. The color of the multimedia outlet (BLACK or RED) will correlate with Sandia's Open/Restricted Access (BLACK) network or Secure (RED) network.

In the IDR, EUTP cables will terminate on wall-mounted EUTP mass-termination frames. Optical fiber cables will terminate in wall-mounted distribution panels.

All RED and BLACK cable and termination components will be installed and physically separated according to DOE's PDS and RED/BLACK separation documents.

The typical number of conductors terminating in an IDR is extremely high, literally thousands. Optimal IDR space allocation requires

precise detailed design for cable termination and cross-connecting.

User Outlet

The user outlet must accommodate Sandia's required suite of cables, conductors, and connectors. Again, the standard intra-building cable distribution to each user outlet includes three 4-pair EUTP cables, one 4-fiber Multimode cable, and one 4-fiber Singlemode cable. The outlet must accommodate three modular RJ45 EUTP connectors, four Multimode ST@II couplers, and four Singlemode ST@II couplers and be available in both red and black colors to promote the recognition of Secure and Open/Restricted Access telecommunications cabling.

EUTP link performance is established by the proper installation of all the individual link components including cable, connectors, and termination blocks, and their individual capabilities. The Sandia-required modular RJ45 EUTP connector was physically designed to snap into a connector panel housed in the user outlet.

The AT&T 40A1 multimedia outlet is the only outlet available that is capable of satisfying all of Sandia's requirements. This multimedia outlet was recently modified to accommodate Sandia's cable and conductor requirements. The modification allowed for eight ST@II terminated optical fibers, four Multimode and four Singlemode. Few other manufactured outlets are capable of handling Sandia's cable and conductor quantities. No other outlets accommodate Sandia's required AT&T modular RJ45 EUTP connector.

The AT&T 40A1 outlet is made of high-impact thermoplastic material and can accommodate up to eight ST@II terminated optical fibers and up to four terminated EUTP 4-pair cables. Each AT&T 40A1 measures 5.5 in. wide, 6.8 in. high, and 1.6 in. deep. A built-in cable spool is centrally located within the outlet. This cable spool allows appropriate amounts of cable slack to be properly stored with acceptable bend radii.

The AT&T 40A1 is designed to be surface-mounted over a standard National Electrical Manufacturers Association (NEMA) 2-in. or 4-in. electrical box. The base of the outlet allows

rear-entry cabling, the most common configuration at Sandia. Additionally, the cover of the outlet has been manufactured with six knockouts. These knockouts can accommodate surface-run cabling from the top or either side of the outlet.

Figure 4 shows the Sandia Standard user outlet. Sandia Standard user outlet specifications are contained in Table 9.

Figure 4. Sandia Standard User Outlet

Optical Fiber Connector/Coupler/Attenuator

For optical fiber, link performance is established by proper installation of all the individual link components including cable, connectors, couplers, and attenuators and their individual capabilities.

All optical fiber connectors, couplers, and attenuators must match the transmission capabilities of the optical fiber conductors. The standard optical fiber connector, coupler, and attenuator for both Multimode and Singlemode applications at Sandia is the AT&T ST@II.

AT&T designed, developed, and patented the straight tip (ST) technology. AT&T has not licensed manufacturing rights to any other optical component manufacturer. All other "ST-compatible" components are reverse-engineered products. Sandia's experience with other so-called "ST-compatible" products has revealed a multitude of inferior or unknown performance characteristics. Sandia interoperability testing revealed dimensional inconsistencies that induced unpredictable connector coupling loss,

material deficiencies resulting in component breakage or low-coupling repeatability, and erratic attenuation losses from inserted attenuators.

AT&T ST®II optical fiber components incorporate many unique advantageous features. AT&T ST®II connectors provide low loss, low reflectance, high repeatability, and stable performance in a small rugged package that can be field-assembled quickly and efficiently. The quarter-turn locking mechanism assures a positive connection to the coupler. Domed zirconia ceramic ferrules provide exceptional durability and allow for a wide operational range of temperature (-40°C to +80°C) and humidity. A properly terminated AT&T domed zirconia ceramic ferrule (Super PC) results in exceptionally low connector loss and reflectance.

AT&T ST® couplers utilize split-sleeve technology for outstanding connector ferrule alignment. The alignment sleeve is a thin-wall tube with a longitudinal slit. The Singlemode sleeve is made of zirconia and requires a connector ferrule diameter of 2.4985 to 2.5 mm for proper alignment. The Multimode sleeve is made of AT&T proprietary engineering plastic and requires a connector ferrule diameter of 2.494 to 2.5 mm for proper alignment.

AT&T Singlemode ST® attenuators provide the same exceptional coupling characteristics as the AT&T ST® coupler. The attenuator assembly is actually composed of two pieces, the block and the buildout. This two-piece construction allows for the insertion or changing of various levels (0, 5, 10, 15, or 20 dB) of attenuation as required by circuit-specific optoelectronic components. The attenuator block is mounted to the coupler panel while the buildout, which contains the attenuator lens, is snapped into the block for circuit completion. The attenuator lens is an AT&T proprietary polymer that yields superior attenuation accuracy and low reflectance. The flexibility of this attenuator assembly is absolutely necessary to facilitate proper circuit per-

formance and future circuit design.

Sandia Standard optical fiber connector/coupler/attenuator specifications are contained in Table 10.

EUTP RJ45 Modular Jack

EUTP link performance is established by the proper installation of all the individual link components including cable, jacks, and mass-termination blocks and their individual capabilities. Sandia requires a modular RJ45 EUTP jack designed to complement the high-quality EUTP cable.

The EUTP modular RJ45 jacks inside the multimedia user outlets must match the transmission capabilities of the AT&T HIGH-5™ EUTP conductors. The AT&T M100BH1-262 HIGH-5™ modular RJ45 jack is able to achieve extremely high transmission capabilities by incorporating an AT&T patented cross-over lead technology. The physical crossed lead configuration is quite simple, yet it allows the modular RJ45 to display superior NEXT performance.

NEXT is the most predominant detrimental transmission characteristic that EUTP links must address. In an EUTP cable, NEXT is controlled by tightly twisting the two conductors of each pair. In AT&T's modular RJ45 jack, a patented cross-over lead technology basically maintains the tight twist configuration of the two conductors of each pair. Other RJ45 jack manufacturers have implemented lead configurations that basically create capacitors in line with the conductors of the pairs. The intention is to achieve acceptable NEXT performance, but this method often sacrifices other important performance parameters such as attenuation and mutual capacitance. Of greater concern are the future limitations that may be imposed by the active component performance of these built-in capacitors.

The AT&T M100BH1-262 HIGH-5™ modular RJ45 jack is configured in an EIA/TIA T568A pin/pair assignment that is consistent with Sandia's Standard.

Figure 5 depicts the eight-position jack pin/pair assignment.

Figure 5. EIA/TIA T568A Eight-Position Jack Pin/Pair Assignments

The AT&T M100BH1-262 RJ45 modular jack has been certified by the Underwriters Laboratories as meeting the standard performance parameters defined in EIA/TIA 568A, *Commercial Building Telecommunications Wiring Standard*.

Sandia Standard EUTP RJ45 modular jack specifications are contained in Table 11.

EUTP Mass-Termination Frames

Again, EUTP link performance is established by the proper installation of all the individual link components including cable, jacks, and mass-termination blocks and their individual capabilities. Sandia requires a mass-termination block designed to complement the high-quality EUTP cable.

The EUTP mass-termination block mounted on a frame in the IDR must match the transmission capabilities of the EUTP conductors. Additionally, the mass-termination blocks must also accommodate Sandia's massive quantity of EUTP cable conductors that terminate in the IDR. The blocks must be arranged in a physical configuration allowing an extremely dense termination array minimizing termination space allocation while optimizing precious IDR space utilization. The termination frames must be available in both red and black colors to promote the recognition of Secure and Open/Restricted Access telecommunications cabling.

The AT&T 110 termination blocks mounted on AT&T frames are the only mass-termination hard-

ware arrays available that satisfy all of Sandia's requirements. The AT&T 110 block provides consistent, reliable, repeatable gas-tight connections for data, voice, and other low-voltage circuits. Each AT&T 110 block is designed to terminate 300 pairs. Up to twelve AT&T 110 termination blocks can be mounted on an AT&T single-sided frame. Each AT&T single-sided frame measures 24 in. wide, 84 in. high, and 12 in. deep (when populated with 110 blocks, surge protectors, and cable routing hardware). This configuration provides the extremely dense termination of 3,600 pairs on a single frame. Maintenance concerns such as frequent patching for adds, deletes, and modifications, as well as ruggedness and ease of termination, were addressed in AT&T's mass-termination frame and block design.

Figure 6 shows Sandia Standard EUTP mass-termination frames populated with twelve 110 blocks.

Figure 6. Sandia Standard EUTP Mass-Termination Frames

Figure 7 shows Sandia Standard EUTP mass-termination frames populated with ten 110 blocks and six hundred surge-protector jacks.

Figure 7. Sandia Standard EUTP Mass-Termination Frames with Protectors

The AT&T 110 EUTP termination block has been certified by the Underwriters Laboratories as meeting the standard performance parameters defined in EIA/TIA 568A, *Commercial Building Telecommunications Wiring Standard*.

Sandia Standard EUTP mass-termination frames specifications are contained in Table 12.

Optical Fiber Distribution Panels

Optical fiber distribution panels must be wall-mounted, high-density modular panels in the IDR and rack-mounted high-density modular panels in the TCC to conform to Sandia's standard IDR and TCC layout designs.

In the IDR, wall-mounted panels will be installed in columns of 6 or 7 panels. Typically, all the wall surface in an IDR will be populated with optical fiber termination panels with the exception of one wall, which is dedicated to

EUTP mass-termination frames. Optimal space utilization, a critical design consideration in the IDRs, is achieved by wall-mounting all cable termination and dedicating all floor space to user network and intelligent hub equipment.

Optimal space utilization is always a critical design consideration in TCCs as well as IDRs. In the TCC, rack-mounted panels will be installed in standard 19-in. equipment racks. Typical terminated fiber counts in a TCC will be much less than the counts in an IDR. Reduced fiber count and floor space that is fully populated with standard 19-in. equipment racks allows rack-mounted, optical fiber termination in the TCC.

AT&T lightguide interconnection units (LIUs) will be used for all optical fiber termination in the IDRs. The AT&T 200A LIU is designed to provide cross-connect and/or interconnect capability in a very dense modular manner. Each 200A LIU houses 24 terminated optical fibers in a small space measuring 7.5 in. wide, 8.75 in. high, and 4 in. deep. Hinged doors with quarter-turn plastic fasteners and locks allow security and address maintenance concerns such as frequent patching for moves, adds, and deletes. NYLATCH® quick fasteners are used to attach the modular coupler panels to the LIU, further increasing the modular design advantage of product flexibility.

Figure 8 shows a Sandia Standard IDR optical fiber distribution panel.

Figure 8. Sandia Standard IDR Optical Fiber Distribution Panel

Figure 9 shows a wall-mounted array of IDR optical fiber panels.

Figure 9. IDR Wall-Mounted Optical Fiber Distribution Panel Array

AT&T lightguide shelf termination (LST) panels will be used for all optical fiber termination in the TCCs. The AT&T LST1U is designed to provide cross-connect and/or inter-connect capability in an extremely dense modular manner. Each LST1U houses 72 terminated optical fibers and only uses 7 vertical inches of rack space. Hinged doors with quarter-turn plastic fasteners and locks provide security and address maintenance concerns such as frequent patching for moves, adds, and deletes. NYLATCH® quick fasteners are used to attach the modular coupler panels to the LST1U, further increasing the modular design advantage of product flexibility.

Figure 10 shows Sandia Standard TCC optical fiber distribution panels. Sandia Standard IDR and TCC optical fiber distribution panel specifications are contained in Tables 13 and Table 14, respectively.

Figure 10. Sandia Standard TCC Optical Fiber Distribution Panel

Cross-Connect Jumpers

Cross-connect jumpers must be composed of connectors and cable that is compatible with the TCC to IDR and IDR to user outlet components to maintain link transmission capabilities.

EUTP cross-connect jumpers must be properly assembled AT&T HIGH-5™ components.

Optical fiber cross-connect jumpers must be properly assembled AT&T ST@II connectors and AT&T Multimode or Singlemode optical fiber cable. Many cable assembly companies are qualified to produce these cross-connect jumpers. Sandia's sole-make components will be required in all of these assembled cross-connect jumpers.

Physical and Logical Topologies

The proper installation of the previously described high-quality cables and termination components will result in superior end-to-end link capabilities. These cabling links will be used to implement all telecommunication networks required at Sandia.

Sandia's intra-building cabling configuration is a STAR with home-run cables from each user outlet to an IDR. Home-run cables are continuous and have no interconnections or splices. Other inferior physical topologies include: point-to-point, bus, and ring.

Figure 11 shows several examples of physical topologies.

Figure 11. Physical Topologies

The major advantage of a STAR *physical* topology is its ability to support any *logical* topology. *Physical* topology refers to the physical arrangement of cables. *Logical* topology refers to the method by which different nodes in a network communicate with one another. It involves protocols, access, and contention at the electronic circuit level.

Some other advantages of STAR physical

topology include: maximum cabling cross-connect flexibility for network configuration modifications, equipment centralization that minimizes administration and maximizes physical security, and graceful, nondisruptive replacement and updates of outdated network equipment.

Again, a STAR physical topology can support any logical topology. Some examples of popular networks and their required logical topologies are: private branch exchange (PBX) requiring a logical star; 802.3 carrier sense, multiple access/collision detect (CSMA/CD) and 802.4 Token Bus, both requiring a logical bus; and 802.5 Token Ring IBM 4/16Mbps, and X3T9.5 FDDI 100Mbps both requiring a logical ring. The logical topologies required by these networks can easily be implemented in a STAR physical topology.

Sandia's intra-building cabling topology is a one-level hierarchy that is EIA/TIA 568A compliant. EIA/TIA 568A standard designations for main cross-connect (MC), telecommunication closet (TC) and work area correlate respectively to Sandia's TCC, IDR, and user outlet. EIA/TIA 568A allows but does not require, intermediate cross-connects (ICs) in the cabling path. Sandia does not use intermediate cross-connects in any intra-building cabling path.

Of particular interest, the EIA/TIA 568A standard states, "The maximum horizontal cable distance (between user outlet and IDR) shall be 90 meters ---." Meeting this and other standards-based cable limitations presents some real design and installation challenges. Cable pathways and IDR quantities, sizes, and locations greatly affect construction cost and schedule.

In summary, Sandia's standard telecommunication cabling infrastructure will be the most technology-independent infrastructure possible. Using current technology, its capabilities are limitless. It will enable every person at Sandia to discover new ways of doing business and hopefully reveal unrealized potential within us all.

Table 1. UTP Cable Labeling, Bit Rates, and Common Cable Type - Applications

EIA/TIA 568A Category	Underwriter Laboratories Level	Supported Bit-Rate (Mbps)	Common Cable Type - Applications
1 & 2	I & II	≤ 1	Aged voice cable - voice and low Kbps data
3	III	≤ 10	Typical voice cable - low-speed LANs (4 Mbps IBM Token Ring and 10 Mbps Ethernet)
4	IV	≤ 16	Low-loss cable - medium-speed LANs (16 Mbps IBM Token Ring)
5	V	≤ 100	Extended frequency cable - high-speed LANs (100 Mbps TP-DDI)

Table 2. Sandia Standard 4-Pair EUTP Cable Specifications

Manufacturer	AT&T
Conductor Quantity	Four twisted pairs
Conductor Gauge and Type	24 AWG solid copper
Characteristic Impedance	100 ohms (± 15) from 1 to 100 MHz
Conductor Pair Attenuation - Maximum (per 100 m)	2.1 dB @ 1 MHz 6.6 dB @ 10 MHz 21.9 dB @ 100 MHz
Worst Pair-Pair Near-End Crosstalk NEXT	≥ 62 dB @ 1MHz ≥ 47 dB @ 10 MHz ≥ 32 dB @ 100 MHz
Cable Outside Diameter	0.22 in. (Riser) 0.18 in. (Plenum)
Cable Weight (per 1000 ft)	23.2 lb (Riser) 18.1 lb (Plenum)
Cable Package	W1000 (1000 ft. in a WE TOTE® box)
AT&T Product Code	1061 004CSL (Riser) (Jacket color - Slate) 2061 004BWH (Plenum) (Jacket color - White)
AT&T COMCODE	106 836 950 (Riser) 106 939 325 (Plenum)

Table 3. Sandia Standard 4-Pair EUTP Color Code

Pair Number	Pair Colors
1	White/Blue
2	White/Orange
3	White/Green
4	White/Brown

Table 4. Sandia Standard 25-Pair EUTP Cable Specifications

Manufacturer	AT&T
Conductor Quantity	25 twisted pairs
Conductor Gauge and Type	24 AWG solid copper
Characteristic Impedance	100 ohms (± 15) from 1 to 100 MHz
Conductor Pair Attenuation - Maximum (per 100 m)	2.1 dB @ 1 MHz 6.6 dB @ 10 MHz 21.9 dB @ 100 MHz
Worst Pair-Pair Near-End Crosstalk NEXT	≥ 62 dB @ 1MHz ≥ 47 dB @ 10 MHz ≥ 32 dB @ 100 MHz
Cable Outside Diameter	0.51 in. (Riser)
Cable Weight (per 1000 ft)	113 lb (Riser)
Cable Package	1000 ft reel
AT&T Product Code	1061 025CSL (Riser) (Jacket color - Slate)
AT&T COMCODE	107 287 484

Table 5. Sandia Standard 25-Pair EUTP Color Code

Pair Number	Pair Colors	Pair Number	Pair Colors
1	White/Blue	14	Black/Brown
2	White/Orange	15	Black/Slate
3	White/Green	16	Yellow/Blue
4	White/Brown	17	Yellow/Orange
5	White/Slate	18	Yellow/Green
6	Red/Blue	19	Yellow/Brown
7	Red/Orange	20	Yellow/Slate
8	Red/Green	21	Violet/Blue
9	Red/Brown	22	Violet/Orange
10	Red/Slate	23	Violet/Green
11	Black/Blue	24	Violet/Brown
12	Black/Orange	25	Violet/Slate
13	Black/Green		

Table 6. Sandia Standard 4-Fiber Multimode Cable Specifications

Manufacturer	AT&T
Cable Descriptor	Accumax™
Fiber Quantity	Four fibers
Fiber Size	Core diameter - 62.5 µm Cladding diameter - 125 µm
Numerical Aperture	0.275
Fiber Attenuation	≤ 3.4 dB/km @ 850 nm ≤ 1.0 dB/km @ 1300 nm
Fiber Bandwidth	≥ 200 MHz-km @ 850 nm ≥ 500 MHz-km @ 1300 nm
Cable Outside Diameter	0.185 in. (Riser) 0.180 in. (Plenum)
Cable Weight (per 100 ft)	1.3 lb (Riser) 1.3 lb (Plenum)
Product Code	LGBC-004D-LRX (Riser) LGBC-004D-LPX (Plenum)
AT&T COMCODE	106 291 008 (Riser) 106 914 971 (Plenum)

Table 7. Sandia Standard Optical Fiber Color Code

Fiber Number	Fiber Color
1	Blue
2	Orange
3	Green
4	Brown
5	Slate
6	White
7	Red
8	Black
9	Yellow
10	Violet
11	Rose
12	Aqua

Table 8. Sandia Standard 4-Fiber Singlemode Cable Specifications

Manufacturer	AT&T
Cable Descriptor	Accumax™
Fiber Quantity	Four fibers
Fiber Size	Core diameter - 8.3 μm Cladding diameter - 125 μm
Mode Field Diameter	8.8 $\mu\text{m} \pm 0.5$
Zero Dispersion Wavelength	1310 ± 10 nm
Fiber Attenuation	≤ 0.4 dB/km @ 1310 nm ≤ 0.3 dB/km @ 1550 nm
Fiber Dispersion	≤ 2.8 ps/nm-km @ 1310 nm ≤ 18 ps/nm-km @ 1550 nm
Cable Outside Diameter	0.185 in. (Riser) 0.180 in. (Plenum)
Cable Weight (per 100 ft)	1.3 lb (Riser) 1.3 lb (Plenum)
Product Code	LGBC-004D-SRX (Riser) LGBC-004D-SPX (Plenum)
AT&T COMCODE	106 291 016 (Riser) 106 914 914 (Plenum)

Table 9. Sandia Standard User Outlet Specifications

Description	AT&T Product Number	AT&T COMCODE	Color	Quantity
Red Baseplate and Faceplate (with one 8-position ST coupler panel and one 4-position RJ45 module panel)	40A1-R	107 190 282	Red	1
Black Baseplate and Faceplate (with one 8-position ST coupler panel and one 4-position RJ45 module panel)	40A1-B	107 190 290	Black	1
Red 8-position ST coupler panel		107 346 918	Red	1 per outlet
Black 8-position ST coupler panel		107 346 926	Black	1 per outlet
Red 4-position RJ45 module panel		107 346 876	Red	1 per outlet
Black 4-position RJ45 module panel		107 346 819	Black	1 per outlet
Red dust cover plug for unused module space in RJ45 module panel (package of 100)	M81-BLK-317	107 250 920	Red	1 per outlet
Black dust cover plug for unused module space in RJ45 module panel (package of 100)	M81-BLK-003	106 837 206	Black	1 per outlet

Table 10. Sandia Standard Optical Fiber Connector/Coupler/Attenuator Specifications

Description	AT&T Product Number	AT&T COMCODE
Multimode ST®II connector	P2020C-Z-125	106 812 274
Singlemode ST®II connector	P3020A-Z-125	106 812 258
Multimode ST® coupler - Bayonet/Threaded	C2000A-2	104 148 028
Singlemode ST® coupler - Bayonet/Threaded	C3000A-2	105 271 142
ST® attenuator buildout block	A3002	106 709 140
ST® attenuator buildout - (≤ 0.3 dB loss and ≤ 40 dB reflectance)	A3070	106 795 354
SM* ST® attenuator buildout - (5 dB loss and ≤ 40 dB reflectance)	A3070B	106 795 362
SM ST® attenuator buildout - (7 dB loss and ≤ 40 dB reflectance)	A3070X1	107 107 140
SM ST® attenuator buildout - (10 dB loss and ≤ 40 dB reflectance)	A3070D	106 795 370
SM ST® attenuator buildout - (15 dB loss and ≤ 40 dB reflectance)	A3070F	106 795 388
SM ST® attenuator buildout - (20 dB loss and ≤ 40 dB reflectance)	A3070H	106 795 396

*, Singlemode

Table 11. Sandia Standard EUTP RJ45 Modular Jack Specifications

Description	AT&T Product Number	AT&T COMCODE	Color	Quantity
HIGH-5™ M-series 8-position RJ45 modular jack (EIA/TIA T568A* pin configuration)	M100BH1-262	106 821 739	White	1

*EIA/TIA T568A is a specific conductor configuration. (See Figure 5)

Table 12. Sandia Standard EUTP Mass-Termination Frames Specifications

Description	AT&T Product Number	AT&T COMCODE	Color	Quantity
Single-sided frame pre-assembled with twelve 300-pair 110 punch-down block modules	XLBET	105 158 182	Black	1
		107 065 591	Red	1
Single-sided frame pre-assembled with ten 300-pair 110 punch-down block modules and, 300 surge protector jacks	XLBET	106 993 017	Black	1
Single-sided frame pre-assembled with ten 300-pair 110 punch-down block modules and, 600 surge protector jacks	XLBET	107 119 091	Black	1

Table 13. Sandia Standard IDR Optical Fiber Distribution Panel Specifications

Description	AT&T Product Number	AT&T COMCODE	Color	Quantity
Lightguide Interconnection Unit	200A LIU	105 535 926	White	1
Coupling Panel	10A (ST)	104 141 858	White	4 per LIU
Vertical Trough	2A8	106 479 761	White	1 per LIU
Horizontal Trough	2A6	106 295 520	White	1 per LIU column

Table 14. Sandia Standard TCC Optical Fiber Distribution Panel Specifications

Description	AT&T Product Number	AT&T COMCODE	Color	Quantity
Lightguide Shelf Termination	LST1U	105 335 871	White	1
Coupling Panel (package of 12)	1000ST	105 428 486	White	1 per LST
Jumper Retainer (one pair)	JR1A	104 411 277	White	1 per LST
Cable Clamp (for nonmetallic cables)	12A2	106 230 337	N/A	1 per LST

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