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Intra-Building Telecommunications Cabling Standards for Sandia National Laboratories, New Mexico

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Intra-Building Telecommunications Cabling Standards for Sandia National Laboratories, New Mexico

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Abstract

This document establishes a working standard for all telecommunications cable installations at Sandia National Laboratories, New Mexico. It is based on recent national commercial cabling standards. The topics addressed are Secure and Open/Restricted Access telecommunications environments and both twisted-pair and optical-fiber components of communications media.

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DO NOT WRITE IN THESE SPACES

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Acknowledgment

For his patience and advice, I would like to thank T. L. Bisbee, 9538, from whom I inherited the telecommunications cabling distribution responsibility. His previous efforts, documented in SAND90-0533, June 1990, were the catalyst for the creation of this document. Special thanks also go to S. A. Gossage, 1954, whose endless enthusiasm, interest, and knowledge in the area of optical communications has so inspired me, and to all my fellow Sandians for their patience and assistance through years of trials and efforts to satisfy their communications needs.

Preface

In the early 1980s, prompted by the need to distribute classified computing capabilities, the Communications Design and Services Departments initiated a Lab-wide Secure computer data distribution system. Several major buildings were chosen as concentration points for the communication equipment required for the distribution system. These concentration points, referred to as Technical Control Centers (TCCs), were selected to serve geographic areas within secured Tech Areas I, IV, and III/V. Originally, the Secure distribution system was composed of copper wiring systems, both intra- and inter-building. It now includes an optical-fiber backbone that interconnects the TCCs and all major buildings. The entire Secure distribution system conforms to the U.S. Department of Energy's Protected Distribution System security requirements.

In the recent past, technology and world relations have undergone enormous change that has created numerous challenges. The challenge faced by the Communications Department at Sandia is to provide two telecommunication distribution systems capable of supporting state-of-the-art communication technologies for all communication needs. One distribution system will be dedicated for Secure telecommunication needs and the other will be for Open/Restricted Access telecommunication needs. The only possible way to create two distinct distribution systems with identical capabilities is *to implement one Cabling Standard*.

This document defines the standard for transmission media and the termination hardware. A companion document, SAND93-0863, *Intra-Building Telecommunications Cabling Pathways and Spaces Standards for Sandia National Laboratories, New Mexico*, is forthcoming from Facilities Engineering, Department 7906. It will incorporate Secure installation requirements such as conduit, labeling, and physical markings and corresponding Open/Restricted Access installation issues.

This *Cabling Standard* is based on recent national standards which have been modified, where appropriate, to meet Sandia's specific telecommunication needs. Implementation of these standards during the recabling of all major buildings will guarantee Sandia's ability to remain one of the premiere high-technology development centers in the world.

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Acronyms

ANSI	American National Standards Institute
ATM	asynchronous transfer mode
AT&T	American Telephone and Telegraph
DOE	Department of Energy
EIA	Electronic Industries Association
EMF	electromagnetic field
EUTP	enhanced unshielded twisted pair
FDDI	Fiber Distributed Data Interface
IDC	Intermediate Distribution Closet
IEC	International Electronic Committee
LAN	Local Area Network
LIU	Lightguide interconnection unit
NEXT	near end crosstalk
OF	optical fiber
PDS	Protected Distribution System
ST	straight tip
TIA	Telecommunications Industry Association
TP-PMD	twisted pair-physical media dependent
TSB	Technical Systems Bulletin
TCC	Technical Control Center
UL	Underwriters Laboratories
UTP	unshielded twisted pair

Intra-Building Telecommunications Cabling Standards for Sandia National Laboratories, New Mexico

Introduction

The advantage of implementing cabling standards in highly technical areas is that all areas of telecommunications will be positively affected with regard to cost, schedule, and performance. Recent national and international efforts to standardize communications protocols illuminated the need to standardize intra-building telecommunications cabling. In July 1991, the American National Standards Institute Electronic Industries Association/Telecommunications Industry Association (ANSI EIA/TIA) published Commercial Building Telecommunications Wiring Standard, EIA/TIA-568, to "define a generic telecommunications wiring system for commercial buildings that will support a multiproduct, multivendor environment." Before the publication of that document, telecommunications cabling had no transmission standards at all. Cabling choices were frequently predicated on specific vendor equipment requirements. The cables of choice ranged from twisted pair to coaxial to optical fiber, with literally hundreds of each type. In a facility such as Sandia's, every unique telecommunication cabling solution was typically a throwaway for two reasons. First, Sandia's "churn" rate (the relocation of staff) has risen as high as 30% per year in recent years. The chance of relocating staff to an area with cabling equivalent to that vacated was extremely small. Second, vendors (for the most part) were interested only in selling and installing products that satisfied immediate customer needs. Little, if any, consideration was given to future telecommunication needs for the life of the building. Replacement of these throwaway systems resulted in additional recabling costs, loss of time, and disruption of operations. This seemingly endless burden of replacing throwaway systems can be stopped only by implementing cabling standards.

The implementation of the cabling standards contained in this document will result in consistent state-of-the-art intra-building telecommunications cabling infrastructures in all areas. The standards in this document are based on current national standard documents such as those in the following list. Sandia's unique advanced telecommunication requirements have been accommodated by the proper modifications to these national standards in areas such as media types, quantities, and security requirements.

ANSI EIA/TIA publications:

- Document 568, Commercial Building Standard for Telecommunications Wiring Standard
- Document 569, Commercial Building Standard for Telecommunications Pathways and Spaces
- Document 570, Residential and Light Commercial Telecommunications Wiring Standard

ANSI Technical Systems Bulletins:

- TSB 36, Additional Cable Specifications for Unshielded Twisted Pair Cables
- TSB 40, Additional Transmission Specifications for Unshielded Twisted Pair Connecting Hardware

Again, implementing the cabling standards contained in this document as part of remodeling, recabling, and cabling of new construction projects will result in consistent state-of-the-art intra-building telecommunications cabling infrastructures. Some of the state-of-the-art technologies that will be supported by the intra-building cable infrastructure are Circuit and Packet Switched Networks (PBX/5ESS Voice and Low-Speed Data), Local Area Networks (Ethernet, Token Ring, Fiber and Copper Dis-

tributed Data Interface), and Wide Area Networks (Asynchronous Transfer Mode). These technologies can be delivered to every desk and can transport data at rates sufficient to support all existing applications (such as Voice, Text and Graphics, Still Images, Full-motion Video), as well as applications to be defined in the future.

Components of the Telecommunications Media

Components of the telecommunications media are critical to the overall transmission capabilities of any distribution system. For Sandia to continue as a premiere high-technology research and development center, all telecommunications infrastructure components must be of the highest quality. All components specified in this document meet (or exceed) the highest levels of performance as stated in national telecommunications standards, and some, such as single mode optical fibers, exceed current national standard cable types. Sandia's state-of-the-art technologies mandate the inclusion of such advanced telecommunications components in all intra-building cabling infrastructures.

This document establishes cabling standards for the two separate telecommunications systems required at Sandia. These systems, the Secure system and the Open/Restricted Access system, must have identical capabilities. The standards set forth in this document are for cable types and termination components to ensure these identical capabilities. They meet or exceed recent (1991) national standards and are expected to meet not only current telecommunications needs, but needs for communications-media technology yet to be developed.

Cable Types

The standard cable types for all intra-building telecommunications at Sandia are unshielded twisted pair (UTP) and optical fiber (OF). The standard intra-building cable distribution to each user outlet at Sandia includes three 4-pair UTP cables, one 4-fiber multimode cable, and one 4-fiber single mode cable.

Unshielded Twisted-Pair Cable

Manufacturing UTP cable capable of transmitting high data rates requires advanced construction techniques and superior materials. This high-quality UTP cable currently supports data rates of 100Mbps. This is the same data rate used by the optical interface in the Fiber Distributed Data Interface (FDDI) Local Area Network (LAN) standard. The ANSI X3T9.5 (FDDI) working group has officially identified the 100Mbps capability of UTP cable as the twisted pair-physical media dependent (TP-PMD) application. In the near future, asynchronous transfer mode (ATM) equipment vendors will be transmitting data rates of 155Mbps over this same high-quality UTP cable.

The standard intra-building cable distribution to each outlet at Sandia will include three 4-pair UTP cables. Each UTP cable must meet specifications contained in Table 1.

This type of 4-pair UTP cable is identified in ANSI EIA/TIA TSB 36 as Category 5 cable. Underwriters Laboratories has recently initiated a test and certification program for all 100-ohm twisted pair cables. UL labeling differs slightly from ANSI EIA/TIA TSB 36 labeling. UL-certified cables will be labeled Level I through Level V, corresponding to ANSI EIA/TIA TSB 36 labels of Category 1 through Category 5. In conversation, the same cable may be referred to as "Level V," "Category 5," "enhanced unshielded twisted-pair (EUTP)," or "low-loss extended-frequency" cable. Table 2 correlates EIA categories to UL levels and lists bit rates and common applications for each category or level.

Multipair (greater than 4-pair) UTP cables are not currently available with Level V performance capabilities. Level III is available now; Level IV has recently been designed by AT&T but is not currently in production. The basic difficulty in producing a multipair cable with extended frequency capabilities is physical assembly, i.e., creating unique twist ratios for each pair in the cable and twist ratios for bundles of pairs. The physical positioning of electrical conductors in near proximity causes many electrical phenomena, two of which are near end crosstalk (NEXT) coupling loss and inductance. Such electrical properties must be addressed by cable construction.

All 4-pair UTP cables have standard color code, which is shown in Table 3.

Table 1. UTP Type: Underwriter Laboratories (UL) Certified Level V

Conductor Quantity	Four twisted pairs
Conductor Gauge Size	24 AWG
Conductor Impedance	100 ohms ($\pm 15\%$) from 1 to 100 MHz
Conductor Pair Attenuation	≤ 6.3 dB per 1000 ft @ 20°C for 1 MHz ≤ 20 dB per 1000 ft @ 20°C for 10 MHz ≤ 67 dB per 1000 ft @ 20°C for 100 MHz
Worst Pair Near End Crosstalk (NEXT)	≥ 62 dB @ 1000 ft for 1MHz ≥ 47 dB @ 1000 ft for 10 MHz ≥ 32 dB @ 1000 ft for 100 MHz
Cable Outside Diameter	0.19 in. (Riser), 0.2 in. (Plenum)
Cable Weight	18.4 lb/1000 ft (Riser), 19.9 lb/1000 ft (Plenum)

Table 2. Correlation of UTP Cable Labeling and Use

ANSI EIA/TIA TSB 36 Category	Underwriter Laboratories Level	Bit-Rate	Common Network Applications
1 & 2	I & II		Typically used for voice and low-speed data in the Kbps range
3	III	≤ 10 Mbps	4Mbps IBM Token Ring and 10Mbps Ethernet
4	IV	≤ 16 Mbps	16Mbps IBM Token Ring
5	V	≤ 100 Mbps	100Mbps TP-PMD Token Ring

Table 3. Standard 4-Pair UTP Color Code

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

Optical Fiber (OF) Cable

Optical fibers have many advantages over metallic conductors. Optical fibers are largely immune to external electromagnetic fields (EMF) and internal conductor signal coupling, are capable of withstanding atmospheres that are caustic to metallic conductors, and are capable of very high bit-rate transmissions across very long distances.

The standard intra-building cable distribution to each outlet at Sandia will include one 4-fiber multimode cable and one 4-fiber single mode cable.

These high-quality cables have been adopted by national standards committees such as EIA, IEEE 802, FDDI, and IEC. Sandia's standard optical fiber cables, both multimode and single mode, are currently AT&T products. Until another vendor's product is qualified by Sandia, both Multimode and Single Mode OF cables must be obtained from AT&T. The critical factor that forces sole-make selection is compatibility. Compatibility must be maintained with the existing Sandia inter-building

OF distribution system. The inter-building distribution system represents over 10 years of design and installation effort and contains more than 7,000,000 installed fiber feet. The total dollar investment is in the tens of millions. Other manufacturers' optical fibers have been tested at Sandia for interoperability with AT&T optical fibers. The testing revealed dimensional inconsistencies such as core diameter, eccentricity, and concentricity, which induce unpredictable coupling loss between dissimilar fibers. The tests also revealed critical transmission compatibility problems, such as intolerable reflectivity at the point of contact between dissimilar fibers. In summary, the use of dissimilar fibers causes unpredictable optical transmission characteristics and prohibits the realization of maximum transmission capabilities built into each component throughout the entire optical distribution system at Sandia.

The multimode and single mode cables must meet the specifications contained in Table 4 and Table 5.

Table 4. Fiber Type: Multimode

Manufacturer	AT&T
Fiber Quantity	Four fibers
Fiber Size	62.5-micron core diameter 125-micron cladding diameter
Numerical Aperture	0.275
Fiber Attenuation	≤ 3.4 dB/km @ 850 nm ≤ 1.0 dB/km @ 1300 nm
Fiber Bandwidth	≥ 150 MHz-km @ 850 nm ≥ 500 MHz-km @ 1300 nm
Cable Outside Diameter	0.175 in. for Riser-rated cable 0.195 in. for Plenum-rated cable
Cable Weight	1.2 lb/100 ft for Riser-rated cable 1.4 lb/100 ft for Plenum-rated cable
Product Code	LGBC-004A-LRX (Riser) LGBC-004A-LPX (Plenum)
AT&T COMCODE	104 272 414 (Riser) 104 272 497 (Plenum)

Table 5. Fiber Type: Single Mode

Manufacturer	AT&T
Fiber Quantity	Four fibers
Fiber Size	8.3-micron core diameter 125-micron cladding diameter
Mode Field Diameter	8.8 ±0.5 microns
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	0.175 in. for Riser-rated cable 0.195 in. for Plenum-rated cable
Cable Weight	1.2 lb/100 ft for Riser-rated cable 1.4 lb/100 ft for Plenum-rated cable
Product Code	LGBC-004A-SRX (Riser) LGBC-004A-SPX (Plenum)
AT&T COMCODE	104 272 455 (Riser) 104 272 539 (Plenum)

NOTE: The decision whether to use cables having Riser- or Plenum-rated jacket material (for both UTP and OF cables) will depend on the particular installation. Sandia's cable jacket of choice is Plenum. However, since all Secure (Red) distribution systems require conduit as the pathway conveyance, cables having Riser-rated jacket material may be used. Other pathway conveyances, such as ladders or trays, may be installed for Open/Restricted Access (Black) distribution systems. These pathway conveyances mandate the installation of cables having Plenum-rated jacket materials.

All OF cables, both multimode and single mode, have a standard color code, shown in Table 6.

Termination Components

Cable termination occurs at the user location and in an intermediate distribution closet

(IDC). At the user location, a single wall-mounted outlet will terminate both UTP and OF cables. This type of outlet is commonly referred to as a multimedia outlet. Buildings inside the Secure Tech Area will have two distribution systems (Red and Black) installed. Each occupant in these buildings will have one Red outlet and one Black outlet. If a building is located outside the Secure Tech Area, it will have only an Open/Restricted Access (Black) distribution system installed. Each occupant in these buildings will have a Black outlet. In the IDC, user UTP cables will terminate on wall-mounted UTP frames and user OF cables will terminate in wall-mounted OF distribution panels. Red/Black cable and equipment separation (per DOE PDS requirements) will be accomplished both at the user outlet and in the IDC.

Table 6. Standard OF Color Code

Fiber Number	Fiber Coating Color
1	Blue
2	Orange
3	Green
4	Brown

User Outlet

At Sandia, a single user outlet must accommodate all of the required cables and conductors. The standard intra-building cable distribution to each user outlet includes three 4-pair UTP cables, one 4-fiber multimode cable and one 4-fiber single mode cable. Currently, only one manufacturer (Panduit) is producing an outlet that will accommodate this cable/conductor configuration. The Panduit outlet is made of high-impact thermoplastic material with an Underwriters Laboratories flammability rating of U.L. 94V.O. It can accommodate up to eight termination modules. Termination module types (UTP and/or OF) will be arranged as in Figure 1. As shown in the figure, the baseplate has a built-in optical fiber cable spool designed to properly store cable slack.

UTP termination/connecting components inside these outlets must match the transmission capabilities of the UTP conductors. The standard UTP termination/connecting components must be UL-certified to ANSI EIA/TIA TSB 40 Category 5. This standard will ensure high bit-rate (100Mbps or more) end-to-end functionality via UTP.

The recent ANSI EIA/TIA TSB 40 standard categorizes UTP termination/connecting components by transmission capabilities. These termination/connecting component categories correspond directly to the ANSI EIA/TIA TSB 36 UTP cable categories. Underwriter Laboratories has recently established a test and certification process to independently certify these new termination/connecting components. Products found to be in compliance with a particular performance program

(ANSI EIA/TIA TSB 40) may be marked with the following statement either on the product or on the smallest-unit carton in which the product is packaged.

**ALSO EVALUATED BY UNDERWRITERS
LABORATORIES INC.
IN ACCORDANCE WITH ANSI EIA/TIA
TSB 40 CATEGORY 5**

Optical Fiber termination/connecting components inside the user outlet must match the transmission capabilities of the OF conductors. The standard optical connector/coupler for multimode and single mode fibers at Sandia is currently the AT&T straight tip (ST).

This high-quality connector/coupler type has been adopted by many national standards committees. The Sandia standard, being sole-make AT&T, is based on three factors. First, AT&T, the creator of the ST technology, has not licensed manufacturing rights to any other optical component manufacturer. All other "ST compatible" components are reverse-engineered, yielding a multitude of inferior or unknown performance characteristics. Second, Sandia testing of other manufacturer's components for interoperability with AT&T components revealed dimensional inconsistencies that induced unpredictable connector coupling loss, and material deficiencies that resulted in component breakage or low coupling repeatability. Third, compatibility must exist with the entire Sandia inter-building OF distribution system. This inter-building distribution system represents over 10 years of design and installation effort, more than 7,000,000 fiber feet, and thousands of AT&T ST connectors and couplers. The total dollar investment is in the tens of millions. As with the OF cable, until another vendor product is qualified by Sandia, both multimode and single mode optical fiber connectors and couplers will be sole-make AT&T STs.

The list in Table 7 contains Panduit and AT&T component part numbers and quantities required to assemble one standard user outlet at Sandia.

Figure 1. Standard User Outlet

Table 7. Standard Components Required for One User Outlet

Description	Manufacturer	Part Number/ COMCODE	Color	Quantity
Baseplate and Faceplate	Panduit	MBXD8RD or MBXD8BL	Red Black	1
Level V UTP 568A* module	Panduit	MUJC588AWH	White	3
Dual ST coupler panel	Panduit	MM38DWH-X	White	4
Blank panel	Panduit	MMB1WH-X	White	1
Multimode STII connector	AT&T	106 812 274	N/A	4
Multimode STII coupler	AT&T	104 148 028	N/A	4
Single Mode STII connector	AT&T	106 812 258	N/A	4
Single Mode STII coupler	AT&T	105 271 142	N/A	4

*568A is a specific conductor configuration. (See Figure 2.)

Figure 2. T568 Eight-Position Jack
Pin/Pair Assignments

IDC UTP Frames and OF Panels

The IDC UTP frames and OF panels must accommodate the number of cables and conductors required by this standard. Again, the standard telecommunications cable configuration for a user outlet at Sandia is three 4-pair UTP cables, one 4-fiber multimode cable, and one 4-fiber single mode cable. Each IDC is capable of servicing hundreds of users. Therefore, the resultant number of conductors terminating in an IDC is high and requires extreme attention to space allocation for termination.

Termination Frame. The UTP termination/connecting components inside the IDC must match the transmission capabilities of the UTP conductors. The standard UTP termination/connecting components at Sandia must be UL-certified to EIA/TIA TSB 40 Category 5. Again, this standard will ensure high bit-rate (100Mbps or more) end-to-end functionality via UTP.

Currently, AT&T is the only manufacturer producing a termination/connecting frame with UL-certified EIA/TIA TSB 40 Level V components that can accommodate Sandia's cable/conductor

configuration and space limitation requirements. The AT&T 110 Patch Panel System has been UL-certified Level V and allows extremely dense termination of UTP conductors. The AT&T 110 Patch Panel System also provides consistent, reliable, repeatable, gas-tight connections for data, voice, and other low-voltage circuits. 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 component designs. (See Figure 3.)

Table 8 part numbers include all components required to terminate up to 3600 Red unshielded twisted pairs and up to 3000 Black unshielded twisted pairs in an IDC.

Termination Panel. The OF termination/connecting components inside the IDC must match the transmission capabilities of the OF conductors. The standard optical connector/coupler for both multimode and single mode fibers at Sandia is the AT&T ST.

Figure 3. Standard IDC UTP Termination Frames

Table 8. Standard IDC UTP Termination Frame Information

Description	Manufacturer	COMCODE	Colors	Quantity
XLBET single-sided frame pre-assembled with twelve 300-pair 110 punch-down block modules and cable routing hardware	AT&T	105 158 182	Black or Red	1
XLBET single-sided frame pre-assembled with ten 300-pair 110 punch-down block modules, 300 surge protector jacks, and cable routing hardware	AT&T	106 993 017	Black	1

Currently, only one manufacturer (AT&T) is producing a termination/connecting panel that will accommodate Sandia's cable/conductor configuration and space limitation requirements. The AT&T lightguide interconnection unit (LIU) panel allows extremely dense termination of OF cables. Maintenance concerns such as frequent patching for adds, deletes, and modifications were designed into the products. (See Figure 4)

Table 9 part numbers include all OF panel components needed to terminate 24 optical fibers in an IDC.

Physical Topology

There are several physical topologies for intra-building telecommunications cabling: point-to-point,

bus, ring, and star. The standard Sandia intra-building physical cabling distribution topology is star. This is also consistent with the ANSI EIA/TIA 568 document. (See Figure 5)

Because of its centralized hub, physical star topology provides maximum flexibility for configuration modifications and minimum administration. Network security can be accomplished by controlling access to the physical star hub, where LAN and other network hubs are located. Telecommunications technology advances can easily be accommodated by replacing out-dated hub equipment at the physical star hub. Network growth can be graceful and non-disruptive with modular hub electronics.

Figure 4. Standard IDC Optical Fiber Termination Panel

Table 9. Standard IDC Optical Fiber Termination Panel Information

Description	Manufacturer	COMCODE	Colors	Quantity
200A LIU Enclosure	AT&T	105 535 926	White	1
10A Coupling Panel	AT&T	104 141 858	White	4
2A6 Vertical Trough	AT&T	106 295 520	White	1
2A8 Horizontal Trough	AT&T	106 479 761	White	1 per 6 LIUs
Multimode STII Connector	AT&T	106 812 274	N/A	24
Multimode STII Coupler	AT&T	104 148 028	N/A	24
Single Mode STII Connector	AT&T	106 812 258	N/A	24
Single Mode STII Coupler	AT&T	105 271 142	N/A	24

Physical star topology can support all logical topologies. (*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 popular networks and their required logical topologies are private branch exchange (PBX) requiring a logical star; Ethernet IEEE 802.3 carrier sense, multiple access/collision detect (CSMA/CD) requiring a logical bus; Token Bus token passing IEEE 802.4 requiring a logical bus, and Token Ring token passing IEEE 802.5 IBM 4/16Mbps and FDDI 100Mbps requiring a logical ring. All of these networks are easily implemented on physical star cabling.

Distance limitations for UTP cabling are derived from the ANSI EIA/TIA 568 document, which states, "The maximum horizontal dis-

tance (between user outlet and IDC) shall be 90 meters . . ." Incorporating this distance limitation into an intra-building distribution system results in numerous challenges in building construction. IDC size, quantity, and placement are critical design considerations that affect overall cost and schedule. Pathways (conduits, cable trays, etc.) and spaces (IDCs) are an integral part of any intra-building telecommunications distribution system. A companion document, to this standard, SAND93-0863, *Intra-Building Telecommunications Cabling Pathways and Spaces Standards for Sandia National Laboratories, New Mexico*, will be created by Sandia Facilities Department 7906 to address all issues pertinent to Sandia's buildings.

The block diagram in Figure 6 is included as a graphical representation of the overall intra-building telecommunications cabling infrastructure.

Figure 5. Physical Topology Examples

Typical Sandia Four-Story Office/Light Lab Building

Figure 6. Intra-Building Telecommunications Cabling

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