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The Creation of Sandia's Telecommunication Cabling Infrastructure

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The Creation of Sandia's Telecommunication Cabling Infrastructure

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Abstract

Sandia National Laboratories in Albuquerque, New Mexico, has adopted strategic, standards-based telecommunication technologies to deliver high-speed communication services to its research and development community. The architecture to provide these services specifies a cabling system capable of carrying high-bandwidth signals to each desktop. While the facilities infrastructure of Sandia has been expanding and evolving over the past four decades to meet the needs of this premier research and development community, the communications infrastructure has remained essentially stagnant. The need to improve Sandia's telecommunication cable infrastructure gave rise to the Intra-building Recabling Project (IRP). The IRP directed Sandia's efforts to modernize and standardize the communications infrastructure throughout its New Mexico campus. This report focuses on the development and implementation of the project's design considerations, concepts, and standards, as well as the adopted transmission media and supporting delivery subsystems.

Acknowledgments

The Intra-building Recabling Project represents a significant financial and technological investment by Sandia to standardize and modernize its communication infrastructure. The authors would like to acknowledge the individuals who contributed to this project's success. The photo below presents the core project team. Their enthusiasm, dedication, teamwork, and commitment provided the foundation upon which all subsequent successes were built.

IRP Team: from left, front row, Frank Martin, 4917; Jon Eberhart, Holmes & Narver, Inc. (H&N); Tim Francis, H&N; Roger Adams, 4917; Ted Wheaton, H&N; Don Gould, 7908; rear, Barbara Doremus, 7908; Orlando Trujillo, 7909; Larry Dresser, 10242; Roger Minor, H&N; Kevin Urenda, Koinonia Architects; Jay Peterson, H&N; Keith Carpenter, H&N; Kathie Gustwiller, GTE; Larry Chavez, 7914-1.

A project of this magnitude has many contributors. It is not possible to name all of them. For those who have worked diligently behind the scenes, the true recognition of your efforts is found in the quality of the installed product.

A special thanks to Bob Dougherty (retired) for his wisdom and vision during the conceptual phase of Sandia's Intra-building Recabling Project.

Finally, sincere thanks to Mary Elizabeth Stevenson-Adams and Imelda Garcia-Francis for their continuous support and love.

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The Creation of Sandia's Telecommunication Cabling Infrastructure

The Landscape of Sandia

Sandia National Laboratories is a world-class scientific and engineering research and development (R&D) laboratory supporting Department of Energy (DOE) initiatives. It is composed of two major sites, with headquarters and laboratories in Albuquerque, New Mexico (see Figure 1), and other lab facilities in Livermore, California, plus minor sites in Hawaii, Nevada, and Washington, D.C.

Figure 1. Sandia National Laboratories' New Mexico campus (28.6 square miles)

Over the last 45 years, Sandia's broadening mission has included meeting the challenges of collaborative research and development efforts. Sandia teams with federal facilities, industries, and universities in technology development across a broad spectrum of engineering disciplines. The Laboratories recognized early on that applying innovative telecommunication technologies was essential in meeting the information exchange demands of current and future missions. Sandia's executive management made a commitment to utilize ATM (Asynchronous Transfer Mode) switching and SONET (Synchronous Optical Network) technologies as the core of the Labs' internal networking strategy. While these technologies were in the early stages of prototyping, Sandia initiated the Intra-building Recabling Project. The team assembled for this project became responsible for upgrading the New Mexico campus's antiquated telecommunications cable infrastructure to support all of Sandia's communication (voice, video, and data) networks. The mission statement of the organizational Center, under which the IRP operates, stresses alignment with corporate strategic directions "based on added value, common need, economy of scale, and suitability to centralized control."

Sandia's Intra-Building Recabling Project

The ability to support information movement demands beyond the foreseeable future received high priority in Sandia's recabling project planning. Among other things, costly past iterations of cabling to accommodate vendor-specific schemes drove Sandia to its recabling commitment. Sandia-specific standards, defining a structured cabling system, were considered essential to meet the requirements of the Lab's networking strategy. From the beginning, the IRP team intended that these new standards would also be implemented in all new construction projects as well as the ongoing moves, adds, and changes within Sandia's campus.

This new infrastructure, at a minimum, had to comply with current national and international telecommunication standards and meet the needs of Sandia's R&D community. In addition, it had to satisfy Sandia management's cost-containment expectations. An aggressive schedule targeted the complete recabling of 9 buildings, as well as supporting the construction of four new buildings, by September 30, 1995. The recabling project installed approximately 7,500 telecommunication outlets in these 13 buildings to meet this schedule, bringing new telecommunication connectivity to 60% of Sandia's New Mexico population. In FY96, five more existing buildings are scheduled for recabling. Figure 2 shows a typical recabled building, one of nine such buildings (plus five new buildings) completed by the end of FY95.

Figure 2. A typical recabled office/light lab building at Sandia/New Mexico.

The IRP team found many formidable challenges within the project, including the following:

- Acquiring, storing, controlling, and distributing large inventories of material.
- Accomplishing construction work in occupied buildings.
- Assembling and managing huge contracting crews to meet aggressive construction schedules.
- Addressing Environmental Safety and Health (ES&H) issues, primarily asbestos abatement.
- Distilling a final design out of the many available options.
- Prioritizing buildings to receive new cabling.

This report focuses on the Intra-building Recabling Project's design concepts, standards, and the final installed configuration of cabling components. Topics discussed here include multimedia outlets, the horizontal distribution system, and the intermediate distribution rooms. This is followed by a brief description of Sandia's enterprise connectivity and how this connectivity is enabled through the Laboratories' evolving high-speed network. The appendix captures lessons learned from the project management experience gained by the IRP team. Included are recommendations based on approaches the IRP team found to be successful during the project.

Sandia's Design Considerations and Concepts

The unique nature of the R&D activities conducted at Sandia National Laboratories gave rise to special design considerations and standards adopted for the campus cabling. The computing bandwidth requirements of thousands of New Mexico users range from downloading simple ASCII text documents from local servers to unprecedented distributed processing via multiple supercomputers, including CRAY YMPs and the Paragon XT. (The Paragon XT is one of the world's fastest computers, clocked at 281 gigaflops using the Linpack benchmark on December 19, 1994.)

Sandia's communication network and attached computing resources are used to conduct ultra-intensive shock wave physics modeling, build coupled oceanographic models, and invent new materials, as well as provide seismic data analyses, solve complex radiative heat transfer problems that are otherwise intractable, and create weapons safety simulations. The networking demands of cooperative research and development agreements (CRADAs) with commercial businesses, medical facilities, and universities also defined data throughput parameters the infrastructure had to accommodate.

A particularly critical design concern for the IRP was information security, both physical and electronic. Inside Sandia's secured area, some buildings required both secure (red) and open/restricted (black) access capabilities. This requirement was satisfied by installing two identical (but physically separate) distribution systems, one red and one black. Buildings outside the secured area required only black, open/restricted access capabilities.

Acknowledging the limitations imposed by old wiring systems, Sandia management approved a cabling infrastructure design that would satisfy the current requirements of Sandia's activities as well as industry cabling standards. The essential concepts behind the IRP included the creation of a standards-based, structured cabling system that provided:

- 1) The capabilities to satisfy telecommunications requirements within Sandia's corporate information architecture.
- 2) Physical protection for the cabling system. The design had to address all present and anticipated security requirements as mandated by the Department of Energy.
- 3) An interface with existing hardware configurations to the greatest extent possible. This would enable the preservation of previous networking hardware investments, primarily legacy LAN hardware and desktop PCs and workstations.
- 4) Flexibility and scalability, meeting the demands of a premier R&D facility for now and the foreseeable future.
- 5) Superior communication channel capabilities. Careful performance and installation consideration had to be given to every cabling component to create integrated end-to-end communication channels that were both predictable and reliable.

These design concepts provided the umbrella under which Sandia's IRP technical staff worked.

Sandia's Design Standards

Sandia's IRP cabling infrastructure design established standards and specifications for user outlets, cabling types, horizontal distribution systems, intermediate distribution rooms (IDRs), and interconnecting components. These design standards incorporated current national and international telecommunication standards, appropriately modified for Sandia-specific requirements, such as security needs and enhanced bandwidth capabilities. They are considered the foundation of Sandia's overall cabling infrastructure design. As an essential step in delivering a uniform telecommunication cabling infrastructure, Sandia's Facilities Organization adopted these IRP design standards. These standards are being deployed in all new building construction, as well as major building renovations.

In order to move away from vendor-specific designs, the IRP incorporated telecommunication standards that have matured over the last decade. Existing industry standards were referenced in areas of telecommunications service entrances, equipment rooms, telecommunications closets, building backbone systems, grounding, bonding and electrical protection, horizontal cabling systems, firestopping, and cable administration.

The Cabling Standard: Sandia's communications engineers faced a difficult task during the IRP's conceptual phase because there were no site-specific design guidelines to follow. Their design solutions were ultimately based upon intimate knowledge of Sandia's mission, current networking configurations, security requirements, islands of state-of-the-art prototype networks, and current telecommunications standards. The resultant Sandia cabling standard¹ included enhanced unshielded twisted pair (EUTP) copper conductor and multimode (MM) and single mode (SM) optical fiber as transmission media types. A full suite of cables per outlet contains: three EUTP four-pair cables, one multimode four-fiber cable, and one single mode four-fiber cable. The amount of cabling required by Sandia's design was immense (see Figure 3).

Figure 3. Installed and unterminated horizontal cabling in an IDR.

¹R. L. Adams, "Intra-building Telecommunications Cabling Standard for Sandia National Laboratories," Sandia Report SAND93-0002 Revised UC-906; Unlimited Release, November 1994.

All of the cables are terminated and presented in one surface-mounted multimedia outlet. The outlets are either red or black, visually corresponding to the secure or the open/restricted access cabling system. (See Figures 4 and 5). Construction teams mounted multimedia outlets in every office to achieve true desktop connectivity. In addition, multimedia outlets were mounted in laboratories, computer rooms, secure vaults, and conference rooms.

Figure 4. Black Multimedia Outlet for Open/Restricted Access connectivity.

Figure 5. Red Multimedia Outlet for Secure connectivity.

Sandia's cabling suite exceeds the recommendations in national and international standards in two very important ways:

- 1) Quantity of conductors — National and international standards recommend a minimum of two circuits per outlet. Sandia's multimedia outlet allows for 7 circuits per outlet. An assumption is made that two fibers will be dedicated for one optical circuit and two pairs of each four-pair EUTP cable will be dedicated to one electrical circuit. This is an extremely conservative deployment of circuits. The near-future development of wave-division and bi-directional optical technologies and eventual utilization of all pairs within four-pair EUTP cables suggests the probable availability of many more circuits within each outlet.

- 2) Conductor types — Sandia's multimedia outlet includes EUTP copper conductors, which exceed current UL Category 5 UTP certification. The outlet also includes single mode optical fibers, which provide more bandwidth capability than recommended by national and international standards.

Sandia's Facilities Engineering Organization has created companion standards to guide their telecommunication construction activities. These documents were compiled in CSI (Construction Specification Institute) format and include a design guide², a standard specification³, and a standard drawing package⁴ for intra-building telecommunication cabling.

As an integral part of the project, detailed metrics were kept for each building. The chart on the following page shows approximate IRP installed horizontal cable metrics to date.

INSTALLED HORIZONTAL CABLE

	EUTP	MULTIMODE	SINGLE MODE
Typical Building	145.98 miles (770,722 ft.)	51.36 miles (271,160 ft.)	51.36 miles (271,160 ft.)
Totals through 9/30/95	940.29 miles (4,964,764 ft.)	308.10 miles (1,626,765 ft)	308.10 miles (1,626,765 ft.)

In addition to the horizontal cable, some indoor-type, high-conductor-count optical fiber and UTP cables were installed as part of the intra-building cabling project. Indoor-type optical fiber and UTP cables connect intermediate distribution rooms (IDRs) with telephone building entrance protector frames and other IDRs. Outdoor-type optical fiber and UTP cables connect intra-building cabling to inter-building cabling by linking main IDRs to Technical Control Centers (TCCs). TCCs are geographically distributed and connected with single mode optical fiber cables, forming Sandia's high-speed campus backbone. Later in this report, the Enterprise Connectivity section discusses the TCC role within Sandia's networking topology.

The Horizontal Distribution Standard: Sandia's original building wiring often utilized daisy-chained wall-mounted metallic enclosures to house horizontal crossconnects (see Figure 6). Over the years, the number of crossconnect enclosures proliferated, and the wiring inside became increasingly scrambled and unmanageable. The condition of the old wiring, punchdown blocks, horizontal crossconnects, intermediate distribution frames, and telephone building entrance protector frames, along with the lack of centralized, environmentally controlled equipment rooms, rendered the interconnectivity of Sandia's networks unreliable at best. It made moves, adds, and changes a challenge for the most seasoned technicians. The dilapidated condition of the crossconnect components, age of the wiring, and inconsistent, inaccurate, or frequently non-existent cable labeling and documentation caused a multitude of maintenance problems.

²"Intra-building Telecommunication Design Standard" (included in Facilities Development Center Design Manual). Locate through the Document Control Clerk.

³"Intra-building Telecommunication Cabling," Standard Specification 16740, December 1995.

⁴Sandia Facilities standard drawings numbered 104011 A1 through A3 and E1 through E7.

Figure 6. Old crossconnect enclosure.

The Intra-building Recabling Project design requires all cabling from the user outlet to be routed directly back to an IDR. The EIA/TIA 568 standard states, "Horizontal cabling shall be a star topology . . ." and "the maximum horizontal distance shall be 90 meters (295 ft). . . . This is the maximum cable length from the mechanical termination of the media in the telecommunications closet [termed IDR at Sandia] to the user outlet in the work area."⁵ This horizontal distribution design eliminates the need for any crossconnect points, but requires the installation of massive amounts of conduit and pull boxes (see Figure 7).

Figure 7. Pull boxes and backbone conduit.

⁵EIA/TIA-568: Commercial Building Telecommunications Wiring Standard, (Electronic Industries Association/Telecommunications Industry Association, 1990, 1991, and 1992.) Section 4.3.

At Sandia, all cables are routed in conduit from the IDR to the multimedia outlet with no splices or crossconnects. DOE security requirements, coupled with stringent fire codes within Sandia, made conduit Sandia's cable pathway selection. The optical fiber and EUTP cables are routed in separate conduits from the IDR through several pull boxes. From a final pull box, smaller conduit connects to a "mixer" box where optical fiber and EUTP cables are combined. From the mixer box, the cables are routed in conduits sized to support single or back-to-back multimedia outlet configurations. The final mixer box provides connectivity for up to nine multimedia outlets. All conduit fills allow for a minimum 10% additional capacity within the conduits to accommodate future needs. Figure 8 is an example CAD drawing of the horizontal backbone design, from IDR to outlet.

Figure 8. Overhead backbone conduit/pull box CAD drawing.

The conduit installations needed to support Sandia's horizontal distribution design were massive. This is dramatically clear in Figure 9 on the following page.

Figure 9. Horizontal conduits.

As with cabling, detailed conduit metrics were kept for each building. The following chart contains approximate IRP installed conduit metrics to date.

	4 INCH	3 INCH	2 INCH	1.5 INCH	1 INCH	3/4 INCH
Typical Building	1.41 miles (7,435 ft.)	1.15 miles (6,094 ft.)	0.98 miles (5,173 ft.)	0.98 miles (5,154 ft.)	1.82 miles (9,600 ft.)	3.35 miles (17,690 ft.)
Totals to Date	14.51 miles (76,642 ft.)	12.70 miles (67,061 ft.)	8.97 miles (47,354 ft.)	8.96 miles (47,282 ft.)	12.72 miles (67,171 ft.)	25.76 miles (135,992 ft.)

INSTALLED CONDUIT

The Intermediate Distribution Room Standard: The IDRs are centralized destinations for all conduit and cabling within a building. Main IDRs connect to individual IDRs within a building, and to telephone building entrance protector frames, as well as to multimedia outlets. Main IDRs are also connected to Technical Control Centers (TCCs) external to the building. At Sandia, the IDRs are located to meet the EIA/TIA 90-meter standard. The number of IDRs in buildings at Sandia varies from one to four, depending on building layout and design. The size of these IDRs ranges from 225 square feet to 600 square feet, depending on the number of IDRs required by particular building layouts. Sandia's designation of "intermediate distribution room" is fitting. (see Figure 10)

Figure 10. Typical IDR approaching completion.

A considerable amount of space is required in each building to accommodate the conduit, equipment racks, copper termination frames, cable tray, and optical fiber interconnect panels. This space is relinquished begrudgingly by building occupants. Finding, retaining, and retrofitting appropriate IDR space usually involves political challenges. Educating building representatives on the benefits and capabilities of the new infrastructure is fundamental to avoid political gridlock. The most difficult political situations are encountered when building space is shared by several different organizations. Each organization expects the others to sacrifice the space necessary to accommodate IDRs. Accurate and unbiased engineering design parameters are used to offer acceptable IDR sizes and locations to frequently riotous building representatives. This was the most difficult challenge to overcome in Sandia's IRP.

Given the difficulty in obtaining the needed space for IDRs, the design required extreme efficiency in floor and wall space utilization. Wall space needed to mount optical fiber interconnect panels consumed the most area within the IDR. In a typical building, an IDR might hold 398 panels. In this example, 19,104 fiber optic connectors would be terminated in the panels. In order to efficiently utilize IDR floor space, 8-foot-tall stem walls were built to increase total wall area, easing the need for additional floor space. In extreme cases, optical fiber interconnect panels were stacked in columns 7 panels high. The panel manufacturer's installation practices recommend stacking in columns 6 high. These IDR design features reduced the needed floor area by as much as 30% and allowed wall space for future growth.

At Sandia, general IDR designs address the following issues: Environmental Safety and Health (ES&H), security, power, lighting, optimal space utilization, architectural finish, and environmental conditioning including cooling, heating, and air circulation. Some specific design features include the following:

Fire Resistance:	Two-hour fire ratings on all walls and one hour on doors with observation glass. The design standard is intended to prevent the entrance of fire into the IDR as well as the spread of fire from the IDR.
Security:	Controlled access with ID tracking and remote control.
Grounding:	Fully grounded according to local codes, National Electrical Code, EIA/TIA 607, and Federal Information Publication (FIPs) 94 standards, including power and signal grounds. A unique grounding design simulating a computer room signal reference grid was utilized.
Power:	Dedicated power for each equipment rack.
Lighting:	50 foot-candles of luminance at 3 feet above the finished floor.
HVAC:	Thermostatically controlled (in each IDR) heating, cooling, and air circulation units.
Termination Frames:	Extremely high-density copper termination frames for EUTP and Category 3 copper conductors.
Space Utilization:	Stem walls constructed to provide additional wall space for optical fiber interconnect panels.
Cable Tray:	Overhead vented-bottom cable tray to facilitate cable installation and routing.
Labeling:	All optical fiber interconnect panels and copper termination frames are labeled for cable maintenance purposes.
Floors:	Non-static floor tile.
Walls and Ceilings:	Bright wall and ceiling finishes to give maximum light reflectivity.

Some major IDR components are illustrated in Figure 11.

Figure 11. IDR Open/Restricted Access side

- ① Single mode optical fiber interconnect panels: Termination and interconnect for single mode fiber.
- ② ISDN power supply and battery backup: Provides -48V for ISDN phone service and 4-hour battery backup during main power outages.
- ③ Multimode fiber interconnect panels: Termination and interconnect for multimode fiber.
- ④ Extra-Large Building Entrance Terminal Frames (XL BETs): Termination and interconnect for up to 3600 twisted pairs per frame.
- ⑤ Overhead vented-bottom cable tray: The cable pathway from the 19-inch equipment racks (to be installed) to frames and panels. (See Figure 12 for populated IDR equipment racks.)
- ⑥ Ground Bus: Interconnects all conduit, punchdown frames, cabletray, and other conductive equipment.
- ⑦ Single mode four-fiber indoor tight buffer cable.
- ⑧ Multimode four-fiber indoor tight buffer cable.
- ⑨ Velcro tie straps to facilitate cable organization and cable dressout.

IDRs are the communication centers for newly cabled buildings. They provide a centralized point for all telecommunications maintenance within the building, including moves, adds, and changes. In addition, equipment racks, active telecommunication electronics, uninterruptible power supplies, termination frames, and any other equipment required for enterprise-wide connectivity usually reside within the IDRs (see Figure 12). Some examples of active telecommunications electronics are:

LAN Hubs/Concentrators

Routers/Bridges

ATM switches and ATM edge devices

Video distribution and conferencing equipment

Multiplexers: statistical, frequency, time, and wave-division.

Figure 12. Populated IDR equipment racks.

Enterprise Connectivity

The Intra-building Recabling Project is an essential part of Sandia's enterprise-wide connectivity plans. With the new cabling infrastructure in place, Sandia's enterprise network can proceed towards its long-range goal. The goal is to achieve ubiquitous deployment of Giga-bit rates to the desktop utilizing SONET technology as the physical transport and ATM technology for electronic switching (see Figure 13). This will allow quick deployment of ATM standardized bit rates (anticipated to include 25, 51, 155, and 622 Mbps) to the desktop. Connectivity from the desktop to the IDR has been discussed previously. Optical fiber connectivity between IDRs and TCCs complete the link between the end user and the enterprise network⁶. TCCs are interconnected with a single mode optical fiber cable backbone providing campus-wide connectivity. As the campus grows, new IDRs and TCCs are introduced into the topology as necessary. Sandia's Intra-building Recabling Project, in conjunction with the Enterprise Networking Project and the ATM Migration Project, has provided virtually unlimited bandwidth and connectivity throughout Sandia's evolving high-speed network, including links to distributed databases and centralized supercomputers.

Figure 13. Sandia's current ATM Migration and Enterprise Networking diagram.

⁶TCCs are the "on ramps" to Sandia's wide area information highway. They house electronics and cabling necessary to multiplex data traffic onto and off of Sandia's enterprise backbone.

Conclusion

The success of this project is essential to the effective management of Sandia's telecommunications needs. The cabling infrastructure within each building is the foundation upon which all present and future telecommunication strategies at Sandia National Laboratories are or will be built.

As the metrics and pictures included in this report suggest, Sandia's IRP faced a multitude of challenges. These challenges included (but are not limited to) multi-million dollar inventory purchases; storing and controlling miles of conduit, hundreds of miles of cable, and hundreds of thousands of cable terminators; labeling thousands of cables; making hundreds of thousands of cabling database entries; performing extensive certification testing; and cutovers for thousands of active telecommunication circuits. To complicate matters, the recabled buildings were occupied throughout construction. Decisions made early in the planning stages were more advantageous than expected, especially in the face of these challenges.

Some of the lessons learned from this extensive and continuing cabling project are described in Appendix A. These lessons should guide the continuing IRP efforts to complete the cabling infrastructure upgrade at Sandia. These lessons may also be useful to other groups developing or modifying a network cabling capability.

Numerous technical challenges and solutions have been captured in the course of this project. However, it is beyond the scope of this report to provide details on such activities. The authors intend to publish further technical reports to supplement this overview.

The success of this project is based on extensive planning and up-front design work. Without a clear understanding of project goals and a firm commitment to a standard set of hardware, the advantages of a new cabling infrastructure at one of the nation's major R&D facilities would not have been realized. Sandia can now move ahead with the broad range of R&D work conducted at the Labs, confident that the telecommunications infrastructure will provide the information exchange needed for the foreseeable future.

Appendix A

Lessons Learned

A project of this nature and scope invariably has a way of taking unexpected twists and turns that could affect schedule and costs. From its inception, the IRP has continuously utilized a corrective feedback process commonly referred to as lessons learned. The lessons learned described below focus on aspects of project management that the IRP team found to be important in implementing the project.

Figure A-1. Sandia's Recabling Material Warehouse.

Material

Early on in the project's planning, Sandia decided to purchase many of the materials needed for the project in order to save considerable expenses. For example, the unit price that Sandia established (based on massive material purchases) was considerably less than what individual contractors could have realized by making multiple purchases in smaller amounts.

In weighing the pros and cons of this kind of ownership, Sandia's IRP planners recognized the following tradeoffs:

PRO - Sandia-purchased materials provided a savings of millions of dollars and insured material consistency throughout the life of the project. Furthermore, a fundamental result of material ownership is enhanced control over material availability and the capability to review the relative performance of contractor material usage, primarily for cable and connectors (high-dollar components). For example, accurate identification of cable waste enabled the project team to revise design parameters and modify installation practices early in the project. In addition, purchased cable spool lengths were modified, which resulted in considerable savings over the life of the project. Specifically, optical fiber reels were ordered in non-standard 14,000-foot sizes, reducing waste, while EUTP copper conductor was ordered in 1,000-foot cardboard containers, easing installation. Accurate knowledge of connector failures prompted Sandia to conduct in-depth component investigations that resulted in the identification and correction of supplier manufacturing problems, as well as field installation problems.

CON - Responsibility for storing, inventorying, and distributing the material had to be addressed. The costs associated with these activities were much less than the savings realized by Sandia's massive material purchases. However, a 7,800 square-foot warehouse had to be located and leased for the duration of the project (see Figure A-1). Shelving had to be installed. A full-time warehouse technician maintained the inventory, tracked the stock, established and maintained a database, and directed distribution.

Whether or not a project team decides to prebuy its material or allows contractors to purchase it, quantities of material, manufacturer selection, product selection, availability, and distribution sources must be carefully analyzed. Any one of these factors can limit the success of a project if not considered in the early stages of planning.

Recabling In Occupied Buildings

Conducting construction projects for any purpose in occupied buildings is a formidable task for the sponsoring organization and extremely inconvenient for occupants. Diplomacy is a quality that cannot be overvalued when dealing with building occupants, the IRP's customers. At Sandia, construction in office and lab areas must be conducted during off hours. This is often the case when "swing space" is unavailable for building occupants to temporarily conduct their business. Building occupants are extremely concerned with office or lab security, as well as damage to experimental apparatus and computing resources. Misplaced furniture, including desks and bookshelves, are also a concern. In this environment, all contractors (installation and termination) suffer from reduced productivity due to daily setup and clean-up requirements demanded by building occupants.

Some of the following suggestions can facilitate construction projects in occupied buildings.

- As early as possible, clearly identify your commitment to the building occupants. Let them know what the project will do for them in terms of capability. Make them aware of the proposed construction schedule and any in-process modifications. Let them know that extraordinary individual circumstances will be considered. Tactfully and respectfully communicate to the occupants that the new cabling will remain part of the building indefinitely whereas the occupants will inevitably relocate. Adhere to the standard design under all but extreme circumstances.
- Don't permit building occupants to direct the contractors. Assign a building coordinator(s) to be the liaison between contractors, occupants, construction inspectors, other stakeholders, and the organization sponsoring the project.
- Accurately monitor and record the whereabouts of all work conducted each night. Building coordinators and construction inspectors must know where in the building the contractors are working. If expensive laboratory or office equipment is damaged, the responsible party must be identified quickly. The initial blame will be placed on the contractors. Accurate contractor work records will be invaluable if building maintenance staff or building occupants are actually responsible. Incidents of this type are extremely disruptive, emotional, and, hopefully, few and far between. Keeping a schedule of the contractors' work location and having an inspector conduct a quick walkthrough at the end of each shift can minimize such incidents.
- Lock in final location and count of multimedia outlets as early on in the design as possible. Expect occupants to change their designated outlet location up through construction. Keep a design change deadline posted and know when the obligation of the organization in charge of the project is over.

Integrating Projects

At Sandia, a typical recabled building requires a one-year cycle. The probability of concurrent construction projects occurring over any one year is extremely high. In many instances, office remodels, renovations, relocations, ES&H-required activities, and IRP efforts overlapped each other. The confusion of having multiple projects conducted in the same area of the same building can be minimized by close coordination with project owners. While this seems self-evident, proactive investigation is a necessity to avoid inevitable conflict. The consequences of different contractors working in the same area are usually schedule delays, confusion, emotional confrontations, change orders, and added expenses.

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