# Strategic Technology Infrastructure for Regional Competitiveness in the Network Economy

## Volume 4: Fiber Optic Infrastructure Design Guide

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# Strategic Technology Infrastructure for Regional Competitiveness in the Network Economy

## Volume 4: Fiber Optic Infrastructure Design Guide

Virginia Tech

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# Preface

This series of reports, entitled *Strategic Technology Infrastructure for Regional Competitiveness in the Network Economy* and packaged in eleven Volumes, is the culmination of a dedicated effort of the following individuals and organizations. Each Volume can be viewed as a stand-alone publication; however, it should be noted that each Volume was written in the context of the overall project. The project utilized the Southside and Southwest Virginia regions as a model for a low-cost Geodesic Mesh network design and viable financial model that could be replicated in any region of the U.S.

## Volumes

1) Rationale, Environment, and Strategic Considerations
2) Connecting the Regional Infrastructure to National and International Networks
3) A Fiber Optic Infrastructure Design for Southside and Southwest Virginia
4) Fiber Optic Infrastructure Design Guide
5) Financial Feasibility and Investment Rationale
6) Leveraging Advanced Optical and Ethernet Technologies
7) Speculative and Alternative Technologies
8) Community, Applications and Services
9) Demographics for Southside and Southwest Virginia
10) Health Information Technology and Infrastructure
11) Education in the 21st Century

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# Organizations and Companies

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# Introduction

The purpose of this guide is to provide information and guidelines for planning, engineering, and building fiber optic infrastructure. The long-term economic well being and quality of life of our communities depend upon the availability of affordable network access and services over fiber optic infrastructure.

## The Problem

The problem is that high-speed transport for digital communications traffic is either not available, or not affordable, to most businesses and residences. The service is needed to support economic development, business, education/training, and many other applications. Those that have not yet participated in the e-business economy may not realize that they need to prepare for it. Unfortunately, even if they do, existing telephone copper cables and cable TV coaxial cables do not have the 2-way bandwidth capacity needed to support the symmetrical 10/100/1000 Mbps (megabit per second) speeds needed. Also, most existing higher tier backbone networks are too slow and/or too expensive to support these higher speeds.

It is possible, as demonstrated by community, municipal, and customer owned fiber optic networks around the world, to deliver 10/100/1000 Mbps access to the premise for as little as $40/mo (e.g., see http://www.gcpud.org/zipp/default.htm). This gives those communities a significant competitive advantage. For an in-depth discussion of technical and economic issues related to fiber optic networking and applications, an excellent book on the subject is *Optical Networks* by Debra Cameron. It provides a good overview of the issues and it contains a plethora of well-researched facts.

Computer communication speeds to the desktop continue to increase. For example, local area network access speeds increased from 10 megabits per second (Mbps) to 100 Mbps. Gigabit Ethernet (Gig-E) is now used for servers and backbone networks. Gig-E is poised for increased use to the desktop as costs continue to drop. For example, an Intel Gig-E card for a PC is currently about $50 and low-end Gig-E switches are under $100 per port. Gig-E is following the same evolutionary trend that 10 Mbps Ethernet and 100 Mbps Ethernet did. In other words, it makes business sense in terms of cost versus productivity today to use Fast Ethernet at 100 Mbps and soon this will be the case for Gig-E as applications evolve. Computer manufacturers such as Dell and others have stated their intention to offer standard 10/100/1000 Base-T Ethernet ports on most of their future computers. 10-Gig-E is now available for network backbones and 40 Gbps speeds are under development. High speed LANs, MANs, and WANs (Local, Metro, and Wide Area Networks) are an essential foundation for supporting business, government, education, health, and other services. The transmission cable infrastructure serving premises and backbone networks needs to support the higher speeds of today and those in the future.

## The Solution

The only practical transmission media that can support the 10/100/1000 Mbps speeds needed today and speeds needed in the future over the outside cable plant is single-mode fiber. It has much greater bandwidth capacity than any other media, so it is the most future-proof available. It supports today's transmission technologies, such as SONET (Synchronous Optical Networks), WDM (Wave Division Multiplexing), PONs (Passive Optical Networks), Ethernet (packet data), ATM (Asynchronous Transfer Mode), and analog-RF signal transmission. It should also support future transmission technologies not yet invented, so it is a good investment for the future.

In addition to the fiber optic infrastructure, higher network layer equipment, such as Ethernet switch-routers and other equipment are needed to provide services over the fiber. This guide focuses on the fiber optic infrastructure, which is the foundation needed to support provisioning of affordable high-speed communication services to premises, within towns/cities, within counties, between counties, and beyond.

# Steps for Planning and Building Fiber Optic Cable Plant

There are three major steps to planning and building fiber optic cable plant. First, put a project plan together along with all the preliminary details and engineering. Second, contract the work. Third, oversee the build-out.

## Develop Project Plan

The first step is to put together all the details for the project plan. One needs to: define goals and objectives; determine locations, spaces, and intermediate access points for the fiber optic cables and associated equipment; plan to purchase, build, or lease, spaces, if needed; plan cable routes and obtain permits and Right-of-Way agreements; specify the materials; estimate the budget. A GIS/Facilities Management system is needed to plan, document, and maintain the infrastructure. Determine how much planning can be done in-house, or if some tasks need to be outsourced, such as determining the cable routes and getting permits and Right-of-Way agreements. Once the required work is defined, then one can either do the work, or find someone to do it.

## Contract with an Engineering and/or Construction Firm

Assuming you plan to outsource the work, then the second major step is to contract with engineering and construction firms to do any remaining engineering and the fiber build. The work could be divided into two separate steps with one firm doing the planning and engineering and a second doing the construction work. For a competitive bid process, prepare an RFI/RFP/RFQ and put it out for bids. If adequate preparation was done in step one, then most of the information needed for the bid request should be available. After receiving a suitable bid, final contracts and agreements must be negotiated. The engineering/construction firm will need to document the cable route, the materials, and the work for project manager approval. The preliminary engineering drawings and associated data bases developed in step one can be used to continue the design and engineering work.

The Appendix lists reference sources for preparing bid documents and contracts, but three are well worth pointing out here. First, see the USDA RUS (Rural Utility Service) Telecommunications Program regulations, bulletins, and forms available for free download at http://www.usda.gov/rus/telecom/publications/publications.htm. It may be useful to spend several days studying the materials. Pay particular attention to RUS Form 515, "Telecommunications System Construction Contract (Labor and Materials)," since appropriate parts of it may be useful for your bid requests and contracts. Also, see RUS bulletins 1751F-630, 640, 642, and 643, which cover design of aerial, buried, and underground plant. Second, spend time studying the *BICSI Customer-Owned Outside Plant Design Manual* chapters on Rights-of-Way, Design Documentation, Scope of Work, and Project Management. Third, study the *SCTE Recommended Practices for Optical Fiber Construction and Testing* chapters on Project Management, documentation, and testing. It also includes a number of potentially useful bid questionnaires and forms. See the Appendix for more details on these and other references, as well as a paper on "Generic Cost Information for Building Fiber Optic Infrastructure."

## Build Cable Infrastructure

Finally, the contractor can start building. Hopefully, all issues with permits and Rights-of-Ways were resolved so that there will be no further delays. Other considerations for the build include procurement of materials by owner and/or contractor, safety, security, milestones, and quality of work. Do not wait until the job is done to check the work, because it may be too late—"an ounce of prevention is worth a pound of cure." Quality assurance should start in step 1 and continue to the end. Any changes in the design should be documented in the GIS/Facilities Management system as they occur, so that when the job is done, all documentation is up to date. The GIS/Facilities Management System is needed to maintain the system documentation and for OAM&P (Operation, Administration, Maintenance, and Provisioning) after the build. If quality control is maintained throughout the build, then all that is left at the end is to make final checks and accept the work. References in the previous section and the Appendix address quality assurance and testing. In addition, see the "Quality Assurance Check List" in the Appendix.

# Design Considerations

## Standards for Compatibility and Reliability

Many communities, campuses, towns, and cities have implemented customer-owned fiber optic infrastructure, or are planning to do so. It is important to design and build infrastructure to standards that support compatibility of the infrastructures and interoperability of the systems that use the infrastructures. Disparate infrastructures should use compatible types of fibers that are reliable and maintainable, since the fibers may need to be patched together to form circuits. Also, the fiber circuits may need to support the same transmission equipment and associated optical requirements.

The reliability of the infrastructure in one region may affect services in another. Some of the factors that affect reliability include robustness, route diversity, redundancy, security, documentation, operation, administration, maintenance, and network management. The infrastructure should provide maximum benefit over an expected life of 20 years, or more. It should be designed to support today's transmission technologies, as well as future technologies, to avoid obsolescence. By adhering to standards, the combined infrastructures will be more reliable, compatible, and interoperable.

## Where can one find useful, practical information for planning and design?

There are numerous books on fiber optic technology, but relatively few cover the details on how to plan, design, and build outside plant fiber optic infrastructure. Some of the better sources are from BICSI (Building Industry Consulting Service International), SCTE (Society of Cable Telecommunications Engineers), RUS (Rural Utilities Services), standards organizations, and product manufacturers. These and many other sources are listed in the Appendix.

# What type of fiber should be used?

## *General Considerations*

Single-mode fiber is required to support higher speeds over outside plant distances. Multimode fiber does not support the necessary speeds and distances. There are two major types of single-mode fiber to consider. One is for local town/city/county areas (metro and local access) optimized for 1310 nm and the other is for long-haul optimized for 1550 nm. The International Telecommunications Union defines them in ITU-T G.652 and G.655 recommendations.

There are four major performance categories of single-mode fiber. First is loss per kilometer for given wavelengths across the spectrum. Second is chromatic dispersion, which causes distortion of signals due to light traveling at different speeds for different wavelengths resulting in shorter operating distances. Third is PMD (Polarization Mode Dispersion), which results in delays between the vertical and horizontal components of a light-wave due to physical irregularities of the waveguide, stress on the cable, changing temperature, vibrations, and other phenomenon. PMD is a major limitation for older fiber. The fourth is signal distortions caused by non-linear characteristics of fiber for multi-wavelength and high-speed signals.

Corning, Inc. is the largest manufacturer of fiber and fiber optic cable, so for analysis purposes, let us consider the types of fiber they have available. Other manufacturers are listed in the Appendix section “Partial List of Vendors for Outside Plant Products and Services.” In addition, the “Fiber Optic Cable Comparison Tables” in the Appendix provide a comparison of major product brands and their optical characteristics. The sources for this information may not be entirely correct, or changes may occur, so verify parameters with manufacturers, if needed.

It is desirable for the fiber infrastructure distances between nodes to support commonly available fiber optic transceivers used in transmission equipment without the need for repeaters and amplifiers. Fiber optic transceivers are commonly available to support distances of 10 km, 20 km, 40 km, 70 km, and 80 km. The shorter distance transceivers typically use 1310 nm and longer distance transceivers typically use 1550 nm. The longer distance, longer wavelength transceivers are much more expensive than those for 1310 nm.

### *ITU-T G.652.C Fiber for Metro and Local Access*

The first type of fiber to consider is known as standard single-mode fiber (SMF) defined by G.652. It is optimized for use at 1310 nm with zero dispersion at that point. It supports the use of lower cost optical transceivers in that band, as compared to much higher cost transceivers for the1550 nm band. While optical loss is less at 1550 nm, the pulse dispersion is greater than at 1310 nm. As shown in Figure 1 below, SMF is mainly usable in the O-Band and the C-Band, but not the E-Band. The most recent enhancement is extended band fiber (E-SMF), also known as Zero Water Peak Fiber, which is defined by G.652.C. Corning brands their version of this type of fiber as SMF-28e. It supports wavelengths from 1285 nm to 1625 nm, including the E-Band, so it has wider usable bandwidth than SMF. Both types are suitable for distances around town and up to roughly 80 km, or 50 miles without repeaters, as determined by commonly available fiber optic transceivers. The cost for SMF-28e has dropped to the point where it is cost effective to use it instead of SMF and it offers wider bandwidth for future applications.

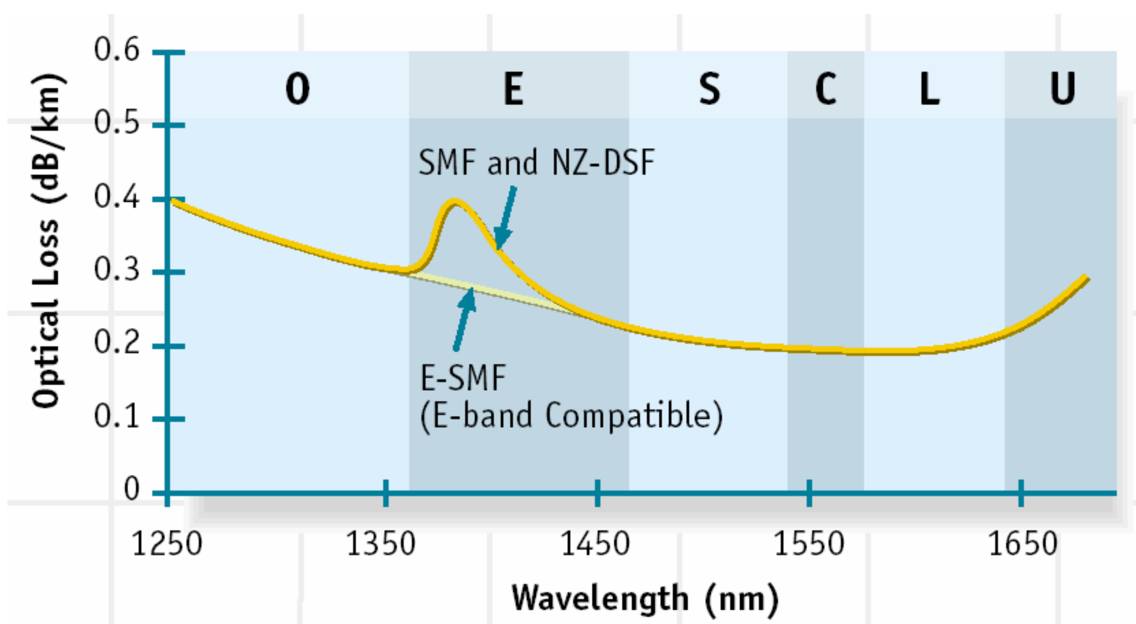


**Figure 1: Loss for Standard SMF versus Extended Band SMF**

## *ITU-T G.655 Fiber for Long-Haul*

The second type of fiber to consider is for long-haul applications beyond 80 km. ITU-T G.655 defines it and it is called NZ-DSF (Non-Zero Dispersion Shifted Fiber). Corning brands their version of this type of fiber as LEAF (Large Effective Area Fiber). It is optimized to support higher speeds and dense wave division multiplexing (DWDM) in the 1550 nm and 1625 nm bands where the optical loss is lowest. It is designed to have a small positive dispersion at 1550 nm to reduce signal distortion caused by fiber non-linear effects. It has low PMD (Polarization Mode Dispersion) at 1550 nm. Figure 2 shows how SMF compares with NZ-DSF.

Another type of NZ-DSF is available with a negative dispersion slope. Corning calls their negative dispersion fiber MetroCor. They recommend it for large metropolitan DWDM applications that use directly modulated positive-chirp lasers in the 1550 nm band. Due to the high cost of DWDM equipment it is better to run extra fiber, if possible, to avoid the need for DWDM. Also, most network equipment is designed for use with standard single-mode, so the SMF-28e fiber type is still the best choice for metro applications.

Another use for negative dispersion NZ-DSF on long-haul routes is to run alternate segments of positive dispersion fiber and negative dispersion fiber, so as to partially negate the effects of pulse dispersion.

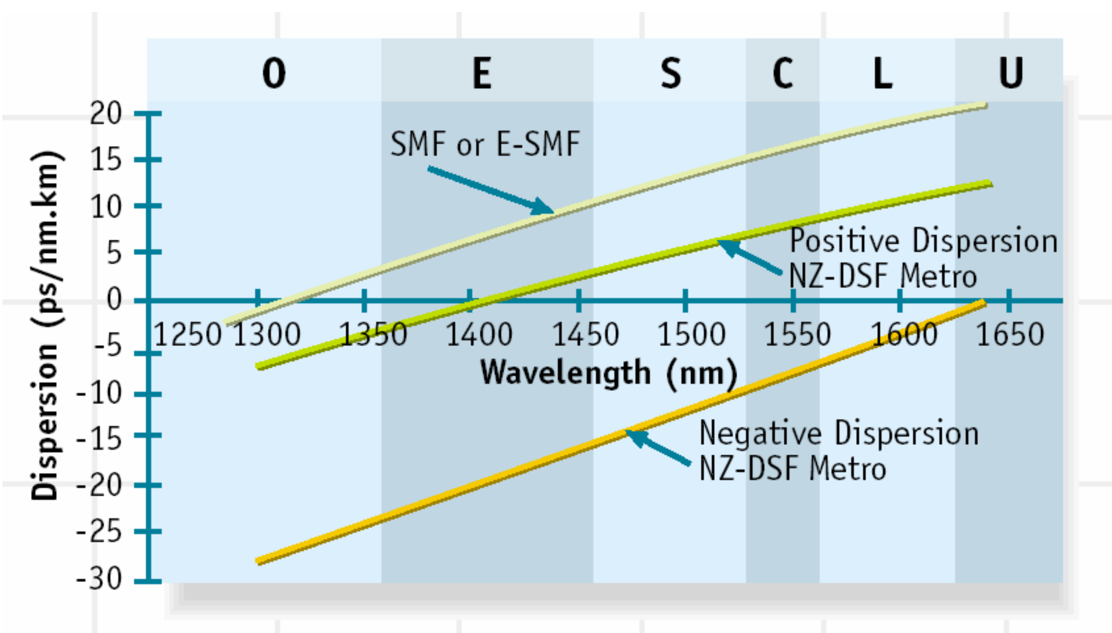


**Figure 2: Dispersion for SMF versus NZ-DSF**

An excellent analysis of the types of fiber, the major brands, and associated applications is available in a 37-page guide written by Alessandro Barbieri, of Cisco Systems. It is a rare document, because it provides data and comparative analysis of different brands all in one place. The title is "A Guide to Select Single-Mode Fibers for Optical Communications Applications" and it is available on the web at http://www.webtorials.com/main/resource/papers/cisco/paper20.htm. You have to register to access the document, but it is free.

## What is the transmission capacity of fiber?

Communications equipment is available today with fiber optic transceivers that support serial channel speeds up to 10 Gbps. Equipment is in development to support up to 40 Gbps, but it may not be economically feasible for a number of years. So, the immediate limitation is the electronics, not the fiber. A workaround is to use wave division multiplexing (WDM), which enables the transmission of multiple 1 Gbps, 2.5 Gbps, 10 Gbps, or 40 Gbps, channels over one fiber. Reportedly, it is possible to achieve combined channel speeds of up to 3.2 Tbps (Trillion bits per second) over a single fiber. Relatively slow 2.5 Gbps channels and circuits are common today, with 10 Gbps being the next jump.

## How many fibers are needed?

Out of context, there is no easy answer to this question, but let us explore the options. The purpose of this guide is to provide guidelines for development of community, town/city, county, and statewide fiber optic infrastructure. Two major categories of fiber networks are local access networks and backbone trunk networks. Refer to Figure 3 for a conceptual drawing of a generic metro/local access fiber network.

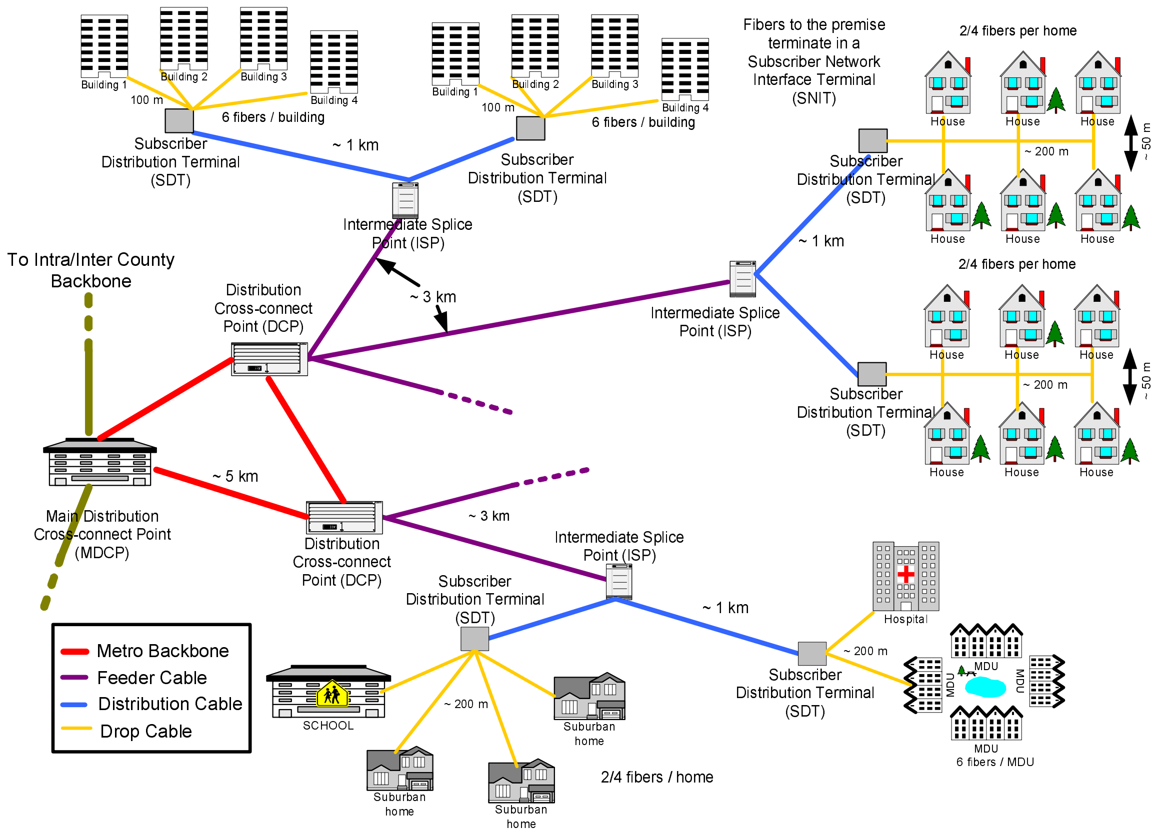


**Figure 3: Generic Metro and Local Access Networks**

For any premise, at least 2-fibers are needed. This is because network equipment today generally uses one fiber for transmit and a second for receive. So, the 2-fibers need to run from each premise all the way to a serving Distribution Cross-connect Point (DCP) where the circuits can be patched to communications equipment, or over trunks to other locations. It is desirable to have a second pair of fibers to the premise for other potential service, but the additional cost for twice as much infrastructure would be needed. This architecture is designed to support most technologies over the life of the infrastructure. It is independent of particular electronic technologies (e.g., Passive Optical Networks (PONs) and other technologies) so that it does not become obsolete when the next generation transport technology becomes available.

Two-fibers to smaller premises may be sufficient, as opposed to four, or more. First, fiber optic transceivers are being developed to provide full-duplex over one fiber. When in common use, they would free the second fiber for another application, or service. In addition, there is a trend to converge voice, data, and video over a single IP/Ethernet/optical connection, which reduces the need for extra fiber. Also, for open access networks, subscribers may have a choice of service providers and not be locked-in to a monopoly provider. All these factors reduce the need for extra fibers to the premise. Larger premises, may need additional fibers. The cost for adding a pair of extra fibers to the premise drop cable is relatively small, so it may be reasonable to include them for potential use, but not terminate them initially. Spare fibers could also be included in feeder cables so that additional circuits could be provisioned to a premise on a case by case basis by going to the field and splicing the appropriate spare fibers together, plus terminating them at each end.

For metro backbone and long-haul trunks, the number of fibers needed are more difficult to determine. One factor is that backbone circuits may operate at much higher speeds than subscriber circuits. For example, a service provider could deliver 10/100/1000 Mbps access to thousands of premises and use Nx10 Gig-E in the backbone to aggregate the traffic. A second factor is the potential use of WDM (Wave Division Multiplexing) that can transmit multiple high-speed channels over a pair of fibers. However, WDM equipment is expensive, so in general, it is better to install sufficient fiber to minimize the need for WDM. Presumably, the cost of WDM will drop over time, so the network capacity can be increased as long as there are still fibers that can be allocated. Clearly, it is important to manage the allocation of fibers and to plan for future needs.

Another consideration is the total cost of installing the infrastructure versus the available budget. This could well be a determining factor. One could pick a number for a trunk/feeder cable, say 72 fibers, determine the cost, and then determine if sufficient funds can be made available. The quantity could be adjusted by increments of 12, as necessary, since cable and components are commonly available in increments of 12. Also, 72 or 144 fiber trunks are quantities to analyze, since patch panels are available for those quantities. If the trunk applications call for two types of fibers, such as standard and long-haul, then they must be factored in. They can use the same patch panels, enclosures, etc. In addition, plan for allocating fibers to access/drop points along a given route. It is desirable to use a “building-block” or “cookie-cutter” approach for structured cabling of outside plant that supports a scalable architecture, which is analogous to structured wiring for buildings.

If possible, plan for the ability to add more fibers later, if needed. Where conduit is used, consider installing spares. For aerial and direct buried, explore obtaining approvals upfront to add a second cable along the same route, if needed. Going back to install fiber again may be more expensive than putting in what is needed the first time, but since one does not always know what the future holds, have a contingency plan ready.

## What cable construction is needed?

All dielectric, non-conductive, cable is desirable where suitable, since it does not need to be grounded and it can be close to power lines. It can be used for aerial, direct bury, and in underground conduit. Armored cables conduct electricity, so they must be grounded at multiple points along the cable route. Unfortunately, for aerial segments where squirrels may chew on the cable, it may be best to use armored cable. Squirrels can still potentially bite through the armor, but it is more of a deterrent.

State and local codes must be checked for grounding requirements, in addition to those specified by the NEC (National Electrical Code) and NESC (National Electrical Safety Code). SCTE (Society of Cable Telecommunications Engineers) recommends grounding fiber optic cables with metallic components every mile for aerial applications and every 3 miles for buried applications, plus at each building and cable entry point.

## What are the fiber optic cable ordering specifications?

Cable distributors deal with brands, not detailed cable construction specifications that can be extracted from manufacturer’s data sheets. So, one method of specifying cable is to order a known good brand, or equivalent. Then, if an alternate bid is received at a lower price, the data sheets, reputation, and references for the product can be investigated to determine if it is acceptable.

Detailed data sheets and warranty for the baseline brand should be required before ordering, as well as for alternates being considered. In addition, manufacturer’s recommended installation practices and guidelines should be required. There is too much work and expense involved to leave anything to chance. If the cables do not meet the data sheet specifications, then what recourse do you have and who is responsible to do what?

Quality assurance test results for each fiber should be required upon receipt of ordered cables and they should be verified as being accurate by testing the fibers. Also, document the color codes for the fibers and the types of fibers in the cable—very important if there is more than one type. As soon as the cables are installed, test each fiber again and compare results with the previous tests. If a problem is detected, then determine who is at fault and what needs to be done about it. Store the test results and traces in your GIS/Fiber Management System for quality assurance, operations and maintenance.

Corning Cable Systems and Corning Fiber are the largest cable and fiber manufacturers. They have a good reputation and support, so it is reasonable to use their products as a baseline from which to compare alternate bids. If you prefer to use another known good vendor as the baseline, then fine. Several other large cable manufacturers, including AFL and Pirelli also use Corning fiber. The second largest fiber manufacturer is reportedly OFS Furakawa (previously Lucent). Their cables also have a good reputation. Additional manufacturers are listed in the Appendix.

It is important to pay attention to the cable manufacturer's performance specifications over the expected operating temperature range for the cable. This will be difficult to verify, except at the temperature tested, so make sure the manufacturer has designed and tested the cables for use over the specified temperature range. This could have a significant impact on system operation, especially if the optical loss budget is tight.

An important ordering specification is the construction type, distance markings on the cable sheath per foot or meter, and the length. If the cable you order is too short, then there will be extra work and expense to fix it. If it is too long, then you can cut it off, or use more slack lengths, but you are stuck with it.

The "Fiber Optic Cable Comparison Tables" in the Appendix show major optical parameters for several brands of cables. This is the type of information generally available in manufacturer's data sheets. One could specify these parameters in a bid specification, but as you can see, the values between manufacturers are similar and some of them would be difficult to verify.

## What type of cable pathway construction should be used?

There are three major types of cable pathway construction. They include aerial, direct-buried, and underground conduit. See the *BICSI Customer-Owned Outside Plant Design Manual* for details and specifications. The *SCTE Recommended Practices for Optical Fiber Construction and Testing* is another good source. Also, obtain cable installation practices from your chosen cable manufacturer for the type of construction. Additional BICSI manuals, NEC, NESC, and RUS sources specified in the Appendix also provide useful information, specifications, and requirements. A partial list of vendor sources with their web site addresses is provided in the Appendix.

Underground conduit is usually the most expensive upfront, but it offers the potential advantage of being able to change, or add, fibers/cables to the particular duct bank, or spare duct bank. Aerial may be the least expensive depending on arrangements. The type of construction used may depend upon the preferred route, available ROW (Right-of-Way), permits, cost, and other factors.

## What cable lengths should be used?

First determine cable route endpoints and any intermediate access/drop points. Then determine cable lengths to go between each point and leave extra length for slack loops and sag if aerial. For a 6-ft reel, cable lengths are available for roughly 13,000 ft to 27,000 ft for single-armor cable with fiber counts of 144 and 60 fibers, respectively. Where appropriate, match access/drop points with splice points. Check with your cable manufacturer for exact lengths available for a given cable diameter and reel size.

## What are examples of materials and work for fiber optic infrastructure?

If you use a GIS cable management system, such as OSPInSight from Advance Fiber Optics (www.ospinsight.com), you can enter preliminary cable routes and materials into the system and it will print out the bill of materials for you along with associated drawings and engineering details. This is an excellent method for planning, preliminary engineering, documenting work for bids, tracking work, and documenting the infrastructure for operations and maintenance.

The RUS (Rural Utilities Service) provides lists of acceptable materials, vendors, and sample contracts. The BICSI and SCTE references listed in the Appendix also provide lists of materials and work. The SCTE reference provides sample bid questionnaire forms that list materials and work. These are a good place to start.

A white paper in the Appendix, "Generic Cost Information for Building Fiber Optic Infrastructure" by Raco, Inc., provides cost details and considerations.

Micrologic, Inc, a contractor in Buckhannon, WV (1-888-651-8431) provided the following list of typical materials and work:

Strand only; materials provide by customer

Strand only composite; includes supplying splicing and installation of ¼" strand, supplying hardware material, lashing wire, clamps, and bolts

Lashing single fiber to strand; lashing wire and fiber supplied by customer

Install anchor and guide; supplied by customer

Bonding of strand to existing ground

Complete bonding of strand to ground

Direct bury of cable 18" deep; cable provided by customer

Burying of conduit

Pulling fiber through existing conduit

Lashing additional cables

Install fiber enclosure

Install butt prep; includes prep and cleaning of fiber tails, install of entrance connectors into enclosure, and organization of splice trays

Fiber splicing

End to end link test with documentation

Additional labor per hour

Equipment installation per hour

Pre test fiber reels

## What are the major sources for materials?

A partial list of vendors are listed in the Appendix section "Vendors for Outside Plant Products and Services." Most are vendors that exhibited at recent trade shows, or were taken from buyers guides. The list is sorted by product/service category. The RUS (Rural Utilities Service) lists many vendors and products in documents available from their web site (see http://www.usda.gov/rus/telecom/index.htm).

## What planning, design, and management tools should be used?

Much of the outside cable plant information is associated with locations. To properly document and track the information requires GIS (Geographical Information System) software in conjunction with outside plant and possibly inside cable plant management software that use a relational database. In addition, streetmap data sets are needed to be able to visually see where the cable plant facilities are in relation to streets and addresses that are geocoded with respect to GPS coordinates. In addition, census, demographic, and business point data sets are useful for planning cable routes and service areas. Data sets showing the location of existing telecommunications POPs and infrastructure are also useful.

So, what software is needed and how much does it cost? There are a small number of products available with numerous options, but an example of one set of solutions for a single-user workstation is as follows:

- MapInfo Professional Version 7: $1495
- MapInfo StreetPro, single-state: $1995
- Advance Fiber Optics OSPM Edit (Outside Plant Manager) for MapInfo: $3900
- MapInfo Annual Maintenance: $395

- MapInfo Technical Support: $299
- OSPM Edit Annual Tech Support & Maintenance: $780

The total cost for a minimal set of 1-user software is about $7390 list upfront, plus $1474 annual software maintenance and technical support. An appropriate computer and low end laser printer to use with the software may cost about $3000. Prices change, so verify the latest.

For multiple users, the next increment from MapInfo for data sets is licensed for up to 5-users for only 30% extra per item, so it is less expensive per user for two or more users. Quarterly updates cost an extra 35% per data set item. For example, the StreetPro data set listed above for up to 5-users with 1-year of quarterly updates would cost $1995 x 1.3 x 1.35, which is about $3501. Unfortunately, the data sets become outdated over time, if not updated. Two and 3-year update subscriptions are discounted further. For small quantities of the base MapInfo Pro and OSPM software packages, there is no multi-user discount typically offered. Both MapInfo and Advance Fiber Optics make available evaluation copies of their basic software.

The more detailed information system planners have access to, the better job they can potentially do for planning cable routes. However, you can easily spend $100,000 and more on data sets, so where do you draw the line? The next minimal set of data sets that are useful for cable route and service planning include:

- MapInfo MapMarker Plus, 1-state: $1995 (can be bundled with StreetPro)—MapMarker converts street addresses to points on the StreetPro map
- MapInfo ExchangeInfo Plus, 1-state: $3200—shows locations of telephone wire centers and service areas
- MapInfo Business Points Data, 1-state, all categories: $6000—shows locations and data in 16 major categories, including business, manufacturing, health, government, education, and more
- MapInfo Census 2000 Boundary Bundle: $995—shows boundaries and census information for states, counties, tracts, block groups, and census blocks

Advance Fiber Optics OSPM Edit is also available for use with ESRI ArcEdit GIS software. We discovered that the MapInfo/OSPM combination is easier to use and less expensive than the ESRI/OSPM combination, but both get the job done. ESRI ArcInfo offers a more powerful set of GIS features than MapInfo, if needed for other applications. Other manufacturer solutions are available also. Several GIS references are listed in the Appendix that provide product overviews, but useful comparative information for telecommunications applications are almost non-existent.

For additional details and information on numerous options, see:

- MapInfo: http://www.mapinfo.com/
- Advance Fiber Optics: http://www.ospinsight.com/
- ESRI: http://www.esri.com/

## What are sources of census and demographic information?

Major sources of information for census and demographic data include:

- U.S. Census Bureau, http://www.census.gov/main/www/cen2000.html
- SRC, http://www.extendthereach.com/
- GeoLytics, http://www.uscensus.info/

### *U.S. Census Bureau*

The original source for census and demographic information is the U.S. Census Bureau. They have an excellent web site that explains what the information consists of and tutorials for how to use it (http://www.census.gov/main/www/cen2000.html). Unfortunately, the available data does not *fully* provide the level of detail needed for local cable plant infrastructure planning. Also, it needs to be viewed graphically using a GIS system to make much sense of it. For example, the smallest geographic area of census information is the block, which they define as “An area bounded on all sides by visible and/or nonvisible features shown on a map prepared by the Census Bureau.” They are variable size areas designated by 4-digit numbers. This makes it difficult to comprehend the information unless it is viewed graphically along with streets, residential, and business point data. The data sets and services provided by the 2000 Census are described in a 4-page document at http://www.census.gov/prod/2001pubs/mso-01icdp.pdf.

The Census Bureau web site provides a query system called American FactFinder that supports queries of selected databases from which reports can be generated and downloaded (see http://factfinder.census.gov/servlet/BasicFactsServlet). This system is great, if you can obtain the information you are seeking. Pay attention to the American FactFinder database query system, because it is a good example of a tool that should not be taken for granted. Why is that?

The Census Bureau makes their raw census data and geographic TIGER files available on-line for download. TIGER stands for Topologically Integrated Geographic Encoding and Referencing system. Unfortunately, these files are very large and they contain many variables. It takes a lot of time and resources to download the information, understand how it is organized, store it in a geodatabase, and figure out how to access it to generate reports and print maps. American FactFinder makes it easy to perform a limited subset of functions online, which can save you a lot of work. At least two commercial companies, SRC and GeoLytics, take it further than American FactFinder to enable desktop access to the information. SRC also provides a more extensive on-line service.

The University of Michigan's Documents Center web site provides a comparative analysis of sources of census/demographic information that is useful (see http://www.lib.umich.edu/govdocs/compcen.html). For additional details, see http://www.lib.umich.edu/govdocs/cen2000.html.

### *SRC*

SRC offers both on-line and PC based software solutions for accessing the massive Census Bureau data. They compress and preprocess data, plus provide a database query front-end to make it easier to access.

SRC offers two on-line services. One is free at http://www.freedemographics.com/. The other is offered for a monthly, or annual fee, and it can be accessed at http://www.demographicsnow.com/default.htm. The fee-based service provides the ability to create customized queries, reports, and maps on-line.

The PC based software product is called Allocate. It is a data engine that compresses, stores, manages, retrieves and displays geographically organized data. The data can include demographic attributes, customer data, or other data that can be organized into standard census or postal geographies. Data can be exported in both ESRI and MapInfo formats. SRC also offers other PC based software products.

### GeoLytics

GeoLytics offers PC based software products similar to SRC's Allocate product. All of their census products come with mapping capabilities so you can see full color maps with the sub-areas you select delineated on the map. They allow exporting of both the data and the geographic boundaries into databases, SAS, SPSS, ArcView, MapInfo, and several other common software packages. For details, see http://www.uscensus.info/.

# Quick Reference to Frequently Asked Questions

1) Why is it difficult for an established telecommunications company to make this investment? (Volume 1, Volume 5)

2) There is already too much fiber in the ground. Why not use what's there? (Volume 1, Volume 2, Volume 6)

3) The principal design criterion driving the development of this infrastructure is that every user has the potential to be a "producer" in the network economy. Is this the same as "broadband", as it is currently hyped in the industry? (Volume 1)

4) Can we quantify the potential jobs that will be created if a region invests in building advanced telecommunications infrastructure? (Volume 1)

5) What should be the Tobacco Commission's role in the deployment of first mile technologies? (Volume 1, Volume 3, Volume 5, Volume 7, Volume 8)

6) How can localities ensure that they get early access to the network? (Volume 1, Volume 5, Volume 8)

7) What kind of success have other regions had with the development of network infrastructure for economic development? (Volume 1)

8) What regulatory factors should be considered when investing in wireless technologies? (Volume 1, Volume 7)

9) Why do we need to connect to network points outside of the tobacco regions? (Volume 2)

10) Once the network is in place, what do we do with it? (Volume 2, Volume 8)

11) Since the business model for inter-regional and inter-county infrastructure did not include the use of conduit facilitating blown fiber strands, what are the circumstances in which this technology is appropriate and financially feasible? (Volume 3, Volume 7)

12) How do existing community networks fit into the overall design? (Volume 3, Volume 5, Volume 6)

13) What are some examples for deployment in the first/last mile? (Volume 3, Volume 7)

14) What type of fiber is recommended? (Volume 3)

15) What would a network design for my county look like? (Volume 3)

16) How much would all this cost? (Volume 3, Volume 5)

17) What is the appropriate organization model for managing and sustaining the Tobacco Commission's investment in critical technology infrastructure? (Volume 5)

18) Tobacco region communities are underserved because the private sector does not see a profitable business case. What makes this feasible from a business perspective? (Volume 5)

19) If the traditional investment model for developing critical technology infrastructure has failed, what is the alternative? (Volume 5)

20) How much would it cost for consumers in the region to use the network? (Volume 5)

21) What technologies enable use of the fiber? (Volume 6)

22) How does the choice of technology to light the fiber impact the cost? (Volume 6)

23) How do wireless technologies fit into this framework? (Volume 7)

24) What is meant by the term "open access"? (Volume 8)

25) What is the difference between the broadband hype and the "next generation" networks? (Volume 8)

26) What are some next generation Internet (NGI) applications? (Volume 8)

# Appendix

## Sources of Information for Planning and Engineering

If one needs information for how to plan and engineer fiber optic infrastructure, it is useful to know where to look it up. This section identifies some of the practical sources, which are more directly pertinent to the tasks.

There are numerous books on fiber optic technology, but relatively few cover the details on how to plan, design, and build fiber optic infrastructure. Some of the better sources are from BICSI (Building Industry Consulting Service International), SCTE (Society of Cable Telecommunications Engineers), RUS (Rural Utilities Services), standards organizations, and product manufacturers. These are covered in more detail below.

Many of the documents listed in this section can be purchased from Global Engineering Documents (http://global.ihs.com/). BICSI and SCTE offer discounts on publications to members, so you may wish to join. These organizations also provide training and other services.

In addition to information in the telecommunications field, one needs information from non-telecomm fields to help address the full scope of work. Some of these include electrical power, HVAC (Heat, Ventilation, and Air Conditioning), Civil Engineering, GIS (Geographical Information Systems), construction, project management, business, and operations. Many of the sources for these are provided in this section.

### *Codes and Regulations*

In addition to the codes and regulations listed below, one must also follow the state/local codes and regulations in areas where work is planned.

- NESC: National Electrical Safety Code 2002 (http://standards.ieee.org/nesc/)
- National Electrical Safety Code Handbook, by David Marne, McGraw-Hill, 2002—includes OSHA standards related to the NESC work rules

- NEC: 2002 National Electrical Code (http://www.nfpa.org/Home/index.asp)
- OSHA: Occupational Safety and Health Administration (http://www.osha.gov/)
- RUS: USDA Rural Utilities Services telecommunications publications from 7 CFR parts 1751, 1753, and 1755 (http://www.usda.gov/rus/telecom/index.htm)

### *Standards*

Planners do not necessarily need copies of the standards publications listed in this section, but it is useful to check out organizations web sites to know what they offer. The BICSI publications listed below provide a good overview of the standards organizations and they address many of the applicable issues. In addition, the BICSI and SCTE documents are much less expensive than those from certain standards organizations.

- ANSI/TIA/EIA-758, Customer-Owned Outside Plant Telecommunications Cabling Standard, Telecommunications Industry Association, 1999. (This standard is included in the set of TIA/EIA Wiring Standards. Also, the material is well covered in the BICSI Customer-Owned OSP Manual.)
- ANSI/TIA/EIA : Wiring Standards (http://global.ihs.com/)
- EIA: Electronic Industries Alliance (http://www.eia.org/)
- IEEE: Institute of Electrical and Electronics Engineers (http://standards.ieee.org/)
- ITU-T: International Telecommunications Union, Telecommunications Sector (http://www.itu.int/ITU-T/)
- TIA: Telecommunications Industry Association (http://www.tiaonline.org/)
- Telcordia Technologies (http://www.telcordia.com/)

### *Industry Publications*

All of the references in this section are highly recommended. The best place to obtain the BICSI and SCTE publications are direct. Their web sites are http://www.bicsi.org/ and http://www.scte.org/home.cfm, respectively. Consider joining as members to take advantage of publication discounts, training, and other services. The current BICSI annual membership fee is $150 for an individual. The current SCTE annual membership fee is $48 for an individual. As a comparison, the current basic IEEE annual membership is $143 for an individual. The IEEE has additional charges to be members of their various societies. One of interest is LEOS, the Lasers and Electro-Optics Society, which is only another $18 per year.

- *Customer-Owned Outside Plant Design Manual, 2nd Ed.*, BICSI, 2001.
- *Telecommunications Distribution Methods Manual, 9th Ed.*, BICSI, 2000.
- *BICSI Telecommunications Cabling Installation, 2nd Ed.,* McGraw-Hill, 2002—this book is sold through bookstores.
- *Recommended Practices for Optical Fiber Construction and Testing, 2nd Ed.,* SCTE (Society of Cable Telecommunications Engineers), 2001.

The "must have" reference to begin with is the BICSI *Customer-Owned Outside Plant Design Manual*. It is available in hard copy and on CDROM.

## *Product Manufacturer Publications*

The following publications are useful and available for free download via the web.

- "Access Solutions Guide," Corning Cable Systems, 2002 (http://www.corningcablesystems.com/web/pubnet/pubnet.nsf/ehtml/asg)
- "LANscape Design Guide, Release 4," Corning Cable Systems (http://www.corningcablesystems.com/web/library/library.nsf/ehtml/index)
- "A Guide to Select Single-Mode Fibers for Optical Communications Applications," Alessandro Barbieri, Cisco Systems (http://www.webtorials.com/main/resource/papers/cisco/paper20.htm)

## *Practical References*

If you want to learn how to design, install, and maintain fiber optic cable plant, then the books in this section should help. More are listed at the end of this paper.

- Eric Pearson, *The Complete Guide to Fiber Optic Cable System Installation*, Delmar, 1997.
- Barry Elliott and Mike Gilmore, *Fiber Optic Cabling, 2nd Ed.*, Newnes, 2002.

- Roger L.  Freeman, *Fiber Optic Systems for Telecommunications*, John Wiley and Sons, New York, 2002.
- Thomas M.  Shoemaker and James E.  Mack, *The Lineman's and Cableman's Handbook*, McGraw-Hill, 2002.
- Ashwin Gumaste and Tony Antony, *DWDM Network Designs and Engineering Solutions*, Cisco Press, 2003.
- Dennis Derickson, *Fiber-Optic Test and Measurement*, Prentice Hall, 1998.
- Bob Chomycz, *Fiber Optic Installer's Field Manual*, McGraw-Hill, 2000.
- Jim Hayes, *Fiber Optics Technician's Manual, 2nd Ed.*, DELMAR, 2001.
- Jerry C.  Whitaker, *AC Power Systems Handbook*, CRC Press, 1997.


## *Additional References and Sources of Information*

Knowing where to look up information needed for planning, engineering, and building fiber optic cable plant can be valuable.  Some of the references given in this section provide pointers to additional lists of references.  This list is unique in that it attempts to cover the full scope of issues relevant to building fiber optic infrastructure.

## *Optical Network Technology and Applications*

References in this section provide a good overview of the technology and the applications.  Debra Cameron's excellent book on Optical Networking provides a well researched overview of optical networking technologies and applications.


- Debra Cameron, *Optical Networking*, A Wiley Tech Brief, Wiley, 2002.
- Steven Shepard, *Optical Networking Crash Course*, McGraw-Hill, 2001.
- Robert C.  Elsenpeter and Toby J.  Velte, *Optical Networking: A Beginner's Guide*, McGraw-Hill/Osborne, 2002.
- David Greenfield, *The Essential Guide to Optical Networks*, Prentice Hall PTR, 2002.
- Daniel Minoli, Peter Johnson, and Emma Minoli, *Ethernet-Based Metro Area Networks,* McGraw-Hill, 2002.
- Daniel Minoli, Peter Johnson, and Emma Minoli, *SONET-Based Metro Area Networks*, McGraw-Hill, 2002.

- Heinz Willebrand and Baksheesh S. Ghuman, *Free-Space Optics: Enabling Optical Connectivity in Today's Networks*, SAMs, 2002.
- Edited by Casimer DeCusatis, *Handbook of Fiber Optic Data Communication, 2nd Ed.*, Academic Press, 2002.
- Edited by Casimer DeCusatis, *Fiber Optic Data Communication Technological Trends and Advances*, Academic Press, 2002.
- Ray Tricker, *Optoelectronics and Fiber Optic Technology*, Newnes, 2002.
- Uyless Black, *Optical Networks, Third Generation Transport Systems*, Prentice Hall, 2002.
- Peter Tomsu and Christian Schmutzer, Next *Generation Optical Networks, The Convergence of IP Intelligence and Optical Technologies*, Prentice Hall, 2002.
- Walter Goralski, *Optical Networking & WDM*, Osborne/McGraw-Hill, 2001.
- Viswanath Mukherjee, *Optical Communication Networks*, McGraw-Hill, 1997.

## *Fiber Optic Network Technology and Theory*

When you are ready to dig deeper into fiber optic technology, the books in this section are a good place to start.

- Djafar K. Mynbaev and Lowell L. Scheiner, *Fiber-Optic Communications Technology*, Prentice Hall, 2001.
- Rajiv Ramaswami and Kumar N. Sivarajan, *Optical Networks, A Practical Perspective, 2nd Ed.*, Morgan Kaufmann, 2002.
- Jeff Hecht, *Understanding Fiber Optics, 4th Ed.*, Prentice Hall, 2002.
- David R. Goff, *Fiber Optic Reference Guide, A practical Guide to Communications Technology, 3rd Ed.*, Focal Press, 2002.
- Ajoy Chatak, K. Thyagarajan, *Introduction to Fiber Optics*, Cambridge, 1998.
- Gunther Mahlke and Peter Gossing, *Fiber Optic Cables, 4th Ed.*, Publicis MCD, 2001.
- Govind P. Agrawal, *Fiber-Optic Communication Systems, 3rd Ed.*, Wiley, 2002.
- Michael Bass and Eric Van Stryland, *Fiber Optics Handbook—Fiber, Devices, and Systems for Optical Communications,* McGraw-Hill, 2002.
- Leo Setian, *Applications in Electro-Optics*, Prentice Hall, 2002.

- Stamatios V. Kartalopoulos, *Introduction to DWDM Technology*, IEEE Press, 2000.
- Thomas E. Stern and Krishna Bala, *Multiwavelength Optical Network, A Layered Approach*, Addison Wesley, 1999.

## GIS (Geographic Information Systems)

Good references are hard to find in the area of GIS, but the ones listed below provide a beginning. Grant Thrall, one of the authors below, is also VP for Business Development at GeoTel. GeoTel offers geographic data for telecommunications (see http://www.geo-tel.com/index.html).

- Paul A. Longley, Michael F. Goodchild, David J. Maguire, and David W. Rhind, *Geographic Information Systems and Science*, Wiley, 2001.
- Grant Ian Thrall, *Business Geography and New Real Estate Market Analysis*, Oxford , 2002.
- George B. Korte, P.E., *The GIS Book*, Onword Press, 2001.
- Charles A. Heatwole, *Geography for Dummies*, Hungry Minds, 2002.

## Civil Engineering

The Civil Engineering references in this section cover numerous aspects of planning and engineering for land development, including the use of GIS. Many of the concepts discussed are useful for telecommunications infrastructure planning.

- T.R. Dion, *Land Development for Civil Engineers, 2nd Ed.*, Wiley, 2002.
- Sidney Dewberry , Editor in Chief, *Land Development Handbook, Planning, Engineering, and Surveying, 2nd Ed.*, McGraw-Hill, 2002.

## Construction Project Management, Contracts, and Cost Estimation

After all said and done, it comes down to project management, construction, and cost. References in this section should be helpful.

- Tom Mochal, TenStep Inc., http://www.tenstep.com/

- Edward R. Fisk, *Construction Project Administration, 7th Ed.*, Prentice Hall, 2003.
- Tarek Hegazy, *Computer-Based Construction Project Management*, Prentice Hall, 2002.
- Richard H. Clough, Glenn A. Sears, and S. Keoki Sears, *Construction Project Management, 4th Ed.*, Wiley, 2000.
- Dave Ogershok, *2002 National Construction Estimator, 50th Ed.*, Craftsman Book Company, 2001.
- Craig Savage and Karen Jones-Mitchell, *Construction Forms and Contracts*, Craftsman Book Company, 2000.

## Writing RFPs and Grant Requests

Writing grant requests and RFPs are a chore, but these references help to make it a little easier.

- Bud Porter-Roth, Request for Proposal, *A guide to Effective RFP Development*, Addison-Wesley, 2002.
- Beverly Browning, *Grant Writing for Dummies*, Hungry Minds, 2001.
- Reva Basch and Mary Ellen Bates, *Researching Online for Dummies*, IDG Books, 2000.

## Providing Services

Once the fiber optic infrastructure is built, if not long before, you need a good business plan. These references should help you understand some of the issues.

- Paul Tiffany and Steven Peterson, *Business Plans for Dummies*, IDG Books, 1997.
- P.J. Louis, *Telecom Management Crash Course*, McGraw-Hill, 2002.
- Howard Berkowitz, *Building Service Provider Networks*, Wiley, 2002.
- Karen G. Strouse, *Strategies for Success in the New Telecommunications Marketplace,* Artech House, 2001.
- Pete Moulton and Jason Moulton, *The Telecommunications Survival Guide*, Prentice Hall PTR, 2001.

- Kornel Terplan and Patricia Morreale, Editors in Chief, *The Telecommunications Handbook*, CRC Press, 2000.
- Karen G. Strouse, *Marketing Telecommunications Services*, Artech House, 1999.
- Geoff Huston, *ISP Survival Guide*, Wiley, 1999.


## *Studies and Reports on High-speed Infrastructure Deployment*

Why not learn from those that have already blazed the trail? Check out the references in this section. All but the Chilson Report are free.


- Customer Owned Fibre Networks, collection of online papers, CANARIE, http://www.canarie.ca/canet4/library/customer.html.
- ZIPP, Grant County Public Utility District, Fiber Optic Network, see http://www.gcpud.org/zipp/default.htm
- "Feasibility Study Broadband Network Infrastructure for the Town of Cary," Rendall and Associates for the Town of Cary, N.C., October 27, 1999.
- "Digital Rivers Final Report," Carnegie Mellon University and 3 Rivers Connect, April 11, 2002, http://www.digitalrivers.info/digital_rivers/index_report.htm.
- "Broadband Access Report," Chilson Enterprises, 2002, http://www.chilson-enterprises.com/report/
- "General guide to a future-proof IT infrastructure," The Swedish ICT Commission, 2001.
- Ross Kelso, "Innovative Bandwidth Arrangements for the Australian Education and Training Sector, Stage 1: Assessment of Overseas Approaches," CIRCIT at RMIT, Aug. 2001.


## *Periodicals and Magazines for Fiber Optic Networking*

- Cabling Business Magazine, http://www.cablingbusiness.com/
- CommsDesign, http://www.commsdesign.com/dcenters/opticalnetworking
- Fiber Optic Product News, http://www.fpnmag.com/scripts/default.asp
- Laser Focus World, http://lfw.pennnet.com/home.cfm
- Light Reading, http://www.lightreading.com/default.asp
- LightWave, http://lw.pennnet.com/home.cfm

- Network World Fusion, http://www.nwfusion.com/edge/topics/optical.html
- Optical Networks Magazine, http://optical-networks.com/
- SPIE, The International Society of Optical Engineering, http://www.spie.org/
- Telephony Online, http://telephonyonline.com/optical/index.htm

### Market Research Organizations

- Communications Industry Researchers, Inc. http://www.cir-inc.com/index.cfm
- KMI Research http://www.kmiresearch.com/
- In-Stat/MDR http://www.instat.com/
- Miercom http://www.mier.com/
- Frost & Sullivan http://www.frost.com/
- Gartner, Inc. http://www.gartner.com/
- Market Research Association http://www.mra-net.org/
- MarketResearch.com http://www.marketresearch.com/
- PricewaterhouseCoopers http://www.pwcglobal.com/
- Information Gatekeepers, Inc. http://www.igigroup.com/st/pages/lightwaveseries.html
- The Telnecity Group http://www.telnecity.com/special_reports.html
- The Tolly Group http://www.tolly.com/
- Wainhouse Research http://www.wainhouse.com/index.html
- Daratech, Inc. http://www.daratech.com/white_papers/gis_review.html

## Generic Cost Information for Building Fiber Optic Infrastructure

Information in this section is provided courtesy of RACO, Inc., Gretna, VA (Tel: 434-656-6676). RACO provides cable plant engineering and construction services.

### Engineering

Basic Engineering Can Run From $6000 to $8000 per mile:

- Right of Way (ROW) selection and acquisition
- Route design

- Preparation of preliminary engineering drawings
- DOT permit applications
- Railroad crossing permit applications
- Pole attachment agreement application
- Preparation of as-builts

Note: If the engineering firm is required to:

- prepare the overall bid package;
- assemble all the necessary forms and bid sheets;
- prepare specific definitions of all units;
- assemble completed bid packages;
- make multiple copies;
- conduct pre-bid conference;
- have an inspector on-site during construction;
- accept the project upon completion of construction;

then all of this can add significantly to the overall “per mile” fee.

## *Aerial Construction*

Aerial construction costs are $12,000 to $15,000 per mile

Some of the variables involved include:

- price of strand
- cable
- hardware
- make ready
- rights-of-way

One of the major cost variables will be how much pole “make-ready” work needs to be done in preparation for the additional cable, i.e., replacing poles, rearranging existing cable or power lines. Depending upon the county, city, or other entity with which you are dealing, this item can present a major "unexpected" expense.

It is critically important to know, as budgets are prepared for fiber optic infrastructure development, whether permission has been secured to attach to existing poles AND exactly what the costs will be.

### *Buried Construction*

Cost for buried construction generally runs from $28,000 to $32,000 per mile.

Costs involved can vary greatly depending upon:

- how much "directional boring" will have to be done
- whether the cable is buried by itself, or placed in an innerduct
- the extent of rock conditions

Extensive rock can greatly inflate buried construction costs.

### *Splicing*

For a typical 40-mile project, with a combination of both aerial and buried construction, splicing costs can run from $90,000 to $110,000. This, of course, depends on the number of splices (and the number of fibers) called for in the engineering design.

### *Cable/Fiber*

Prices can vary significantly from supplier to supplier, depending greatly upon the fiber specifications, fiber count, and the total project footage.

### *Major Issues to Address*

- Early identification of collaborators
- Pole attachment agreements

- Railroad crossing permits
- Land use permits from local DOT
- Clear understanding with local DOT what the project entails
- Clear understanding with local government officials as to the scope of the project
- Clear understanding between the owners and the general contractor as to timelines, expectations, quality of work, use of subcontractors, etc.
- Early identification of who can speak for and make decisions on behalf of the owner
- Development of a comprehensive construction, maintenance, and network management plan

## Quality Assurance Check List

This quality assurance check list is provided courtesy of Corning Cable Systems (www.corningcablesystems.com). Corning Cable Systems offers a complete set of fiber optic cables, components, and engineering services, including quality acceptance services described in this section.

This section describes check lists for:

- Post Installation Inspection Overview
- Outside Plant (Aerial)
- Outside Plant (Duct Installation)
- Outside Plant (Direct Buried Installation)
- Inside Plant

At the beginning of each of the main sections that describe inspection guidelines for aerial, duct, direct buried, and inside plant, there are references listed that include Corning SRPs (Standard Recommended Procedures) applicable to the type of cable plant. The SRPs are available from Corning Cable System's web site.

## Post Installation Inspections

Perform a visual inspection of the entire outside plant route, checking for any obvious problems, but additionally perform detailed inspections on randomly chosen sections and on all critical areas.

The items to be checked will include:

- Cable Bend Radius
- Cable Location and Proper Clearance
- Messenger Attachment
- Bonding & Grounding
- Drip Loops, Deadends, & Crossovers
- Lashing; Splice Closures and Slack Storage
- Ducts and Innerduct
- Cable Exposure
- Warning Signs
- Documentation.

The inspection will be completely non-intrusive, meaning no sealed components will be opened for inspection.

Perform a thorough inspection of the Inside Plant optical network, checking for:

- Cable Routing & Fire Safety
- Hardware Installation
- Rack Grounding
- Splicing and Connectorization
- Documentation
- Testing

Finally, perform testing spot checks to validate the installer's testing and to look for system connection errors such as cross-splicing.

At the completion of the inspection, provide a detailed Post Inspection Report, described below.

Specific inspection descriptions are below:

## Quality Inspection of Outside Plant (Aerial)

### References

- Corning Cable Systems Standard Recommended Procedure SRP-005-010 “Fiber Optic Cable Placing – Lashed Aerial”
- National Electrical Safety Code (NESC)
- BICSI Telecommunications Distribution Methods Manual (TDMM)
- Local Electrical Safety Codes (based on specific county or municipality)

### Cable Bend Radius

- Inspect Cable Bend Radius to ensure that manufacturer’s minimum cable bend radius is not violated at points where the cable turns (splice locations, pole transitions, slack storage, route direction changes that exceed 45 degrees, and transitions around installed equipment).
- Inspection Frequency: 100% of slack loops, pole transitions, and direction changes exceeding 45 degrees shall be inspected.
- Record/Report findings of compliance.

### Cable Location and Proper Clearance

- If the fiber optic cable is light in weight and its sag in aerial span is small, it should normally occupy the uppermost available communication space on the pole (see SRP-005-010).
- Inspect Cable Strand for proper minimum clearance from electric power lines and other cables that may sag near the fiber optic cable.  Determine the clearance between the fiber optic cable and existing facilities, using an appropriate measuring rod or other means, and note whether clearance complies with the National Electric safety Code (NESC) and appropriate local safety codes.

- This requirement applies to cable that is all-dielectric as well as that with metallic components, as there is always a risk of flashover (sparking) from a power line to the metallic messenger.
- Inspection Frequency:  10% of pole spans shall be measured for clearance.
- Record/Report findings of compliance.

### *Messenger Attachment*

- When the installation is a new build on a dedication messenger (i.e.  not overlashed), verify the messenger Outer Diameter (OD).
- Inspect the messenger for proper attachment to the pole, ensuring that standard hardware (eyebolts, clamps, etc.) are used.
- Inspection Frequency: 10% of pole spans shall be inspected for correct messenger components.
- Record/Report findings of compliance.

### *Bonding & Grounding*

- Inspect the installation for proper external grounding of all splice closures, to ensure the closure is grounded to the messenger.
- Inspect installation of the messenger to ensure the messenger is connected to the pole ground.
- No closures will be opened to determine whether the cable is properly attached to internal closure grounding components and whether the internal components are connected to external grounding components.
- Inspection Frequency: 100% of closures shall be inspected for grounding to the messenger.
- Record/Report findings of compliance.

### *Drip Loops, Deadends, and Crossovers*

- Ensure that drip loops are not used where optical cable is overlashed to existing coaxial cable, to prevent the possibility of the fiber optic drip loop migrating along the strand.  While this does not affect either cable plant reliability, or transmission quality, drip loop movement can detract from the overall appearance of the cable plant (see SRP-005-010).

- When drip loops are not present, inspect pole crossings to ensure the cable will not rub against the three-bolt messenger suspension clamp. This can be accomplished by using a larger spacer in the cable support strap, or a split plastic tube surrounding the cable.
- When drip loops are used, inspect the shape of the loop to ensure that it is the “smooth-curve” type. Under no circumstances should any other shapes be used. (See SRP-005-010 for proper dimensions and spacing).
- When drip loops are used, inspect for straps and spacers (in the absence of lashing wire support) to support the cable, ensuring that they are installed at least 4 inches from the drip loop and are tight enough to prevent their movement along the strand while permitting longitudinal travel by the cable.
- Inspect messenger intersections at deadends and aerial crossovers to ensure the optical cable is routed on the inside of the intersection.
- Inspection Frequency: 10% of poles shall be inspected for drip loop compliance, and proper deadend/crossover routing.
- Record/Report findings of compliance.

### *Lashing*

- Inspect lashing to ensure it is double-lashed when optical cable is installed over existing aerial cables or when cable is installed over railroads and roadways.
- Inspect lashing to ensure that it is not loose, twisted, weaving, or unraveling along the strand.
- Inspect lashing to ensure it has at least one wrap per linear foot, and is the correct size standard lashing wire for the cable and strand. (Actual spec depends upon stand and cable bundle OD).
- Inspect lashing for proper termination at each pole with a lashing wire clamp, cable spacers, and a triple wrap around the messenger as it enters the clamp.
- Inspection Frequency: 10% of pole spans shall be inspected for proper lashing and lashing termination.

### *Splice Closures and Slack Storage*

- Inspect splice closure locations to ensure that slack cable loops are stored at least 4 feet from the poles unless they are protected by a cable enclosure.

- Inspect splice closures to ensure they are mounted to the strand per manufacturer's recommended procedures.
- Inspect splice point slack to ensure enough slack remains to bring the closure to the ground and into a convenient work area, such as a tent or splice vehicle.
- Inspect slack loops to ensure the cables do not exceed the recommended minimum bend radius.
- Inspection Frequency: 100% of splice locations and slack storage locations shall be inspected for proper mounting and slack storage techniques.
- Record/Report findings of compliance.

*Documentation*

- Check installer's documentation to ensure it annotates the following:
  - Exact location of all splice points.
  - Sheath mark at the beginning and ending of every span, slack loops, and high risk intersections.
  - Amount of slack stored in slack loops.
- Inspection Frequency: 100% of splice locations, slack storage locations, and high risk intersections shall be inspected for proper documentation.
- Record/Report findings of compliance.

## *Quality Inspection of Outside Plant (Duct Installation)*

NOTE: All manholes and handholes are assumed to be readily accessible without pumping to see the components within.

*References:*

- Corning Cable Systems Standard Recommended Procedure SRP-005-011 "Fiber Optic Cable Placing – Duct"
- National Electrical Safety Code (NESC)
- BICSI Telecommunications Distribution Methods Manual (TDMM)
- Local Electrical Safety Codes (based on specific county or municipality)

### *Cable Bend Radius*

- Inspect Cable Bend Radius to ensure that manufacturer's minimum cable bend radius is not violated at points where the cable turns (manholes, handholes, pull points, duct route, closure entries, transitions to aerial).
- Inspection Frequency: 10% of manholes, handholes, pull points, pedestals, and storage locations for proper bend radius.
- Record/Report findings of compliance.

### *Ducts and Innerducts*

- Inspect the duct or innerduct to ensure that the "fill ratio" does not exceed 50%.
- Inspect continuous innerduct in manholes to ensure it is attached to racks without violation of cable bend radius and in accordance with locally prescribed standards.
- Inspect that cable is covered by innerduct or split duct where innerduct is not continuous through a manhole (this includes places where innerduct is spliced together).
- Inspection Frequency: 10% of manholes/handholes should be inspected for duct/innerduct requirements.
- Record/Report findings of compliance.

### *Bonding & Grounding*

- Inspect the installation for proper external grounding of all splice closures, to ensure the closure is grounded to the manhole or handhole ground, and whether that ground is properly grounded.
- No closures will be opened to determine whether the cable is properly attached to internal closure grounding components and whether the internal components are connected to external grounding components.
- Inspection Frequency: 100% of closures shall be inspected for external grounding.
- Record/Report findings of compliance.

### *Splice Closures and Slack Storage*

- Inspect splice point slack to ensure enough slack remains to bring the closure out of the manhole, handhole, or pedestal and into a convenient work area, such as a tent or splice vehicle.
- Inspect slack loops to ensure the cables do not exceed the recommended minimum bend radii.
- Inspection Frequency: 100% of splice locations and 10% of slack storage locations shall be inspected for slack storage techniques.
- Record/Report findings of compliance.

### *Documentation*

- Check installer's documentation to ensure it annotates the exact location of all splice points.
- Check installer's documentation to ensure it annotates the sheath mark at manholes, handholes, pull points, and pedestals and at every splice location.
- Check installer's documentation to ensure it annotates the amount of slack stored in slack loops.
- Inspection Frequency: 100% of splice locations shall be inspected for location and sheath marks. Spot check sheath mark and slack storage documentation for 10% of manholes, handholes, pull points, and pedestals.
- Record/Report findings of compliance.

## *Quality Inspection of Outside Plant (Direct Buried Installation)*

### *References*

- Corning Cable Systems Standard Recommended Procedure SRP-005-012 "Fiber Optic Cable Placing – Direct Buried"
- National Electrical Safety Code (NESC)
- BICSI Telecommunications Distribution Methods Manual (TDMM)
- Local Electrical Safety Codes (based on specific county or municipality)

*Cable Bend Radius*

- Inspect Cable Bend Radius to ensure that manufacturer's minimum cable bend radius is not violated at points where the cable turns (manholes, handholes, pull points, duct route, closure entries).
- Inspection Frequency: 10% of manholes, handholes, pull points, pedestals, and storage locations for proper bend radius.
- Record/Report findings of compliance.

*Cable Exposure*

- Inspect that no cable is exposed along route.
- Inspect that no cable is exposed at transition points, such as approaches to handholes, manholes, and poles.

*Warning Signs*

- Cross-check installer's documentation to verify the actual location of buried optical cable warning signs are consistent with the documented locations.
- Inspection Frequency: 10% of documented warning sign locations shall be physically verified.
- Record/Report findings of compliance.

*Documentation*

- Check installer's documentation to ensure it annotates the exact location of all splice points.
- Check installer's documentation to ensure it annotates the sheath mark at manhole, handhole, pull point, and pedestal and at every splice location.
- Check installer's documentation to ensure it annotates the amount of slack stored in slack loops.
- Inspection Frequency: 100% of splice locations shall be inspected for location and sheath marks.  Spot check sheath mark and slack storage documentation for 10% of manholes, handholes, pull points, and pedestals.
- Record/Report findings of compliance.

## *Quality Inspection of Inside Plant*

### *References*

- Corning Cable Systems Standard Recommended Procedure SRP-005-014 "Intrabuilding Installation of Corning Cable Systems Fiber Optic Cable"
- National Electrical Safety Code (NESC)
- BICSI Telecommunications Distribution Methods Manual (TDMM)
- Local Electrical Safety Codes (based on specific county or municipality)

### *Cable Routing & Fire Safety*

- Inspect Cable Bend Radius to ensure that manufacturer's minimum cable bend radius is not violated at points where the cable turns (fiber entrance cabinets, duct entrances, hardware entrances, ladder racks, etc.).
- Inspect cable routing to ensure the cable is not deformed, pinched, or otherwise compressed by other cables, securing straps, or sharp edges.
- Inspect cable entrance to ensure that no more than 50' of non-fire rated outside plant cable is routed within a building unless enclosed within a rigid metal conduit or EMT. Otherwise, the OSP cable must be transitioned to a flame-rated cable within 50' of its entrance to the building. (See NESC Article 770-50)
- Inspect all indoor cable to ensure that flame-rated cable is used solely within the confines of its rated application or a less restrictive application (for instance riser rated cable used in riser or general application only – not in a plenum environment).
- Inspect the deployment of cables to ensure that they comply with all local codes and standards, in addition to the advisories of the National Electric Safety Code (NESC).
- Inspection Frequency: 100% of inside plant cabling shall be inspected for compliance with fire & safety codes.
- Record/Report findings of compliance.

### *Hardware Installation*

- Inspect that all hardware is properly mounted into frames per manufacturer's recommendations.

- Inspect each cable end to ensure the cable is properly strain-relieved to minimize risk to the fibers from accidental pulling on the cable or natural expansion/contraction effects.
- Inspect each cable with rigid components (central members, rods, armor, etc.) to ensure the rigid components cannot damage the fibers in case of mechanical agitation or expansion/contraction effects.
- Inspect each cable end to ensure it is properly terminated per manufacturer's recommended procedures for both the cable and the hardware to which it is attached.
- Inspection Frequency: 100% of cable ends shall be inspected for compliance.
- Record/Report findings of compliance.

### *Rack Grounding*

- Inspect that all fiber-related racks are properly grounded to the building ground.
- Inspect that all hardware to which cable containing metallic components is mounted is properly grounded to the rack.
- Inspection Frequency: 100% of cable ends shall be inspected for compliance.
- Record/Report findings of compliance.

### *Splicing and Connectorization*

- Spot check fiber splice trays to ensure that manufacturer's recommended procedures have been followed (securing of splices, splice protection, routing of fibers, securing of tubes, etc.)
- Spot check optical connectors to ensure that connectors have been installed per manufacturer's recommended procedures, checking for proper assembly, excess epoxy, security of boot, attachment to aramid yarns (if applicable), etc.
- Inspect each connector installed into an adapter to ensure the connector is properly seated and that the fiber is not under tension or in violation of bend radius limitations.
- Inspection Frequency: 10% of splice trays and connectors shall be inspected for compliance with manufacturer's installation guidance. 100% of connectors shall be checked for fiber tension.
- Record/Report findings of compliance.

### *Documentation*

- Inspect hardware labels to ensure they have been marked with the proper usage labeling. Spot check to determine accuracy of labels.
- Inspection Frequency: 10% of labels shall be spot checked for accuracy.

### *Testing*

- Perform spot checks to verify installer's system testing, including OTDR tests and End-to-End Attenuation testing.
- Perform OTDR Tests on 10% of available fibers to compare to installer's test results. Although fibers should be chosen randomly in general, the selected set should include commonly cross-spliced fiber and tube colors (Brown, Orange, Red, Blue and Aqua).
- Perform OTDR tests on all unterminated fibers, if the installer did not record OTDR traces on these fibers after installation.
- Perform End-to-End Attenuation testing on 10% of terminated and unterminated fibers, to compare to installer's test results and ensure system operability.
- Report all findings outlining contractor test results and verification results. Highlight non-compliant test results.

### *Post Inspection Report*

- Provide a detailed report to the customer on the findings of the inspection. The report shall consist of a listing of all sections chosen for inspection and any discrepancies or concerns noted at that location. Discrepancies will carry a notation as to the severity of the issue and whether it requires any corrective action.
- Additionally, recommend a corrective action to remedy any discrepancies that require action for system performance or long-term reliability.
- This report shall be provided to the customer within 5 business days following completion of the inspection.
- Any discrepancies which constitute safety violations or pose an immediate threat to the operational system shall be identified to the customer as soon as possible after they are discovered, without waiting for the formal report to be issued.

- Corrected deficiencies should be re-inspected and a final inspection report issued after all discrepancies have been corrected and re-inspected.

## Functionality Needed for Cable Management System

Advance Fiber Optics, Inc., provided the following white paper that describes the need for a fiber optic cable management system. They developed fiber optic management software to support their engineering and construction business, so they have first-hand knowledge of the requirements (see http://www.ospinsight.com). Some vendors refer to this type of software as Asset Management and/or Facilities Management software.

### *Why You Need a System for Managing Your Network*

### *Common Tasks*

For a telecommunications provider to remain competitive, it is imperative they perform a number of day-to-day activities to not only maintain the existing system, but also plan to expand the network and introduce new technologies. These tasks happen to be those that a Fiber Management System not only aids in executing, but in many cases, completes the tasks in seconds, where it now would take tens of minutes, or even hours. Thus, for the tasks listed below, an FMS can save hundreds of man-hours per year.

*Some specific examples of common tasks:*

- Management of OSP Facilities
- System Capacity Accounting
- System Build Accounting
- Lease / Own Accounting
- Bandwidth Accounting

*Maintenance of OSP Facilities*

- Cable Cut Restoration
- Traffic Routing
- Call Before You Dig
- Ability to Locate Facilities

- Equipment / Hardware Mortality Planning
- Test Equipment Interfaces
- Technician's General Understanding of the Network

*Designing OSP Facilities*

- Prototyping and Analysis
- Planning and Budgeting
- Loss Estimation Analysis
- Splice Cut Sheets

*Planning OSP Facilities*

- Marketing Analysis
- Sales Analysis

*Customer Support*

- Trouble Ticket Management
- Provisioning Support

*Future Technology Analysis*

- WDM Studies
- Polarization Maintaining Fiber Studies
- Fiber-to-the-curb Studies
- Erbium-Doped Fiber Amplifier (EDFA) Studies

## *A central repository*

A primary reason for implementing a system is to organize all of your network documentation (maps, engineering drawings, photos, documents, OTDR traces, etc.) into one archive so that you can actually find information about your network on demand.

The more forward-thinking companies may actually have all of their CAD engineering drawings stored electronically and if they're really looking ahead, their network mapped in a GIS system, such as MapInfo®, ArcInfo®, Intergraph®, and others.

However, even with maps and drawings archived on a server, there is absolutely no relationship between the maps, CAD, and any tabular data. In other words, the records are in disparate formats, and can only be retrieved by opening the application they are stored in. In any event, they are still difficult to retrieve, and difficult to relate to anything.

So, an electronic system which stores data and maps in a relational database offers the ability to retrieve any information about the network (maps of fiber or copper routes, graphics of distribution panels, and data supporting every asset) on demand, and from different vantage points within the database (remember, it's relational).

### *Day-to-day maintenance, operations and reporting*

Having all of your network's information located in a single archive makes it possible to set up a schedule for daily operations and maintenance. An example of this could be the creation of a maintenance program as a result of failing equipment; say, a leaking splice enclosure. By identifying the faulty enclosure, the network administrator could perform queries on all enclosures, based on equipment type, or by manufacturer, or model, or install date, or by contractor. This would allow technicians to identify all enclosures specified by the query, and then establish a schedule to examine them for possible problems.

Additionally, reports on network growth (construction), fiber in service, fiber available, customer types, installed fiber and equipment in specific areas (for tax purposes), and a host of other needs can be easily and quickly performed.

### *Locating faults to minimize disasters*

One of the most frustrating, and agonizing, tasks of managing a network is locating faults. While most networks have redundancy built in to prevent loss of service, the break in the fiber or copper cable must still be located and repaired as quickly as possible. The traditional method of finding a fault involves shooting the OTDR trace to obtain a distance to the break, then pulling out maps of the network and calculating, by the scale on each map, the distance to the fault.

Multiple hours are generally required to accomplish this. However, with a fiber management system, the process is both faster and easier because:

- All data is in one location
- The data is also related
- You can identify the location from which the OTDR was shot, enter the distance into a fault locating field, and in a matter of seconds view the approximate location on an electronic map

Supporting documentation, such as maps, cable data, splice schematics at the nearest enclosure, and a report listing the customers that are on the affected fibers can be produced in just a few seconds. So by the time a fault is located the traditional way, it could be already repaired as a result of using a fiber management system.

## *Prototyping new routes*

Engineering a new cable route, even when running a spur from the ring to a customer's location, can be an expensive proposition, especially when CAD drawing time costs are included. While fiber management systems aren't intended to provide the detail that CAD does, they can provide a nearly cost-free method for testing possible routes prior to actually engineering the build. And for budgeting, the prototype routes can be populated with equipment and materials to provide a complete picture of the upcoming build, and this can be given to the network designers to fully engineer.

## *What Needs to Be Documented*

What you are trying to build is a virtual model of your network. While "virtual" means an electronic facsimile, you are essentially mimicking every asset in your network: cable routes, equipment, splice enclosures, buildings, distribution frames--the works.

Of course, the amount of assets to be documented depends on how detailed you want your network model to be, and how your company intends to use the data. Most providers see a fiber management system database as a focal point for their entire business. In addition to serving the needs of outside plant engineers and maintenance, sales will use it to win new customers; marketing will leverage the data to expand your company's influence and market share. Accounting will want information for billing and tax purposes.

Conversely, a company might only require minimal data to run the system. Those items below that are marked with an asterisk (*) provide the minimum information required to establish a fiber management system. The rest are data categories necessary to create a complete outside plant, fiber management database.

### *Cable Information*

- The number of fibers in the cable*
- The cable type (manufacturer and model)
- Install year, company, and work order (if available)
- Reel info (reel number, test company, test year, optical length, physical length, attenuation) (if available)

### *Access Point Information (manholes, handholes, aerial splices or slack coil)*

- Location (address, cross streets, placement, etc.)*
- Type/size
- Plate or cover markings

### *Splice Enclosure Information*

- The access point where the enclosure is located*
- Closure type (manufacturer, model/part numbers, size, capacity, ports)
- Install year, company, and work order (if available)
- Splice key detail (what cables enter the enclosures and how are the fibers spliced)*
- Sequential numbers/markings (if available)

### *Building Information*

- Location (street address, city, state, zip code, latitude/long coordinates)*
- Name*
- CLLI codes (if available)

### *Fiber Distribution Panels*

- The building where the panel is located*
- The location of panel within the building (room, bay, shelf)
- The panel type (manufacturer, model number, panel layout, and connector type)
- Install year, company, and work order (if available)
- Termination key (what cables enter the panel and what jacks are the fibers terminated or spliced into)*
- Sequential numbers/markings (if available)

### *Equipment*

- The building where the equipment is located*
- The location of equipment within the building (room bay, shelf, slot)
- Install year, company, and work order (if available)
- Type (OC-3, OC-12, etc.)
- Manufacturer, model number, and connector type
- OSP fibers connected to equipment*

### *Duct Information*

- Conduit and type
- Innerduct
- The route of the duct/conduit
- The route of the innerduct

### *Pole Information*

- The location of the pole
- The identification number
- The cables attached to the pole
- Cables of other providers and companies also attached to the pole

### *Customer Information*

- Customer name
- Contact name and telephone number

## Documents

- CAD drawings of routes
- CAD drawings of buildings (floor plans)
- Contracts, work orders, disaster recovery plans, etc.
- Photos
- Manufacturers' drawings
- Butterfly drawings of access point

A well-engineered software package will allow you to use it as a tool to catalogue your outside documents – CAD, photos, etc. – by location or equipment, making retrieval much easier and quicker.

## How Data are Gathered and Input

For those just initiating the construction process, this data can be gathered in the field during the build according to the requirements of the software. For example, OSP InSight system comes with specially formatted worksheets in Microsoft Word® for documenting splice locations, termination locations, equipment, and poles.

Next, the data needs to be entered and verified in an orderly process.

Here is what we recommend:

- Develop standards for all data. Decide on colors and line styles for drawing fiber routes. Create a naming/numbering standard for all network assets that all participants in the company will adhere to.
- Review the hard copy and electronic data first with engineering to verify accuracy
- You should create a "Data Input and Verification Report" sheet that accompanies the hard copy data in order to track and verify input progress and accuracy. Typically an engineer is responsible for this
- Input the data into your system. The person inputting the data should complete his or her section of the sheet in order to maintain a log for what data has been entered

- The engineer responsible should compare the hard copy data with that input into your system to verify accuracy. Remember, whatever goes in is what will come out when you need it most. And you don't want garbage going in…
- Once the electronic data are verified, store the hard copies appropriately; NEVER destroy them.

## *Selecting a Fiber Management System*

Like any mission-critical application, a fiber management software system should be chosen with great care. After all, it will be the repository of ALL of your network data, and it will be relied upon for many functions throughout your company to supply specialized data about the network.

Because of this critical nature, you should consider the following list (and it is a long one) of questions as you evaluate software from different vendors. The more "yes" answers you obtain, the closer you will be to the ideal system for your network.

## *Relating Spatial and Non-spatial Data*

Can you place the following items on a map and link the map object to non-spatial attributes stored in a relational database?

- Buildings
- Access points (handholes, manholes, pedestals, etc.)
- Fiber distribution panels
- Cable spans (fiber, copper)
- Splice enclosures
- Conduit
- Innerduct
- Poles

## *Splicing Capabilities*

Does the software have the ability to splice individual fibers from various cables at a splice enclosure?

Can it show a splice schematic for any splice location?

- Does the splice schematic list the cable bundles and fiber colors?
- If a splice is changed, will the change be reflected when a route is traced through that location? (Does the change ripple through the database?)
- Can the splicing handle copper splicing with bridge taps?

## *Cable Information Capabilities*

- Does the software have the ability to show the cable attributes?
- Does it list the cable color code?
- For every fiber/pair in any cable, does it have the capability to click on the cable on the map and obtain the end to end connectivity throughout the network?
- Can it track the cable sequential markings for true physical cable length?
- Will it show slack loop locations with the amount of slack loop at the location?
- Does ability to edit color codes for fiber and copper cables of all sizes?
- Does it relate the cable segment to the reel of cable that it came from?
- For each fiber/pair of any cable span, can it determine which may have problems, such as a break, or if they are different fiber types, such as Truewave?
- For each fiber/pair of any cable span, can it list which are leased and if so, to whom?
- Can it track the placement of the cable such as underground, aerial, etc.?
- Does it provide a general scale factor for the cable that will take the length from a physical length to an optical length?
- Does it identify the owner of the cable?
- Does it relate to a materials database that has information about various types of cable?

## *Access Point Information*

Does it have the ability to:

- Track size and type of manhole, hand hole, pedestal, etc.?
- Show the attributes of the access point?
- Associate all cables with the access point they go through?

- Associate all conduit with the access point they go to?
- Show any lid markings on the manhole?
- Link to outside data sources such as drawings, photos, etc. that relate to the access point?
- Click on an access point and easily view all sequential markings and part number markings from each cable in that access point?
- Relate splice enclosures to the access point they are contained in?

### *Splice Enclosure Information*

- Does it relate to cables entering the enclosure?
- Can it track who entered what enclosure, when, and with what work order number?
- Does it label enclosure information on a map next to the enclosure?

### *Fiber Distribution Frame Information*

- Does it show the FDF on a map and relate it to the building it belongs in?
- Can it graphically show the front of the FDF?
- Does it relate the FDF to the cable(s) entering it?

### *Termination Information*

Does it have the ability to:

- Show how each fiber/pair of each outside plant cable entering a building is terminated to each panel jack in a Fiber Distribution Frame (FDF)?
- Show the status for each panel jack?
- Show the ring number for each panel jack?
- Show the type of connector for each panel jack?
- Give a priority for each panel jack?
- Show the user for each panel jack?
- Click on a panel jack and show the associated route that the signal would take as it goes throughout the network?

- Click on a panel jack and find a fault on the map when given a distance from that panel jack to the fault? The fault must be shown on a map and the results must also show the associated fiber/pair in the cable span that caused the fault.
- Locate the FDF in a building when given room, bay, and shelf information?
- Link to outside data sources such as drawings, photos, etc. that relate to the FDF?
- Produce a report that shows all of the cable spans/splice locations /FDF's/etc. that the signal went through to arrive at the final destination when the route from a particular panel jack is highlighted?
- Connect patch cords between jacks of the FDF and other FDF's as well as electronic equipment?
- Relate OTDR traces to panel jacks and display those traces in the native format that the traces were taken in?
- Relate loss information to each panel jack and show a history of when past measurements had been taken?
- Show how a route splits the signal and the various directions a signal may go if an optical splitter or bridge tap is encountered?
- Show a history of OTDR traces taken at the jack?

## *Documents*

- Does it to relate to engineering and other design documents and let you view them in their native format?
- Can you easily view the relation between an object on the map and a document that will provide more detailed information?

## *Conduit/Duct Bank*

Does it:

- Show the duct bank route?
- Relate the duct bank to the access points at either end?
- Track the length of the duct bank?
- Show which cables go in which inner duct?
- Indicate if it is leased or not, and if so, to whom?

- Let you connect and track innerduct; reserve it for future use?
- Show the depth of the duct bank at each access point it goes through?

## Poles

- Does it have the ability to show poles on a map?
- For each pole link, does it associate attributes such as pole type, owner, height, etc.?
- Can it show the pole attachment list for all companies on a given pole?

## Software Architecture

The software must:

- Have a version that is PC based and can be used to edit.
- Offer a version that is simply read only.
- Be able to scale to an enterprise system in a client/server architecture.
- Offer an enterprise system that provides read only access via a web browser.
- Be scalable to hundreds of users.
- Use Oracle as the backend for the enterprise version
- Have the ability to take a "snapshot" of the data to load onto a field computer for portability.
- In an enterprise version, store all spatial data in a database, not simply as drawing files.

## Documentation / Support

- Are electronic help files available?
- Is full training documentation offered?
- Are training courses available, at both a training facility and the customer's site?
- Is technical support must be available and for how long each day?

## Reports

Does the system offer:

- The ability to select any region to determine the amount of sheath length, fiber length, or route length?
- A materials report - amount of materials being used and where?
- A termination report - how fibers on various rings are allocated?
- A "taper" report - how a cable tapers throughout the network, where each fiber/pair ends?
- A fiber use report - what is available, and where?
- A duct use report - what is available, and where?
- A cable placement report - what is aerial, underground, etc.  and the location?

### *Design/Work Orders*

- Can you do mid-level design for routes (mid-level will show the route, but not the engineering detail that would include utilities, etc.)?
- Does it let you key in splicing information, test the splice as far as connectivity, and print out a splicing work order with associated location detail?
- Does it have the ability to track work order numbers for enclosures, distribution frames, cable spans, etc.?

### *Transmission Equipment / Customers*

- Can you add transmission equipment and identify the equipment rings?
- Will it relate the equipment with the fiber distribution frame jack it is connected to?
- Does it relate customers to the equipment?

### *Editing*

- Does it allow you to draw a cable and, as you click on the enclosure or frame it stops at, automatically relate the cable to that object in the database?
- Will it let you do a "sheath opening" and place an enclosure at the middle of a cable span and have the fibers/pairs in that cable automatically spliced together?
- Can you click and add enclosures, access points, distribution frames, buildings, and slack loops with their associated non-spatial information?

### *Background Base Data*

- Is a library of relatively accurate street maps available?
- Can it import various vector and non-vector files from outside vendors and have the files ortho-rectified?
- Do the base maps support a variety of projection systems?

### *General*

- Is it really a system or merely applications strung together that make it difficult to operate?
- Is the system relatively fast?
- Is it easy to use?
- Is there adequate training provided by the vendor? A day or two in class is just not enough time to get up to speed on creating maps and editing/inputting data Is there a maintenance agreement available that lets you budget for software upgrades?
- Does the vendor offer data conversion services to help you get your system up and running fast?

### *Establishing, documenting and teaching standards*

- Determining line styles and colors for map objects
- Agreeing on naming/numbering nomenclature for system attributes
- Establishing rules for information entered into various data fields
- Hold training classes for new personnel, review courses for all

### *Establish file locations*

- Will you be working in a workgroup environment with the need to archive data on a server (a "Golden” database)?
- Will you be working with stand-alone computers and databases?

### *Establish back-up procedures*

- Manual back-ups (to a back-up directory)
- Server back-ups (routine)

- Back-up schedules (end-of-day, every day)
- Identify persons responsible for server back-ups

### *Creating a procedure for updating/adding new builds to your database*

- Determine at which point the documentation and mapping of a new build is integrated with the existing system
- Identify the technicians and engineers responsible for integrating this data
- Develop input and verification procedures to ensure accurate and timely updates to network database

### *Create worksheets for contractors to use when documenting builds*

- Determine what your software system requires (your system vendor should really provide this)
- Distribute copies to all of your engineers, technicians, and contractors
- Include worksheets in the implementation of the database updating process

### *Develop a plan for implementing system upgrades when they arrive from your vendor*

- Determine hardware requirements
- Maintain a current list of all active system users
- Create a schedule and a list of operations to complete system upgrades
- Identify and train the personnel that will carry this out

## Partial List of Vendors for Outside Plant Products and Services

Below is a partial list of vendors that exhibited at recent trade shows. Some of the categories may not be correct and a given company may offer products and services in multiple categories that are not indicated. Nonetheless, the links provide a quick method for accessing the company sites and should be useful.

| Category | Company | Web Page |
|---|---|---|
| Cable | AFL Telecommunications/Alcoa | http://www.alcoa.com/afl_tele/ |
| Cable | Alcatel | http://www.alcatel.com/ |
| Cable | Cable Connection & Supply Co. | http://www.cableconnectionsupply.com/ |
| Cable | CommScope | http://www.commscope.com/ |
| Cable | Condumex Wire and Cable | http://www.condumex.com/ing/ |
| Cable | Corning Cable Systems | http://www.corningcablesystems.com/ |
| Cable | General Cable Corp. | http://www.generalcable.com/ |
| Cable | Hesfibel USA., Inc. | http://www.hesfibel.com/ |
| Cable | Krone, Inc. | http://www.kroneamericas.com/ |
| Cable | Loos & Company, Inc. | http://www.loosco.com/ |
| Cable | Nexans | http://www.tdstool.com/ |
| Cable | OFS | http://www.ofsoptics.com/ |
| Cable | Optical Cable Corporation | http://www.occfiber.com/ |
| Cable | Pirelli Cables and Systems LLC | http://www.pirelli.com/ |
| Cable | Remee Products Corporation | http://www.remee.com/ |
| Cable | Sterlite Optical Technologies | http://www.sterliteoptical.com/ |
| Cable | Sumitomo Electric Lightwave | http://www.sumitomoelectric.com/ |
| Cable | SUPERIOR ESSEX | http://www.superioressex.com/ |
| Cable | Teltek Sales, Inc. | http://www.telteksales.com/ |
| Cable | TVC Communications | http://www.tvcinc.com/ |
| Components | 3M | http://www.3m.com/market/telecom/ |
| Components | ACP International | http://www.acpinternational.com/ |
| Components | BRASBAND/PROVITEL | http://www.brasband.com |
| Components | Carson Industries, Inc. | http://www.carsonind.com/ |
| Components | Channell | http://www.channellcomm.com/ |
| Components | Charles Industries, Ltd. | http://www.charlesindustries.com/ |
| Components | Communications & Electrical | http://www.ceslive.com/ |
| Components | Electric Motion Company, Inc. | http://www.electricmotioncompany.com/ |
| Components | EMAR, Inc. | http://www.emarinc.com/ |
| Components | ETCO Specialty Products, Inc. | http://www.etcospecialtyproducts.com/ |
| Components | Fiber Solutions, Inc. | http://www.fibersinc.com/ |
| Components | Fitel Interconnectivity Corp. | http://www.fitelconn.com/ |
| Components | Galvan Industries, Inc. | http://www.galvanizersonline.com/ |
| Components | Highline Products | http://www.highlineproducts.com/ |
| Components | ICM Corporation | http://www.icmcontrols.com/base.html |
| Components | MacLean Power Systems | http://www.macleanpower.com/ |
| Components | Mar-Don Corporation | http://www.multicentric-seal.com/ |
| Components | Metrotech Corporation | http://www.metrotech.com/ |
| Components | Moore DP, LLC | http://www.mooredp.com/ |
| Components | Napco, Inc. | http://www.napcoinc.com/ |
| Components | Neptco, Inc. | http://www.neptco.com/ |
| Components | PenCell Plastics | http://www.pencell.com/ |
| Components | Preformed Line Products | http://www.preformed.com/ |
| Components | Primex Manufacturing Ltd | http://www.primex.ca/ |
| Components | Senior Industries | http://www.seniorindustries.com/ |
| Components | SPC Telequip | http://www.spc.net/ |
| Components | Synertech Moulded Products, Inc. | http://www.synertechproducts.com/ |
| Components | Telect | http://www.telect.com/ |
| Components | TelStrat | http://www.telstrat.com/ |

| Category | Company | Web Page |
|---|---|---|
| Components | Thomas & Betts | http://www.tnb.com/ |
| Components | Tyco Electronics | http://www.tycoelectronics.com/ |
| Components | Uniseal, Inc. | http://www.uniseal.com/ |
| Components | URASEAL, Inc. | http://www.uraseal.com/ |
| Components | Zylec Corporation | http://www.zylec.com/ |
| Conduit | American Pipe & Plastics, Inc | http://www.ampipe.com/ |
| Conduit | Arnco Corporation | http://www.arncocorp.com/ |
| Conduit | Conduit Repair Systems, Inc. | http://www.conduitrepair.com/ |
| Conduit | DH Supply Company, Inc. | http://www.dhsupply.com/ |
| Conduit | Dura-Line Corp | http://www.duraline.com/ |
| Conduit | Eastern Wire & Conduit | http://www.easternwire.com/ |
| Conduit | Group Timberline, Inc. | http://www.condu-grip.com/ |
| Conduit | JM Manufacturing Company, Inc. | http://www.jmpipe.com/ |
| Conduit | Maloney Technical Products | http://www.maloneytech.com/ |
| Conduit | Osburn Associates, Inc. | http://www.osburnassociates.com/ |
| Conduit | OSI Plastics | http://www.osiplastics.com/ |
| Conduit | Performance Pipe | http://www.cpchem.com/ |
| Conduit | Plastics Pipe Institute, Inc. | http://www.plasticpipe.org/ |
| Conduit | PWPipe | http://www.pwpipe.com/ |
| Const. Tools | Acme Staple Company, Inc. | http://www.acmestaple.com/ |
| Const. Tools | Allied Bolt | http://www.alliedbolt.com/ |
| Const. Tools | Altec Industries, Inc. | http://www.altec.com/ |
| Const. Tools | Aluma-Form | http://www.alumaform.com/ |
| Const. Tools | Baker Equipment Engineering Co. | http://www.bakerequipment.com/ |
| Const. Tools | BAND-IT-IDEX, Inc. | http://www.band-it-idex.com/ |
| Const. Tools | Batavia Services, Inc. | http://www.laddermatters.com/ |
| Const. Tools | Benner-Nawman, Inc. | http://www.benner-nawman.com/ |
| Const. Tools | Buckingham Manufacturing Co. | http://www.buckinghammfg.com/ |
| Const. Tools | Cementex Products | http://www.cementexusa.com/ |
| Const. Tools | Century Wire Products Corp. | |
| Const. Tools | Clauss Fiberoptic | http://www.claussco.com/fiberopt.htm |
| Const. Tools | Compass Equipment Leasing, Inc. | http://www.compassequipment.com/ |
| Const. Tools | Condux International, Inc. | http://www.condux.com/ |
| Const. Tools | CooperTools | http://www.coopertools.com/ |
| Const. Tools | DCD Design & Manufacturing, Ltd. | http://www.dcddesign.com/ |
| Const. Tools | Empire Level Mfg. Corporation | http://www.empirelevel.com/ |
| Const. Tools | Fiber Trucks & Trailers, Inc. | http://www.fibertrailers.com/ |
| Const. Tools | GDS and Associates, Inc. | http://www.gdscarsoncity.com/ |
| Const. Tools | General Machine Products Co., Inc. | http://www.gmptools.com/ |
| Const. Tools | Georgia Underground & Supply | http://www.georgiaunderground.com/ |
| Const. Tools | Goss, Inc. | http://www.gossonline.com/ |
| Const. Tools | Greenlee Textron | http://www.greenlee.textron.com/ |
| Const. Tools | Harger Lightning & Grounding | http://www.harger.com/ |
| Const. Tools | Herculine Corp./Pacific Strapping | http://www.pacstrap.com/ |
| Const. Tools | Jameson Corporation | http://www.jamesoncorp.com/ |
| Const. Tools | Jonard Industries Corp. | http://www.jonard.com/ |
| Const. Tools | Line-Ward Corporation | http://www.lineward.com/ |
| Const. Tools | Lynn Ladder & Scaffolding Co., Inc. | http://www.lynnladder.com/ |
| Const. Tools | Masterack | http://www.masterack.com/ |

| Category | Company | Web Page |
|---|---|---|
| Const. Tools | McIntire Company | http://www.mcintireco.com/ |
| Const. Tools | McLaughlin Mfg. Company | http://www.mightymole.com/ |
| Const. Tools | Nesco, Inc. | http://www.nescosales.com/ |
| Const. Tools | OK Industries, Inc. | http://www.okindustries.com/default.htm |
| Const. Tools | Pelsue | http://www.pelsue.com/ |
| Const. Tools | Primus-Sievert, Inc. | http://www.primus-sievert.com/ |
| Const. Tools | Schonstedt Instruments | http://www.schonstedt.com/ |
| Const. Tools | Sherman & Reilly, Inc. | http://www.sherman-reilly.com/ |
| Const. Tools | Team Fenex Ltd. | http://www.teamfenex.com/ |
| Const. Tools | Terex Telelect, Inc. | http://www.telelect.com/ |
| Const. Tools | Time Manufacturing Company | http://www.versalift.com/ |
| Contractor | Barton Southern | http://www.bartonsouthern.com/ |
| Contractor | Cablerunner North America | http://www.cablerunnerusa.com/ |
| Contractor | Gabe's Construction & Engineering | http://www.gabes.com/ |
| Contractor | J. Fletcher Creamer & Son, Inc. | http://www.jfcson.com/ |
| Contractor | Michels Corporation | http://www.michels-usa.com/ |
| Contractor | MOUNTAIN, LTD | http://www.mountainltd.com/ |
| Contractor | New Concept Tool | http://www.newcomtech.com/ |
| Contractor | Paramount Designs, Inc. | http://www.paramount-designs.com/ |
| Energy Equip. | American Power Conversion | http://www.apcc.com/ |
| Energy Equip. | BTECH, Inc. | http://www.btechinc.com/ |
| Energy Equip. | Circa Telecom USA, Inc. | http://www.circaent.com/ |
| Energy Equip. | Dimensions Unlimited, Inc. | http://www.dimensionsunlimited.com/ |
| Energy Equip. | Exeltech | http://www.exeltech.com/ |
| Energy Equip. | LEC Services, Inc. | |
| Energy Equip. | Metallic Power | http://www.metallicpower.com/ |
| Energy Equip. | Midtronics, Inc. | http://www.midtronics.com/ |
| Energy Equip. | Northern Technologies, Inc. | http://www.northern-tech.com/ |
| Energy Equip. | Proton Energy Systems | http://www.protonenergy.com/ |
| Energy Equip. | Red Simpson, Inc. | http://www.redsimpson.com/main.htm |
| Energy Equip. | Saft | http://www.saftbatteries.com/ |
| Energy Equip. | Transtector Systems, Inc. | http://www.transtector.com/ |
| Energy Equip. | Valere Power, Inc. | http://www.valerepower.com/ |
| Fiber Strands | Bekaert Corporation | http://www.bekaert.com/ |
| Fiber Strands | Belden Communications | http://www.belden-cd.com/ |
| GIS/Mgmt S/W | Acterna | http://www.acterna.com/ |
| GIS/Mgmt S/W | ADC | http://www.adc.com/ |
| GIS/Mgmt S/W | Advance Fiber Optics | http://www.ospinsight.com/ |
| GIS/Mgmt S/W | Aether Systems | http://www.aethersystems.com/ |
| GIS/Mgmt S/W | C.I.S., Inc. | http://www.cisfocus.com/ |
| GIS/Mgmt S/W | CADTEL Systems, Inc. | http://www.cadtel.com/ |
| GIS/Mgmt S/W | MAPCOM Systems, Inc. | http://www.mapcom.com/ |
| GIS/Mgmt S/W | MESA Solutions/Telcordia Technologies | http://www.mesasolutions.com/ |
| GIS/Mgmt S/W | Rainbow Technology Corporation | http://www.rainbow.com/ |
| GIS/Mgmt S/W | RiT Technologies Ltd. | http://www.rit.co.il/ |
| GIS/Mgmt S/W | Santronics | http://www.santronics.com/ |
| Network Equip. | Added Communications | http://www.addedcommunications.com/ |
| Network Equip. | Adtran | http://www.adtran.com/ |

| Category | Company | Web Page |
|---|---|---|
| Network Equip. | Advanced Fibre Communications | http://www.afc.com/ |
| Network Equip. | Almatec | http://www.almatec.com/index_e.html |
| Network Equip. | Alpha Technologies, Inc. | http://www.alpha.com/ |
| Network Equip. | Argus Technologies | http://www.arguscorp.com/ |
| Network Equip. | ARRIS/Keptel Products | http://www.arrisi.com/index_01.asp |
| Network Equip. | Avaya, Inc. | http://www.avaya.com/ |
| Network Equip. | GoDigital Networks | http://www.godigital.com/ |
| Network Equip. | Harris Corporation | http://www.harris.com/ |
| Network Equip. | Marconi Communications | http://www.marconi.com/ |
| Network Equip. | Norscan, Inc. | http://www.norscan.com/ |
| Network Equip. | Occam Networks, Inc. | http://www.occamnetworks.com/ |
| Network Equip. | Optical Solutions | http://www.opticalsolutions.com/ |
| Network Equip. | OZ Optics LTD | http://www.ozoptics.com/ |
| Network Equip. | Quest Controls, Inc. | http://www.questcontrols.com/ |
| Network Equip. | RBN, Inc. | http://www.rbni.com/ |
| Network Equip. | Samsung Telecommunications | http://www.samsungtelecom.com/ |
| Network Equip. | Sierra Monitor Corporation | http://www.sierramonitor.com/ |
| Network Equip. | Wilcom, Inc. | http://www.wilcominc.com/ |
| Organization | BICSI | http://www.bicsi.org/ |
| Organization | Common Ground Alliance | http://www.commongroundalliance.com/ |
| Organization | DSL Forum | http://www.dslforum.org/ |
| Organization | Kasten, Wagner, Pennington | http://www.kwponline.com/ |
| Organization | NTDPC-Nat Tele Damag Prev. Council | http://www.ntdpc.com/ |
| Organization | TIA | http://www.tiaonline.org/ |
| Other | Almetek Industries, Inc. | http://www.almetek.com/ |
| Other | American Innotek | |
| Other | American Polywater Corporation | http://www.polywater.com/ |
| Other | BW Technologies | http://www.bwtnet.com/ |
| Other | Cable Spinning Equipment Co., Inc. | |
| Other | CasChem, Inc. | http://www.cambrex.com/ |
| Other | Chemque, Inc. | http://www.chemque.com/ |
| Other | Dantherm HMS, Inc. | http://www.dantherm-hms.com/ |
| Other | DielectricRadiodetectionRiserbond | http://www.dielectric.com/ |
| Other | Electromark Company | http://www.electromark.com/ |
| Other | Erin Rope Corp. | |
| Other | Fibertek, Inc. | http://www.fibertek.com/ |
| Other | FOF, Inc. | http://www.popnwork.com/ |
| Other | Frick, William & Company | http://www.fricknet.com/ |
| Other | Light Brigade | http://www.lightbrigade.com/ |
| Other | Manhole Barrier Systems | http://www.manholebarriersystems.com/ |
| Other | Oldcastle Precast, Inc. | http://www.oldcastle-precast.com/ |
| Other | Panasonic Personal Computer Co. | http://www.panasonic.com/ |
| Other | Photonix | http://www.photonix.com/ |
| Other | Polymer Technology Services | http://www.ptsinc.net/ |
| Other | Porter Graphics | http://www.portergraphics.com/ |
| Other | Presco | http://www.presco.com/ |
| Other | Prosser Pumps | http://www.prosserpumps.com/ |
| Other | P-T Technologies | http://www.pttech.net/ |

| Category | Company | Web Page |
|---|---|---|
| Other | Puregas/Mobile Tool International | http://www.puregas.com/ |
| Other | REPNET, Inc. | http://www.macmagicians.com/clients/repnet/ |
| Other | Strongwell | http://www.strongwell.com/ |
| Other | SubSurface Instruments | http://www.sslocators.com/ |
| Other | Tech Products, Inc. | http://www.techproducts.com/ |
| Other | Terra Tape/Reef Industries, Inc. | http://www.reefindustries.com |
| Other | Thermo Bond Buildings | http://www.thermobond.com/ |
| Other | Triplett Corporation | http://www.triplett.com/ |
| Other | VacStar | http://www.vacstar.com/ |
| Other | Vantech/Safetyline | http://www.safetyline.com/ |
| Other | Weco Products, Inc. | http://www.wecoproducts.com/ |
| Other | Wellington Leisure Products | http://www.wellingtoninc.com/ |
| Other | Wells Cargo, Inc. | http://www.wellscargo.com/ |
| Other | Work Area Protection | http://www.workareaprotection.com/ |
| Service Prov. | American Digital Technologies, II LLC | http://www.adtcorp.net/ |
| Service Prov. | Calix | http://www.calix.com/ |
| Service Prov. | Expertech Network Installation | http://www.expertech.net/ |
| Service Prov. | IPEG Corporation | http://www.ipegcorp.com/ |
| Service Prov. | KGP Telecommunications, Inc. | http://www.kgptel.com/ |
| Service Prov. | Magnetek/J-Tec/ADS | http://www.magnetek.com/ |
| Service Prov. | Martin Group | http://www.martin-group.com/ |
| Service Prov. | Mid-State Consultants | http://www.mscon.com/ |
| Service Prov. | Multilink, Inc. | http://www.multilink.com/ |
| Service Prov. | NextGen | http://www.nextgen.net/ |
| Service Prov. | Osmose, Inc. | http://www.osmose.com/ |
| Service Prov. | SiteMaster | http://www.sitemaster.com/ |
| Service Prov. | Sparton Technology, Inc. | http://www.sparton.com/ |
| Service Prov. | Spediant Systems, Inc. | http://www.spediant.com/ |
| Service Prov. | Telplexus, Inc. | http://www.telplexus.com/ |
| Service Prov. | Trend Communications | http://www.trendcomms.com/ |
| Service Prov. | Utility Technical Services, Inc. | http://www.utsleak.com/ |
| Service Prov. | Verizon Logistics | http://www.vzlogistics.com/ |
| Service Prov. | Wire DynamiX | http://www.wiredynamix.com/index.html |
| Supplier | Butler Communications | http://www.butlersupply.com/ |
| Supplier | Graybar | http://www.graybar.com/ |
| Supplier | Jones Broadband International | http://www.jonesbroadband.com/ |
| Supplier | Mohawk, Ltd. | http://www.mohawkltd.com/ |
| Supplier | Power & Telephone Supply Co. | http://www.ptsupply.com/ |
| Supplier | Sprint North Supply | http://www.sprintnorthsupply.com/ |
| Supplier | Westek Electronics, Inc. | http://www.westekelectronics.com/ |
| Test Equip. | AMREL Telecom, Inc | http://www.amrel.com/home.html |
| Test Equip. | Aurora Instruments | http://www.aurora-instr.com/ |
| Test Equip. | Consultronics, Inc. | http://www.consultronics.com/ |
| Test Equip. | Electro Rent Corporation | http://www.electrorent.com/ |
| Test Equip. | Electrodata, Inc. | http://www.electrodata.com/ |
| Test Equip. | EXFO | http://www.exfo.com/ |
| Test Equip. | Fluke Networks | http://www.flukenetworks.com/ |
| Test Equip. | HD Telecom, Inc. | http://www.hdtelecom.com/ |

| Category | Company | Web Page |
|---|---|---|
| Test Equip. | Independent Technologies, Inc. | http://www.independenttech.com/ |
| Test Equip. | LoopExpert Technologies, Inc. | http://www.loopexpert.com/ |
| Test Equip. | Maxrel Corporation | http://www.maxrel.com/ |
| Test Equip. | Megger | http://www.megger.com/ |
| Test Equip. | Metro Tel Corporation | http://www.metrotelcorp.com/ |
| Test Equip. | Newcom Technologies, Inc. | http://www.tdstool.com/ |
| Test Equip. | Nutmeg Utility Products, Inc. | http://www.nutmegutility.com/ |
| Test Equip. | PUPCO, Inc. | http://www.pupcoinc.com/ |
| Test Equip. | RenTelco | http://www.rentelco.com/ |
| Test Equip. | Sunrise Telecom, Inc. | http://www.sunrisetelecom.com/ |
| Test Equip. | Telefonix Technology | http://www.telefonix.com/ |
| Test Equip. | TSI/Opto-Tech | http://www.tsi.com/ |
| Test Equip. | USAT | http://www.intruckcomputing.com/ |
| Test Equip. | Wyle Laboratories | http://www.wylelabs.com/ |
| | Advantage Power | |
| | Craftmark | |
| | Infrantel Communications | |
| | JODE CORP | |
| | Kustt | |
| | Lozon | |
| | Nixon Power Services Co. | |
| | Pneumatic Specialties, Inc. | |
| | Pro-Mark Utility Supply | |
| | Reliable High Performance Products | |
| | Rycom Industries, Inc. | |
| | Schultz Comm., Inc. | |
| | Silver Telecommunications | |
| | Southern Instruments & Control | |
| | Stellar RAD OSS | |
| | TC | |
| | Telemark Solutions-Microfusion | |
| | Tempo | |
| | Tunnel Mill Polymer | |
| | Unicord Corporation | |
| | Uticom Systems, Inc. | |

# Fiber Optic Cable Comparison Tables

| Standard Single Mode Fibers | | | | |
|---|---|---|---|---|
| Parameter | Corning SMF-28* | Alcatel 6900* | OFS- SSMF* | Lucent Matched Cladding (MC) SMF* |
| | | | | |
| Atten @ 1310 nm (dB/km) | <= 0.35 | <= 0.34 | <= 0.4 | 0.35-0.4 |
| Atten @ 1550 nm (dB/km) | <= 0.22 | <= 0.24 | <= 0.25 | <= 0.3 |
| Atten @ water peak 1383 +/- 3 nm | < 2.1 dB/km | < 2.1 dB/km | < 1.5 dB/km | < 2 dB/km |
| Atten v/s Wavelength: 1285 - 1330 nm | 0.05 dB/km (max diff) | 0.035dB/km (max diff) | NA | 0.1 dB/km (max diff) |
| Atten v/s Wavelength: 1525 - 1575 nm | 0.05 dB/km (max diff) | 0.03 dB/km (max diff) | 0.05 dB/km (max diff) | 0.05 dB/km (max diff) |
| Mode Field Diameter @ 1310 nm | 9.2 +/- 0.4 um | 9.0 +/- 0.5 um | 9.3 +/- 0.5 um | 9.3 +/- 0.5 um |
| Mode Field Diameter @ 1550 nm | 10.4 +/- 0.8 um | 10.2 +/- 1.0 um | 10.5 +/- 1.0 um | 10.5 +/- 1.0 um |
| Typical Core Diameter | 8.2 um | 8.8 um | 8.8 um | 8.3 um |
| Zero Dispersion Wavelength | 1302nm<=λ<=1322nm | 1300nm<=λ<=1320nm | 1300nm<=λ<=1322nm | 1300nm<=λ<=1322nm |
| Dispersion Coefficient @ 1550 nm | NA | NA | 18 ps/nm*km | 18 ps/nm*km |
| Zero Dispersion Slope | <=0.092 ps/km*nm^2 | <=0.092 ps/km*nm^2 | <=0.092 ps/km*nm^2 | <=0.088 ps/km*nm^2 |
| PMD link Value | <= 0.1 ps/vkm | <= 0.1 ps/vkm | <= 0.5 ps/vkm | NA |
| | | | | |
| * ITU-T G.652 Compliant | | | | |

| Extended Band Single Mode fibers | | | |
|---|---|---|---|
| Parameter | Lucent Allwave | Corning SMF-28e * | Alcatel 6901 Enhanced SMF * |
| | | | |
| Attenuation @ 1310 nm (dB/km) | <= 0.39 | <= 0.35 | <= 0.34 |
| Attenuation @ 1385 nm (dB/km) | <= 0.31 | <= 0.32 | <= 0.32 |
| Attenuation @ 1550 nm (dB/km) | <= 0.23 | <= 0.22 | <= 0.21 |
| Attenuation @ water peak 1383 +/- 3 nm | < 0.31 dB/km | < 0.31 dB/km | < 0.33 dB/km |
| Atten v/s Wavelength: 1285 - 1330 nm | 0.05 dB/km (max diff) | 0.03 dB/km (max diff) | 0.035 dB/km (max diff) |
| Atten v/s Wavelength: 1525 - 1575 nm | 0.05 dB/km (max diff) | 0.02 dB/km (max diff) | 0.03 dB/km (max diff) |
| Mode Field Diameter @ 1310 nm | 9.2 +/- 0.4 um | 9.2 +/- 0.4 um | 9.0 +/- 0.4 um |
| Mode Field Diameter @ 1550 nm | 10.5 +/- 1.0 um | 10.5 +/- 0.8 um | 10.2 +/- 1.0 um |
| Effective Area | 80 um^2 | NA | NA |
| Zero dispersion Wavelength (nm) | 1300 <= λ <= 1322 | 1302 <= λ <= 1322 | 1310 +/- 10 nm |
| Dispersion Slope @ 1550 ps/nm*nm*km | <= 0.092 | <= 0.092 | <= 0.090 |
| PMD link Value | <= 0.1 ps/vkm | <= 0.08 ps/vkm | <= 0.08 ps/vkm |
| PMD Individual fiber | <= 0.05 ps/vkm | <= 0.2 ps/vkm | NA |
| | | | |
| * ITU-T G.652 Compliant | | | |

| Non Zero Dispersion Shifted Fibers - Comparison | | | | |
|---|---|---|---|---|
| Parameter | LEAF - Latest Generation | Alcatel 6912 Teralight Ultra* | Pirelli Widelight * | OFS Truewave RS (Reduced Slope)* |
| | | | | |
| Atten @ 1310 nm (dB/km) | <= 0.25 | <= 0.25 | NA | <= 0.4 |
| Atten @ 1550 nm (dB/km) | <= 0.25 | <= 0.22 | <= 0.23 | <= 0.24 |
| Atten @ water peak 1383 +/- 3 nm | < 1.0 dB/km | < 0.7 dB/km | NA | < 1.0 dB/km |
| Atten v/s Wavelength: 1525 - 1575 nm | 0.05 dB/km (max diff) | 0.05 dB/km (max diff) | NA | 0.05 dB/km (max diff) |
| Mode Field Diameter @ 1550 nm | 9.2 to 10 um | 9.2 +/- 0.5 um | 8.1 +/- 0.5 um | 8.4 +/- 0.6 um |
| Effective Area @ 1550 nm | 72 um^2 | 63 um^2 | 50 um^2 | < 70 um^2 |
| Dispersion in C- Band ps/nm*km | 2.0 <= D <= 6.0 | 5.5 <= D <= 10 | -10<= D<= -4.5 | 2.6 <= D <= 6.0 |
| Dispersion in L- Band ps/nm*km | 4.5 <= D <= 11.2 | 7.5 <= D <= 13.4 | -6.5 <= D <= -0.1 | 4.0 <= D <= 8.9 |
| Dispersion Slope ps/nm*nm*km | NA | <= 0.052 | NA | <=0.05 ps/km*nm^2 |
| PMD link Value | <= 0.1 ps/vkm | <= 0.04 ps/vkm | <= 0.2 ps/vkm | <= 0.1 ps/vkm |
| | | | | |
| | | | | |
| * ITU-T G.655 Compliant | | | | |

| Dispersion Shifted Single Mode Fibers | | |
|---|---|---|
| Parameter | Corning SMF/ CPC3 | Pirelli (FOS) SM-DS Cat.A* |
| | | |
| Attenuation @ 1310 nm (dB/km) | <= 0.5 (typical) | <= 0.39 (typical) |
| Attenuation @ 1550 nm (dB/km) | <= 0.25 | <= 0.20 |
| Atten v/s Wavelength: 1525 - 1575 nm | 0.05 db/km (max diff) | 0.05 db/km (max diff) |
| Mode Field Diameter @ 1550 nm | 8.1 +/- 0.65 um | 8.1 +/- 0.65 um |
| Typical Core Diameter | 8.2 um | NA |
| Zero Dispersion Wavelength | 1535nm<=λ<=1565nm | 1535nm<=λ<=1565nm |
| Zero Dispersion Slope | <=0.085 ps/km*nm^2 | <=0.085 ps/km*nm^2 |
| Total Dispersion (ps/nm*km) | <= 2.7 (1525nm-1575nm) | <= 2.7 (1525nm-1575nm) |
| PMD link Value | <= 0.1 ps/vkm | NA |
| | | |
| * ITU-T G.653 Compliant | | |

| Non Zero Dispersion Shifted fiber OFS Family | | | | |
|---|---|---|---|---|
| Parameter | Truewave OFS (TW-AT&T) | Truewave classic (TW-C) | Truewave Plus (TW+ | Lucent Truewave RS (Reduced Slope)* |
| | | | | |
| Atten @ 1310 nm (dB/km) | 0.4 (typical) | NA | NA | <= 0.4 |
| Atten @ 1550 nm (dB/km) | <= 0.25 | <= 0.25 | <= 0.25 | <= 0.24 |
| Atten @ water peak 1383 +/- 3 nm | < 2.05 dB/km | NA | NA | < 1.0 dB/km |
| Atten v/s Wavelength: 1525 - 1575 nm | 0.05 dB/km (max diff) | NA | NA | 0.05 dB/km (max diff) |
| Mode Field Diameter @ 1550 nm | 8.4 +/- 0.6 um | 8.4 +/- 0.6 um | 8.4 +/- 0.6 um | 8.4 +/- 0.6 um |
| Typical Core Diameter | 6.0 um | NA | NA | NA |
| Effective Area @ 1550 nm | 52.1 um^2 | 52.0 um^2 | 52 um^2 | NA |
| Zero Dispersion Wavelength | 1515 +/- 20 nm | 1511 +/- 17 nm | 1597 +/- 15 nm | 1515 +/- 20 nm |
| Dispersion @ 1550 ps/nm-km | 2.4 +/- 1.5 | 2.7 +/- 1.2 | 3.7 +/- 1.0 | 4.4 +/- 0.5 |
| Dispersion Slope @ 1550 nm | <=0.069 ps/km*nm^2 | <=0.068 ps/km*nm^2 | <=0.068 ps/km*nm^2 | <=0.05 ps/km*nm^2 |
| PMD link Value | <= 0.5 ps/vkm | <= 0.5 ps/vkm | <= 0.5 ps/vkm | <= 0.1 ps/vkm |
| | | | | |
| * ITU-T G.655 Compliant | | | | |

| Non Zero Dispersion Shifted fiber OFS Family | | | | |
|---|---|---|---|---|
| Parameter | Truewave OFS (TW-AT&T) | Truewave classic (TW-C) | Truewave Plus (TW+ | OFS Truewave RS (Reduced Slope)* |
| | | | | |
| Atten @ 1310 nm (dB/km) | 0.4 (typical) | NA | NA | <= 0.4 |
| Atten @ 1550 nm (dB/km) | <= 0.25 | <= 0.25 | <= 0.25 | <= 0.24 |
| Atten @ water peak 1383 +/- 3 nm | < 2.05 dB/km | NA | NA | < 1.0 dB/km |
| Atten v/s Wavelength: 1525 - 1575 nm | 0.05 dB/km (max diff) | NA | NA | 0.05 dB/km (max diff) |
| Mode Field Diameter @ 1550 nm | 8.4 +/- 0.6 um | 8.4 +/- 0.6 um | 8.4 +/- 0.6 um | 8.4 +/- 0.6 um |
| Typical Core Diameter | 6.0 um | NA | NA | NA |
| Effective Area @ 1550 nm | 52.1 um^2 | 52.0 um^2 | 52 um^2 | NA |
| Zero Dispersion Wavelength | 1515 +/- 20 nm | 1511 +/- 17 nm | 1597 +/- 15 nm | 1515 +/- 20 nm |
| Dispersion @ 1550 ps/nm-km | 2.4 +/- 1.5 | 2.7 +/- 1.2 | 3.7 +/- 1.0 | 4.4 +/- 0.5 |
| Dispersion Slope @ 1550 nm | <=0.069 ps/km*nm^2 | <=0.068 ps/km*nm^2 | <=0.068 ps/km*nm^2 | <=0.05 ps/km*nm^2 |
| PMD link Value | <= 0.5 ps/vkm | <= 0.5 ps/vkm | <= 0.5 ps/vkm | <= 0.1 ps/vkm |
| | | | | |
| * ITU-T G.655 Compliant | | | | |

| Non Zero Dispersion Shifted Fiber Pirelli Family | | |
|---|---|---|
| Parameter | Freelight * | Widelight * |
| | | |
| Attenuation @ 1310 nm (dB/km) | NA | NA |
| Attenuation @ 1550 nm (dB/km) | <= 0.23 | <= 0.23 |
| Attenuation @ water peak 1383 +/- 3 nm | NA | NA |
| Atten v/s Wavelength: 1525 - 1575 nm | NA | NA |
| Mode Field Diameter @ 1550 nm | 9.6 +/- 0.4 um | 8.1 +/- 0.5 um |
| Effective Area @ 1550 nm | 72 um^2 | 50 um^2 |
| Dispersion in C- Band ps/nm*km | 2.0 <= D <= 6.0 | -10<= D<= -4.5 |
| Dispersion in L- Band ps/nm*km | 4.5 <= D <= 11.2 | -6.5 <= D <= -0.1 |
| Zero Dispersion slope | NA | NA |
| PMD link Value | <= 0.1 ps/vkm | <= 0.2 ps/vkm |
| | | |
| * ITU-T G.655 Compliant | | |

| Non Zero Dispersion Shifted Fibers Corning family | | | |
|---|---|---|---|
| Parameter | Corning SMF-LS CPC6 | LEAF - Latest Generation | Corning Metrocore |
| | | | |
| Attenuation @ 1310 nm (dB/km) | < 0.5 | <= 0.25 | <= 0.50 |
| Attenuation @ 1550 nm (dB/km) | <= 0.25 | <= 0.25 | <= 0.25 |
| Attenuation @ water peak 1383 +/- 3 nm | < 2.0 dB/km | < 1.0 dB/km | < 0.4 dB/km |
| Atten v/s Wavelength: 1525 - 1575 nm | 0.05 dB/km (max diff) | 0.05 dB/km (max diff) | 0.05 dB/km (max diff) |
| Mode Field Diameter @ 1550 nm | 8.4 +/- 0.5 um | 9.2 to 10 um | 7.6 to 8.6 um |
| Effective Area @ 1550 nm | NA | 72 um^2 | NA |
| Dispersion in C- Band ps/nm*km | -3.5 <= D <= -0.1 | 2.0 <= D <= 6.0 | -10 <= D <= -1 |
| Dispersion in L- Band ps/nm*km | NA | 4.5 <= D <= 11.2 | NA |
| PMD link Value | <= 0.2 ps/vkm | <= 0.1 ps/vkm | <= 0.2 ps/vkm |

| Non Zero Dispersion Shifted fibers Alcatel Family | | | |
|---|---|---|---|
| Parameter | Alcatel 6910 Teralight* | Alcatel 6912 Teralight Ultra* | Alcatel 6911 Teralight Metro* |
| | | | |
| Attenuation @ 1625 nm (dB/km) | <= 0.28 | <= 0.25 | <= 0.28 |
| Attenuation @ 1550 nm (dB/km) | <= 0.25 | <= 0.22 | <= 0.25 |
| Attenuation @ water peak 1383 +/- 3 nm | < 1.5 dB/km | < 0.7 dB/km | < 1.0 dB/km |
| Atten v/s Wavelength: 1525 - 1575 nm | 0.03 dB/km (max diff) | 0.05 dB/km (max diff) | 0.05 dB/km (max diff) |
| Mode Field Diameter @ 1550 nm | 9.2 +/- 0.5 um | 9.2 +/- 0.5 um | 9.2 +/- 0.5 um |
| Effective Area @ 1550 nm | 63 um^2 | 63 um^2 | 63 um^2 |
| Dispersion in C- Band ps/nm*km | 5.5 <= D <= 10 | 5.5 <= D <= 10 | 5.5 <= D <= 10 |
| Dispersion in L- Band ps/nm*km | 7.5 <= D <= 13.8 | 7.5 <= D <= 13.4 | 7.5 <= D <= 13.4 |
| Dispersion Slope @ 1550 ps/nm*nm*km | <= 0.058 | <= 0.052 | <= 0.052 |
| PMD link Value | <= 0.08 ps/vkm | <= 0.04 ps/vkm | <= 0.08 ps/vkm |
| | | | |
| * ITU-T G.655 Compliant | | | |

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