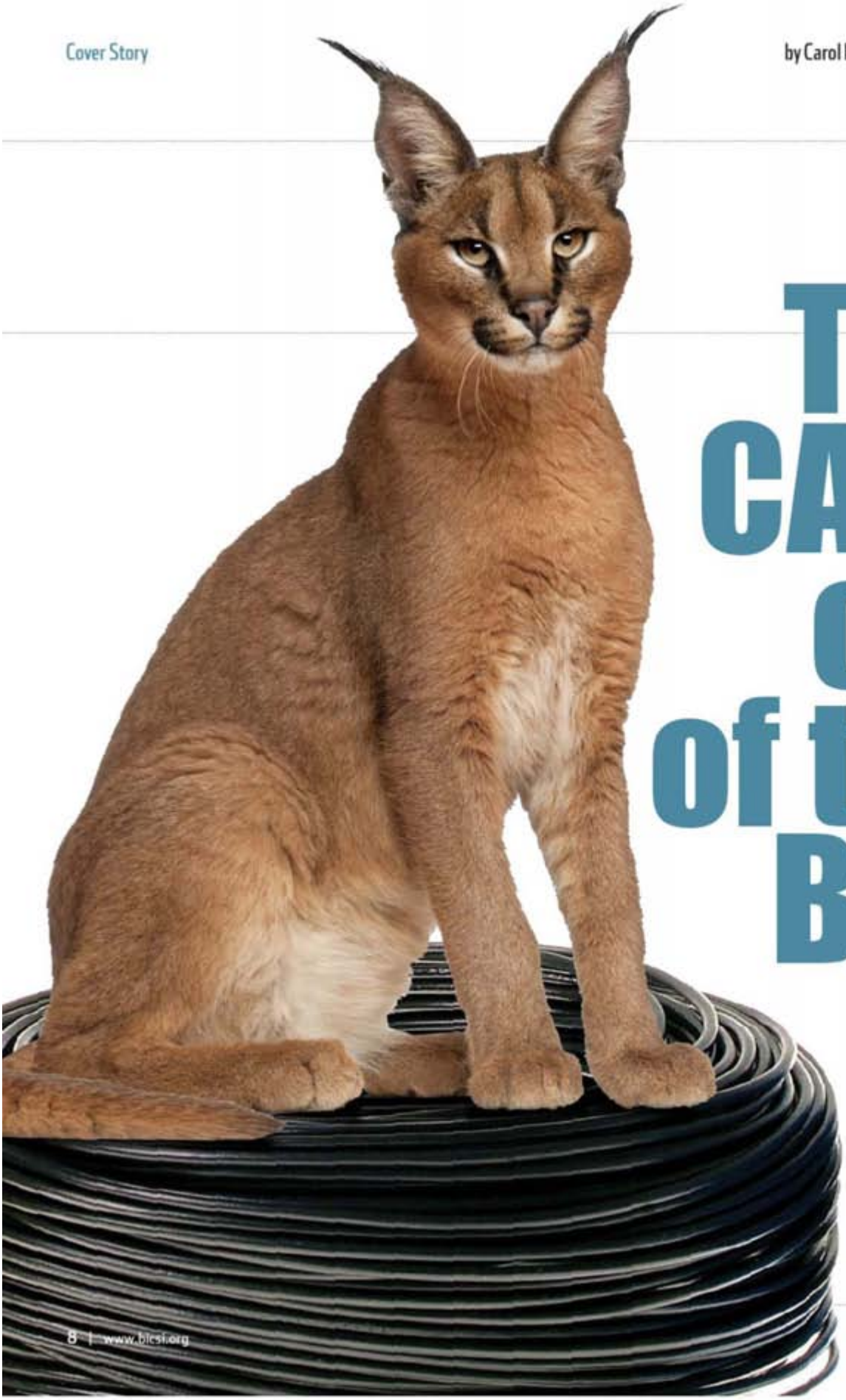
by Carol Everett Oliver, RCDD, ESS



The CAT's out of the Bag

The Story of the Category

All it took was one question posted on LinkedIn, and as the saying goes, the CAT's out of the bag. The question started as a fact-finding mission to distinguish separate applications for three twisted-pair category copper cables—category 5e, 6 and 6A. I am constantly being asked to differentiate the applications among these three cabling categories and wanted real-life views on the topic from industry consultants, installers, end users, manufacturers and distributors.

With more than 100 comments during a six-month span, the LinkedIn® posting became one of 2012's hottest and longest debates among industry LinkedIn groups, including the BICSI Official Group, BICSI Northeast Region, BICSI RCDD, TekTalk and Structured Cabling Professionals. On many of the LinkedIn group sites, the posting grew and branched out to unrelated topics, reminding me of the children's "telephone game" where secrets are whispered from one person to the next and the initial topic is somewhat skewed by the time it reaches the final person.

Given the amount of eye-opening views on the topic gathered from LinkedIn members, I decided to conduct further research and interviews with industry icons on the history of category cable, the current applications and the future of copper cabling—all of which is compiled into this historical article that aptly coincides with BICSI's 40th Anniversary.

Look What the CAT Dragged In

Most of us know that the first recognized category cable was category 3. But what came before that? Was there a category 1 and 2? The answer to that question comes all the way from Spain. Luis Semprun, owner of Data Structures in Madrid, says, "The answer stems way back from the dinosaur ages before there were standards. The first 'Ethernetsaurus' cable was actually a telephone-grade cable, and then grade 2 was for integrated services digital network (ISDN) systems."

Early IBM Type cables, dating back to the 1980s, preceded the design of the category cables (courtesy of Berk-Tek).

David "Bo" Conrad, RCDD, of Bo Enterprises, explains that there actually was no category 1, but that in the 1970s, the cable was defined as plain old telephone service (POTS) with a rating of 64 kilohertz (kHz) to support analog voice signals.

"Most homes were wired with this quad wire, whose four conductors were red, green, yellow and black, capable of supporting two phone lines," he says. "This cable type also supported the 64 kilobits per second (kb/s) speeds of RS-232 type cable, which converted Digital Equipment Corporation (DEC) cabling to a twisted-pair format."

Since there were no standards at that time, all cabling was proprietary, and a battle commenced between computer manufacturers like IBM and DEC. "At that time, IBM really owned the computer market-

The decision to specify category 6A over category 6, or category 6 over category 5e, is based on many factors, including the applications' bandwidth requirements, installed environment and facility life cycle.

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place and had a version of unshielded twisted-pair (UTP) cable called Type 3. It was rated at 1 megahertz (MHz) to support the new 4 megabits per second (Mb/s) token ring protocol for networking their computers," Conrad explains.

Phone systems were an early adopter of twisted-pair and high pair count cabling, whereas computer cabling was mainly coaxial-based, especially at the early mainframe stages—long before minicomputers, personal computers and LANs. "While the computer protocol war was happening between the two main protocols and computer giants—Ethernet from DEC and token ring from IBM—a smaller company from the Silicon Valley, called Synoptics, revolutionized Ethernet's RG-8 thicknet and RG-59 thinnet coaxial style cables by developing a modular RJ-45 twisted-pair hub that could support 10BASE-T at 16 MHz," recalls Conrad. This was the precursor to the first defined twisted-pair cable, known as category 3.

"IBM lost the first battle to Ethernet and tried again later with category 4, a twisted-pair cable with a rating of 20 MHz to support their 'faster' 16 Mb/s token ring," adds Conrad. "We all know that Ethernet and UTP won this network battle, especially with the introduction of the 100BASE-T standard, which replaced hubs with switches… and cabling obsolescence continues to be driven by computer technology; then and now."

Leveling the CAT Playing Field

Before category cables were officially recognized and before industry standards for twisted-pair cabling existed, Anixter introduced a program at the 1989 BICSI Winter Conference to differentiate cable performance criteria for the cabling they offered. According to the program, which was later purchased by Underwriters Laboratories® (UL®), level 1 was a 24 American wire gauge (AWG) copper cable used only for voice applications. Level 2 cable handled IBM mainframe and minicomputer terminal transmission, as well as some early slow-speed (1 to 2 Mb/s) LAN protocols, like attached resource computer network (ARCnet). Level 3 was designated as the minimum quality twisted-pair cable to handle 10BASE-T Ethernet and active 4/16 Mb/s token ring.

"Many people jumped on the bandwagon to define data cables," says Pete Lockhart, one of the originators of the program who worked at Anixter from 1988 to 2011. "That included the National Electrical Manufacturers Association (NEMA), which started writing specifications before the Telecommunications Industry Association (TIA), and Northern Telecom, which presented a white paper at the International Wire and Cable Symposium (IWCS) on a twisted-pair cable that could handle 16 Mb/s of Ethernet and token ring."

These efforts ultimately provided a design concept for level 4 type cabling and established a random testing program through UL. According to Lockhart, by the 1991 BICSI Conference held in Scottsdale, Ariz., a level 5 UTP cable design was defined to run up to 100 Mb/s to 100 meters (m [328 feet (ft)]). "That was the game changer for copper cabling," he says.

Many of us in the industry have wondered how the 100 m (328 ft) twisted-pair distance limitation came into existence. According to Lockhart, an industry study in the late 1980s looked at the average distance between the telecommunications room and telecommunications outlet/connector. The average run was 67 m (220 ft). Manufacturers of active components (i.e., transmitters, receivers and switches) were therefore designing their equipment to transmit to 100 m (328 ft).

Breeding Standards

Today, there are three main standards bodies that serve the U.S. telecommunications industry—Institute of Electrical and Electronics Engineers® (IEEE®), TIA and BICSI. However, there is also influence from the international standards body of the International Organization for Standardization/International Electrotechnical Commission (ISO/IEC). IEEE defines the protocol and data rates of Ethernet and defines Layers 1 and 2 of the Open Systems Interconnection (OSI) model. TIA specifies the cabling structure, including media categories, fiber and copper components, general environment and implementation requirements. BICSI provides installation guidelines and best practices for specific environments like health care, education, data centers and security.

Cable classifications were originally considered "types" and then "levels," but in standards' nomenclature, the term "category" emerged. In 1985, the Computer & Communications Industry Association (CCIA) asked the Electronic Industries Association (EIA) to develop a cabling standard that would define a generic telecommunications wiring system for commercial buildings to support a multiproduct, multi-vendor environment. This would be a cabling system defined to run all current and future networking systems over a common topology using common media and connectors.

Two years later, the manufacturers of Ethernet-based equipment were looking at using twisted-pair telephone cable for computer transmission. In 1990, the IEEE released the 802.3 Ethernet standard 10BASE-T—where the "10" represents the speed of 10 Mb/s, the "BASE" represents baseband transmission and the "T" refers to twisted-pair. In 1991, the EIA, together with TIA, published the first telecommunications cabling standard called ANSI/TIA/EIA-568, and structured cabling was born.

At that time, cabling systems were categorized in terms of their frequency bandwidth and improved specifications. The TIA standards defined the cabling components (i.e., cables, connecting hardware and patch cords), permanent links and channels by performance categories. The first category UTP copper cable was category 3, designed to reliably carry data up to 10 Mb/s. Soon thereafter, TIA TSB-36 specified two higher grades of UTP cable—category 4 and category 5. Category 3 was relegated to mainly two-line telephone systems and 10BASE-T. Category 4 was specified for data rates of 16 Mb/s and performance up to 20 MHz. It was quickly replaced by higher-bandwidth category 5.

Category 5 was defined in ANSI/TIA/EIA-568-A in 1995 and was specified for frequencies up to 100 MHz. It was developed to deploy Fast Ethernet networks such as 100BASE-T. Categories 3 and 5 were not limited to four pairs but often were constructed with 100 pairs for backbone applications. Category 5 had an expected useful life of about 10 years, but in 2001, the next generation of category 5e was ratified in ANSI/TIA/EIA-568-B.2 and became the media for Gigabit Ethernet, or 1000BASE-T.

"Insertion loss deviation was the 'Achilles' heel' of category 5. We needed tighter specifications and electrical performance parameters for Gigabit Ethernet," says Lockhart. "At that time, category 6 was actually on the table, but TIA decided to add the needed return loss specification and create category 5e, which did not change the frequency."

Category 5e ensured that additional parameters were satisfied, including headroom for near-end crosstalk (NEXT), equal level far-end crosstalk (ELFEXT) and return loss. In addition, category 5e introduced the characterization of power sum crosstalk, the cumulative interfering signals from each pair, calculated via a power sum algorithm when using all four pairs simultaneously.

Data transmission speeds continued to escalate along with increased network performance requirements. In 2002, category 6 was ratified in ANSI/TIA/EIA-568-B.2-1, more than doubling the performance bandwidth from 100 MHz to 250 MHz. Along with category 6 came tighter electrical specifications, which created additional testing parameters and the characterization of component balance for improved immunity against noise, in the form of electromagnetic interference (EFI) or radiofrequency interference (RFI). Category 6 was designed to last a decade and is still the preferred cable standard for most of today's LAN installations.

Although category 6 is recognized by the IEEE 802.3 Ethernet Working Group to run short lengths of 10 gigabit per second (Gb/s) applications, it is not the recognized standard media for these applications. It is therefore not

When a CAT has Class

by Valerie Maguire, BSEE

North American and international cabling performance standards committees work hand-in-hand with applications development committees worldwide to ensure that new grades of cabling will support the latest innovations in signal transmission technology. TIA standards are often specified by North American end users, while ISO/IEC standards are more commonly referred to in the global marketplace.

While the technical requirements of the North American and international standards are very similar for various grades of cabling, the terminology for the level of performance within each committee's standards can be confusing. In TIA standards, cabling components (e.g., cables, connecting hardware and patch cords) are characterized by a performance "category" and are combined to create permanent links or channels that are also described by that performance "category." In ISO/IEC, components are characterized by a performance "category" and the respective permanent links and channels are described by a performance "class." TIA and ISO/IEC equivalent grades of performance are characterized by their frequency bandwidth and are shown in Table 1.

TIA categories and ISO/IEC classes of structured cabling that are recognized for the support of data-speed applications are specified in the standards listed in Table 2. Note that both standards bodies are working on developing requirements for the next generation of twisted-pair cabling targeted to support 40 Gb/s transmission rates.

FREQUENCY BANDWIDTH	TIA (COMPONENTS)	TIA (CABLING)	ISO/IEC (COMPONENTS)	ISO/IEC (CABLING)
1 – 100 MHz	Category 5e	Category 5e	Category 5e	Class D
1 – 250 MHz	Category 6	Category 6	Category 6	Class E
1 – 500 MHz	Category 6A	Category 6A	Category 6_A	Class E_A
1 – 600 MHz	n/s	n/s	Category 7	Class F
1 – 1,000 MHz	n/s	n/s	Category 7_A	Class F_A

Table 1: TIA and ISO Equivalent Cabling Classifications

TIA CABLING STANDARDS

Category 5e: ANSI/TIA-568-C.2, *Balanced Twisted-Pair Telecommunications Cabling and Components Standard*, 2009
Category 6: ANSI/TIA-568-C.2, *Balanced Twisted-Pair Telecommunications Cabling and Components Standard*, 2009
Category 6A: ANSI/TIA-568-C.2, *Balanced Twisted-Pair Telecommunications Cabling and Components Standard*, 2009
Category 8: ANSI/TIA-568-C.2-1, *Specifications for 100Ω Next Generation Cabling*, under development

ISO/IEC CABLING STANDARDS

Class D: ISO/IEC 11801, 2nd Ed., *Information technology – Generic Cabling for Customer Premises*, 2002
Class E: ISO/IEC 11801, 2nd Ed., *Information technology – Generic Cabling for Customer Premises*, 2002
Class EA: Amendment 1 to ISO/IEC 11801, 2nd Ed., *Information technology – Generic Cabling for Customer Premises*, 2008
Class F: ISO/IEC 11801, 2nd Ed., *Information technology – Generic Cabling for Customer Premises*, 2002
Class FA: Amendment 1 to ISO/IEC 11801, 2nd Ed., *Information technology – Generic Cabling for Customer Premises*, 2008
Name Under Development: ISO/IEC 11801-99-x, Part 2, *Guidance for balanced cabling in support of at least 40 Gb/s data transmission*, under development

Table 2: TIA and ISO/IEC Standards

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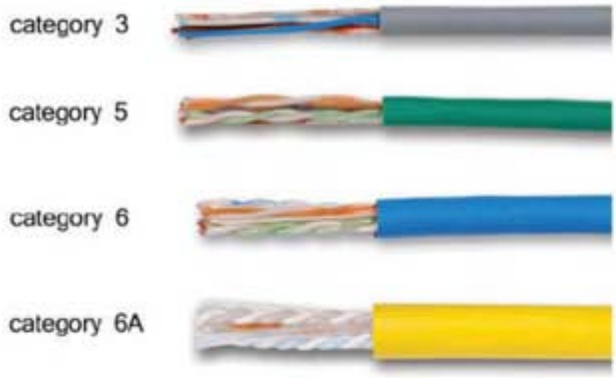

As the category numbers increase, the pair twisting gets tighter. This is due to the increased speed and bandwidth characteristics and to mitigate any attenuation or crosstalk issues (courtesy of Berk-Tek).

recommended for new installations because alien crosstalk performance must be verified with a time-consuming and onerous field qualification process. Whereas primary, internal crosstalk is interference created between pairs within the same jacket, 10GBASE-T is sensitive to alien crosstalk or undesired external signal coupling between adjacent cabling components.

In 2008, category 6A was ratified in ANSI/TIA-568-B.2-10 to create a copper twisted-pair solution for 10GBASE-T, which is prequalified to meet alien crosstalk requirements, thereby removing the need for extensive field testing. Category 6A was developed for bandwidths up to 500 MHz and was designed to be more robust through features such as a tighter pair twist and overall metal foils or increased separation between pairs in adjacent cables to address balance and signal interference.

Many CAT Lives

It has been five years since the last of the category cable was standardized in North America. The information technology systems (ITS) industry currently recognizes four types of twisted-pair, 100 ohm copper category cables—category 3 (1 to 16 MHz), mainly used for telephone; category 5e (1 to 100 MHz), category 6 (1 to 250 MHz) and category 6A (1 to 500 MHz). All of these are available in unshielded or shielded constructions.

Let us circle back to the original question posed on LinkedIn, which asked where and when which category cable—category 5e, 6 or 6A—should be specified. The decision to specify category 6A over category 6, or category 6 over category 5e, is based on many factors, including the applications' bandwidth requirements, installed environment and facility life cycle. There is currently a decline in the installation of category 5e and a shift to higher bandwidth cables. Keith Clark of Datacom Sales & Associates, summed it up in his LinkedIn post. "Annually, we are seeing growth in 6A, strong growth in 6 and a decline in 5e." Following are some of the real-life differentiators and opinions.

- **Category 5e still has a place**—Most of the category 5e installations currently being specified are based on the current installed base (retrofitting to an existing category 5e system), a shorter life cycle of the facility and lower bandwidth requirements (i.e., word processing and accounting spreadsheets).

  "My belief is that 90 percent of computer work is really glorified word processing, and as such, [category] 5e would be a winner all day long. Slow desktop performance is nearly always the computer being full of junk (i.e., from surfing the Web)...We still specify a lot of [category] 5e, especially where there are budget constraints or if a client will be in a location for less than five years," says Glenn Sexton, president and CEO at Northwest Information Systems.

- **Category selection should depend on building life cycle**—"Would you recommend a roof that would only last a couple of years when the life cycle of the building is much longer?" asks Alexander (Alex) Smith, RCDD, president of Connectivityworx. "I recommend various categories of cable to our clients depending on a number of criteria, and life cycle costing should definitely be considered."

- **Category selection is based on bandwidth (and migration path)**—Category 6A is recommended by most industry professionals to handle the migration to 10 Gb/s. While some enterprise environments are still operating at 100 Mb/s, many others have migrated to 1 Gb/s. These speeds are adequate for email and spreadsheet sharing, but other environments have a need for much higher bandwidth.

  Smith makes some interesting points regarding bandwidth and headroom (i.e., cable bandwidth allowance

above standards specifications). "If the client site is populated with high-bandwidth users and time-sensitive requirements, they may benefit from that extra headroom by incrementally improving network performance and reducing slow time. However, this may require a network analysis and would assume that the networking hardware and server architecture are fully optimized for maximum performance," he says.

- **Category selection is determined by market and environment**—"Category 6 is now the de facto standard for most large projects (i.e., new office buildings, K-12 schools, dormitories), and we see category 6A in new hospital construction and some science labs," says Thomas McNamara, RCDD, senior technology consultant at BVH Integrated Services, Inc.

  Clark adds, "If you are dealing with health care, education or oil and gas, these industries realistically benefit by installing a category 6A cable plant—health care due to the file sizes of digital imaging, education due to one-time installation or minimal funding for later upgrades, and oil and gas because they have the budgets and large bandwidth requirements.

  According to David Stoltz, RCDD, specification engineer for Leviton, the current trends in the adoption of higher transmission speeds and category 6A is not limited to environments like health care, but also due to advancements in chip technology and processing power needed in the cable plant.

- **Cable selection should be based on technology**—According to Robert Carlson, vice president of global marketing for Siemon, for anyone planning to be in a facility for three or more years, the proper selection of cable should be based on the direction of technology. "Based on continual technology advancements like new 10GBASE-T chip technology, higher densities and lower power trends for providing higher bandwidth and faster speeds to support the ever increasing amount of Internet, network and storage traffic, one should strongly consider the most advanced copper and optical fiber cabling systems to get the most out of the cabling investment," he says. "Cabling is the most difficult component of a network to upgrade and the most disruptive to replace. It is a small fraction of the cost of network electronics and will support two to three generations of active equipment."

- **Category selection needs to address power**—Power over Ethernet (PoE) allows power and data to be delivered through one twisted-pair copper cable. Category 6 or higher cabling is the preferred choice for PoE and PoE+ because of its somewhat larger conductors and improved heat dissipation characteristics. Shielded cabling adds the ability to dissipate even more heat in hotter environments or when supporting PoE+ or higher applications. "If a client is in a leased premises with a five-year lease and does not plan to deploy 10 Gigabit Ethernet but does plan to deploy voice over IP (VoIP) or PoE, then I recommend category 6… If a client owns the facility, such as a college or industrial facility, then I would recommend a minimum category 6A screened twisted-pair (ScTP) and ideally a category 7_A fully shielded twisted-pair system," says Smith of Connectivitywerx.

- **Cable selection may be dependent on pathway size**—"The biggest impediment for category 6A is the size of the cable. Few, if any, existing pathways can readily accommodate the cabling. However, for new construction, pathways and spaces should, at the very least, be designed to support category 6A," says Larry Farmer, principal consultant/client relations executive at Diamond Technology Services.

  In a comment on designing pathways, Tom McAllister, RITP, national sales manager for comCables, says, "Let's be standards compliant. If we really want to help future proof our clients' facilities, then we should recommend larger pathways, conduits, back boxes and wire managers so that when the time comes, the next generation of cabling will fit without tearing up the walls."

- **Shielded category cables perform best under duress**—Categories 5e, 6 and 6A are available in shielded versions that offer the best immunity to noise and are considered the higher performing twisted-pair cabling options. Smith, who is located in Canada and

Category 7 and 7_A are internationally recognized cables and are shielded for maximum protection against noise and interference (courtesy of Siemon).

mainly follows international standards, says, "The rationale for recommending category 6A ScTP over category 6A UTP is based on the benefit that alien crosstalk becomes a non-issue with a screened or shielded cable." It should be noted that a shielded category 6A is often also smaller in diameter than an unshielded category 6A.

On the CATwalk

What is next for the future of category cables? Notwithstanding the challenge in getting category 7 and category 7_A widely accepted in North America, the outlook for copper category cables seems to be aimed at higher bandwidths requiring tighter test parameters as we move toward 40 and 100 Gigabit Ethernet. There is also a shift toward intelligent buildings that are looking to deploy copper twisted-pair cables to attach building automation devices to the network. In addition to its high bandwidth capabilities, category 7 and 7_A cabling offers some unique advantages for intelligent buildings, such as cable sharing that allows some lower speed, one- or two-pair applications (i.e., voice, cable TV, closed-circuit TV, access control and building automation controls) to be shared over one four-pair cable and telecommunications outlet/connector to reduce materials and pathway space versus running a separate cable for each application.

In the fall of 2012, IEEE 802.3 announced the formation of the IEEE 802.3 Next Generation BASE-T Study Group. The new group is tasked to determine the goals and objectives for the next generation of the IEEE 802.3 BASE-T family of technologies for Ethernet transmission over twisted-pair cabling. It is likely that a 40 Gb/s copper twisted-pair application will become standardized within four years.

While the use of 10 Gb/s continues to grow in the data center, recent developments in wireless technology are also now providing a reason for customers to adopt category 6A in the office environment. Continued revisions to the wireless standards have enabled the proliferation of wireless devices in almost all environments, and IEEE 802.11ac incorporates several new improvements to accommodate this growth and substantially increases the aggregate bandwidth capacity. Within two years, access points will have the ability to overfill a 1 Gb/s pipeline. A 10 Gb drop to the access point is not a far-off reality as it is estimated that by 2015,

wireless access points will provide a theoretical aggregate capacity of 6.9 Gb/s. The densities of the access points may also continue to increase as the access point reach capability drops. With the explosion in wireless originated traffic that is forecasted to continue its exponential growth, some industry experts recommend installing two cables of category 6A or shielded category 6 when planning for long-term wireless infrastructure.

The TR-42.7 Copper Cabling Subcommittee is currently developing *ANSI/TIA-568-C.2-1, Balanced Twisted-Pair Telecommunications Cabling and Components Standard, Addendum 1: Specifications for 100 ohm Next Generation Cabling*. In October 2012, the committee met to look at objectives for supporting 40 and 100 Gb/s and additional support for PoE and PoE+, which could include a twisted-pair media to exceed category 6A specifications. The name of "category 8" has been initially selected as the next iteration of copper twisted-pair cabling.

"Although TIA is not actively developing a standard for category 7_A at this time, it is acceptable to specify ISO/IEC's class F_A cabling in the North American markets," says Valerie Maguire, global sales engineer for Siemon. "The rationale is that, in addition to being recognized by BICSI, NEMA, IEEE and other standards organizations, class F_A is simply a superset of TIA category 6A requirements. With its superior performance, class F_A cabling is better positioned to support extended lengths, reduced latency and reduced power consumption than category 6A when a 40 Gb/s application is finally approved."

Lastly, copper cable to connect building automation systems is the media choice for IP convergence in intelligent buildings, and both TIA and BICSI are looking at creating standards and documentation for these systems. In fact, the term "building automation" will likely be replaced with "intelligent building."

As demonstrated in this article, much has evolved during BICSI's 40 years of history. Convergence is now here, and our industry will continue to watch more applications evolve and attach themselves to the data networks. This will likely provide the "CATs" with many more lives and plenty of parades on the CATwalk. END