**Fiber Optic Operation**

Today, the use of fiber optic systems to carry digitized video, voice and data is universal. In business and industry, fiber optics have become the standard for terrestrial transmission of telecommunication information. In military and defense, the need to deliver ever larger amounts of information at faster speeds is the impetus behind a wide range of retrofit and new fiber optic programs. Although still in its infancy, fly-by-light flight control systems may someday replace fly-by-wire systems with cabling which is lighter, smaller and safer. Fiber optics, combined with satellite and other broadcast media, represents the “new world order” for both commercial telecommunications as well as specialized applications in avionics, robotics, weapon systems, sensors, and transportation.

Functionally, fiber optic systems are similar to the copper wire systems they are rapidly replacing. The principle difference is that fiber optics uses light pulses (photons) to transmit data down fiber lines, instead of electronic pulses to transmit data down copper lines. Other differences are best understood by taking a look at the flow of data from point to point in a fiber optic system.

The “encoding” side of an optical communication system is called the transmitter. This is the place of origin for all data entering the fiber optic system. The transmitter essentially converts coded electrical signals into equivalently coded light pulses. A light-emitting diode (LED) or an injection-laser diode (ILD) is typically the source of the actual light pulses. Using a lens, the light pulses are funneled into the fiber optic connector (or terminus), and transmitted down the line.

Light pulses move easily down the fiber optic line because of the principle of “total internal reflection,” which basically holds that whenever the angle of incidence exceeds a certain value, light will not emit through the reflective surface of the material, but will bounce back in. In the case of optical communications systems, this principle makes it possible to transmit light pulses down a twisting and turning fiber without losing the light out the sides of the strand.

At the opposite end of the line, the light pulses are channelled into the “decoding” element in the system, known as the optical receiver or detector. Again, the actual fiber to detector connection is accomplished with a specialized fiber optic connector/terminus. The purpose of an optical receiver is to detect the received light incident on it and to convert it to an electrical signal containing the information impressed on the light at the transmitting end. The information is then ready for input into electronic based devices, such as computers, navigation control systems, video monitors and so on.

**Cable Construction**

There are typically five elements that make up the construction of a fiber optic cable: the optic core, optic cladding, buffer, strength member and outer jacket. The optic core is the light-carrying element at the center of the optical fiber. It is commonly made from a combination of highly purified silica and germania. Surrounding the core is the optic cladding made of pure silica. The combination of these materials makes the principle of total internal
reflection possible, as the difference in materials used in the core and the cladding creates an extremely reflective surface at the point where they interface. Light pulses entering the fiber core reflect off the core/cladding interface and thus remain within the core as they move down the line.

Surrounding the cladding is a buffer material which acts as a shock absorber to protect the core and cladding from damage. A strength member, typically Aramid, surrounds the buffer adding critical tensile strength to the cable to prevent damage from pull forces during installation. The outer jacket protects against abrasion and environmental damage. The type of jacket used also defines the cable’s duty and flammability rating.

Rays of light passing through a fiber do not travel randomly. Rather, they are channeled into modes—the thousands of possible paths a light ray may take as it travels through the fiber. A fiber can support as few as one mode and as many as tens of thousands. The number of modes in a fiber is significant because it helps determine the fiber’s bandwidth. Multimode fibers have a much larger core than singlemode fiber, allowing hundreds of rays of light to propagate through the fiber simultaneously. Singlemode fiber has a much smaller core, allowing only one mode of light to propagate through the core. Paradoxically, the higher the number of modes, the lower the bandwidth of the cable. The reason is dispersion.

“Modal” dispersion is caused by the different path lengths followed by light rays as they bounce down the fiber (some rays follow a more direct route down the middle of the fiber, and so arrive at their destination well before those rays which waste their time bouncing back and forth against the sides). “Material” dispersion occurs when different wavelengths of light travel at different speeds. By reducing the number of possible modes, you reduce modal dispersion. By limiting the number of wavelengths of light, you reduce material dispersion.
Fiber Optic Terminology:

**Attenuation**
Loss or decrease in power from one point to another in a fiber optic cable.

**Bandwidth**
The information carrying capacity of an optical fiber, expressed in MHz/km. The measure is dependent upon wavelength and type of light source.

**Attenuation Limited Operation**
The condition in a fiber optic link when operation is limited by the power of the received signal (rather than by bandwidth or by distortion). Attenuation is usually measured in decibels per kilometer (db/km) at a specific wavelength. The lower the number, the better the fiber.

**Bandwidth Limited Operation**
The condition prevailing when the system bandwidth, rather than the amplitude of the signal, limits performance. The condition is reached when modal dispersion distorts the shape of the waveform beyond specified limits.

**Bend Radius**
Radius a fiber or fiber optic cable can bend before breaking or suffering increased attenuation.

**Decibel (dB)**
Unit for measuring the relative strength of a signal. The same unit is utilized to measure insertion loss.

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Glenair custom single and multichannel fiber optic connectors utilize the latest composite thermoplastic materials technology and are designed for use with Glenair’s family of fiber optic connector accessories.

**Fiber Optic Backshells**
Fiber optic strands are robust and reliable. But they may not be manhandled (clamped, bent, or crushed) with the same vigor one might employ when working with a fat copper conductor. For this reason, fiber optic connector and cable accessories are designed to reduce bending and to eliminate compression forces. Needless to say, conventional connector backshells such as cable clamps and strain reliefs which apply compression forces directly to the cable, are not appropriate for use in fiber optic assemblies. Likewise, accessory elbows, conduit transitions, and other fittings which subject fiber optic cables to abrupt changes in direction beyond the acceptable bend radius of the fiber are equally risky. In both cases, the dangers are either outright breakage of the fiber optic core or attenuation of the optical signal.

Glenair’s composite thermoplastic fiber optic accessories—including elbows, transitions and end-bells—are designed with smooth 45° or 90° bends to insure the non-abrupt routing of the cable. Composite Outil-Clamps and heat shrinkable boots provide strain relief without applying severe compression to the cable. Glenair’s cable overmolding capability enables the integration of unique straight or angular shapes directly into the termini, has traditionally relied on a machined stainless steel ferrule incorporating a precision micro-drilled hole. Glenair’s fiber optic termini for D38999 Series III connectors are qualified to MIL-PRF-29504/4 and /5 requirements. Unique precision ceramic ferrules, with concentricity and diametric tolerances controlled within a micron (.00004 of an inch), meet the needs of high bandwidth and low allowable insertion loss applications. Glenair’s ferrules are approximately 10 times more accurate than alternative designs, and have reduced insertion loss values from 1.5db to less than .5db.

Glenair’s FiberCon® Backshells are specifically designed to meet the unique requirements of the media. For both single fiber leads as well as multichannel applications, FiberCon® provide full support and vibration dampening while allowing the fiber to “float” as required to eliminate micro-bending. Fiber optic terminations derive from electrical in one critical way: during connector mating the fiber optic spring-loaded socket or pin retracts from .040 to .080 inches. It is critical that the backshell design accommodates this movement within the shell cavity to prevent data loss due to micro bending which leads to localized light refraction. The unique rubber support grommet utilized in Glenair’s design employs the same layout pattern as the connector shell—providing both necessary axial alignment, as well as strain relief and float.

When evaluating the costs and benefits of moving to fiber, it is important to adopt both a short and long term view. In the short term, it is arguably less expensive to simply continue using copper cabling to meet an incremental expansion of data communication needs. This avoids the expense of adding the transmitters, converters, repeaters, connectors, termini, receivers and so on needed for integrating optical fiber into an existing electronic system.

**Fiber Optic Costs and Benefits**

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Fiber Optic Terminology: 

Misalignment Loss 
The loss of power resulting from axial misalignment, lateral displacement, and end separation.

Optical Time Domain Reflectometer (OTDR) 
Testing system for fiber strands in which an optical pulse is transmitted through the fiber and the resulting backscatter and reflections are used to estimate attenuation and identify defects and the sources of localized losses.

Source 
The means used to convert an electrical information carrying signal to a corresponding optical signal for transmission by fiber. The source is usually a Light Emitting Diode (LED) or Laser.

Transceiver 
An electronic device which has both transmit and receive capabilities.

Transducer 
A device for converting energy from one form to another, such as optical energy to electrical energy.

Transmission Loss 
Total loss encountered in transmission through a system.

Transmitter 
An electronic package which converts an electrical signal to an optical signal.

Source: Glenair, Inc.

Packaging Solutions for Inside the Box

When fiber leads are used within equipment enclosures or other protected environments, the interconnect assembly generally looks something like the figure below: a wall mount or jam nut mount receptacle connector (“A”) with simplex fiber leads. This receptacle connector is used to penetrate the enclosure and mate to the external environmental plug connector.

The simplex leads within the protected enclosure commonly route to the transceiver optical device, and are terminated to commercial connectors such as ST, FC, SC, LC (or other) connectors at the “B” end. Glenair can also supply pigtail assemblies of this type with a FiberCon® backshell and/or a protective length of conduit. This design approach ensures strict alignment of the fiber strands to the connector, optimum strain relief to the individual fibers as well as crush protection.

The use of a short length of conduit and a small end-bell fitting is recommended in applications where a heat or abrasion source within the box may damage the fiber media. In most cases, analysis of the available space is critical to ensure such interconnect hardware does not interfere with the electronics package inside the box. This basic packaging is appropriate for any equipment—such as a radar, camera, shipboard console, antenna and so on—with an internal fiber wire servicing an optical transmitter/receiver.

Glenair can supply the complete interconnect assembly, including the connector, transceiver, and optional backshell fittings and conduit. Glenair’s ASAP Fiber Optic Cable Sets are specifically designed for applications of this type.

Packaging Solutions for External Point to Point Applications

While inside-the-box applications may be conveniently terminated in the field during the installation of the electronic equipment, other fiber optic interconnect cables lend themselves to factory termination and assembly. This is due to the rugged nature of the environments in which they are used. When fiber optic cables need to withstand rough handling, caustic and corrosive fluids or other sources of physical or environmental stress, the interconnect package needs to be extremely tough, and the cables are generally factory-terminated with the appropriate protective materials. Factory assembly is also called for when there are no restrictions or impediments to providing a pre-built harness or assembly, such as unpredictable distances between bulkheads or other site-specific routing problems. Factory-terminated fiber optic cables are typically multichannel, with sometimes as many as 30 fiber optic channels. Examples include ship-to-shore phone/data cables, fuel cell cable harnesses, intra-car railway cables, and other harsh environmental applications.

The range of performance requirements for rugged, external cables includes strain-relief, environmental sealing, high tensile pull, crush resistance and chemical resistance. Electromagnetic shielding can also be a requirement in hybrid copper/fiber cables. Packaging generally takes three forms:

1. Overmolded cable harnesses
2. Metal core or...
Appendix

### Fiber Optic Technology and Packaging

**Packaging Options**

- Polymer-core conduit assemblies, and (3) Armored cable equipped with environmental and/or shield terminating backshells.

**Overmolded Harnesses**

Overmolded designs are specified when field repairability is not an anticipated requirement and harsh environmental and mechanical stress conditions warrant extra protection of the fiber media and terminations. Overmolding technology employs specialized tooling to construct ruggedized, sealed transitions between the cable and the connector and any transition hardware. Overmolding is ideally suited for complex multi-leg harnesses because the many transitions are otherwise difficult to seal with conventional shrink-boots. Overmolding typically uses environmentally resistant jacketing such as Polyurethane. Overmolded cables are extremely firm and can protect the factory terminations from a broad range of environmental and mechanical stress generation mechanisms.

Glenair can integrate its own fiber optic connectors, backshell accessories, termini and cable into such cables—providing a complete, turnkey system. Glenair also offers point-to-point overmolded cable sets with plug-to-plug, plug-to-receptacle and receptacle-to-receptacle connectors as a standard catalog offering. And because termin-retraction is a critical requirement of MIL-DTL-38999 type connectors, Glenair’s unique fiber-optic backshells which facilitate termini retraction and eliminate micro-bending are a critical component in every overmolded cable.

**Conduit Assemblies**

Conduit is a perfect material for the protection of fiber optic media and for the construction of factory-terminated assemblies. As a wire protection material, conduit has a number of unique advantages over other packaging, such as armored cable and even overmolding. First and foremost, conduit systems offer greater flexibility than other ruggedized designs. This is critical in applications such as intra-car railway data transmission lines, where the ability of the harness to flex and bend with the repetitive motion of the rail car is a critical requirement. Conduit is also known for its excellent pull strength, high crush resistance, and relative light weight. Perhaps most important, conduit fittings and transitions can more easily be opened for repair or to expand the number of fiber lines. Additionally, conduit assemblies make use of a wide range of existing fittings and transitions, including lightweight composite versions, to meet virtually any configuration and lay-up requirement.

Glenair high-temperature overmolded cable assemblies are ideally suited for fiber optic and hybrid fiber/copper applications in exposed, harsh environments. Overmolding of fiber is a unique Glenair strength, and has been utilized as a packaging solution in such diverse applications as fighter jet fuel-cell cables and rooftop telecommunication cabling.

Conduit provides an ideal packaging media for fiber optic cables. The material is highly flexible and can be terminated at the factory with a wide range of shielding, jacketing and other specialized materials. Conduit may be opened for maintenance and repair or to expand the number of lines.

Glenair offers complete in-house capabilities for the construction of fiber optic conduit assemblies. In addition to helically molded polymer materials, we also offer a metal-core conduit product which provides unmatched crush-resistance and EMI protection (for hybrid copper/fiber applications). Both styles of tubing may be outfitted at the factory with braided shielding and external jacketing, or supplied as discrete components for customer assembly. Glenair manufactures all the necessary branched transitions and fittings for every connector and/or feed through configuration.

**Reinforced Cable/Backshell Assemblies**

Reinforced extruded cable provides a third packaging option for rugged application environments. Multichannel fiber optic cable is available in a broad range of designs. Depending on customer requirements for fiber type, strength members, jacketing material and other component-level options.

Glenair can extrude short-run fiber optic cable for most high-performance applications. The cable becomes the backbone of this packaging solution. A ruggedized, environmental backshell is an equally key component in the armored cable assembly. Such backshells allow for the termination of overall shielding, the provision of additional strain-relief and/or environmental protection of the cable to connector transition.

But the most important design consideration behind the use of such specialized backshells is the ability to provide some level of repairability to the assembly. Unlike overmolded solutions, the reinforced extruded cable/backshell package allows maintenance technicians to open the cable for field service. Backshells are selected for functionality (strain-relief, shield termination, and so on) and for compatibility with the chosen connector. Glenair is able to provide turnkey assemblies of this type as well as all the discrete components—from the extruded cable to the backshells, connectors, termini, dust-caps and other fiber optic interconnect accessories.
of the fiber leads. The boxes may be positioned in a centralized location to provide service to multiple pieces of electronic equipment. Additionally, long lengths of stripped cable can be sealed away in the box for subsequent repair and maintenance. Typical box configurations feature either convoluted tubing and environmental feed-through fittings, or in-line and box-mounted fiber optic connectors. Glenair is uniquely positioned to provide integrated fiber optic cable junction boxes of this type. Our line of CostSaver Composite Junction Boxes are specifically designed for use in harsh EMI and environmental applications: where field termination of fiber media is a difficult and cumbersome operation.

Glenair’s background in providing fiber optic interconnect solutions for the navy has led to the development of some completely unique solutions for the field termination of fiber. Glenair offers a unique backshell and conduit assembly that perfectly suits this requirement. As the illustration below depicts, the Glenair retractable backshell and conduit assembly provides all the working room necessary for easy field termination of fiber.

The third major packaging category for fiber optic applications covers those situations in which a pre-assembled cable or harness cannot be used due to the difficulty of cable installation and routing. A classic example is found in shipboard installation, where the fiber optic cable often has to travel a great distance between the various equipment components in the system. A below-deck control room, for example, may rely on sensors or communications equipment located on the mast of the ship. Between these two elements lies a complicated maze of deck-plating, impenetrable mast of the ship. Between these two elements lies a complicated maze of deck-plating, impenetrable

Obviously, it would be impossible to install a factory-terminated assembly into this maze of holes and walls. So, long (trunk) cable runs are completed from point “A” to point “B” and the termination of the fiber optic connector is completed on site at each end of the cable. The challenge is to provide technicians with the ability to strip back an adequate length of the cable to complete the individual fiber line terminations as well as some subsequent way to protect the stripped-back cable from environmental damage.

One solution to the problem is to mount a junction box at each end of the system and bring the trunk cable into the box for subsequent termination of the contacts and protection of the media. Such junction boxes also aid in the routing and storage of fiber-optic cable. In the event a termination is damaged, both the conduit and box may be opened to access the termini and the wire-loops for easy repair.

The broad utilization of fiber optics in airframe applications, such as for in-flight entertainment and other complex electrical/optical interconnect systems, currently demands transmitter and receiver solutions that are reduced in size and weight. Designed for use in protocol-specific application environments such as IEEE 802.3-2005 GB Ethernet, these small form-factor copper-to-fiber media converters reduce weight and complexity while still meeting shock, vibration, and fiber-link distance requirements of traditional F/O transmitter/receiver equipment. In addition to 100BASE-T and DVI compliant converters, many IFE applications are able to utilize optoelectronic contacts in transmitter and receiver roles directly incorporated into ARINC 801 and other standard airframe connector packages. These ultra-lightweight transmitter/receivers are designed for the rigorous of in-cabin use and multiple electrical to fiber optic junctions. The technology supports GB Ethernet, AFDX, Fibre Channel, DVI, HDMI and more.

In this application, Glenair was able to provide a complete, turnkey interconnect assembly which included both the light-weight composite junction box, as well as the conduit, fittings, fiber optic connectors and termini. Termination and test of the fiber media and installation of all fittings was completed at the factory to ensure quality and to facilitate fast installation in the field. The box doubles as an environmentally controlled storage area for additional lengths of fiber-optic cable. In the event a termination is damaged, both the conduit and box may be opened to access the termini and the wire loops for easy repair.

**Fly-by-Light**

Front-line aircraft are now integrating fiber optic media into their avionic and flight control systems. Glenair’s CostSaver Composite Boxes are being used as interconnection junction boxes in fiber optic systems, and as instrument cases in high-speed fiber optic data systems. The innovative products, including composite MIL-DTL-38999 type Series III Connectors, MIL-PRF-29504 qualified termini, Glenair extruded fiber optic cable, as well as feed-through fittings and adapters are all chosen for their ability to reduce the size and weight of the interconnect package while improving the safety, reliability and performance of the flight control system.

**Reduced Form Factor Copper to Fiber Media Conversion**

Introduction to Fiber Optic Interconnect Technology and Packaging

Packaging Options

Packaging Solutions for Field Termination

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Fiber optic systems carrying digitized video, voice and data continue to multiply. High-speed fiber optic interconnect technologies enable specialized applications in avionics, robotics, weapon systems, sensors, space and other high performance environments. Precision-engineered fiber optic contacts, or termini, are the key to delivering low data loss and reliable, repeatable performance in fiber optic connection systems.

The advantages of a connection system that can transmit the equivalent of 24,000 telephone calls simultaneously through fibers thinner than a human hair go beyond this mind-boggling data transmission rate. Fiber optic systems save size and weight, are immune to EMI interference, are electrically isolated for spark-free performance, and transmit signals that are nearly impossible to intercept for enhanced security.

The challenge for many fiber optic applications is environmental. With data continuing to multiply, transmitting through a fiber core only 9.3 microns in diameter, a single speck of dust on a conventional butt-joint contact terminus could completely disrupt transmission. This might not be a problem in a controlled, sealed environment—but a military communication shelter rapidly deployed in a windy desert, or a metropolitan commuter train speeding down a gritty, snow-rapidly deployed in a windy desert, or a metropolitan environment—but a military communication shelter could completely disrupt transmission. The low insertion loss Eye-Beam™ offers comparable performance to standard butt joint termini in a package that’s built to withstand rugged use and frequent mating/de-mating in field conditions.

The Glenair Eye-Beam™ contact utilizes an innovative free-floating expanded beam lens and ultra-high precision ceramic alignment sleeves as well as custom designed nickel alloy terminus bodies to ensure perfect axial alignment and optimal optical performance. Best of all, the Eye-Beam™ can be integrated into virtually any circular or rectangular connector package.

**Tactical Field Deployment**

Mobile Tactical Shelters are an integral part of Army and Marine battlefield communication systems. These mobile, rapidly deployable shelters provide a vital communication capability. Voice over IP (VoIP) technology allows voice, video and data to be consolidated into one fiber cable system, greatly simplifying deployment. The fiber optic interconnect system for these shelters must be reliable in extreme environments, and able to stand up to rapid mating and de-mating in the field.

**Rapid “Daisy-Chaining” of Tactical Fiber Cables**

Tactical military applications rely on rapid, trouble-free deployment of interconnect cabling. Glenair GFOCA hermaphroditic expanded beam connectors and cables are the perfect solution for frequent mating and unmating of fiber optic cabling in harsh application environments. The sealed Eye-Beam™ expanded beam interface prevents contamination of the optical path, while the hermaphroditic coupling provides operational flexibility and cost savings. Glenair offers both discrete connectors as well custom cable assemblies and field-ready spooled cable sets.

**Extreme Harsh Environments**

Rail system interconnect design presents many challenges. Reducing weight is a critical issue in high-speed and Maglev rail systems. Shielding electromagnetic interference is also important, especially in sensitive electronic systems such as engine monitoring and diagnostic sensors. Basic mechanical protection of interconnect cables, conductors and contacts is a standard requirement especially when frequent mating and unmating is required, or when cables are routed through exposed intercar or undercar locations. To ensure rapid and accurate car linking and cabin reconfigurations, interconnects must be easy to couple and keyed to avoid mis-mating. Vibration, shock and connector decoupling problems are also common in rail applications, and require focused attention when selecting shell materials and mating technologies. As passenger and crew safety is paramount, interconnection systems must not compound flammability, smoke or toxicity risks.
**Fiber Optics for High Definition Broadcasting**

Fiber optic systems are implemented in remote television broadcast systems for sporting events or on-location news reporting. In the television industry this is known as electronic field production, or EFP. Multi-camera video editing, advanced graphics and sound equipment must be reliable and portable, built into a truck or van—a “control room on wheels”—where space is at a premium.

A single fiber optic connection can simultaneously transport bidirectional digital and analog video, as well as two-way camera control, audio, data, sync, tally/call, prompter, and intercom signals between a high-definition camera and the mobile studio truck. A fiber optic system transmits signals digitally and optically, so broadcasters and producers are assured of the highest quality audio and video, free from interference or grounding problems.

Broadcast fiber optic interconnect systems must be quickly deployable for on-location news broadcasting, and able to stand up to the rigorous conditions presented on the sidelines of a football game or a weather report from the site of a tropical storm. Glenair Eye-Beam™ termini provide the space-saving and lightweight, yet rugged and durable connection that this exciting industry demands.

**Eye-Beam™ Solutions and Future Applications**

At Glenair, we are serious about the business of engineering the right solution for every application. We continue to design and enhance fiber optic solutions for standard military and commercial connectors, and develop new fiber optic technologies for exciting new applications like robotics and future soldier systems.

**MIL-DTL-38999 Connectors**

The MIL-DTL-38999 connector is currently the most commonly specified multi-pin cylindrical interconnect for fiber optic aerospace applications. When used to connect multiple strands of fiber simultaneously, the D38999 connector functions as a container or shell for the precision termini which perform the actual marriage of the fiber strands.

Glenair’s unique alignment techniques maximize optical performance and provide reliable, repeatable interconnection of optical fibers. Ferrule design—critical to performance—has traditionally relied upon a machined stainless steel terminus incorporating a precision micro drilled hole. Glenair’s unique precision ceramic ferrules, with concentricity and diametric tolerances controlled within one micron (.00004 of an inch), meet the needs of high bandwidth and low allowable insertion loss applications. In fact, Glenair’s ferrules are approximately 10 times more accurate than alternative designs, and have reduced insertion loss values from 1.5dB to less than .5dB (typical loss for Glenair termini is .3 dB).

Glenair has engineered Eye-Beam™ MIL-DTL-38999 connectors for use in applications such as high definition video camera equipment, high speed routers for long haul transmission, and military and commercial avionics applications.

**Eye-Beam™ Fiber Optics in Robotics**

Robots are relied on in manufacturing and industry to do jobs in dangerous or dirty environments. They are also employed in increasingly complex tasks in bomb detection and disposal, earth and space exploration, laboratory research, and remote surgical systems. Glenair COTS (Commercial Off-The-Shelf) Eye-Beam™ fiber optic termini can provide reliable high-speed data transmission in the challenging environments that these robotic applications present.

**GFOCA Hermaphroditic Fiber Optic Connection System**

Hermaphroditic coupling eliminates the need for adapters and male and female mating halves. Hermaphroditic housings also allow for rapid deployment without the use of male and female mating halves or other adapters, creating low loss Singlemode, Multimode and Hybrid ‘daisy-chained’ links in a variety of insert arrangements.

The rugged and reliable Glenair GFOCA Connection System with Eye-Beam™ termini is used by the Army for long-run battlefield ground system communications, and is also well-suited to dockside naval communications, down-hole drilling and other harsh environment applications.

**The Eye-Beam™ Revolution**

Glenair continues to make substantial investments in equipment, tooling, research and the industry’s best engineering talent to develop new fiber optic technologies. Glenair Eye-Beam™ fiber optic termini will solve environmental challenges for today’s demanding fiber optic systems, and we will continue to develop the right solutions for tomorrow’s applications—especially in the area of expanded beam fiber optic technologies.

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**The Glenair Eye-Beam™ Fiber Optic Revolution**

But make no mistake: the overriding challenge is environmental. Rail and transportation systems represent one of the most challenging environments for the long-term survivability and reliability of interconnect cables and assemblies. From high-speed rail transportation systems to heavy railway freight lines, the standard daily fare of the rail industry is one harsh environmental challenge after another.

Glenair Eye-Beam™ fiber optics in a ruggedized, reverse-bayonet connector package meet the environmental challenges of rail systems, standing up to shock, vibration, moisture, and temperature fluctuation while delivering the reliable high-speed data transmission advantages of fiber optics.

**Eye-Beam™ Off-The-Shelf (OTS) Fiber Optic Terminations**

Glenair’s OTS termini are in stock and immediately available, as well as custom designed with any variety of interconnect in fiber optic aerospace applications. A fiber optic system transmits signals digitally and optically, so broadcasters and producers are assured of the highest quality audio and video, free from interference or grounding problems.

Broadcast fiber optic interconnect systems must be quickly deployable for on-location news broadcasting, and able to stand up to the rigorous conditions presented on the sidelines of a football game or a weather report from the site of a tropical storm. Glenair Eye-Beam™ termini provide the space-saving and lightweight, yet rugged and durable connection that this exciting industry demands.

**Eye-Beam™ Solutions and Future Applications**

At Glenair, we are serious about the business of engineering the right solution for every application. We continue to design and enhance fiber optic solutions for standard military and commercial connectors, and develop new fiber optic technologies for exciting new applications like robotics and future soldier systems.

**MIL-DTL-38999 Connectors**

The MIL-DTL-38999 connector is currently the most commonly specified multi-pin cylindrical interconnect for fiber optic aerospace applications. When used to connect multiple strands of fiber simultaneously, the D38999 connector functions as a container or shell for the precision termini which perform the actual marriage of the fiber strands.

Glenair’s unique alignment techniques maximize optical performance and provide reliable, repeatable interconnection of optical fibers. Ferrule design—critical to performance—has traditionally relied upon a machined stainless steel terminus incorporating a precision micro drilled hole. Glenair’s unique precision ceramic ferrules, with concentricity and diametric tolerances controlled within one micron (.00004 of an inch), meet the needs of high bandwidth and low allowable insertion loss applications. In fact, Glenair’s ferrules are approximately 10 times more accurate than alternative designs, and have reduced insertion loss values from 1.5dB to less than .5dB (typical loss for Glenair termini is .3 dB).

Glenair has engineered Eye-Beam™ MIL-DTL-38999 connectors for use in applications such as high definition video camera equipment, high speed routers for long haul transmission, and military and commercial avionics applications.

**Eye-Beam™ Fiber Optics in Robotics**

Robots are relied on in manufacturing and industry to do jobs in dangerous or dirty environments. They are also employed in increasingly complex tasks in bomb detection and disposal, earth and space exploration, laboratory research, and remote surgical systems. Glenair COTS (Commercial Off-The-Shelf) Eye-Beam™ fiber optic termini can provide reliable high-speed data transmission in the challenging environments that these robotic applications present.

**GFOCA Hermaphroditic Fiber Optic Connection System**

Hermaphroditic coupling eliminates the need for adapters and male and female mating halves. Hermaphroditic housings also allow for rapid deployment without the use of male and female mating halves or other adapters, creating low loss Singlemode, Multimode and Hybrid ‘daisy-chained’ links in a variety of insert arrangements.

The rugged and reliable Glenair GFOCA Connection System with Eye-Beam™ termini is used by the Army for long-run battlefield ground system communications, and is also well-suited to dockside naval communications, down-hole drilling and other harsh environment applications.

**The Eye-Beam™ Revolution**

Glenair continues to make substantial investments in equipment, tooling, research and the industry’s best engineering talent to develop new fiber optic technologies. Glenair Eye-Beam™ fiber optic termini will solve environmental challenges for today’s demanding fiber optic systems, and we will continue to develop the right solutions for tomorrow’s applications—especially in the area of expanded beam fiber optic technologies.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>Marine Bronze</td>
<td>Unplated</td>
<td>AMS-4640 alloy, unplated</td>
<td>1000</td>
<td>Conductive</td>
<td>-65 to +200°C</td>
<td></td>
<td>Marine and geo-physical applications</td>
</tr>
<tr>
<td>AL</td>
<td>Aluminum</td>
<td>Alumiplate, Clear Chromate</td>
<td>MIL-DTL-83488, Class 2, Type II over electroless nickel</td>
<td>500</td>
<td>Conductive</td>
<td>-65 to +175°C</td>
<td></td>
<td>Approved for MIL-DTL-38999L and MIL-DTL-83513G.</td>
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<tr>
<td>ZM</td>
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<td>Zinc-Cobalt, Clear Chromate</td>
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<td>500</td>
<td>Conductive</td>
<td>-65 to +175°C</td>
<td></td>
<td>Glenair’s standard black zinc-nickel</td>
</tr>
<tr>
<td>ZN</td>
<td>Aluminum</td>
<td>Zinc-Cobalt, Black</td>
<td>MIL-DTL-83488, Class 2, Type II over electroless nickel</td>
<td>500</td>
<td>Conductive</td>
<td>-65 to +175°C</td>
<td></td>
<td>Glenair’s standard black zinc-nickel</td>
</tr>
<tr>
<td>ZU</td>
<td>Stainless Steel</td>
<td>Electroless Nickel</td>
<td>MIL-DTL-38999, Class 4B, Type IV over electroless nickel</td>
<td>500</td>
<td>Conductive</td>
<td>-65 to +175°C</td>
<td></td>
<td>Glenair’s preferred gold cadmium finish</td>
</tr>
<tr>
<td>Z1</td>
<td>Stainless Steel</td>
<td>Passivate</td>
<td>SAE AMS-2700</td>
<td>500</td>
<td>Conductive</td>
<td>-65 to +200°C</td>
<td></td>
<td>Glenair’s standard passivated stainless steel</td>
</tr>
<tr>
<td>Z2</td>
<td>Stainless Steel</td>
<td>Electroless Nickel</td>
<td>MIL-DTL-83488, Class 2, Type II over electroless nickel</td>
<td>500</td>
<td>Conductive</td>
<td>-65 to +200°C</td>
<td></td>
<td>Approved for MIL-DTL-38999L.</td>
</tr>
<tr>
<td>ZC</td>
<td>Stainless Steel</td>
<td>Zinc-Cobalt, Black</td>
<td>MIL-DTL-83488, Class 2, Type II over electroless nickel</td>
<td>500</td>
<td>Conductive</td>
<td>-65 to +200°C</td>
<td></td>
<td>Glenair’s standard zinc-cobalt over stainless steel</td>
</tr>
<tr>
<td>ZDR</td>
<td>Stainless Steel</td>
<td>Zinc-Cobalt, Black</td>
<td>MIL-DTL-83488, Class 2, Type II over electroless nickel</td>
<td>500</td>
<td>Conductive</td>
<td>-65 to +175°C</td>
<td></td>
<td>Use ZR for new design</td>
</tr>
<tr>
<td>ZL</td>
<td>Stainless Steel</td>
<td>Electrodeposited Nickel</td>
<td>SAE-AMS-80-290, Class 2, Type II over electroless nickel</td>
<td>500</td>
<td>Conductive</td>
<td>-65 to +200°C</td>
<td></td>
<td>Glenair’s standard black nickel-plated stainless steel</td>
</tr>
<tr>
<td>ZM</td>
<td>Stainless Steel</td>
<td>Electroless Nickel</td>
<td>SAE-AMS-80-290, Class 2, Type II over electroless nickel</td>
<td>500</td>
<td>Conductive</td>
<td>-65 to +175°C</td>
<td></td>
<td>Used on hermetic connectors. Use ZM for other applications.</td>
</tr>
<tr>
<td>ZMT</td>
<td>Stainless Steel</td>
<td>Nickel-PTFE</td>
<td>MIL-DTL-83488, Class 2, Type II over electroless nickel</td>
<td>500</td>
<td>Conductive</td>
<td>-65 to +175°C</td>
<td></td>
<td>Glenair’s preferred gold cadmium finish</td>
</tr>
<tr>
<td>ZN</td>
<td>Stainless Steel</td>
<td>Zinc-Cobalt, Black</td>
<td>MIL-DTL-83488, Class 2, Type II over electroless nickel</td>
<td>500</td>
<td>Conductive</td>
<td>-65 to +175°C</td>
<td></td>
<td>Glenair’s standard black zinc-nickel</td>
</tr>
</tbody>
</table>

Notes:
- **M**: Used for military applications.
- **F**: Used for fiber optic applications.
- **N**: Used for non-military applications.
- **X**: Used for medical applications.
- **Z**: Used for aerospace applications.
- **S**: Used for space applications.
- **R**: Used for automotive applications.
- **C**: Used for commercial applications.
- **E**: Used for electrical applications.
- **P**: Used for precision applications.
- **G**: Used for general applications.
- **A**: Used for industrial applications.
- **B**: Used for building applications.
- **L**: Used for lighting applications.
- **K**: Used for kitchen applications.
- **D**: Used for decorative applications.
- **H**: Used for home applications.
- **W**: Used for window applications.
- **V**: Used for vehicle applications.
- **O**: Used for optical applications.
- **T**: Used for testing applications.
- **Q**: Used for quality applications.
- **R**: Used for research applications.
- **S**: Used for scientific applications.
- **E**: Used for education applications.
- **P**: Used for performance applications.
- **G**: Used for general applications.
- **A**: Used for industrial applications.
- **B**: Used for building applications.
- **L**: Used for lighting applications.
- **K**: Used for kitchen applications.
- **D**: Used for decorative applications.
- **H**: Used for home applications.
- **W**: Used for window applications.
- **V**: Used for vehicle applications.
- **O**: Used for optical applications.
- **T**: Used for testing applications.
- **Q**: Used for quality applications.
- **R**: Used for research applications.
- **S**: Used for scientific applications.
- **E**: Used for education applications.
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- **G**: Used for general applications.
- **A**: Used for industrial applications.
- **B**: Used for building applications.
- **L**: Used for lighting applications.
- **K**: Used for kitchen applications.
- **D**: Used for decorative applications.
- **H**: Used for home applications.
- **W**: Used for window applications.
- **V**: Used for vehicle applications.
- **O**: Used for optical applications.
- **T**: Used for testing applications.
- **Q**: Used for quality applications.
- **R**: Used for research applications.
- **S**: Used for scientific applications.
- **E**: Used for education applications.
- **P**: Used for performance applications.
## Fiber Optic Appendix

### Glenair Connector Plating Code and Mil-Spec Connector Finish Code Cross-Reference

#### MIL-DTL-38999 Series III Finish Code

<table>
<thead>
<tr>
<th>Material, Finish</th>
<th>Recommended Glenair Material/Finish Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Aluminum, Cadmium Plated, Clear Chromate</td>
</tr>
<tr>
<td>B</td>
<td>Aluminum, Cadmium Plated, Olive Drab</td>
</tr>
<tr>
<td>C</td>
<td>Aluminum, Anodize, Hardcoat</td>
</tr>
<tr>
<td>D</td>
<td>Stainless Steel, Passivated</td>
</tr>
<tr>
<td>E</td>
<td>Aluminum, Electroless Nickel</td>
</tr>
<tr>
<td>N</td>
<td>Stainless Steel, Electrodeposit Nickel (Hermetic)</td>
</tr>
<tr>
<td>P</td>
<td>Aluminum, Pure Dense Aluminum (AlumiPlate™)</td>
</tr>
<tr>
<td>R</td>
<td>Aluminum, Electroless Nickel</td>
</tr>
<tr>
<td>T</td>
<td>Aluminum, Nickel PTFE</td>
</tr>
<tr>
<td>U</td>
<td>Aluminum, Cadmium Plated, Clear Chromate</td>
</tr>
<tr>
<td>X</td>
<td>Aluminum, Cadmium Plated, Olive Drab</td>
</tr>
<tr>
<td>Z</td>
<td>Aluminum, Black Zinc-Nickel</td>
</tr>
</tbody>
</table>

#### MIL-DTL-38999 Series II and III Finish Code

<table>
<thead>
<tr>
<th>Material, Finish</th>
<th>Recommended Glenair Material/Finish Code</th>
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<tbody>
<tr>
<td>C</td>
<td>Aluminum, Anodize, Hardcoat</td>
</tr>
<tr>
<td>F</td>
<td>Aluminum, Electroless Nickel</td>
</tr>
<tr>
<td>G</td>
<td>Aluminum, Electroless Nickel (Space Grade)</td>
</tr>
<tr>
<td>H</td>
<td>Stainless Steel, Passivated (Space Grade)</td>
</tr>
<tr>
<td>J</td>
<td>Composite, Cadmium Plated, Olive Drab</td>
</tr>
<tr>
<td>K</td>
<td>Stainless Steel, Passivated</td>
</tr>
<tr>
<td>L</td>
<td>Stainless Steel, Electrodeposit Nickel</td>
</tr>
<tr>
<td>M</td>
<td>Composite, Electroless Nickel</td>
</tr>
<tr>
<td>N</td>
<td>Stainless Steel, Electrodeposit Nickel (Hermetic)</td>
</tr>
<tr>
<td>P</td>
<td>Aluminum, Pure Dense Aluminum (AlumiPlate™)</td>
</tr>
<tr>
<td>R</td>
<td>Aluminum, Electroless Nickel</td>
</tr>
<tr>
<td>S</td>
<td>Stainless Steel, Electrodeposit Nickel</td>
</tr>
<tr>
<td>T</td>
<td>Aluminum, Nickel PTFE</td>
</tr>
<tr>
<td>U</td>
<td>Aluminum, Cadmium Plated, Olive Drab</td>
</tr>
<tr>
<td>X</td>
<td>Aluminum, Cadmium Plated, Olive Drab</td>
</tr>
<tr>
<td>Y</td>
<td>Stainless Steel, Passivated</td>
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<tr>
<td>Z</td>
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#### MIL-DTL-28849 Finish Code

<table>
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<th>Material, Finish</th>
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<tr>
<td>A</td>
<td>Aluminum, Cadmium Olive Drab over Nickel</td>
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<tr>
<td>B</td>
<td>Stainless Steel, Cadmium-Black over Nickel</td>
</tr>
<tr>
<td>L</td>
<td>Aluminum, Nickel PTFE</td>
</tr>
<tr>
<td>S</td>
<td>Aluminum, Zinc Nickel, Non-Reflective</td>
</tr>
</tbody>
</table>

#### SAE AS50059 Class Code

<table>
<thead>
<tr>
<th>Material, Finish</th>
<th>Recommended Glenair Material/Finish Code</th>
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<tbody>
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<td>A, B, C, D, E, DJ, F, P, R, W</td>
<td>Aluminum, Cadmium Plated, Olive Drab</td>
</tr>
<tr>
<td>H, K</td>
<td>Stainless Steel, Electroless Nickel</td>
</tr>
<tr>
<td>L, U</td>
<td>Aluminum, Electroless Nickel</td>
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</tbody>
</table>

#### MIL-DTL-26482 Finish Code

<table>
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<tr>
<th>Material, Finish</th>
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<tbody>
<tr>
<td>Series I</td>
<td>Aluminum, Cadmium Plated, Olive Drab</td>
</tr>
<tr>
<td>Series 2 Class L</td>
<td>Electroless Nickel</td>
</tr>
<tr>
<td>Series 2 Class W</td>
<td>Aluminum, Cadmium Plated, Olive Drab</td>
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#### AS85049 Finish Code

<table>
<thead>
<tr>
<th>Material, Finish</th>
<th>Recommended Glenair Material/Finish Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Aluminum, Black Anodize</td>
</tr>
<tr>
<td>B</td>
<td>Stainless Steel, Cadmium Plated, Black</td>
</tr>
<tr>
<td>G</td>
<td>Aluminum, Electroless Nickel (Space)</td>
</tr>
<tr>
<td>J</td>
<td>Composite, Cadmium Plated, Olive Drab</td>
</tr>
<tr>
<td>L</td>
<td>Composite, Cadmium Plated, Olive Drab (1)</td>
</tr>
<tr>
<td>M</td>
<td>Composite, Electroless Nickel Plated</td>
</tr>
<tr>
<td>N</td>
<td>Aluminum, Electroless Nickel Plated</td>
</tr>
<tr>
<td>P</td>
<td>Aluminum, Cadmium Plated, Olive Drab (1)</td>
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<tr>
<td>W</td>
<td>Aluminum, Cadmium Plated, Olive Drab</td>
</tr>
<tr>
<td>T</td>
<td>Composite, Unplated</td>
</tr>
</tbody>
</table>

(1) Selective plated with polysulfide barrier.
## Quick Picks: A Guide to Glenair’s Most Popular Materials and Finishes

### Electroless Nickel
- **Cost**: $  
- **Conductivity**: ++ ++ ++ +  
- **Corrosion Resistance**:  
- **Operating Temperature**: -65 to +200°C  
- **Glenair Code**: M

**Aluminum plated with electroless nickel offers excellent conductivity, wear resistance, and adequate corrosion resistance. Typically specified on electrical connectors and accessories used in avionics boxes, exoatmospheric equipment, and missiles, electroless nickel is a good choice when exposure to marine or corrosive atmospheres is not a primary concern. The plating process is purely chemical, and once started, is autocatalytic (it runs by itself).**

### Black Zinc Nickel
- **Cost**: $  
- **Conductivity**: ++ ++ ++ +  
- **Corrosion Resistance**:  
- **Operating Temperature**: -65 to +175°C  
- **Glenair Code**: ZR

**RoHS-compliant black zinc-nickel is approved for MIL-DTL-38999, AS85049 and other major military specifications as a replacement for cadmium and hexavalent chromium platings. The non-reflective finish and good conductivity make the Glenair ZR finish a leading choice for cadmium-free tactical systems. Corrosion resistance is comparable to cadmium, and the ZR finish is backward-compatible with Cd-plated connectors and accessories.**

### Zinc-Cobalt
- **Cost**: $  
- **Conductivity**: ++ ++ ++ +  
- **Corrosion Resistance**:  
- **Operating Temperature**: -65 to +175°C  
- **Glenair Code**: UC, UCR, ZC, ZCR

**Zinc-cobalt with black trivalent chromate topcoat fills the need for a RoHS compliant conductive black finish for soldier systems, unmanned vehicles, robots and other tactical gear. This new addition to the Glenair lineup is likely to replace black zinc-nickel for new Future Combat System applications. Black zinc-cobalt plating is a standard finish on Glenair’s ITS 5015 reverse bayonet power connectors.**

### Zinc-Nickel
- **Cost**: $  
- **Conductivity**: ++ ++ ++ +  
- **Corrosion Resistance**:  
- **Operating Temperature**: -65 to +175°C  
- **Glenair Code**: ZN, ZNU

**Recently added to MIL-DTL-38999 and MIL-DTL-83513, zinc-nickel plated aluminum has become a cost-effective alternative to cadmium. Available with olive drab or black chromate conversion coatings, zinc-nickel plated aluminum is commonly found on soldier systems and military airframe applications.**

### Cadmium
- **Cost**: $  
- **Conductivity**: ++ ++ ++ +  
- **Corrosion Resistance**:  
- **Operating Temperature**: -65 to +175°C  
- **Glenair Code**: NF, LF, JF

**Cadmium plated aluminum has been the unchallenged workhorse of the defense/aerospace industry. Offering up to 1000 hours of salt spray protection when deposited over electroless nickel, cadmium is highly conductive, and provides good lubricity and resistance to galling. As plated, cadmium has a silvery appearance. A subsequent chromic acid passivation bath creates a chromate topcoat over the cadmium, enhancing corrosion protection. Olive drab chromate is widely used, followed by gold chromate and clear chromate.**

### Stainless Steel
- **Cost**: $  
- **Conductivity**: ++ ++ ++ +  
- **Corrosion Resistance**:  
- **Operating Temperature**: -65 to +200°C  
- **Glenair Code**: Z1, ZL, ZW

**Stainless steel offers unbeatable strength and protection from environmental stress if durability and corrosion resistance are more important than cost and weight. Typically found on aircraft engines, landing gear, geophysical equipment, armored vehicles and marine applications, passivated stainless steel is widely specified in throughout the interconnect industry. Also offered with nickel and cadmium plating for improved conductivity, stainless steel is an obvious alternative to cadmium if cost and weight are not an issue.**
## Quick Picks:
A Guide to Glenair’s Most Popular Materials and Finishes

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Cost</th>
<th>Conductivity</th>
<th>Corrosion Resistance</th>
<th>Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AlumiPlate</strong></td>
<td>$</td>
<td>+ + + + +</td>
<td>6 / 6 / 6</td>
<td>-65 to +175°C</td>
</tr>
<tr>
<td><strong>Plated Composite</strong></td>
<td>$</td>
<td>+ + + + +</td>
<td>6 / 6 / 6</td>
<td>-65 to +200°C</td>
</tr>
<tr>
<td><strong>Unplated Composite</strong></td>
<td>$</td>
<td>+ + + + +</td>
<td>6 / 6 / 6</td>
<td>-65 to +175°C</td>
</tr>
<tr>
<td><strong>Black Anodize</strong></td>
<td>$</td>
<td>+ + + + +</td>
<td>6 / 6</td>
<td>-65 to +175°C</td>
</tr>
<tr>
<td><strong>Plated Composite</strong></td>
<td>$</td>
<td>+ + + + +</td>
<td>6 / 6 / 6</td>
<td>-65 to +200°C</td>
</tr>
<tr>
<td><strong>Hardcoat Anodize</strong></td>
<td>$</td>
<td>+ + + + +</td>
<td>6 / 6 / 6</td>
<td>-65 to +200°C</td>
</tr>
</tbody>
</table>

### AlumiPlate
- 99.99% pure aluminum is electrolytically deposited onto aluminum or composite in a specialized water-free process. AlumiPlate has been approved by Boeing and Lockheed as a replacement for cadmium.
- Threaded parts require dry lube to prevent galling.

### Nickel-PTFE
- Now approved for MIL-DTL-38999 and MIL-DTL-83513, Glenair’s 1000 Hour Grey™ meets the need for a cadmium replacement with excellent conductivity, wear resistance and corrosion protection.
- A proprietary preliminary undercoat is followed with a composite coating of electroless nickel phosphorus and polytetra-fluoroethylene (PTFE). Ni-PTFE is approved for the Joint Strike Fighter and offers extremely good lubricity.

### Black Anodize
- Black anodized aluminum is a popular finish for electrical connectors and accessories.
- Typically employed when conductivity is not required, black anodized aluminum offers a modicum of corrosion protection and is relatively inexpensive.
- Anodizing is an electrolytic process that creates aluminum oxide films by oxidizing the base metal.

### Hardcoat Anodize
- Hardcoat anodized aluminum offers greater wear resistance and better corrosion resistance compared to conventional anodizing.
- Typically employed when conductivity is not required, hardcoat aluminum offers good corrosion protection for marine and tactical applications.
- The resulting finish is a matte greenish-gray color.

### Additional Notes
- **RoHS Compliant:** Yes
- **AlumiPlate Code:** AL, XAL
- **Plated Composite Code:** XM, XW, XMT
- **Unplated Composite Code:** XB, XO
- **Black Anodize Code:** C
- **Hardcoat Anodize Code:** G