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Design Considerations for Harsh-Environment Connectivity

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As humans continue to explore the depths of the oceans, the heights of the mountains, and the far reaches of galaxies, the technologies we use in these extreme conditions push computing and connectivity to its limits. However, for the computing systems and robotics used in these applications, failure is not an option. To succeed in these harsh environments and meet continually increasing requirements, engineers must use creative, collaborative strategies.

The connector industry is being called on to provide power and data products that can meet or exceed demanding and ever-changing requirements. Connectors need to meet electrical, optical, and mechanical requirements within lightweight and compact form factors. They must be able to perform in challenging environments where extreme temperatures, punishing vibrations, and chemicals may be present. Durable, high-reliability connectors are critical in systems that connect sensors, valves, cameras, thermocouples, and other components to computer controls. If a connector does not meet the strict standards indicated for its specific usage, it can result in catastrophe.

Harsh environments such as space require extremely reliable technologies. This space suit incorporates push-pull LEMO K Series connectors in the gloves, which warm the fingers of astronauts conducting extravehicular activities.

Experienced connector engineers and designers know that the minimum requirements for success in any environment include the ability to meet electrical and mechanical specifications, such as the number of pairings, number of conductors, and/or specific materials. Human factors, such as ease of use, quick connect/disconnect, blind-mating, and remote access are often overlooked until the very end of the design process.

This article will address several critical factors as they pertain to a variety of harsh environment use cases, with the goal of encouraging designers to consider these at the start of the design process rather than as an afterthought. Connector manufacturers are a great resource and can help improve the product design throughout the process. For instance, application engineers can help you choose whether off-the-shelf, semi-custom, or fully customized solutions are required to meet your needs, and they can also refer you to alternative suppliers when necessary.

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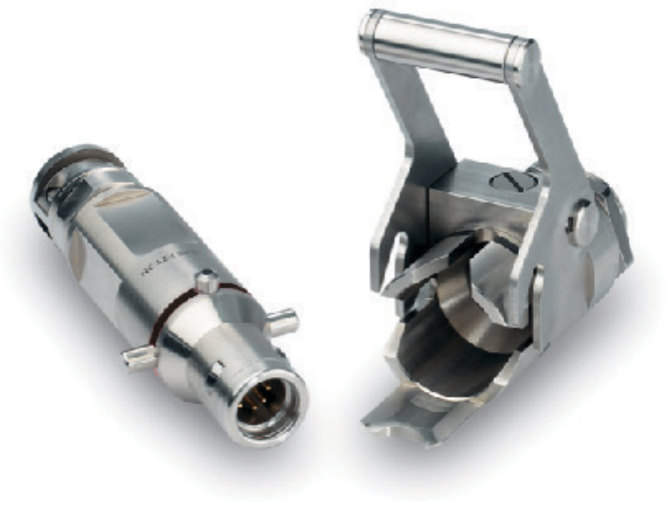


LEMO's N Series remote-handling, self-latching connectors are suitable for use in nuclear environments.

The Harshest Environments

Assume that you need to specify a connector that will last for 30 years and be hardened against radiation. These specifications are common for connectors used in space or nuclear power facilities. The most difficult design constraints will be the environmental (e.g., space and radiation), electrical, and mechanical requirements specific to that connector. These requirements can be met by using stainless steel components with EPDM jacketing to ensure high reliability and longevity. However, suppose that in this application, the connectors must be manipulated remotely by a robot controlled by humans via CCTV. These constraints can be solved by having two flat sides on the connector for the robotic grips, wide alignment keyways for more forgiving handling, and a high contrast indicator line to show when the connector is fully mated.

For space applications, there are additional electromechanical and environmental requirements to consider, including the use of low-outgassing materials. In modern space applications, many types of equipment are designed to be reused, repaired, and upgraded. Reliability and longevity are key. This means consideration must be given not only to the number of mating cycles but many other factors, based on the specific application.

In space exploration, there may be more than one environment to consider and human factors that need to be met. For example, on the International Space Station, the environmental conditions inside the station are quite different than those encountered outside of the facility. During a spacewalk, astronauts wear what NASA calls a personal spacecraft. These suits and their portable life-support system (PLSS) must keep the wearer safe and cool while allowing for movement and communications. While the astronaut's body is kept cool, their hands must be kept warm, so the gloves are heated through special connectors in each finger while the cooling garment is connected to a tank in the PLSS that recirculates water. All the connectors must pair flawlessly and be extremely reliable as well as durable, as the suits provide life support and are also reused.

Unmanned Vehicles

Unmanned vehicle applications run the gamut of harsh environments, spanning land, sea, air, and space. Applications in areas such as military, agriculture, surveillance, and topography often require platforms to be interchangeable in the field, so connectors are mated and unmated many times. In high-vibration applications, a stepped ratchet coupling mechanism performs better than a standard detent mechanism. In high-intensity RF environments, such as signal jamming equipment, connector shells with triple-walled construction provide critical protection for low-level internal

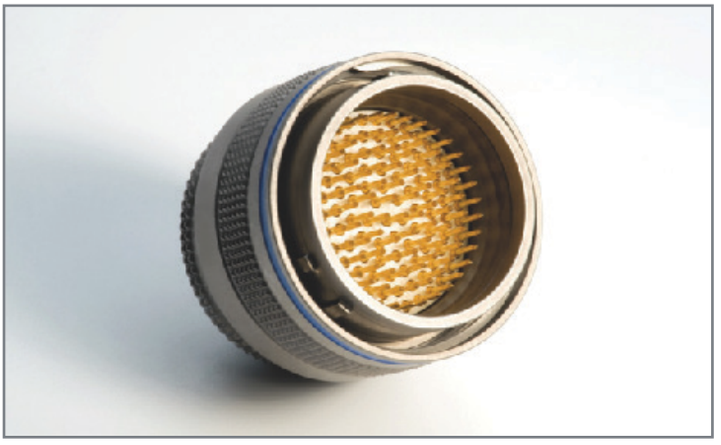
LEMO's K Series features a housing with triple-wall metal construction to provide excellent shielding in extreme EMI environments.

signals, while lightweight aluminum housings provide weight and space savings. The ability to use the same connector across all the equipment whenever possible reduces training, inventory, and lowers the price per unit for the buyer as well as the manufacturer.

As with space, unmanned vehicles will have connections both inside and outside of the vehicle. Therefore, it is important to consider both environments as well as any human or robotic factors that must be met for servicing the vehicles.

Military Communications

Push-pull connectors are ideal for military environments, as they facilitate quick connections and disconnections, as well as blind mating for situations where hidden connections or low visibility are factors. The connector materials must not break or deform under excessive force or due to corrosion, and the contact physics, shell, and sealing materials require extreme consideration during the design process as well. Electrical contacts with heavy gold plating are corrosion-resistant and support increased cycle life, while anodized aluminum and fluorosilicone generally address the shell and sealing material requirements. If a breakaway connector is required, the amount of force must be specified, as it will vary based on the use.



Heavy gold plating on electrical contacts helps LEMO's connectors resist corrosion and support more mating cycles.

In extremely harsh environments, LEMO's T Series connectors with black chrome housings provide excellent corrosion resistance as well as stealth in military communications applications.

Medical

Hospitals and clinical settings may not appear to be harsh environments. However, equipment used in these spaces is subject to sterilization and high numbers of mating cycles, which means that environmental considerations, along with temperature range and ingress protection, are critical to the specification process. Radiation resistance is another environmental factor that may be important for equipment used in radiologic diagnostics and treatments.

Still, selecting durable connectors is often not enough to guarantee success. Usability and an error-proof design are also important as the incorrect placement of a connector can cause damage to the housing or the cable. For example, a connector

projecting from the bottom of a cart can become a tripping hazard, be hit by other equipment, or even sever cables. Connectors with multi-angle cable exit options help with cable management.

Expensive surgical robotic systems require large connectors that will be in extensive use for a decade or more. Because large connectors are heavy, alternative materials, such as aircraft-grade aluminum, can be used to reduce weight and increase longevity.

LEMO's Anglissimo Plug allows designers to choose from eight different cable exit angles.

Pipeline inspection gauges and other high-pressure equipment benefit from LEMO's threaded-coupling W or V Series, which have a central strength member to absorb tugging forces.

Remote Monitoring

For telemetry applications, low latency is critical, as these devices provide real-time data either directly to a computer or to a controller in a remote location. Remote monitoring of water levels and flows, pipe inspection, and seismic activity introduce harsh conditions not seen in other types of telemetry. Both the cable and connectors are subject to weather extremes, variable flow conditions, and unknown particulates and pH while in situ.

Pipeline inspection gauges (PIG) are another application type that presents unique challenges for connectors. In addition to the operating harsh environment, smart PIGs transmit telemetry as well as camera signals and are subject to extremely strong intermittent forces due to tugging and pulling of the cable as they maneuver through the pipe infrastructure. The resultant forces mean that the cable must contain a strength member secured to the connector to avoid damage to the fiber optic and electrical conductors.

If a connector used for flow monitoring is external to the pipe, only environmental conditions need be considered. If, for any reason, the connector is exposed to the flow within the pipe, shear and/or impingement forces must be considered to ensure that the connector can withstand them as well. In addition, the thermal and corrosive properties of the fluid may require a change to the material composition of the connector.

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Multiple Element Integration

Connectors that can handle multiple media and multiple functions, including high-speed data, such as single-pair Ethernet and Ethernet with impedance-matched pairing, coaxial, and even fiber optic transmissions for cameras, sensors, and 3-D imaging, can contribute to the overall success of a system. Combining two or more elements into a single connector (e.g., data and power, or fiber optics and electrical) can serve a specific application by taking advantage of the modularity of a commercial off-the-shelf (COTS) connector.

Using COTS connectors instead of MIL-SPEC solutions can save costs and provide weight and space savings. LEMO COTS connectors are tested to many of the same mechanical and electrical standards as MIL-SPEC connectors and, in most cases, meet or exceed them.

LEMO's M Series uses a stepped ratcheting coupling mechanism that tends to tighten in high-vibration applications.

Customization

Designing the cable and the connector simultaneously can avoid mismatched wire gauges or other problems, so it is ideal to work with a connector manufacturer that offers cabling capabilities or can work with your preferred cable supplier.

Some applications truly require a connector to be designed and built to a unique set of requirements. For customized connectors, the manufacturer will collaborate with the design engineer to ensure that this is a product that they can manufacture and deliver. The end-product application, all electromechanical specifications, the life cycle, as well as the target price range and volume will be considered by the manufacturer.

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Summary

These use cases emphasize the need to look at the entire scope of how and where connectors are used in the application or system, rather than just focusing on harsh-environment requirements. Taking a more holistic view results in better design in all environments, not just harsh ones. Connector manufacturers are an invaluable asset throughout the design process and can help ensure the success of these demanding applications.

Harsh Reality – Optimizing Connectivity

Harsh environments put stress on the entire system and the connectivity products that serve it. Optimal system design considers quantitative and qualitative requirements in order of importance and incorporates as many as possible to end up with a reliable and safe solution.

Primary Requirements:

- Application-specific
- Electromechanical and optical considerations
- Environmental
- Life cycle, longevity, and reliability

Other Considerations:

- View the interconnect as a system (i.e., concurrent cable and connector design)
- Combine multiple elements into one connector whenever possible
- Ensure that combined elements are matched
- Human factors including ease of use, blind-mating, ergonomics, biomechanics, connector placement, and cable management