NORTHWIRE INC

# WHITE **PAPER**

Custom vs. Off-the-Shelf Cables: Performance & Cost Advantages for Off-Road Heavy Equipment

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# Introduction

The off-road heavy equipment industry requires cable and cable assemblies that can withstand extreme conditions while ensuring reliable operation. With increasing density of sensors, cameras, LiDAR, GPS, autonomous controls, etc., high reliability custom composite cables have had and will continue to have significant impact on the performance of critical equipment operations. Many of the cable requirements for heavy equipment cannot be addressed with standard off-the-shelf cables. Choosing a supplier that can help design a cable for your specific application is key to extended performance, durability, and reliability.

High-performance, custom cable solutions are essential for meeting the unique demands of off-road heavy equipment. Engineered to precise specifications, they can incorporate specialized plastics, connectors and shielding to maximize performance and minimize the risk of failure during extended severe-duty use.

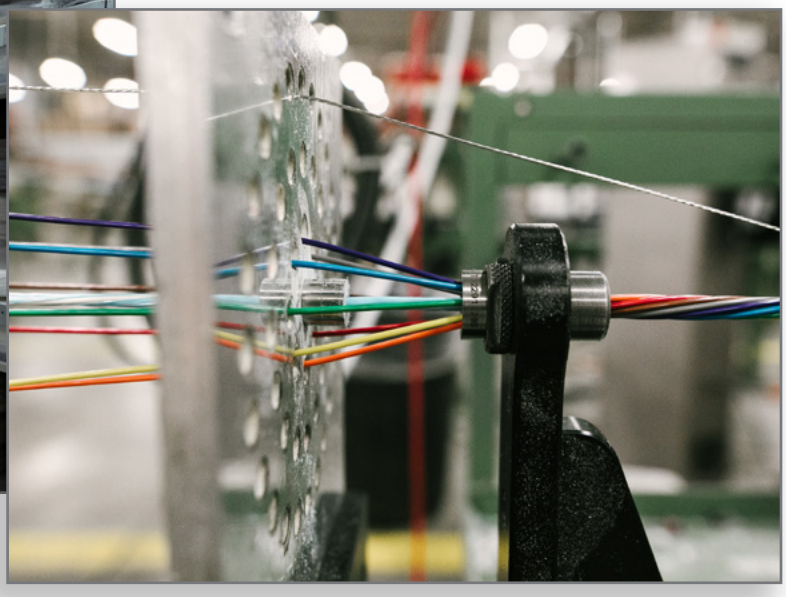
This white paper explores the critical role of custom-engineered cable and cable assembly solutions in off-road heavy equipment applications and how they compare to standard off-the-shelf cables. It examines performance trade-offs, outlines key advantages of application-specific designs and provides guidance on material selection, environmental considerations and design recommendations.

# Why Use Custom Cables vs. Off-the-Shelf Cables?

Compared to off-the-shelf alternatives, custom-engineered cable and cable assembly solutions provide substantial long-term cost advantages, superior performance and extended life in severe-duty environments. Designing a custom cable/assembly that is engineered to fit the needs of your application delivers long-term value, providing measurable performance and reliability that extend for years and even decades throughout the lifecycle of the equipment.

A key advantage is the ability to tailor the cable construction and materials to meet specific environmental, mechanical, electrical and aesthetic requirements, ensuring optimal functionality and compliance with any application requirement. Additionally, partnering with an experienced cable manufacturer provides value beyond material customization, as process parameters can be engineered to enhance critical performance characteristics such as flexibility, durability, signal integrity and overall reliability.

In most cases, custom cables and cable assemblies incur higher costs during the initial low-volume prototype phase. However, the cost benefits of custom solutions become evident as production scales. Once full-scale manufacturing is reached, the pricing stabilizes, leading to significant long-term savings. Custom cables offer enhanced durability, reducing replacement costs, and minimizing downtime, thereby improving operational efficiency and product reliability.



# Designing Off-Road Industrial Cables for Cost-Effective Long-Term Performance

To optimize the performance-to-cost ratio of cables and cable assemblies, it is recommended to prioritize design and engage with a custom cable supplier early in the initial concept phase, ideally soon after defining your cable requirements.

**Don't forget these often-missed requirements:**

- EMI
- Flex life – What is the exact bend radius, duration, number of bends, temperature?
- Bend radius – How is the cable being routed?
- Pull strength – What is the pull strength for cable and cable/connector interface?
- Environmental – UV, water, chemical and abrasion.
- Processing – Removal of jacket (ROJ), overmolding and cable markings.

In these demanding applications, the cable and cable assembly will be the primary source of electrical failures in your electronic devices. Incorporating cable design considerations into the Design Failure Mode and Effects Analysis (DFMEA) helps address potential issues proactively, preventing costly design constraints later in the development process.

**Pictured above are two types of agriculture harnesses**

# Performance & Reliability of Custom Cables

Many factors play a part in the design of custom cables to deliver maximum durability and performance for off-road heavy equipment applications. While standard off-the-shelf cables meet basic electrical needs, they are not engineered for specialized environments or extreme conditions. The table below compares common failure modes of standard cables with the performance advantages of custom-engineered solutions.

| Standard Off-the-Shelf Cable vs. Custom Cable Benefits/Solutions | | |
|---|---|---|
| **Conductor Properties** | | |
| **Factor** | **Standard Cable** | **Custom Cable Benefits/Solution** |
| **Vibration** | Not optimized for mechanical stress causing them to fatigue or break over time. | Vibration Resistance: Custom cables use optimized stranding, fillers, and damping materials to withstand continuous vibration. |
| **High-Flex** | Not built for continuous flexing causing them to fail over time. | High-Flex Performance: Engineered for repeated motion, custom high-flex designs prevent conductor work hardening and jacket cracking. |
| **Jacket Offerings** | | |
| **Factor** | **Standard Cable** | **Custom Cable Benefits/Solution** |
| **Abrasion** | Abrasion-resistant jacketing capabilities are not typically available in standard cables. | Abrasion Resistance: Heavy-duty jackets and specialty compounds protect against wear in harsh or high-contact environments. |
| **Cold Bend** | Standard cables often stiffen, crack, or lose performance in extreme cold. | Cold Bend / Low-Temperature Flexibility: Custom materials maintain flexibility and mechanical integrity in extreme cold. |
| **UV** | Little UV protection is offered in standard cables causing them to degrade, chalk, or crack faster under sun exposure. | UV Resistance: UV-stable jackets extend outdoor service life, providing far better protection to sun exposure. |
| **Temp Rating** | Fixed-range offerings causing the cable to fail in extreme environments. | Temperature Rating Optimization: Materials can be selected to meet specific high- or low-temperature requirements. |
| **Chemical** | Standard insulation and jackets, may swell or deteriorate with various chemical exposure. | Chemical Resistance: Custom compounds that withstand oils, fuels, solvents, fertilizers, and cleaning agents safeguards cables in engine compartments and harsh environments. |

| | | |
|---|---|---|
| **Color** | Limited color options | Wide range of custom colors available |
| **OD** | Limited dimensions, may not fit your application | Designed to meet specific gromet, cutout, and connector requirements |
| **Internal Offerings** | | |
| **Component** | **Standard Cable** | **Custom Cable Benefits/Solution** |
| **Shielding (All)** | There are limited shielding options on standard cables. | Foil, braid, serve, or combination shields can be selected and tuned for EMI, RFI, or mechanical needs |
| **Separator Tapes** | Typically, whatever is standard material used by the manufacturer and not driven by end application. | Custom use of tapes improves flexibility, stripping characteristics, thermal stability, and cable longevity. |
| **Cabling Core Design** | Standard cable cores are fixed and not optimized for specific applications. | Tailored core configurations improve roundness, flexibility, signal integrity, and mechanical performance.<br>Color rotation of conductors can be arranged to optimize layout for contact/pin termination. |
| **Conductor Count** | Limited to standard configurations | Designed to meet application specific conductor count and gauge sizes available |
| **Water ingress** | Typically, no to little protection is offered against water ingress causing standard cables to fail in wet environments. | Water Ingress Protection:<br>Tailored constructions such as water-blocking tapes, fillers, and sealed jackets prevent moisture penetration |
| **Strength Members** | Limited options available | Kevlar, monofilament, steel |
| **Hybrid Constructions** | Limited options available | Optical fibers, tubes, power + data combinations, multiple gauge sizes, and more. |

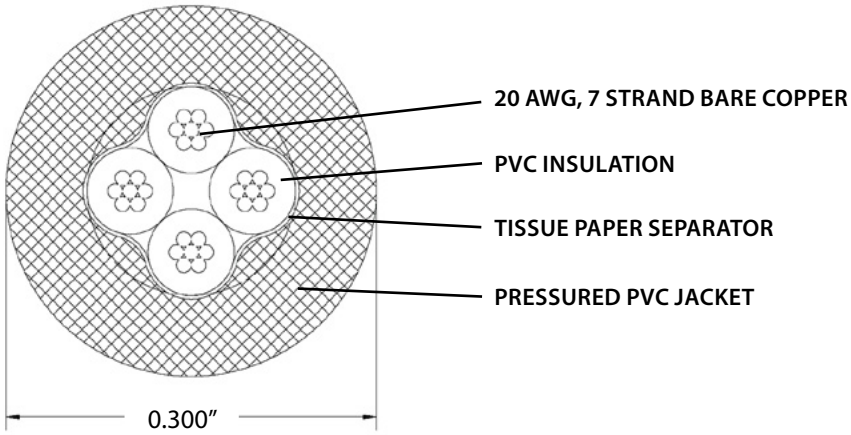
## Standard Off-the-Shelf Cable vs. Custom Cable

By clearly defining the application requirements and understanding how the cable will be used, targeted design engineering strategies can be implemented to extend cable life and improve overall performance in a specific design. This can be achieved using the following methods:

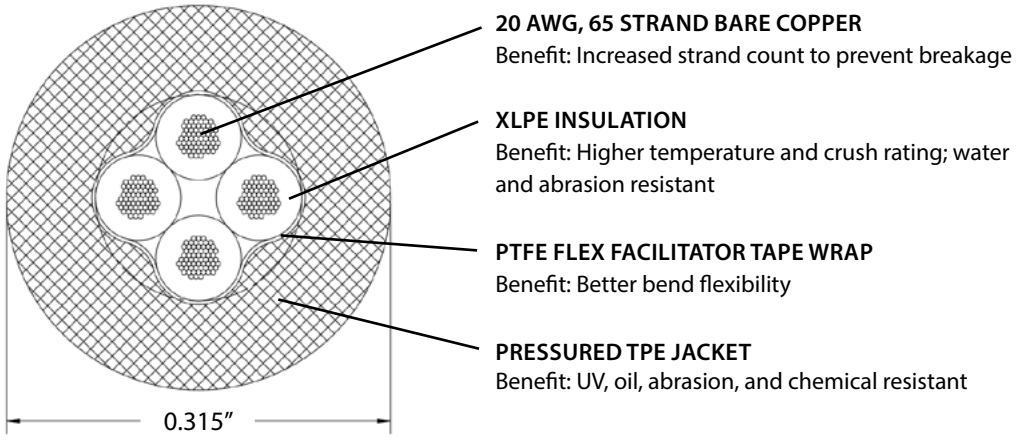
- Ensuring copper style and strand count meet vibration and flex requirements
- Incorporating water blocking cable designs such as anti-capillary copper, water blocking filler, water blocking tape wrap, and choosing the correct jacket material.
- Including flex facilitating wraps and materials for longer cable life in high-flex applications.
- Designing the cable core for high-flex life or static applications.
- Ensuring the cable outer diameter (OD) matches a connector or grommet size for sealing and better operation.

Below is a comparison of a standard cable and a custom cable for an application used in an extreme environment with constant vibration and exposure to the elements.

### Standard cable available for this application:




### Custom cable designed specifically for this application and environment:



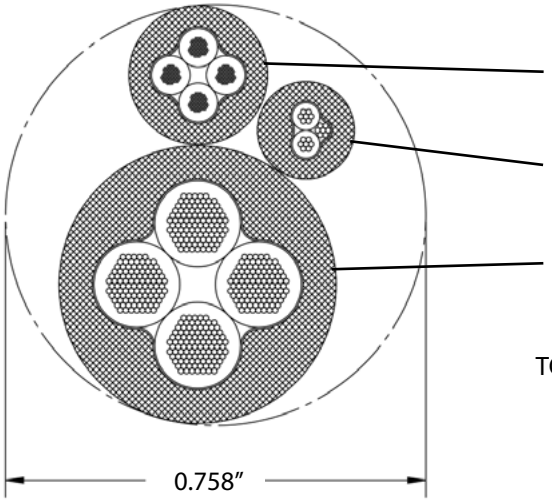
## Standard Cables vs. Custom Composite Cables

Composite cables combine functions and wire gauge sizes allowing a single cable to support multiple functions such as power, brake, and data transfer in one cable. Additionally, composite cables can:

- Reduce the number of cables for aesthetics and ease of routing
- Reduce the overall OD of multiple cables to one cable
- Reduce the number of connectors
- Reduce the number of tie / support points of the cable length

Below is a comparison of 3 standard cables and a custom composite cable for a single application that requires both data and power. The composite cable incorporates material better suited for the application while reducing the overall OD of the cable.

### 3 Standard Cables:



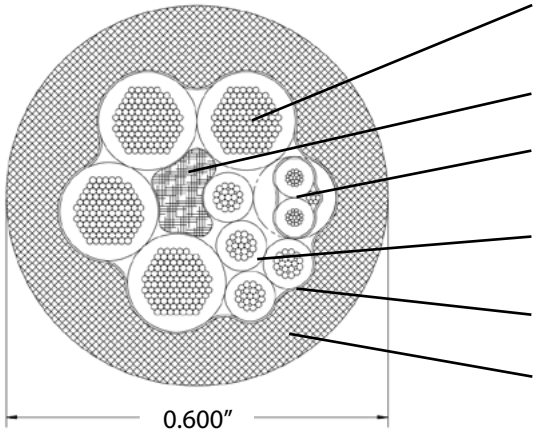

**4 CONDUCTOR, 18 AWG**
**PVC INSULATION**

**TWISTED PAIRS, 22 AWG**
**PVC INSULATION**

**4 CONDUCTOR, 10 AWG**
**PVC INSULATION**

TOTAL OD OF ALL 3 STANDARD CABLES: **0.758”**

### Composite cable combining the same functions of the above cables into one:




**4 CONDUCTOR, 10 AWG BARE COPPER**
**XPLE INSULATION**

**POLYESTER WATER BLOCK FILLER**

**TWISTED PAIRS, 22 AWG TINNED COPPER**
**XPLE INSULATION**

**4 CONDUCTOR, 18 AWG BARE COPPER**
**XPLE INSULATION**

**PTFE FLEX FACILITATING TAPE WRAP**

**TPU JACKET**

TOTAL OD OF COMPOSITE CABLE: **0.600”**

# Off-Road Heavy Equipment Applications & Use Cases

Now that we have outlined the benefits of custom cable solutions, the next section explores key applications and real-world use cases within off-road heavy equipment.

## Applications

There are many applications that fall under the off-road heavy equipment industry; below are a few key applications for construction, agriculture, forestry and mining:

- **Engine Compartment Sensing & Controls** – Temperature, oil level, fan and cooling systems, fuel management and computer management
- **External Attachments** – Sprayers, balers, position sensing, solenoid controls, lighting and GPS location
- **Video Monitoring** – 360° video safety, crop sensing and autonomous driving systems
- **In-Cab Systems** – Lighting, monitoring and controls
- **Sensors** – Suspension, arm and bucket location and speed

## Use Cases

The following pages explore use cases showcasing application-specific cable designs built to solve customer requirements and support reliable operation in extreme environments.

## Construction Application Use Cases

Custom cable and harness solutions for construction vehicles such as excavators, bulldozers, graders, skid steers, scrapers, telehandlers and wheel loaders.

### Paving Equipment

**Application and Customer Requirements:**

- Durable - UV & water resistant
- Long-term coil retention
- Heavy chemical resistance
- Severe-duty use

**Example of a Custom Cable Solution: Industrial Coil Cord**

- 3 conductor 18 AWG subassembly
- 2 twisted pair 22 AWG XLPE 125C
- 5 conductor 22 AWG XLPE 125C
- Coil Cord
- Polyurethane jacket

### Crawlers/Dozers

**Application and Customer Requirements:**

- Durable - UV & water resistant
- Oil and chemical resistance
- Withstands high vibration and shock
- Quick-turn engineering

**Example of a Custom Cable Solution: Industrial Construction**

- 8 conductor 16 AWG XLPE
- Foil shield with drain
- TPE weather resistant jacket

## Agriculture Application Use Cases

Heavy-duty cables for agricultural equipment such as tractors, harvesters, sprayers, livestock barns and equipment.

### Harvester Coil Cord

**Application and Customer Requirements:**

- Durable - UV & water resistant
- Long-term coil retention
- Quick-turn engineering

**Example of a Custom Cable Solution:**
**Industrial Coil Cord**

- 4 conductor 18 AWG TPE
- Polyurethane jacket

### Ag Sprayer Sensor Cable

**Application and Customer Requirements:**

- Durable - UV & water resistant
- Long-term coil retention
- Quick-turn engineering

**Example of a Custom Cable Solution:**
**Sensor Cable**

- 2 twisted pair 20 AWG
- 2 conductor 18 AWG
- Water blocking tape wrap
- XLPE insulation
- TPE Jacket

## Mining Application Use Case

Mining cable assemblies for drills, loaders, underground haul trucks, and long wall processing.

### Long Wall Mining

**Application and Customer Requirements:**

- Durable - UV & water resistant
- Long-term coil retention
- Quick-turn engineering
- MSHA approved

**Example of a Custom Cable Solution:**
**Long Wall Mining Cable**

- 3 twisted pair 14 AWG
- 2 conductor 18 AWG
- PTFE tape wrap - for insertion into the hydraulic hose

## Forestry Application Use Case

Forestry applications requiring impact-resistant, high-torque cable solutions for equipment such as skidders, cutters, bunchers, mulchers, and chippers.

### Forest Harvester Vision Systems

**Application and Customer Requirements:**

- Durable - UV & water resistant
- Long-term coil retention
- Quick-turn engineering
- Assemblies/Over mold

**Example of a Custom Cable Solution:**
**Industrial 100 BASE T1 + 2C 18 AWG power/TPE jacket**

- 1 unshielded twisted pair 22 AWG - 100 Base T1
- 2 conductor 18 AWG - XLPE
- TPE weatherproof jacket
- M12 over mold assembly

## Retractile Coil Cord Use Cases

Retractile coil cords for continuous bend applications, external controls/walk along controls, telescoping light, security, antenna, and trailers.

### Telescoping Trailers

**Application and Customer Requirements:**

- Durable - UV & water resistant
- Long-term coil retention
- Quick-turn engineering

**Example of a Custom Cable Solution:**
**Industrial Coil Cord**

- Large diameter
- 1:5 retracted to extended ratio
- Composite POWER + DATA Category Ethernet
- Industrial outdoor capabilities
- Assembly capabilities

### Front End Loader

**Application and Customer Requirements:**

- Durable - UV & water resistant
- Long-term coil retention
- Quick-turn engineering

**Example of a Custom Cable Solution:**
**Retractile Coil Cord**

- 2 triads - 18 AWG - XLPE
- 2 conductor 18 AWG - XLPE
- TPU abrasion and weatherproof jacket

# Conclusion

As off-road heavy equipment continues to evolve with increased integration of advanced sensors, cameras, LiDAR, GPS, and autonomous controls, the role of the cable system becomes increasingly critical to overall equipment reliability and performance. Standard, off-the-shelf cables are rarely designed to withstand the extreme mechanical, environmental, and electrical demands found in severe-duty applications. Relying on off-the-shelf cables can lead to unnecessary risk, downtime, and long-term cost.

Custom cable and cable assembly solutions address these challenges by tailoring materials, construction, and manufacturing processes to the exact requirements of the application. While initial development costs may be higher, the long-term benefits of improved durability, reduced maintenance, and lower total cost of ownership make custom solutions the smarter choice. Partnering with an experienced custom cable manufacturer helps ensure reliable performance today while supporting the next generation of heavy equipment systems.

To learn more about Northwire's off-road heavy equipment cable solutions or to collaborate on your next cable design, visit northwire.com.

# About Us

Northwire is a leading designer and manufacturer of custom cables, cable assemblies, and wire solutions for demanding applications across various industries, including off-road heavy equipment, aerospace, defense, medical, industrial, and automation. With a strong focus on engineering excellence, Northwire specializes in developing high-performance, durable, and reliable interconnect solutions tailored to meet stringent environmental, electrical, and mechanical requirements.

As a subsidiary of the LEMO Group, Northwire leverages advanced technology, rapid prototyping, and in-house testing to ensure compliance with industry standards such as UL and RoHS/REACH. We are Quality Management System certified to ISO 9001:2015, AS9100 D, ISO 13485:2016, and ISO 17025:2017 as a CSA Group quality testing facility. Our company is committed to providing customers with custom-engineered solutions, short lead times, and exceptional support, helping to optimize performance, cost efficiency, and long-term reliability.

With a customer-centric approach, Northwire offers direct collaboration with design engineers, enabling seamless integration of cables and assemblies into complex systems. Whether for mission-critical aerospace applications or high-flex industrial automation, Northwire delivers innovative and tailored cable solutions that meet the evolving demands of modern industries.


**NORTHWIRE**
110 Prospect Way
Osceola, Wisconsin 54020
United States

Phone: 1 715 294 2121
Fax: 1 715 294 3727
**www.northwire.com**