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The Advantages and Challenges of Using Fiber-optic Cable

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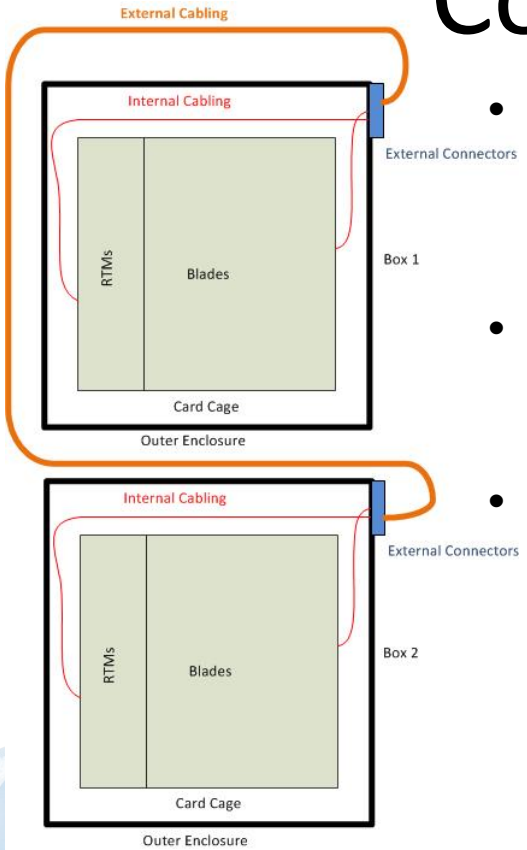
Fiber Optics

- The use of optical is widespread in the **telecommunication and commercial IT** industries.
- Adoption for **airborne** applications is widespread, and **naval and ground mobile** are starting to use more optical interconnects.
- Technical need for fiber is driven by **higher speed processors.**
- There are **other benefits of fiber** that are sometimes overlooked.

Agenda

- A **typical customer deployment** of fiber optics
- **Trade-offs** in cost and weight, routing
- **Challenges** of using fiber instead of copper interconnects

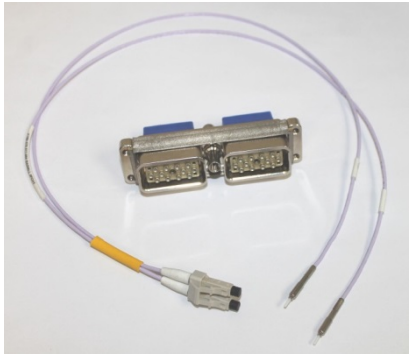
Composite Example

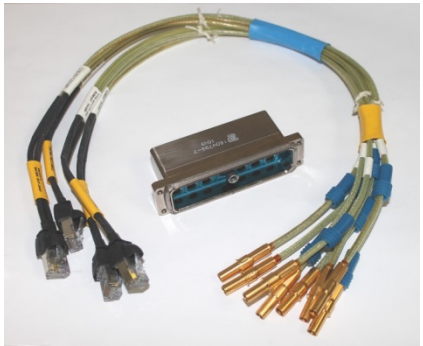


- **Airborne Application:**
  - Must meet ARINC Standards
  - Weight, cost, EMI/EMC and long-term (20 years) reliability is critical
- **Within box:**
  - Multiple blades and RTM with I/O that must be externalized
  - All enclosure I/O via external connectors on box
- **Cabling:**
  - For comparisons, focus will be on 1GbE over copper vs fiber
  - Cabling consist of:
    - Connection from boards to external I/0: ~2 ft of cable
    - Connections between the boxes: ~20 ft
    - All connectors and mating connectors

Ethernet Connections

- **Optical:**
  - Single Mode
  - Loose Structure Fiber
  - Pull-proof
  - Will support ***12*** Ethernet connections
- **Copper:**
  - Quadrax
  - Will support ***6*** Ethernet connections





Cabling and Connectors: Costs

What is the overall cost for providing 12 Ethernet connections from boards in Box 1 to boards in Box 2, including cabling and all connectors?

Cable:

- For shorter cables, there is little difference between copper and fiber.
- For longer runs, fiber cost is more expensive.

Connectors:

- Fiber connectors are more expensive than Quadrax but support a higher density.
- Copper requires strain relief mechanism.

- Within the box, the costs are roughly the same, but
- Between the boxes, fiber is *significantly more expensive*.
- For the total cost, ***fiber is ~35% higher!***

Cabling and Connectors: Weight

What is the overall weight for providing 12 Ethernet connections from boards in Box 1 to boards in Box 2, including cabling and all connectors?

Cable:

- Fiber is significantly less than Quadrax.

Connectors:

- For equal density, connector weight is roughly the same.

- Total weight for Quadrax solution: **16.4 lb**
- Total weight for fiber solution: **2.02 lb**
- Fiber solution is ***~13% the weight of Quadrax***

Routing of Cable

Correct routing is need to ensure performance, long term reliability of the cables and connectors, and serviceability.

- **Quadrax/Copper:**
  - Significant industry experience
  - Bend radius somewhat important
  - Strain relief important to protect cable/connector interface
  - Chafing a concern over the long run
- **Optical:**
  - New technology
  - Need to understand how fiber works
  - Bend radius more important

Basics of Fiber-optic Cable

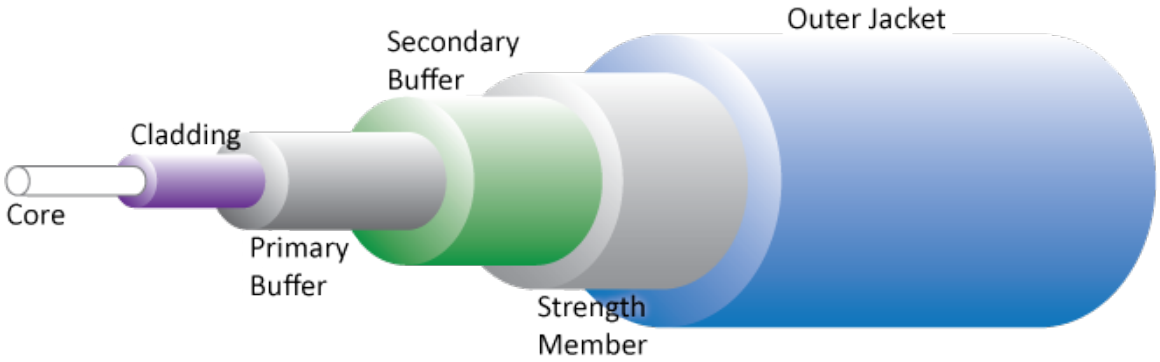
Fiber-optic cable:

- **Loose structure:** Movement between secondary buffer and strength member
- **Tight structure:** No movement between secondary buffer and strength member

Connectors:

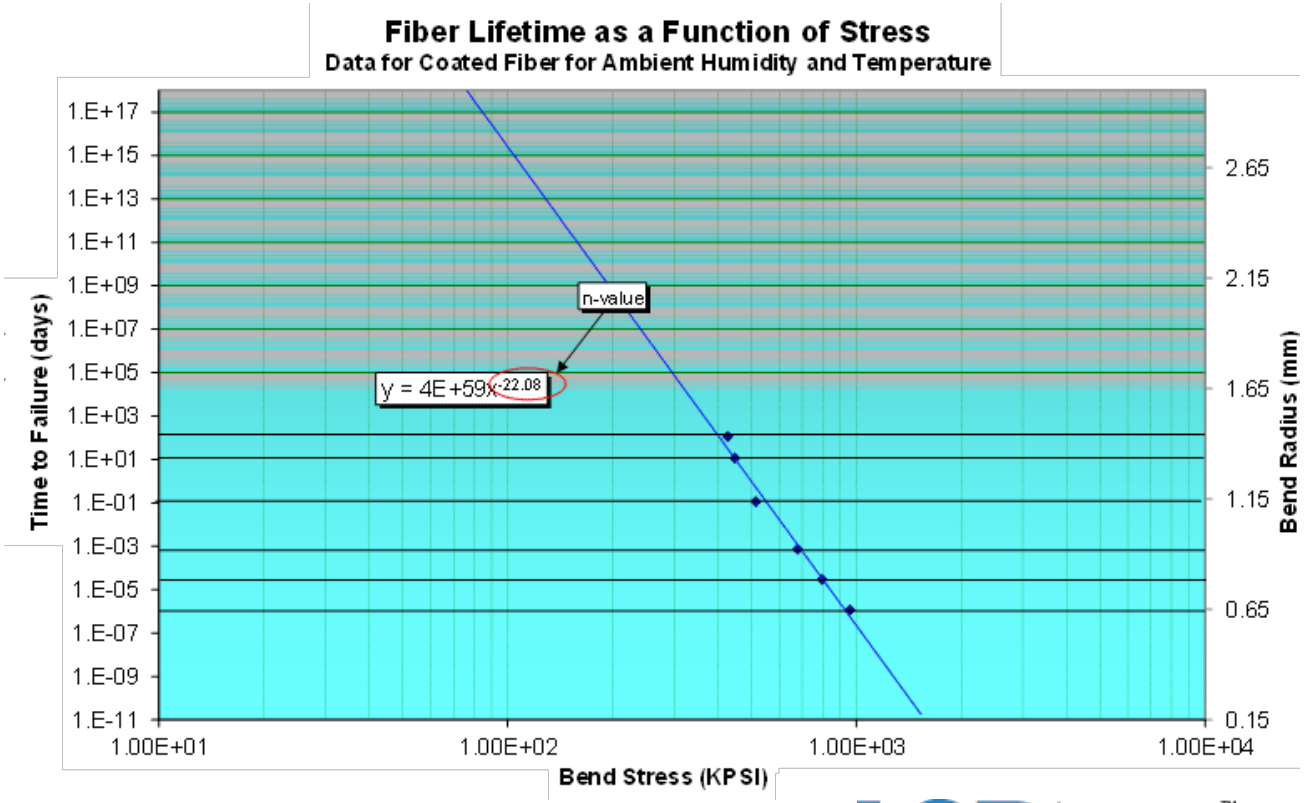
- **Pull-proof:** Cannot pull fiber out of connector
- **Non-pull-proof:** Can pull fiber out of connector w/ ~5lb of force

Typically, loose cable is used with pull-proof connectors, and tight cable is used with non-pull-proof connectors.



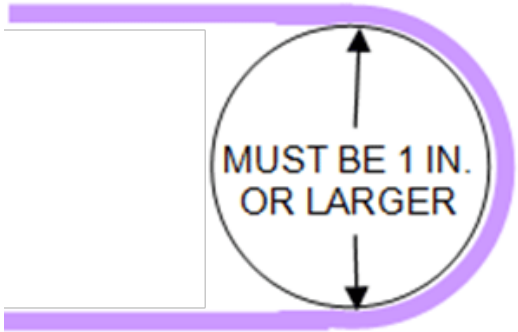
Bend Stress Leads to Stress Corrosion

O.S. Gebizlioglu and C.R. Krkjian, "Optical Fiber Strength and its Relationship to Dynamic Mechanical Properties of Fiber Coatings by Direct Measurements on Fibers", MRS Symp. Proc. Vol. 531, 1998



The Obvious Conclusion

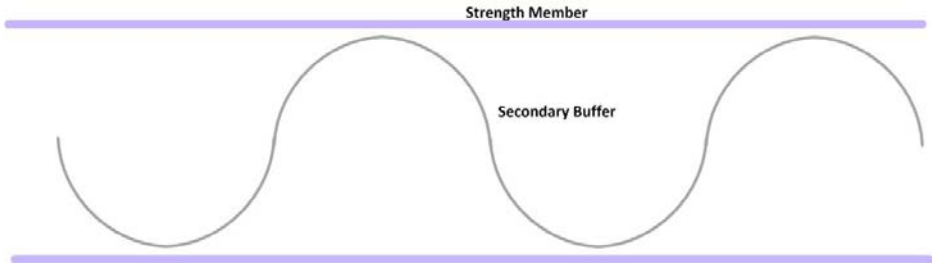
- Bend radius of fiber is ***critical!***
- ***Never*** bend a fiber smaller than a 1 inch diameter while handling or installing or during final dressing. It will break inside and ***cannot*** be repaired!
- ***Avoid*** putting stress on the fiber cable.
- ***However …***



The Not-so-obvious Conclusion

There is more than one way to "bend" a cable!

Compression creates "ripples" between strength member and secondary buffer.
This type of failure is typically called ***blocked cable breakage.***



What Causes Blocked Cable Failures?

- Stress is applied to the cable by connecting fiber on both sides.
  - Each connection ***will push the fiber back into the jacket*** by ~ .5mm
  - ***The jacket is "shorter" than the fiber!***
- Free movement of the fiber within the jacket is ***restricted.***
- The result:
  - ***Increased light loss*** across fiber
  - Fiber breaks ***days to years*** after both sides have been connected

How to Address These Issues

- **Preconditioning** (Thermal cycling) of fiber:
  - Over time, the ***jacket can shrink*** by up to 5%.
  - Fiber is typically preconditioned on the spool, but it is usually ***insufficient***.
  - Preconditioning of individual fibers is needed ***after*** fiber has been cut to final length.
- Optical Backscatter Reflectometer
- Where possible, use **service loops**.
- **Limit restriction** of fiber movement.

Summary

- There is a ***price premium*** for fiber, however …
- Weight advantage of fiber is ***significant!***
- Installing fiber requires ***specific training and practices*** to make it reliable over the long term.

Thank you!

Questions?