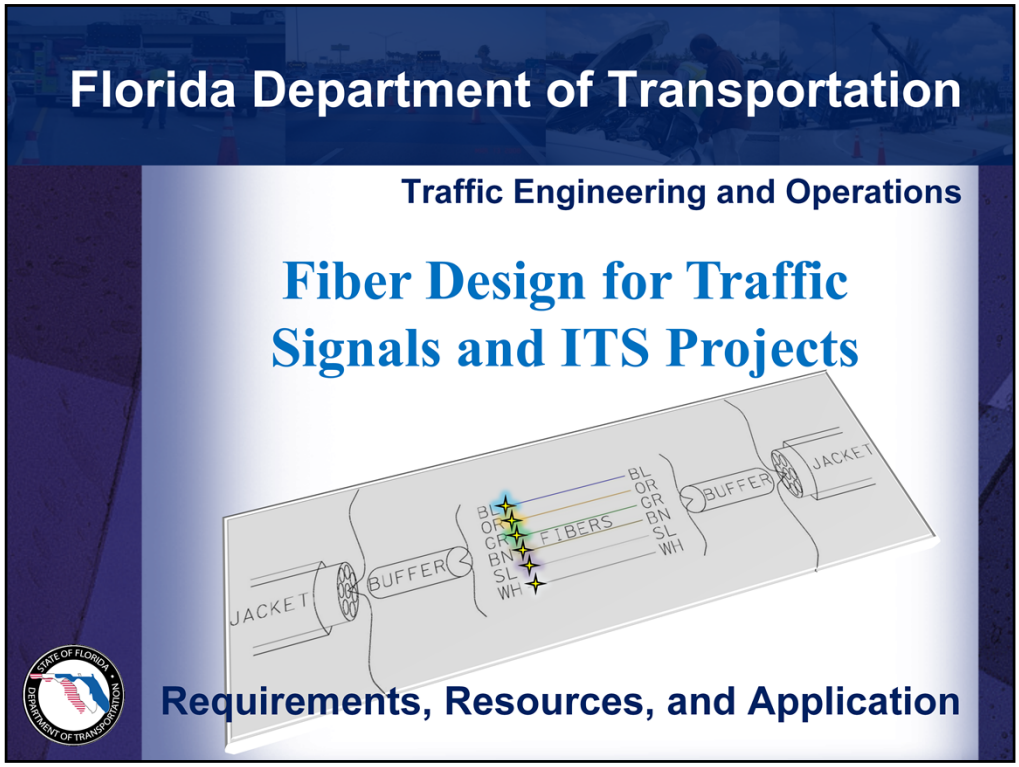
2013 Design Training Expo




<click>Good <morning/afternoon> everyone and welcome to the FDOT Traffic engineering and operations Fiber Design for Traffic Signals and ITS Projects for Designers

A 50 minute presentation on general requirements, resources, and application of fiber optic cable as it relates to our traffic industry.

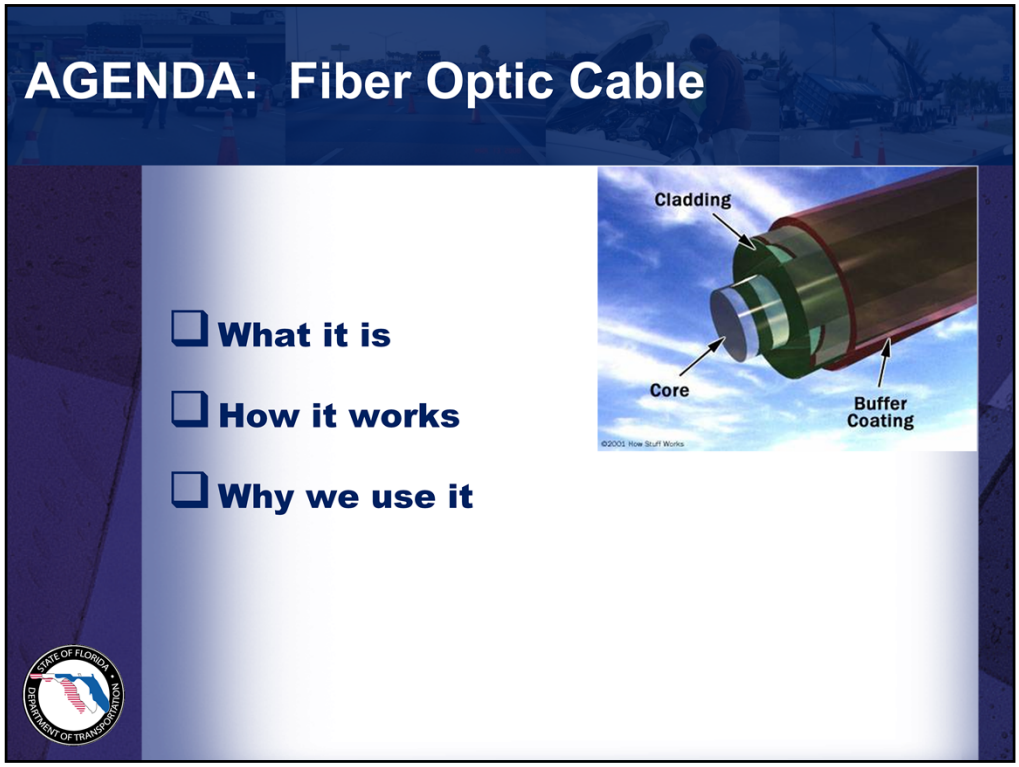
I am your presenter, Steve Johnson

I began my career in the Army as a Communication Security (COMSEC) specialist, followed by a few years as consultant to DoD and other federal agencies.

I then spent 8 years as a Telecom engineer and construction manager before finding my real passion in the ITS industry about 11 years ago.

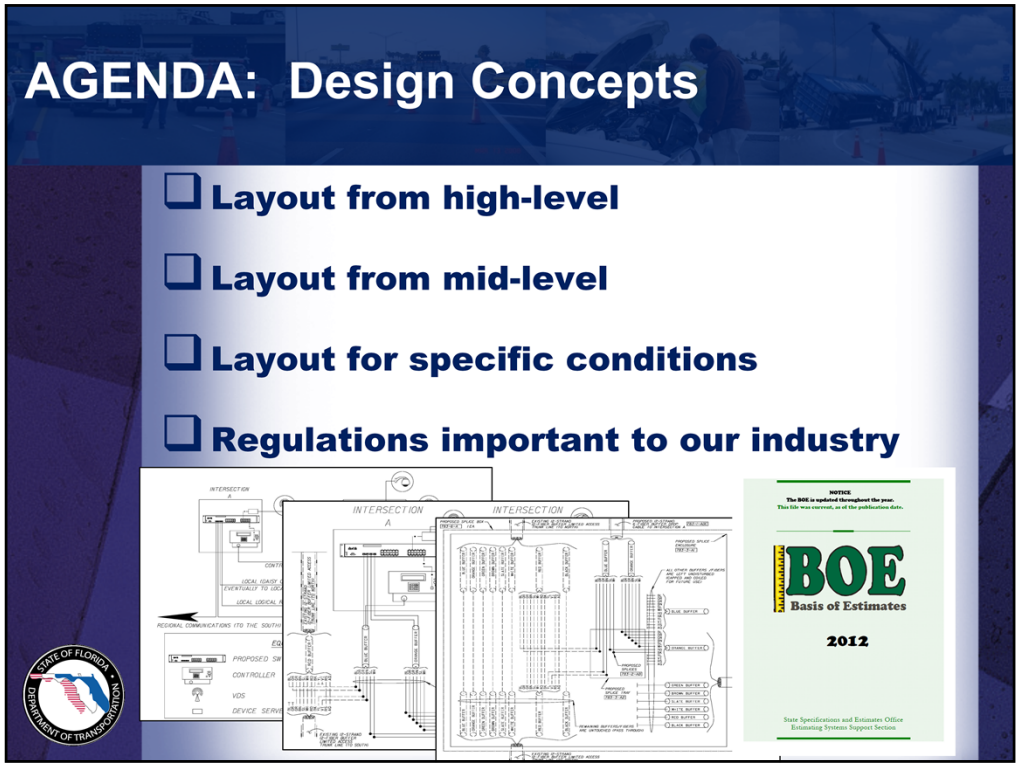
The purpose of this presentation is to answer a request from the districts to address the **general** practices of communications design as it relates **specifically** to fiber optic cable and **its** application **in** ITS and signal design

The majority of subject matter discussed today is pulled from the following resources (which I'm sure most of you are familiar with)… and supplemented by hands-on experience and lessons learned

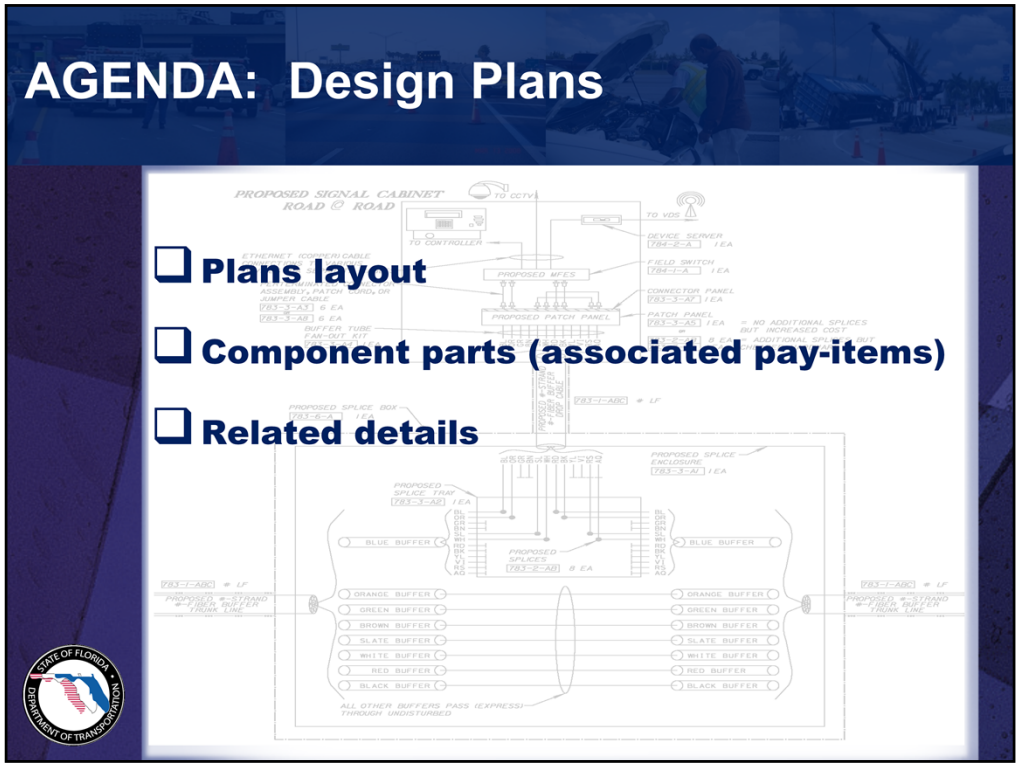



Thus, our agenda today is to cover a series of topics that fall under the umbrella of fiber optic cable as it relates to our industry:

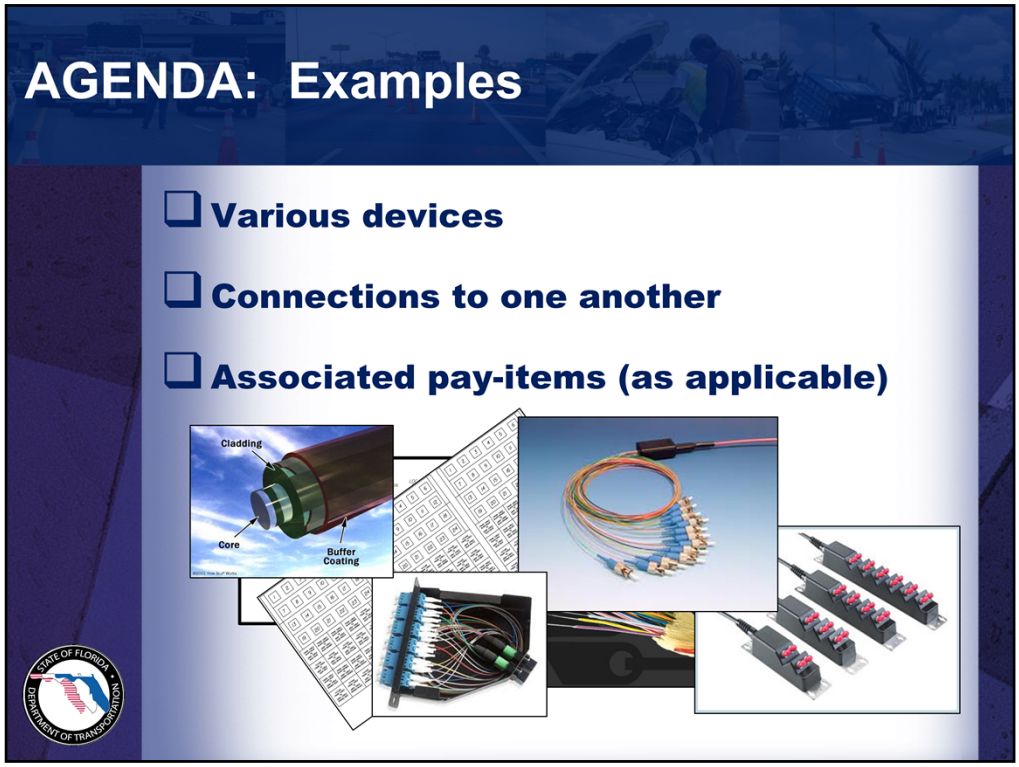
We will cover general properties of fiber optic cable: what it is, how it works, why we use it, and regulations generally important to us…



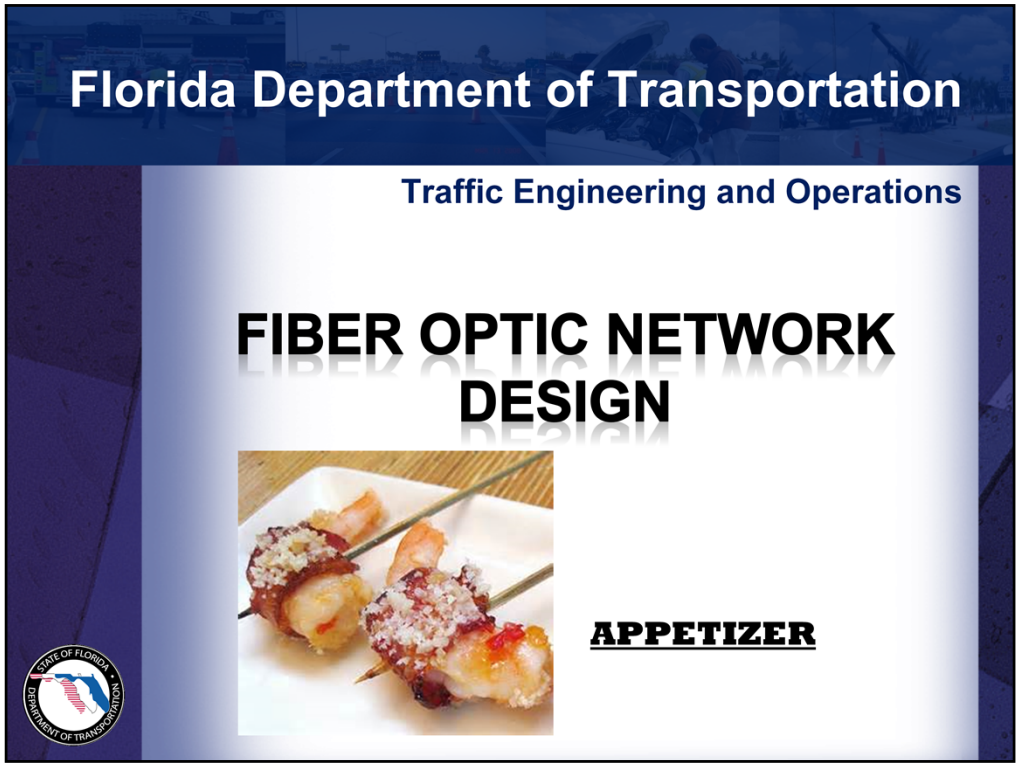

Fiber design concepts: Layout from high-level, mid-level, and specific conditions, and general regulations or standard practices…



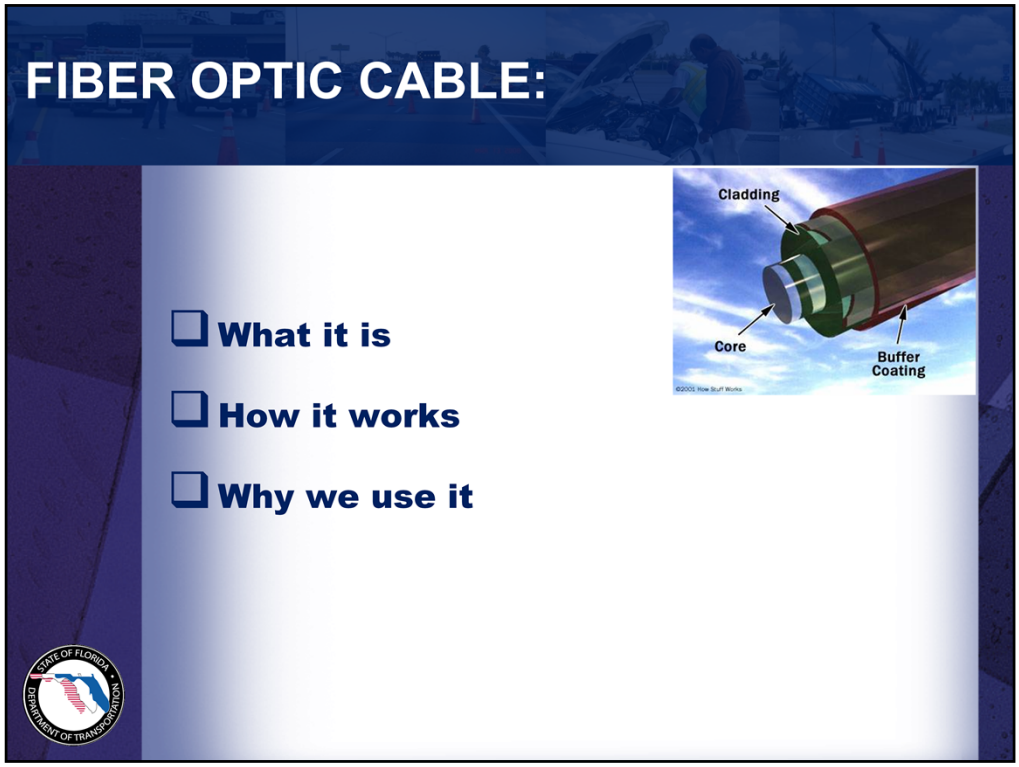

Fiber design in plans – Best Practices



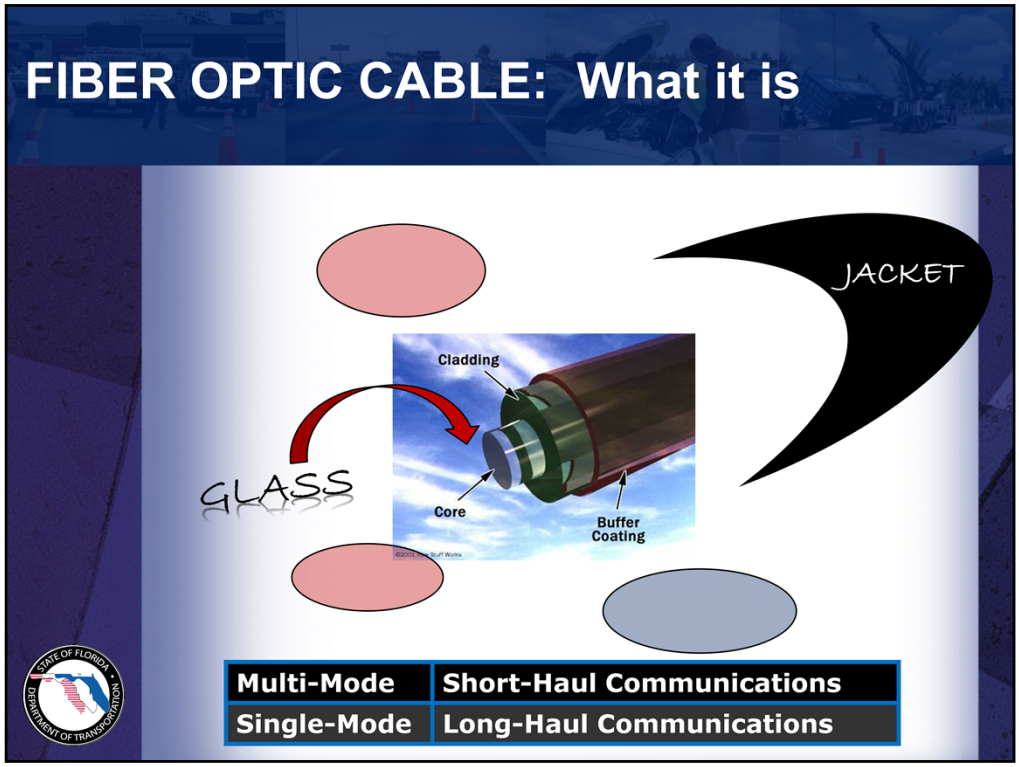

And finally, go over some general examples to help visualize what it is we are dealing with…




Now, on to why we are here:  50 minutes is not nearly enough time to cover this topic in anyway except as a primer. By that, I mean that I will try to provide an overview of key topics that will hopefully stimulate you to do some more in depth follow up study as well give you some resources for doing so. Think of this as the fiber optic design appetizer.



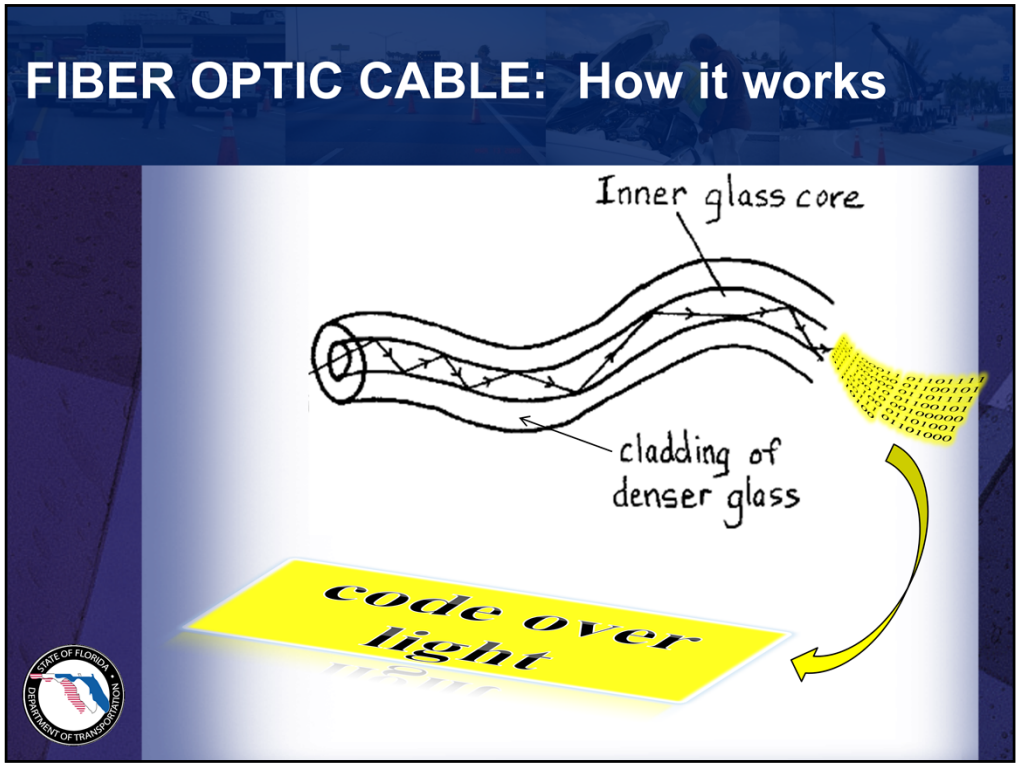

We begin at the basic level of fiber optic cable itself. What it is, how it works, and why we use it




So - Fiber optic cable. What is it? In a word <click> – glass. To be a bit more specific, fiber optic cable is cable primarily consisting of glass. It has a very clear glass tube called a “core” <CLICK> surrounded by less clear glass called “cladding.” <CLICK>

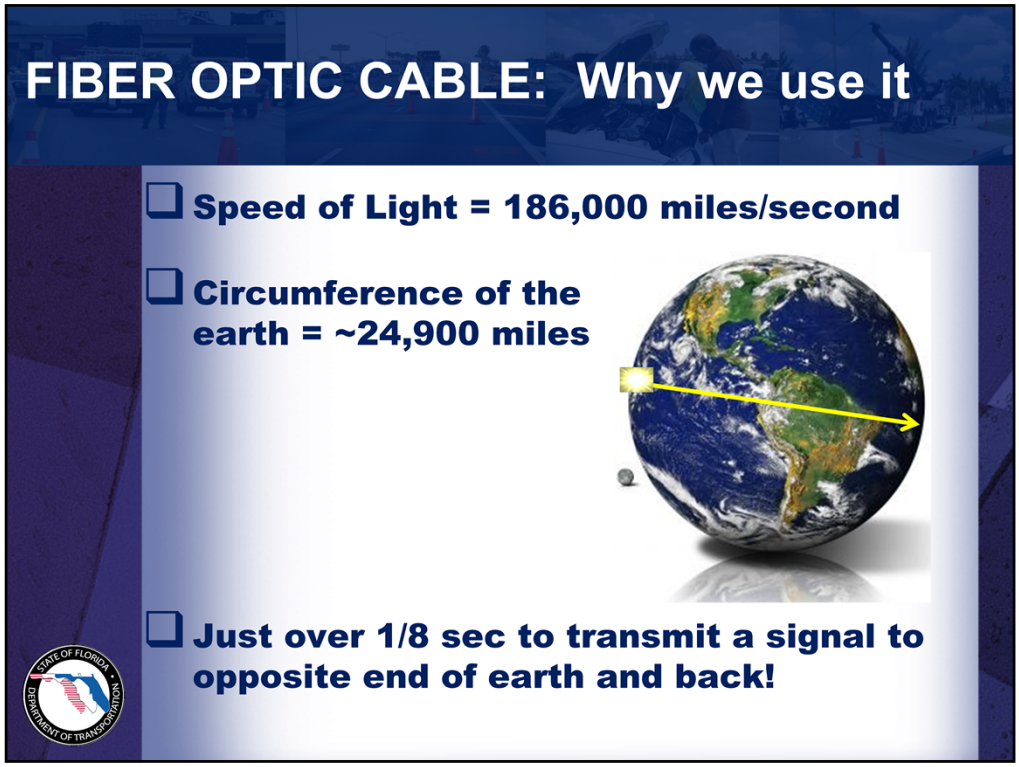
There are other components to the general cable <CLICK> such as the buffer and jacket but the primary component of fiber optic cable is the optical fiber.

<click> There are also two primary types of fiber –multi-mode and single-mode – which you’ll have to research on your own for detailed information but I’ll mention here that multi-mode fiber is used for short-haul communications and single-mode is for long-haul…




<click>The reason for the difference in clarity between the cladding and the core is to assure that light introduced in the core remains in the core <click> via the property of the index of refraction. This is important because we know how to interpret code transmitted over light. Code over light you say? – That is one of those subjects that can take the whole day but it is enough to know that the use of fiber optic cable is to transmit code using light in much the same way we use sound to transmit speech or Morse code over copper wire or even more synonymously, light towers to signal of shorelines to vessels.

Therein lies the reason why we use fiber optic cable; to communicate. But why really?

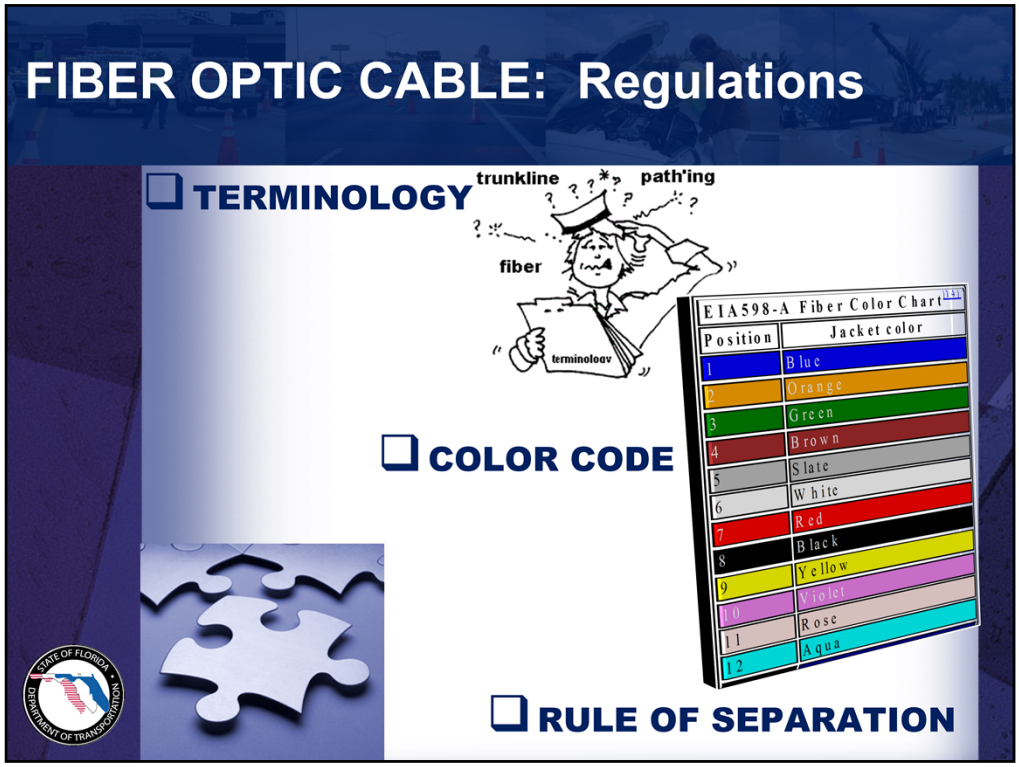



<click>Here's some facts you might find interesting:

The speed of light is approximately 186,000 miles per second

<click>Circumference of the earth is 24,901.55 miles at the equator which we could assume is the distance for worst case to send and receive a message. Adding in the fact that we engineers know that we don't have direct paths to the opposite side let's double that distance to be safe (since we like large values of safety anyway)<click>, that means it takes a total of ~0.2677586 seconds <click> (or a little over 1/8 of a second) to circle the earth.

The SPEED of light, our ability to code in light, resistance to signal degradation (allowing us to transmit light over very large distances) and resistance to external interference (such as electromagnetic, cross-talk, and others…) are why fiber is the ideal communication medium of today - And that is why we use it.




There are a number of nuances in regulations or standard practices related to fiber cable that are important to our industry but I will summarize here, the more important ones to build upon for use in later examples, those being <click>:

Terminology

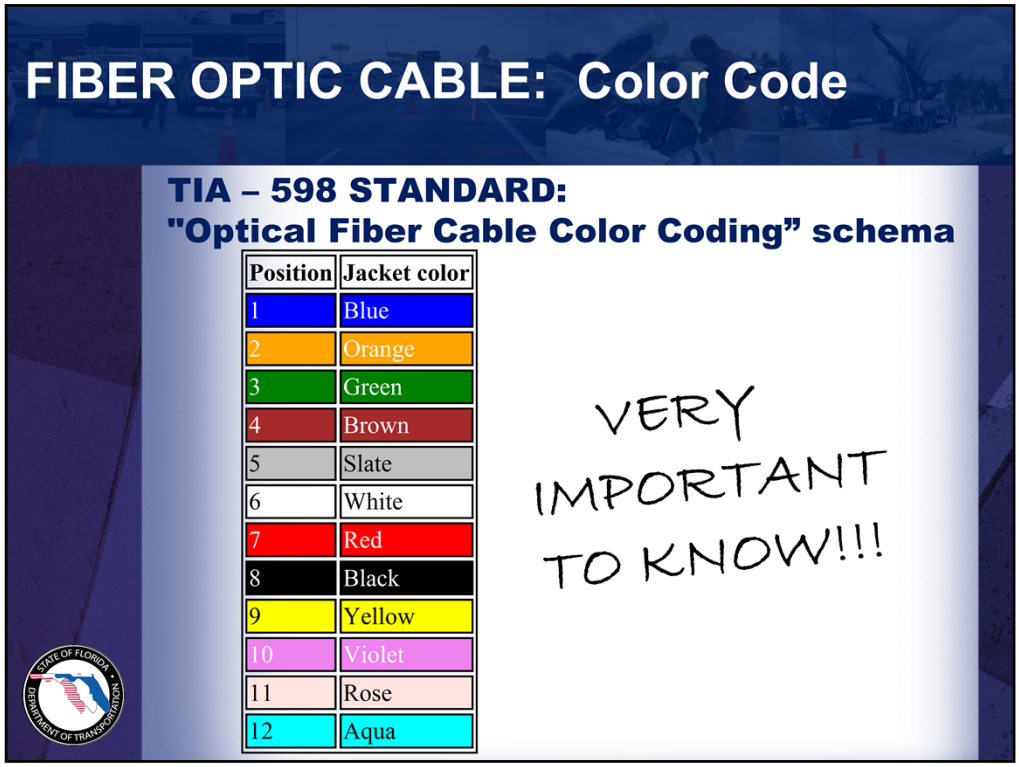
Color code

And

The Rule of Separating FOC from everything else – by the way, I will interchange fiber optic cable with F.O.C. and fiber optic network with FON throughout this presentation, just note that they are, respectively, the same…

# FIBER OPTIC CABLE: Terminology

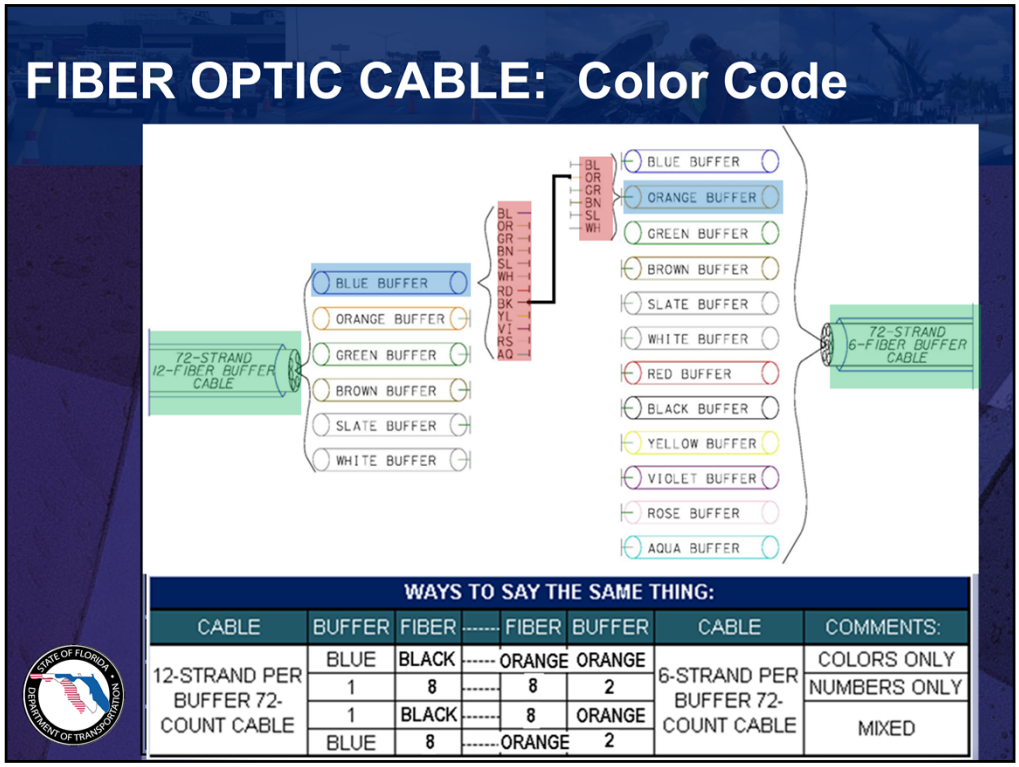
- **Backbone (or Trunk circuit)**
  - **Carries data from multiple network segments or VLANS ~ Has the highest demand for capacity and requires the highest level of protection**
- **Distribution (or Branch circuit)**
  - **Geographically branches off of the backbone and carries data from a smaller portion of the network ~ may still have multiple segments (VLANS)**
- **Drops (or stub circuits)**
  - **Branches off of distribution and carries data at the local equipment cabinet (or hub) level**
- **Splices/Terminations**




Whether a backbone, distribution or drop cable, the standard for Color Code remains the same:

<click>Our industry follows the Telecommunications Industry Association - TIA-598 standard,

<click>"**Optical Fiber Cable Color Coding" schema.** It is used to identify individual fibers in a cable - which is crucial to understand for use in ITS design and review.




**WAYS TO SAY THE SAME THING:**

| CABLE | BUFFER | FIBER | ------ | FIBER | BUFFER | CABLE | COMMENTS: |
|---|---|---|---|---|---|---|---|
| 12-STRAND PER BUFFER 72-COUNT CABLE | BLUE | BLACK | ------ | ORANGE | ORANGE | 6-STRAND PER BUFFER 72-COUNT CABLE | COLORS ONLY |
| | 1 | 8 | ------ | 8 | 2 | | NUMBERS ONLY |
| | 1 | BLACK | ------ | 8 | ORANGE | | MIXED |
| | BLUE | 8 | ------ | ORANGE | 2 | | |

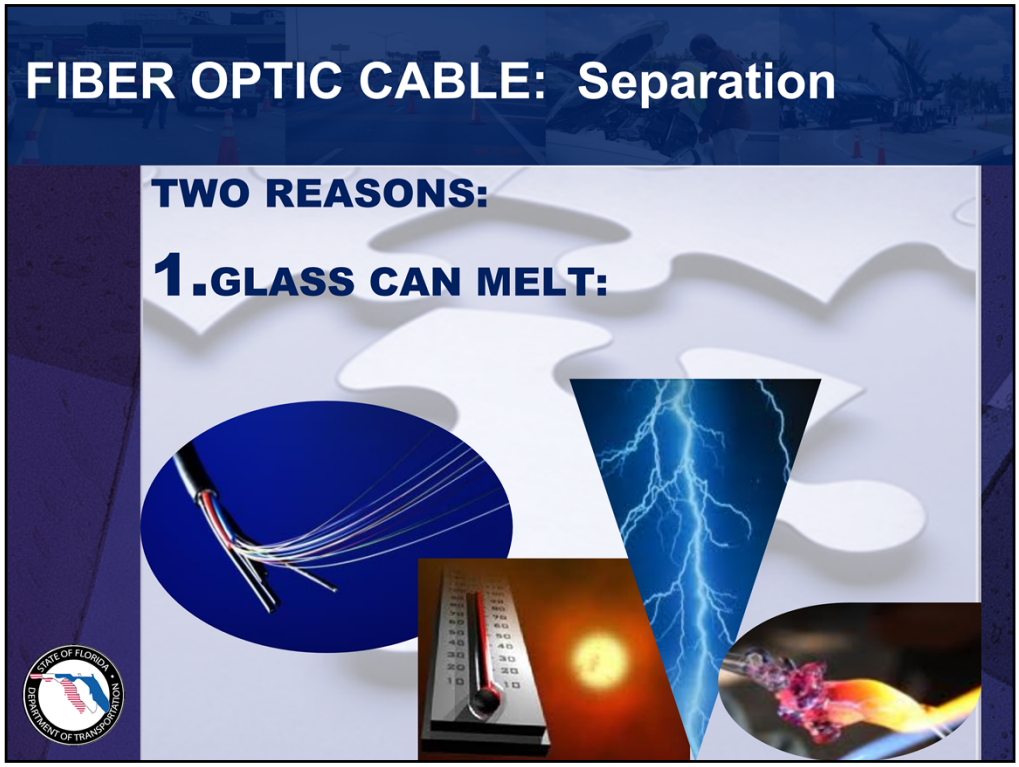
There are two primary methods of conveying fiber designations from this color code. One by direct relay of the colors and the other by associated numbers:

<CLICK>As an example – we have here two types of cables… a 12-fiber per buffer 72-count cable and a 6-fiber per buffer 72-count cable.

<click>Here are the individual fibers following the convention shown coming out of the assigned buffers which also follow the convention. And finally the jacket labeling the cable - highlighted earlier.

<click>Here we are showing a connection between the black fiber of the blue buffer spliced to the orange buffer's orange fiber.

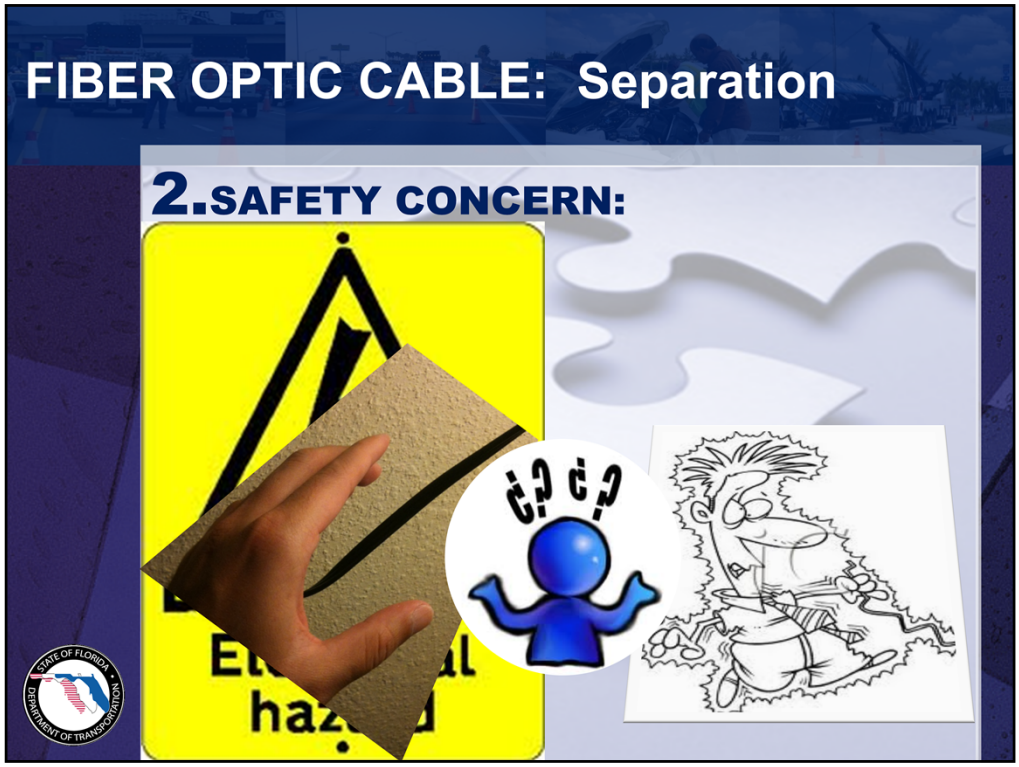
<CLICK>And here are a few other ways to say the same thing. It is important to take away from this section that the understanding of this standard is crucial to designers and design reviewers.




Regarding the rule for separating FOC from everything else there are two reasons for doing so.

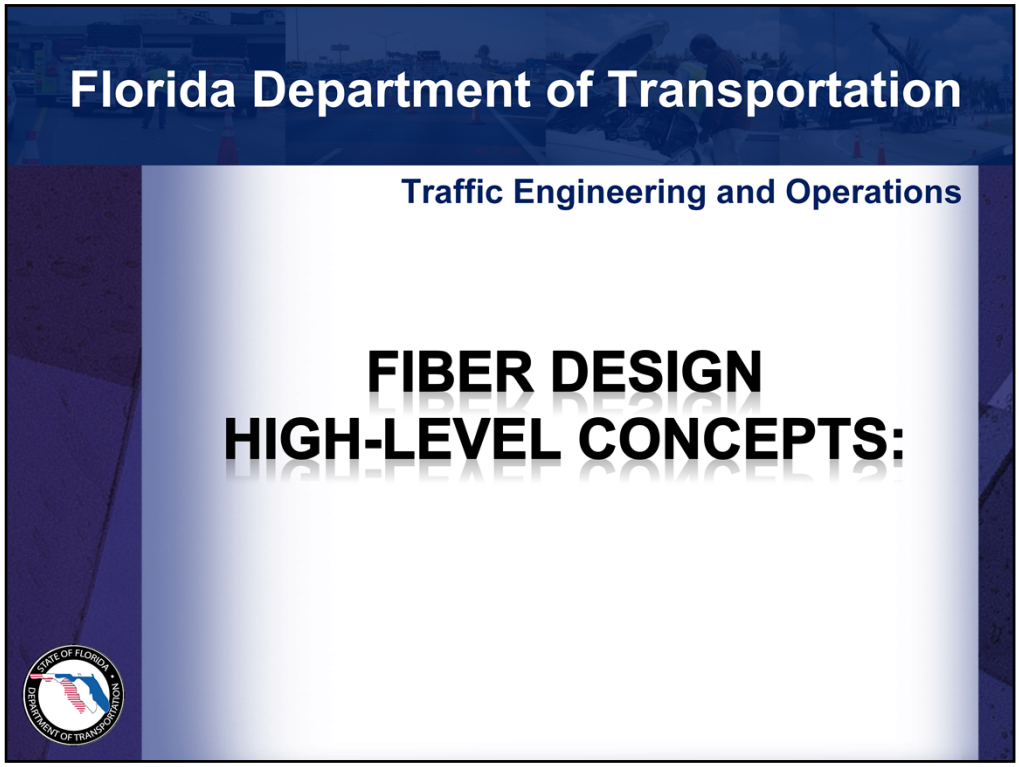
The first is due to the idea that fiber will <click> melt if exposed to heat flash from co-located conductive cables experiencing atypical current (from service spikes or lightning phenomena).

Whether it be tone wire, signal cable, or power conductors, if the medium is electrically conductive, it can flash, generate heat, and thus melt glass…

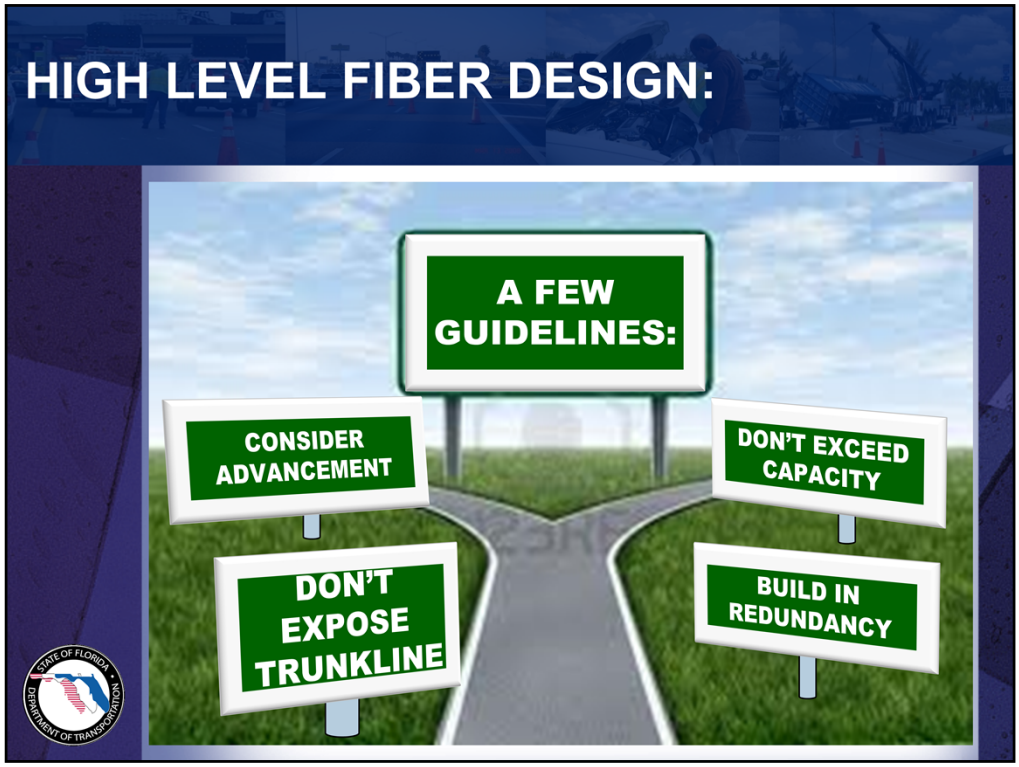



The other reason is related to the first but more from a safety perspective.

Because fiber is non-conductive, technicians have a tendency to get lax in safety practices and the fear is that a live conductive cable is mistaken as a fiber cable - resulting in an unfortunate experience.

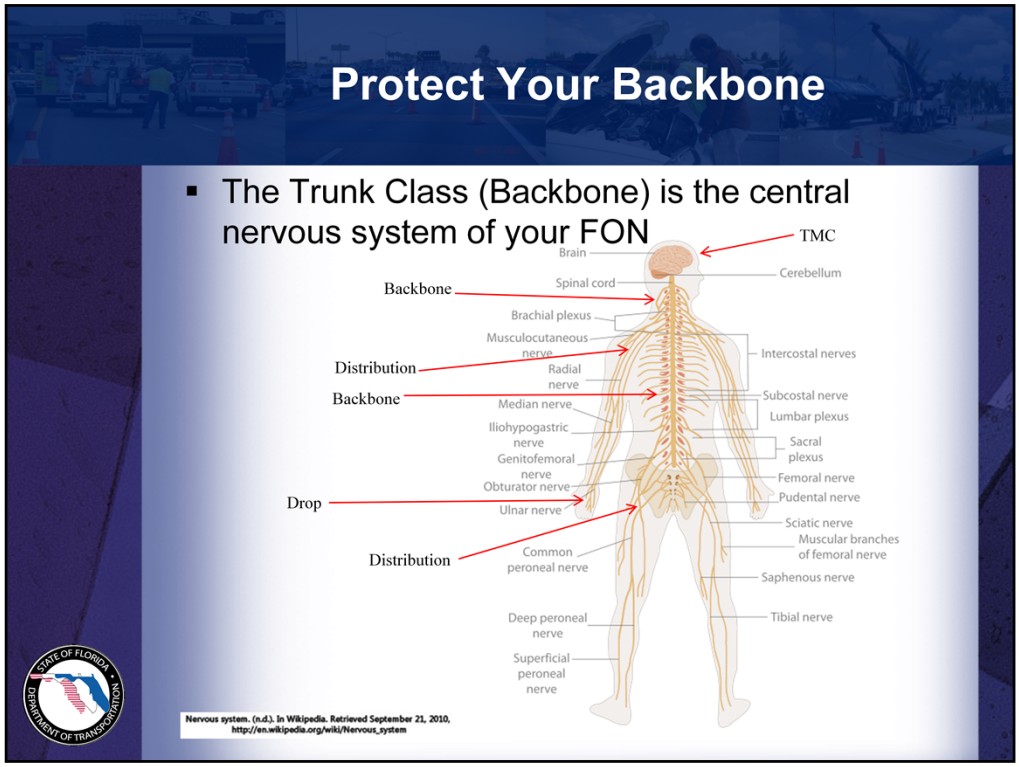



Building on our foundational concept of fiber – we get to overall general fiber design concepts: Remember, we use fiber to transmit data or in other words, communicate. Just as I am presenting to you today, there are rules to communication that need to be adhered to in order to communicate properly. This is what governs fiber design – from a very general perspective




From that high level perspective, there are just a few guidelines <click> that must be followed – either due to state specifications, industry standards, and/or simply good communications design approaches. These are<click>:

1. Don't expose your trunkline cable wherever possible
2. Make sure you have redundant paths for fail over
3. Don't exceed capacity
4. Consider Advancement – Future expansion




If you are in an accident and damage your spinal column, your physical ability to function is determined by how far down the spine the injury occurs.

Lower back – lumbar = lower extremities affected

Mid back – Thoracic = lower extremities AND some body functions such as bowel control

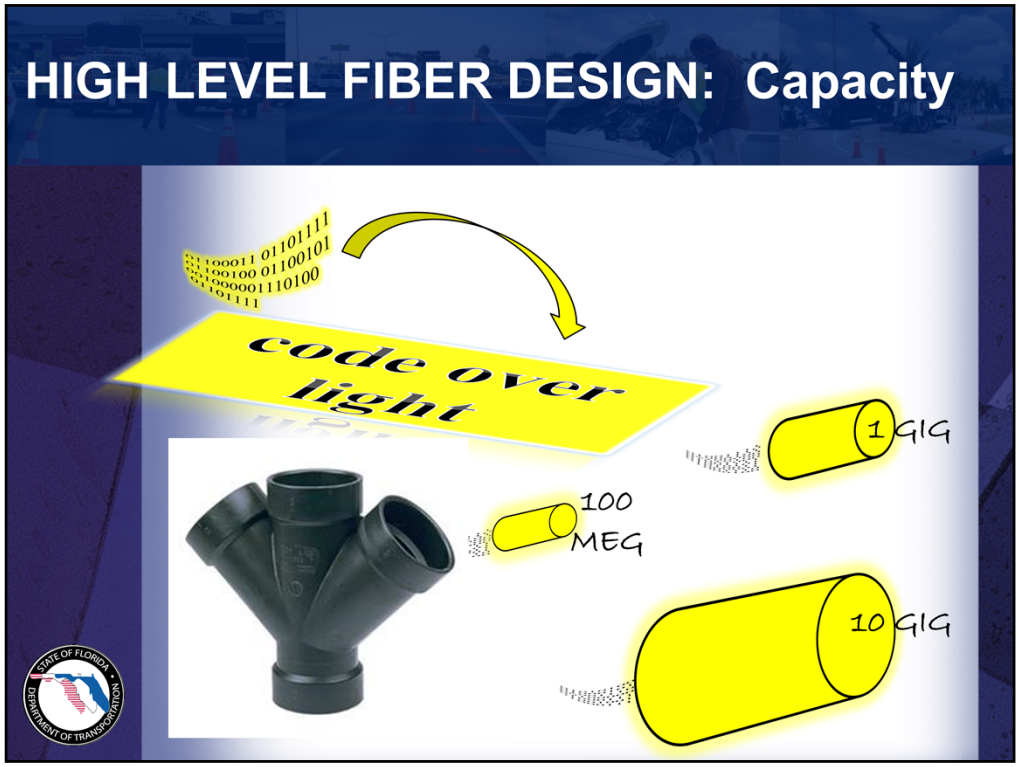
Neck – Cervical C6 & C7 = quadriplegic

Neck – Cervical C5 or above = no respiration = life support

Neck – Cervical C3 or above = NO LIFE SUPPORT

Failure along Distribution or Drop circuit will only affect downstream of that circuit

Failure along backbone is very CRITICAL and without redundancy, your network could be on life support

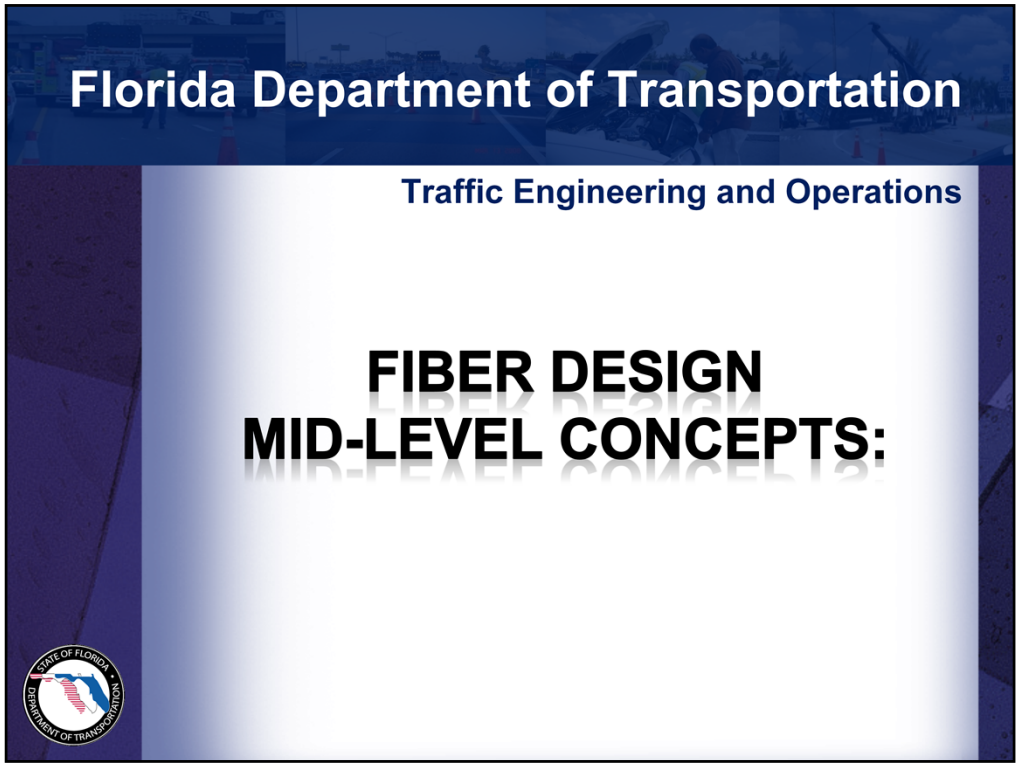



Thirdly, we introduce a somewhat new concept to today's material – capacity – and the rule of not exceeding it.

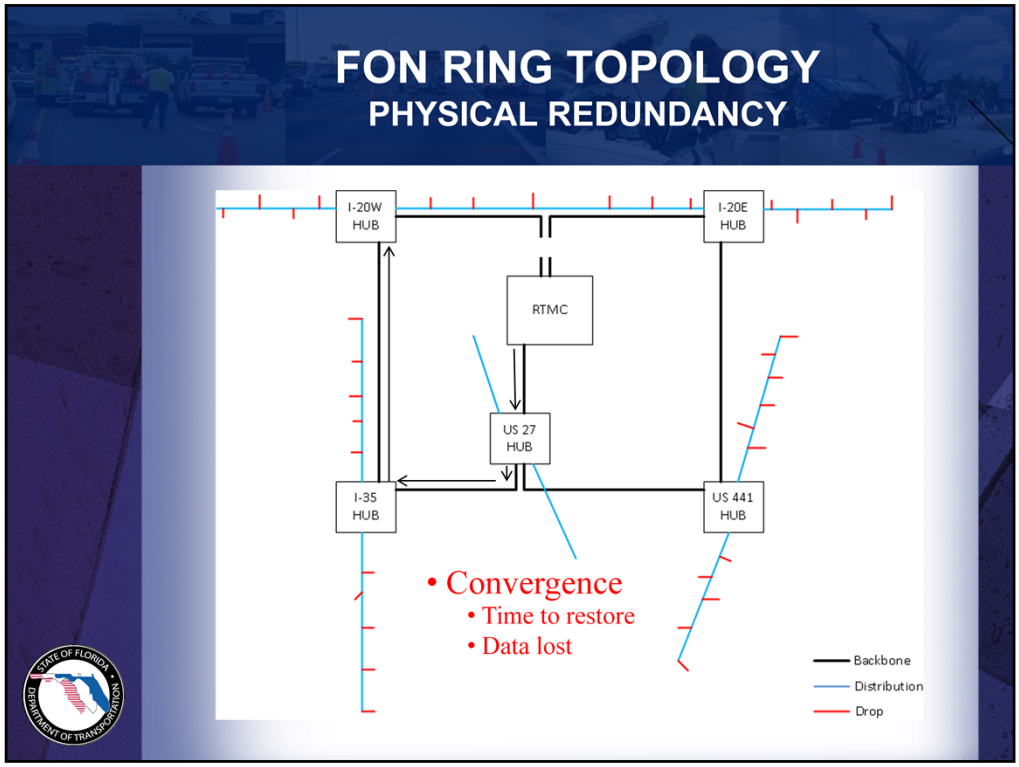
We talked about Backbone, Distribution and Drop cable. Another set of terms for the same thing is often used when discussing capacity. These are Core, Distribution and Access respectively.

Capacity – is the amount of data we can push through any given fiber optic link or network path.

<click> Plumbing analogy – Sizing must follow a simple hierarchy. Core or backbone should have the largest capacity, followed by distribution and then access




With a grasp of these high-level “guidelines” we’ll dig a little deeper into design concepts…




Example of a redundant ring design

• Backbone

• Distribution

• Drops

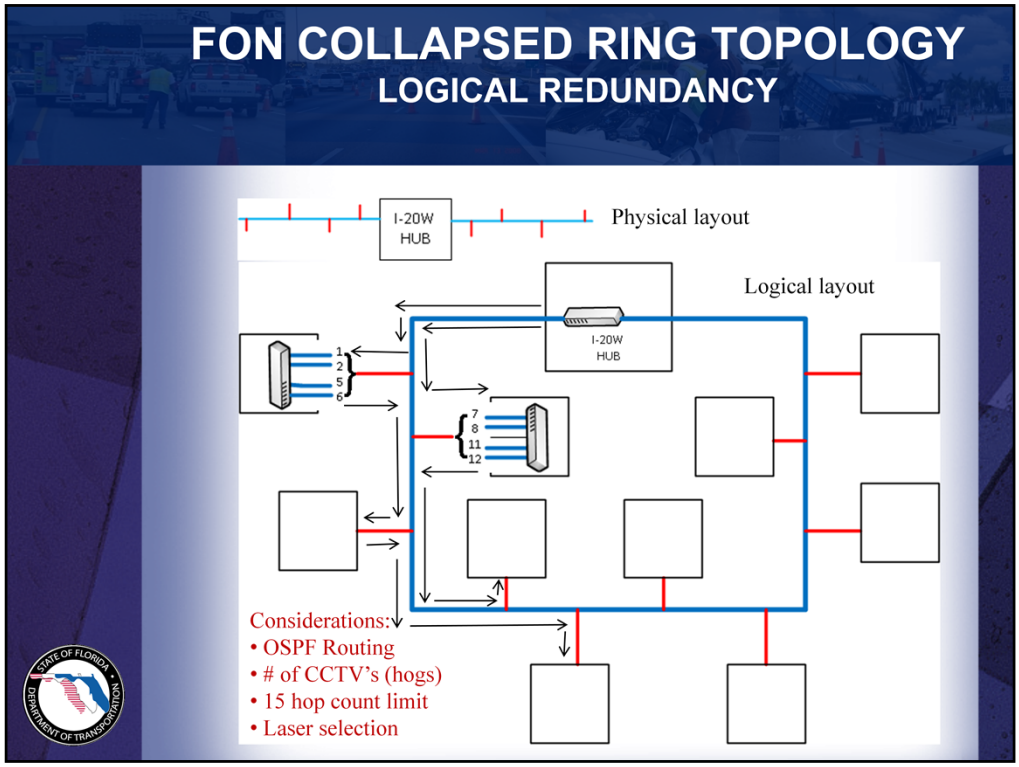
Backhoe or bore rig cuts your backbone <click>

Now the network switches will search for a failover path to restore the network – This is called convergence

We measure the effectiveness or efficiency of the network's convergence by:

• Time it takes to restore full communications

• The amount of data lost during convergence




Distribution and drops – engineering for logical redundancy

<click> Lets examine the I-20W hub distribution from our previous example

<click> Distribution hub, local equipment hubs, Physical (common cable sheath) vs. logical layout (switch ports create logical [collapsed] ring

<click> Drop fibers – designing for redundancy and cost effectiveness

<click> Logical paths (routes) <click>

Why do I say to alternate your fiber pairs throughout the distribution segment? Lets see what happens to our routes if we have a failure. <click>

Common Interruptions to service

<click> Bad Jumper Cable

<click> Bad port in switch

<click> Bad GBIC (laser)

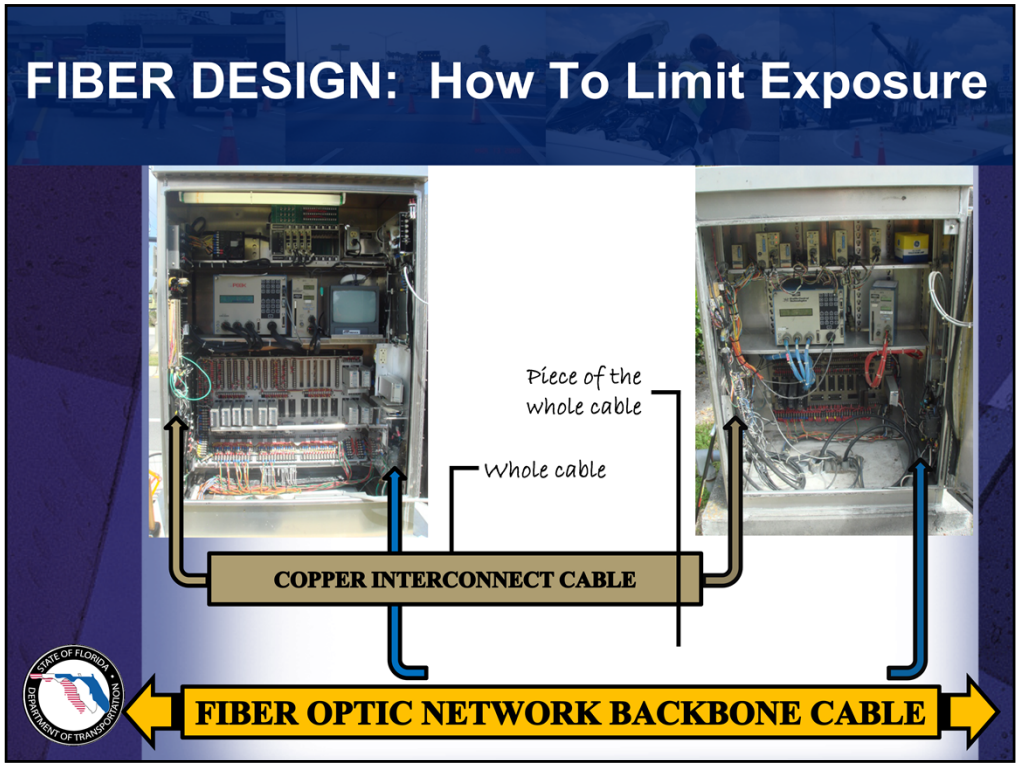
<click> Power outage _ RPM/GFI Story

<click> Willie Nilly <click>

Less Common but more critical

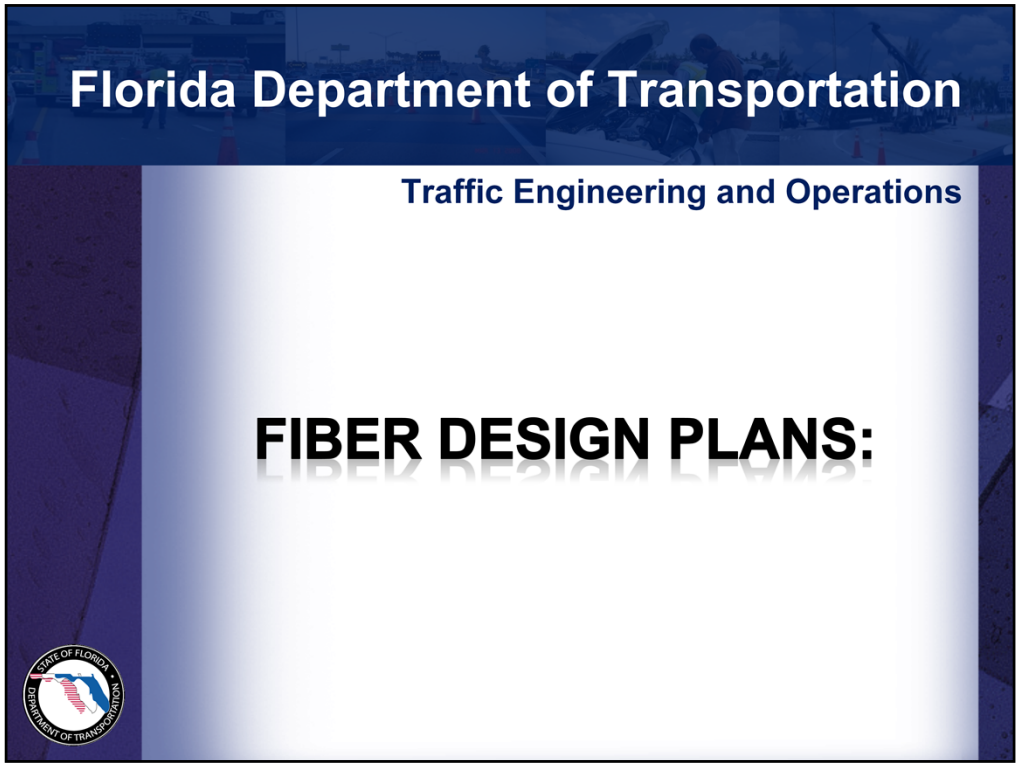
<click> Backbone segment cut – <click> new path

<click> Distribution segment cut – <click> new path

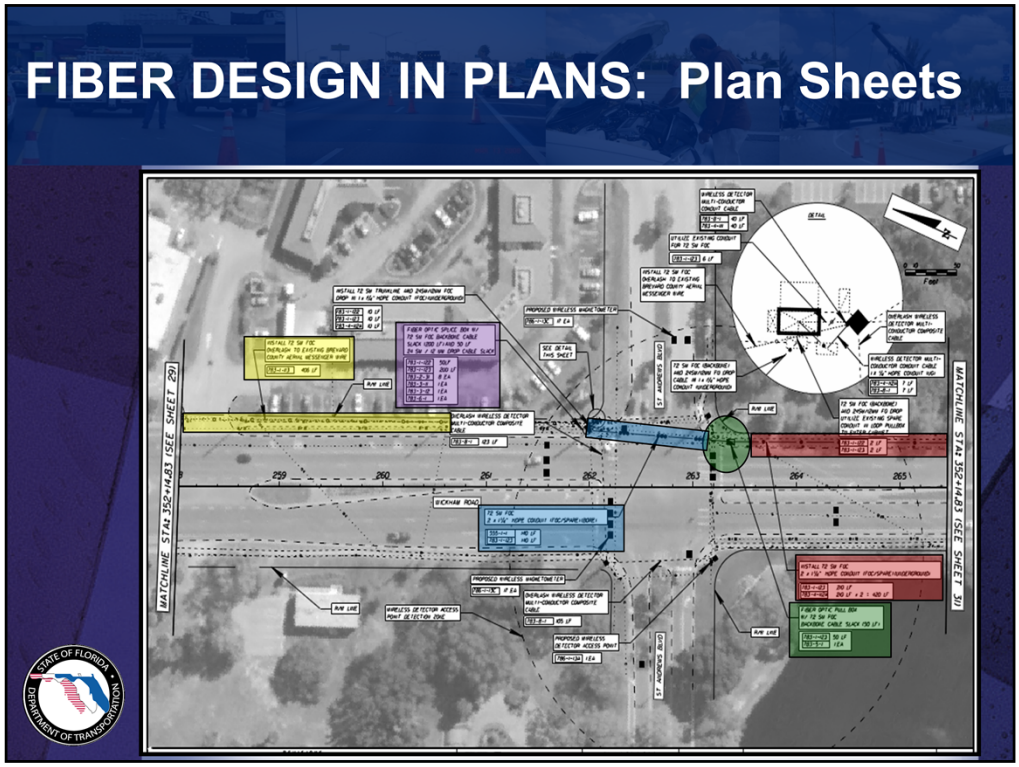



Recall our rule of minimizing backbone exposure. When designing or reviewing design of a communications system be sure this guidance is followed. <click>A common misconception is the design of a fiber interconnect system between signalized intersections is the same as a copper one. <click>In principle they are the same since the intent is to allow communications between the sites however, fiber interconnect (as opposed to copper interconnect) is usually just a component of the overall communications traffic being transmitted. Or in other words, <click>as copper interconnect is specifically used to grant communications between signal cabinets only, fiber interconnect is usually a piece of the overall communications granted by a fiber optic network. As such, it is common to follow a drop cable configuration…

So what is a drop-cable configuration you ask? Well, a drop-cable is a fiber optic cable typically (though not necessarily) of an equal or lesser number of fibers that connects between a trunkline cable and a node or site where 1 or more end communication devices is connected. <click>The point here is that we are reducing our backbone exposure by keeping it out of an area that is more exposed to outside influences. Doing so reduces potential of severe network communication outages from events such as this…



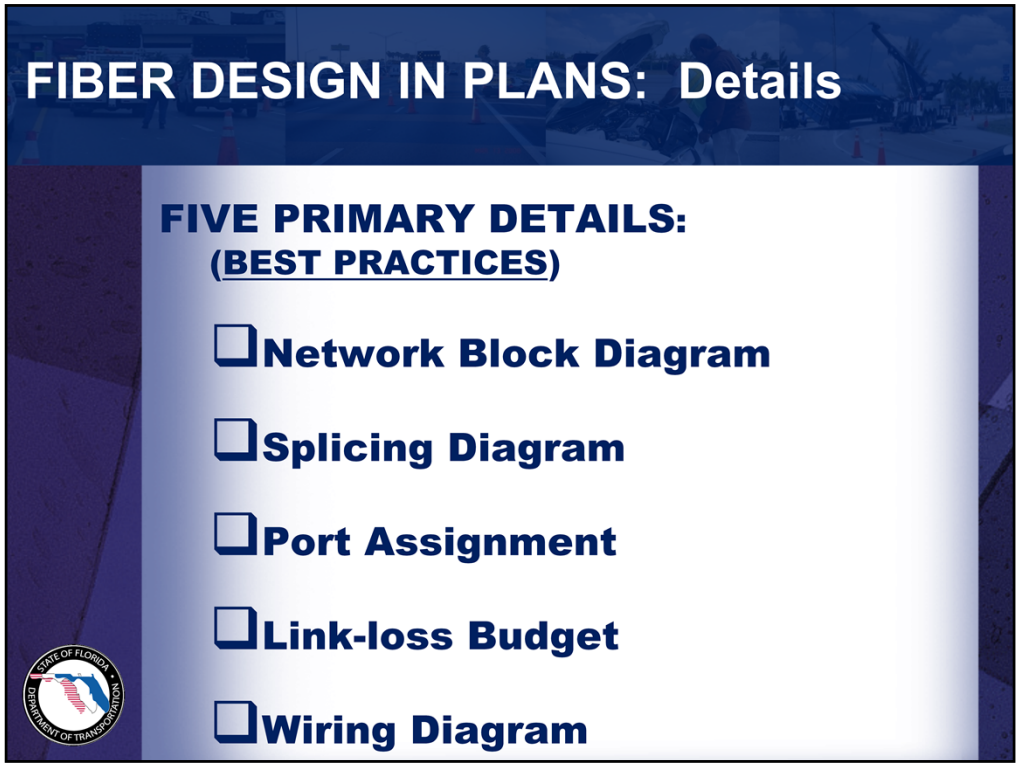

Now we are relatively equipped to review examples but prior to doing so, we'll go over the design plans and components that are pertinent to our goals…



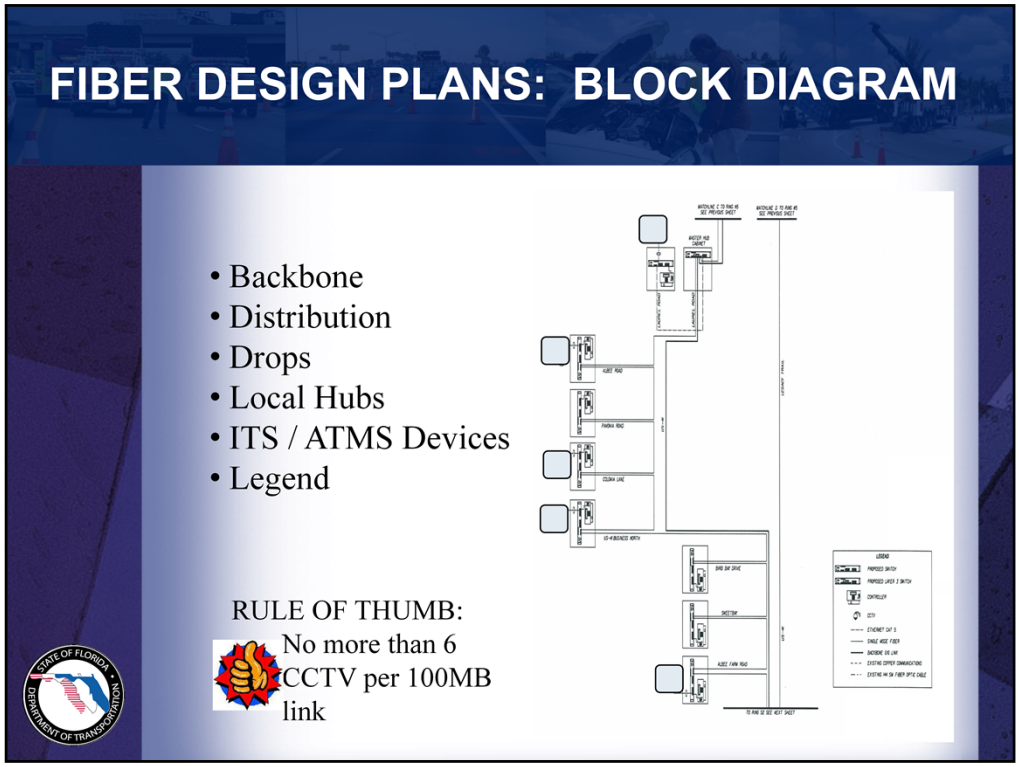

Of standard plan sheets (ITS design and signal interconnect), we will limit our discussion to general items typically encountered as they relate to FOC only. These are: conduit, pull-boxes, FOC itself, and splicing or termination hardware. We will review the details of each during our examples section. For now, this overview is provided as reference to note what is shown on typical plan sheets…

It is more important at this time to simply point out what is what on the plan sheet, where in this sample page, we show the:

- <click>pull-boxes,
- <click>Routes (aerial and underground or bore) along with the Fiber optic cable, and
- <click>splicing or termination hardware



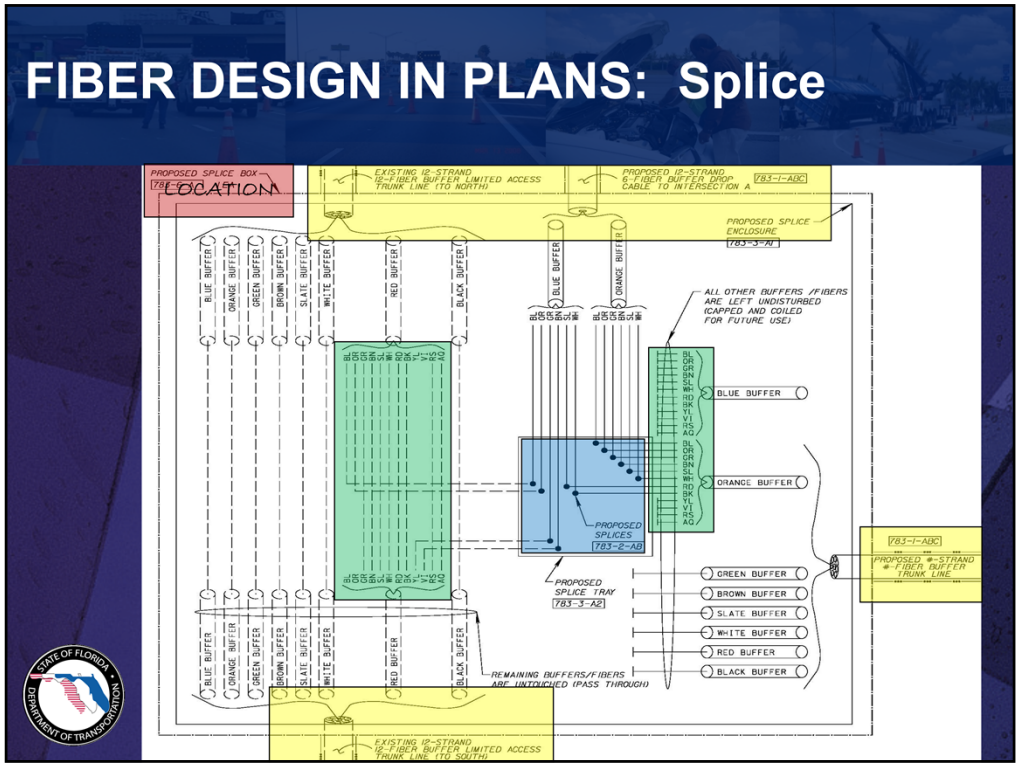

There are four primary detail sheet types in addition to the general plan sheets that are important to us in ITS and signals related to Fiber Optic Cable specifically. These are the<click>: Network Block Diagram, Splicing Diagram, port assignment, and link-loss budget details. Each of these detail sheets provides insight on the designed paths for the communications of the project and are crucial to understand if you are designing or reviewing design.



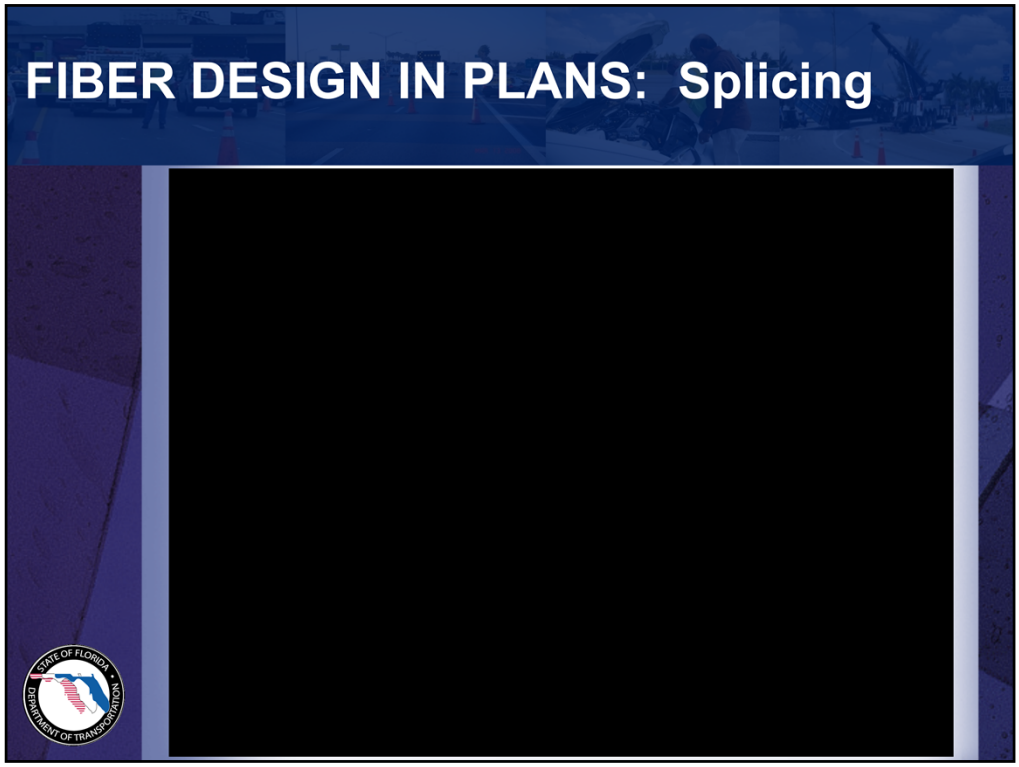

A Network Block Diagram is synonymous to a project layout sheet in that it depicts a high-level view - but of the general communication paths of the project. It provides general communications information such as backbone, distribution segments, logical routes and equipment for each drop

Some argue that this information is not necessarily needed and you could piece together the information from the plans and other details but similar to the project layout, it is helpful to have a bird's eye view of the design intent.

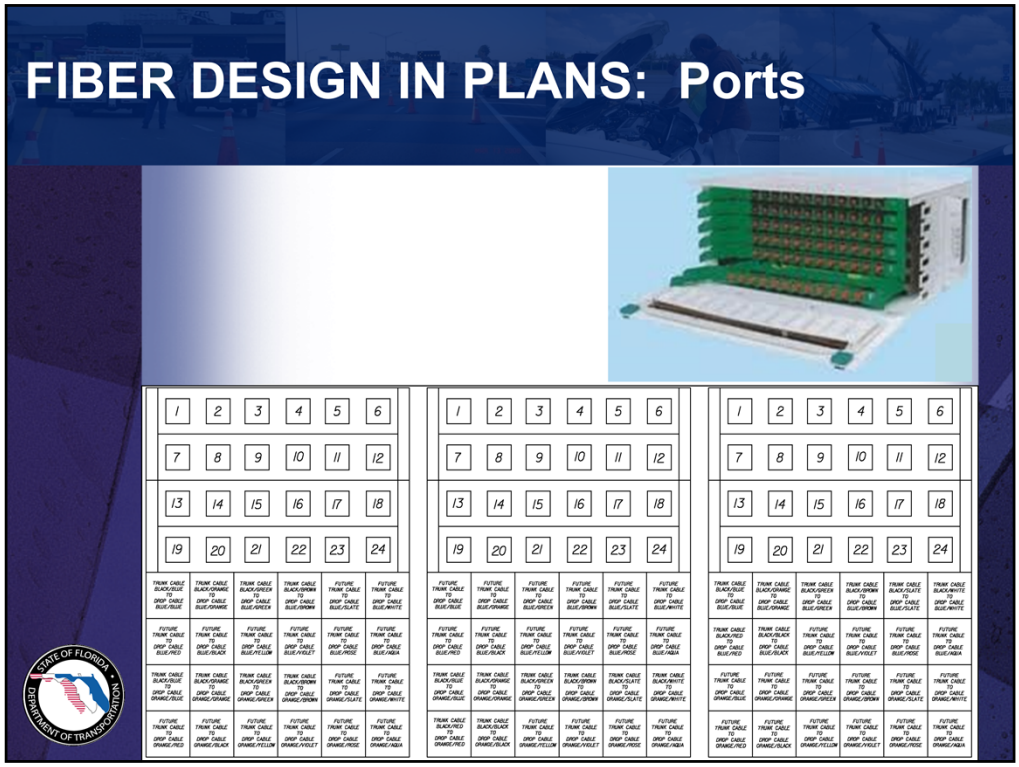
A quick scan of the block diagram can reveal how many CCTV are on each segment, <click> which is critical to allocating fibers in a way that addresses capacity and load balancing. Good Rule of thumb is 6 cameras per 100M link.



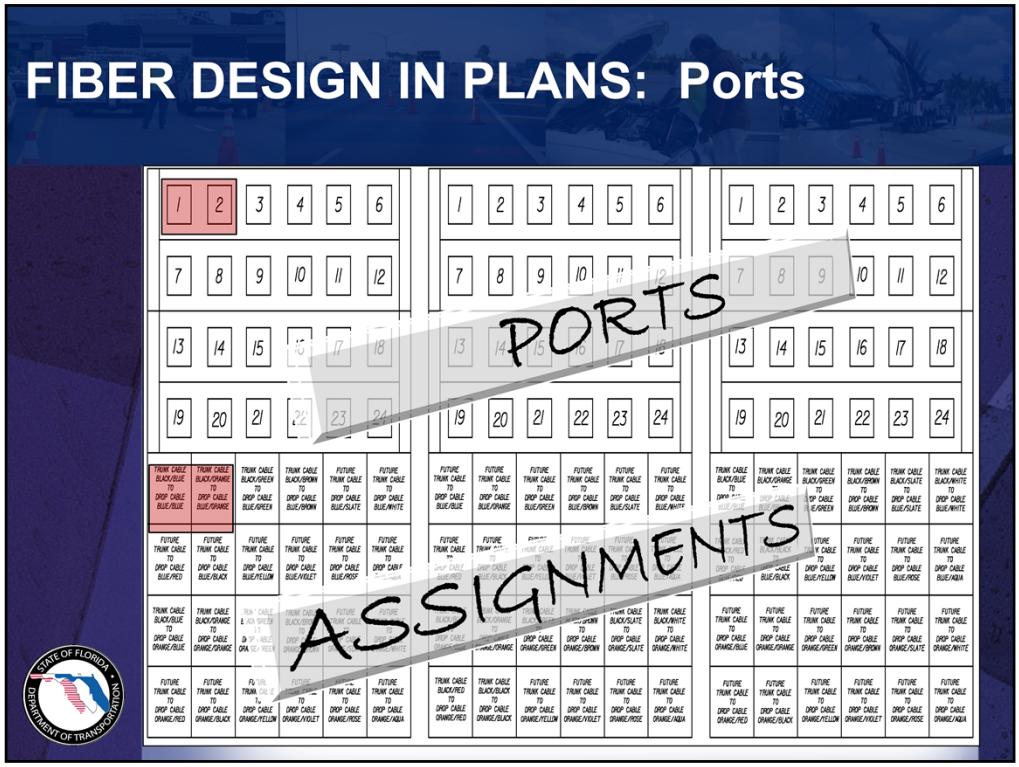

The splicing diagram is where we actually get to the detailed level of fiber optic cable design. These details depict precise plans on tie-ins <click> (which identifies the general location the diagram depicts), <click> fiber assignments (what ties to what), <click> connections (or splices), and <click> cable assignments (drop or trunk).




A quick aside about splicing. Show of hands on who knows what it is, has an idea, or has no clue? <click>Splicing is defined as, “to join or unite.” As with inductive loops, power service wire, conduit, etc, - with FOC, it means the same thing. Thus, when you call out a splice, your are simply showing the connection of one end of a fiber to another. Playing is a quick clip of how an optical fiber splice is performed…




port assignment details take us to the final level of detail with regards to fiber optic cable. These details simply identify where the exact location each of the individual fibers of a cable are terminated. There is nothing more to it other than that really. With the ports assigned, you now have the termini of any given fiber and can, with the general knowledge of today's material, trace a fiber's path end to end…




The components of the port assignment detail are pretty simple. You have the port and you have the assignment. These details are not typically developed for simple designs since the assignments are straightforward and repetitive (and can be handled via project notes or notes in a detail). Port assignment details are usually reserved for designs that involve the integration of main communication nodes such as regional field communication hubs or management centers; which is where a large number of paths intersect and divert

# FIBER DESIGN IN PLANS: Links

SAMPLE LINK-LOSS BUDGET SPREADSHEET

| Distance (km) | Allowable loss over length per wavelength (dB) | | Number of connection types | | Allowable loss per connection Type (dB) | | Total allowable loss (dB) | |
|---|---|---|---|---|---|---|---|---|
| | 1310nm (0.4dB/km) | 1550nm (0.3dB/km) | Fusion (dB) | Connector (dB) | Fusion (0.1dB per) | Connector (0.5dB per) | 1310nm | 1550nm |
| 5 | 2 | 1.5 | 3 | 2 | 0.3 | 1 | 3.3 | 2.8 |

SAMPLE LINK-LOSS BUDGET SPREADSHEET

| Typical Route | Distance (km) | Allowable loss over length per wavelength (dB) | | Number of connection types | | Allowable loss per connection Type (dB) | | Total allowable loss (dB) | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1310nm (0.4dB/km) | 1550nm (0.3dB/km) | Fusion (dB) | Connector (dB) | Fusion (0.1dB per) | Connector (0.5dB per) | 1310nm | 1550nm |
| 1 | 5 | 2 | 1.5 | 3 | 2 | 0.3 | 1 | 3.3 | 2.8 |
| 2 | 1 | 0.4 | 0.3 | 1 | 1 | 0.1 | 0.5 | 1 | 0.9 |
| 3 | 2 | 0.8 | 0.6 | 2 | 2 | 0.2 | 1 | 2 | 1.8 |
| 4 | 3 | 1.2 | 0.9 | 3 | 3 | 0.3 | 1.5 | 3 | 2.7 |
| 5 | 4 | 1.6 | 1.2 | 4 | 4 | 0.4 | 2 | 4 | 3.6 |

Now, we get to link-loss budget detail. The link-loss budget detail sheet contains the calculations based on the FDOT and/or manufacturer's specification

Recall this example <click>?

The link-loss budge detail sheet is simply the application of this formula to all typical routes experienced by the design – end to end.

<click>And by typical, I do mean any of the unique paths that are followed by any one fiber or group of fibers in the designed route. It is more often than not that a design contains a high-count backbone fiber cable that only implements 12 or so of the fibers for immediate use.

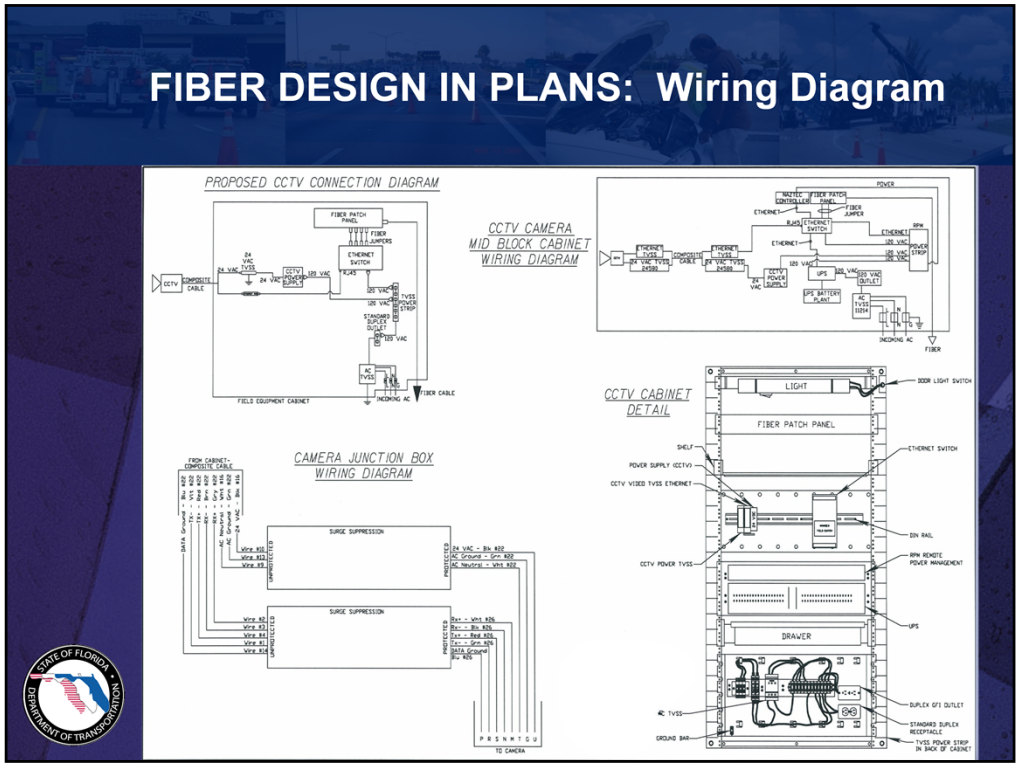
# FIBER DESIGN IN PLANS: Links

SAMPLE LINK-LOSS BUDGET SPREADSHEET

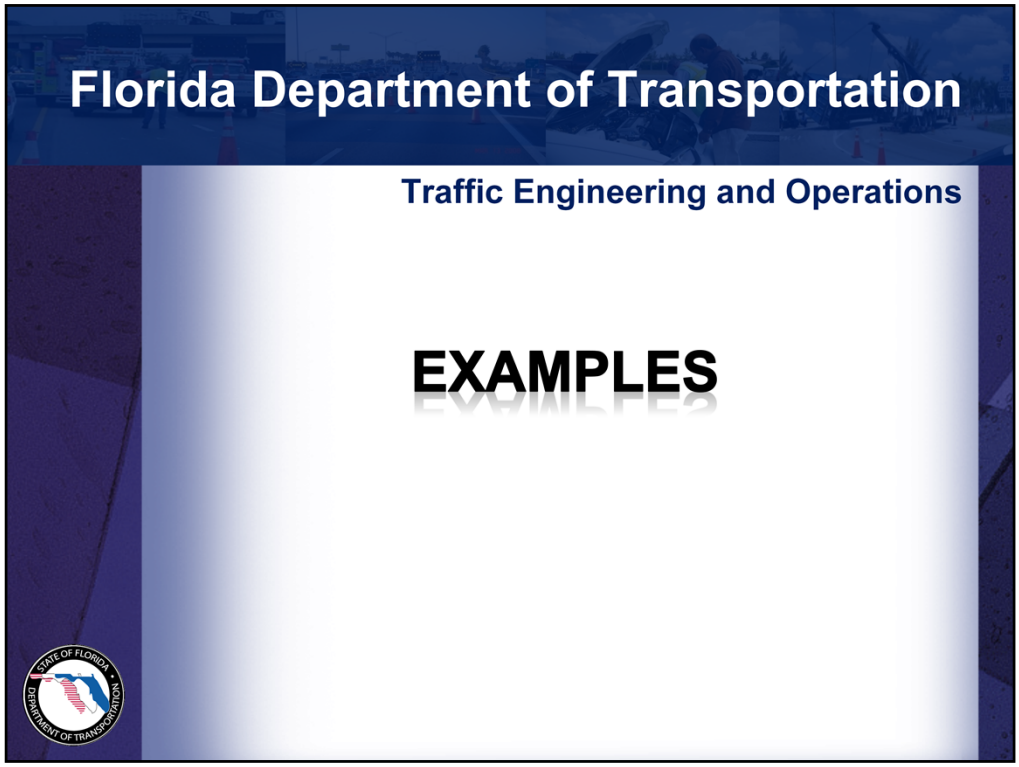
| Typical Route | Distance (km) | Allowable loss over length per wavelength (dB) | | Number of connection types | | Allowable loss per connection Type (dB) | | Total allowable loss (dB) | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1310nm (0.4dB/km) | 1550nm (0.3dB/km) | Fusion (dB) | Connector (dB) | Fusion (0.1dB per) | Connector (0.5dB per) | 1310nm | 1550nm |
| 1 | 5 | 2 | 1.5 | 3 | 2 | 0.3 | 1 | 3.3 | 2.8 |
| 2 | 1 | 0.4 | 0.3 | 1 | 1 | 0.1 | 0.5 | 1 | 0.9 |
| 3 | 2 | 0.8 | 0.6 | 2 | 2 | 0.2 | 1 | 2 | 1.8 |
| 4 | 3 | 1.2 | 0.9 | 3 | 3 | 0.3 | 1.5 | 3 | 2.7 |
| 5 | 4 | 1.6 | 1.2 | 4 | 4 | 0.4 | 2 | 4 | 3.6 |

**! Consideration:**
**-----Failover link loss budget.**

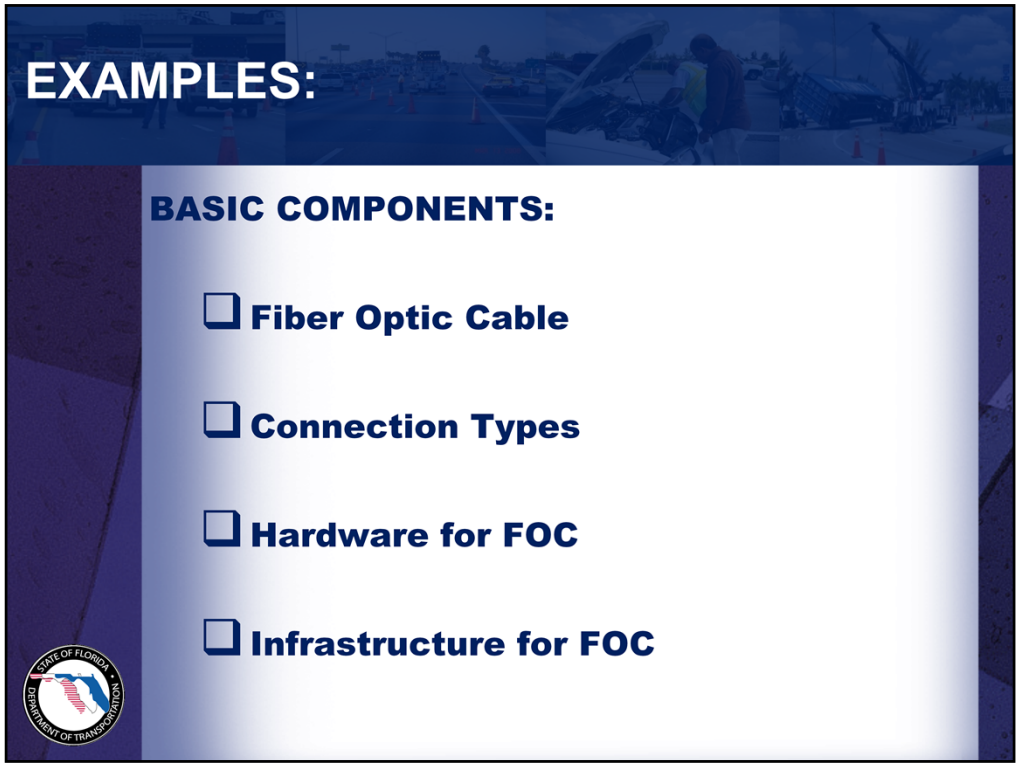
The basic components are those identified in the earlier example where we have <click> the physical length of the cable, <click>the number of intermittent connections (splices and jumpers), and <click> the total allowable loss between the termini of the route. The total value (in dB loss) is the maximum loss allowed by the run <click> and is what should be checked against when provided field test values…




Wiring diagram shows actual connection of all components at the cabinet / device location



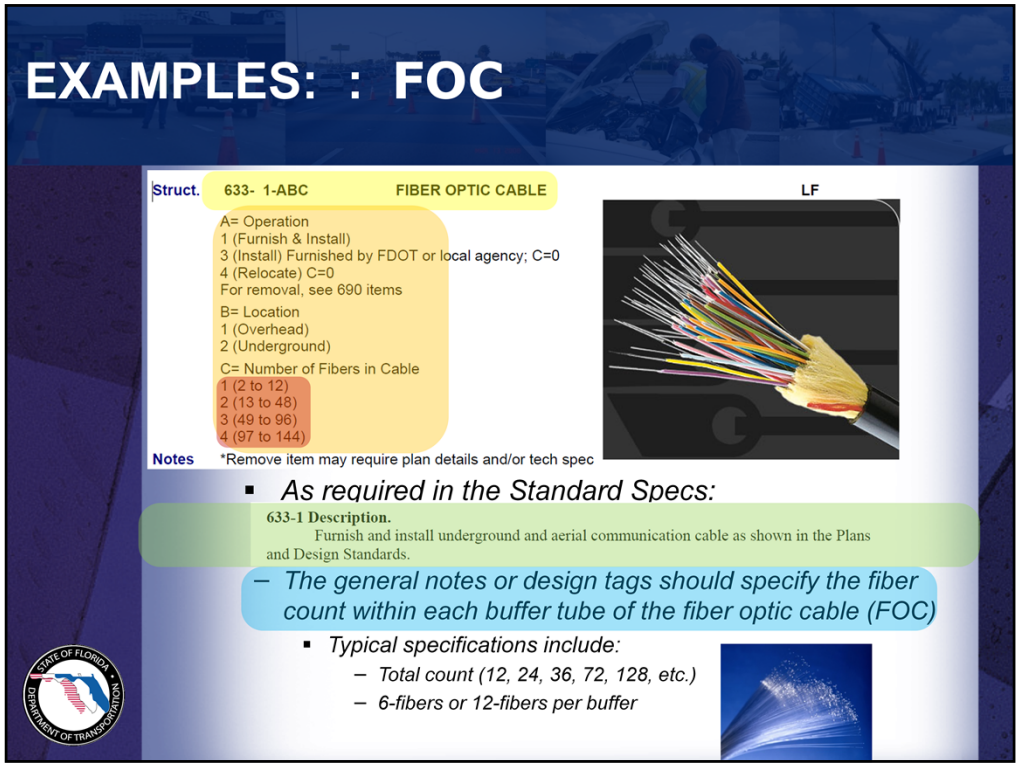

We have finally reached the examples section where we will summarily go over the information we have covered thus far. As has been our theme, we will avoid getting into the various forms the example could take and stick with the general concepts. Again, it will be your onus to research the concepts and massage them to fit your specific needs…




Components important to us today are:

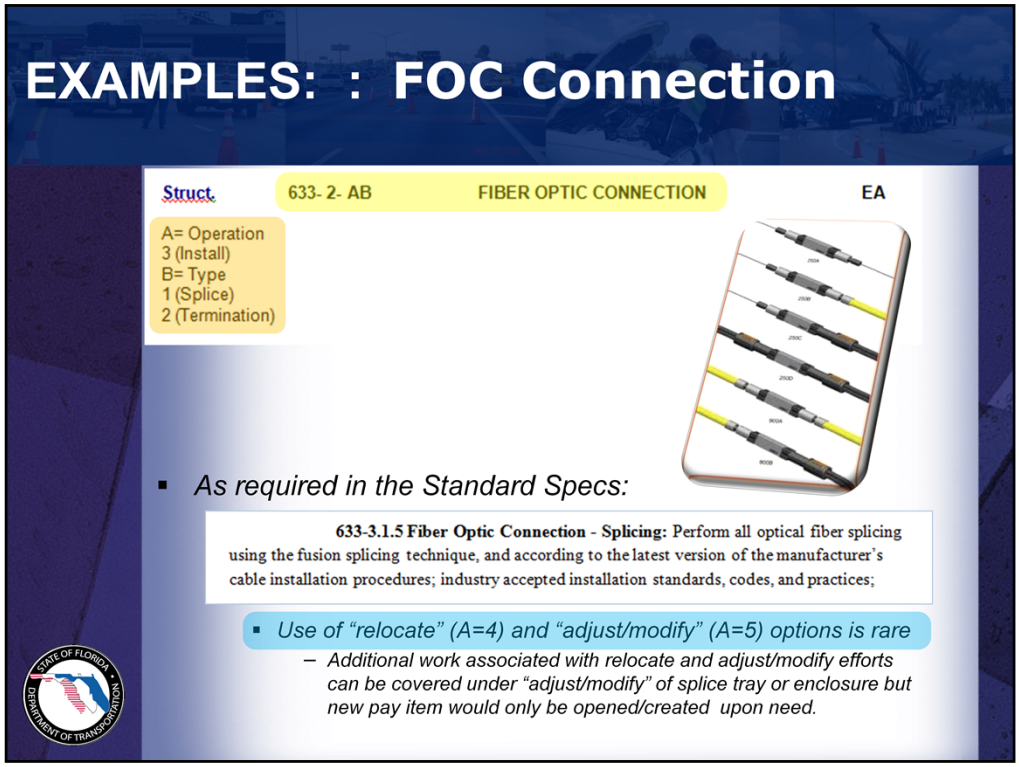
1. <click>Fiber optic cable, <click>connection types: splices and terminations. We'll also review a little extra about connection to fiber and connections of other kinds to help understand the nuances, <click>hardware for fiber optic cable: enclosures, patch panels, and the like AND, <click>Infrastructure for fiber: conduit and pull boxes

Some of the following slides are sourced from FDOT D1 ITS general training documents developed last year. These slides concisely capture each of the components laid out in our list…, we'll quickly discuss them and then move on to stage two of this example section.



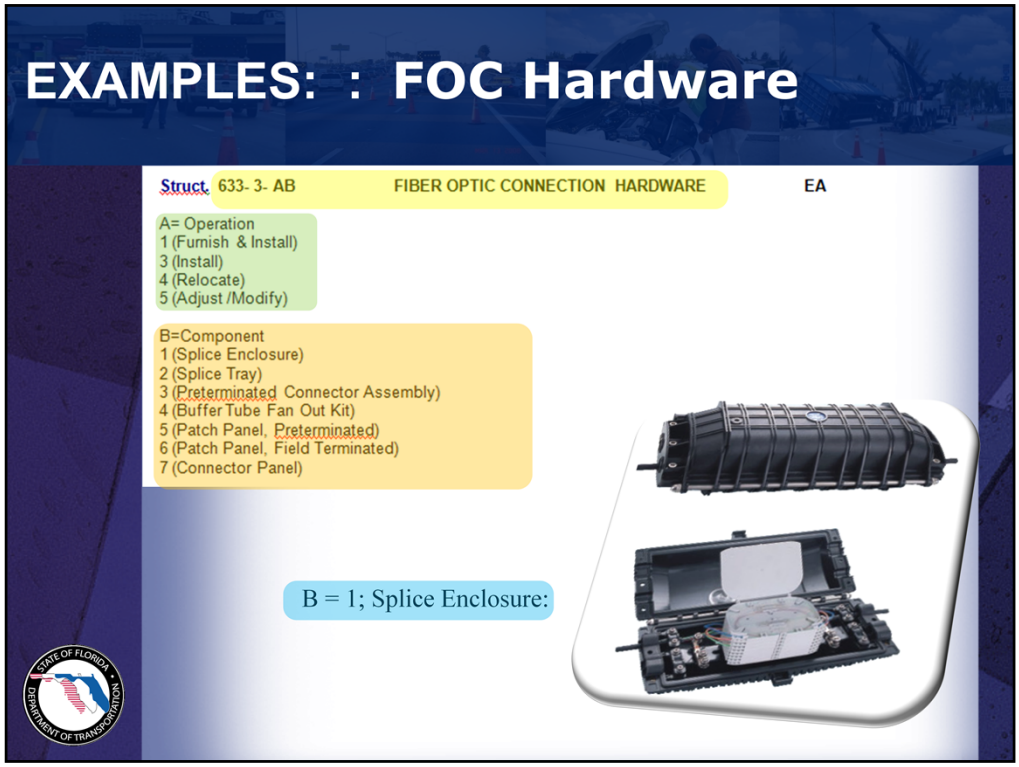

A quick clarification before we begin this section is to emphasize that many specifications and pay-items are in the process of being moved and consolidated between ITS, Signalization, and lighting. Historically, a lot of specification and pay-items had overlap and duplication even though materials and installation methods were essentially the same. A group comprised of several offices within FDOT is gradually moving and consolidating specifications, standards, and pay items in an effort to reduce unnecessary duplication and help consistency….

So we have here a layout of the new 633-1 group. It was formerly content duplicated here and in the 783-1 group for fiber optic cable. The point of this slide - and the ones to follow - is to quickly note some general information and provide a quick summary picture for your edification. The quick summary here is the BOE structure <click> , a blurb from the state standards <click>, and a note of what to look or lookout for regarding cable count <click>. Since you can see in the BOE structure <click> the pay-item does not identify a specific count, it is important to identify the fiber count somewhere in plans to accurately design and/or review the design




Moving on to the 633-2 series we come to connections for fiber optic cable. As you can see, there are only two types <click>. One is a fusion splice (as demonstrated in our earlier video), the other termination. Interpretation of lingo becomes a slight concern since a termination can include a fusion splice so it has been a common practice to only see the splice pay-item used. The intent of the differentiation though is to identify where fiber may be coupled without the use of fusion splicing; such as mechanical splicing <click>. Overall though, the cost for each is generally the same and the reason why the termination pay-item is sometimes neglected. As noted on the slide <click> the use of relocation or adjust/modify is rare since the effort is typically rolled into work required to access the tray or enclosure housing the connection and the Install splice pay-item is used to pay for the connections.

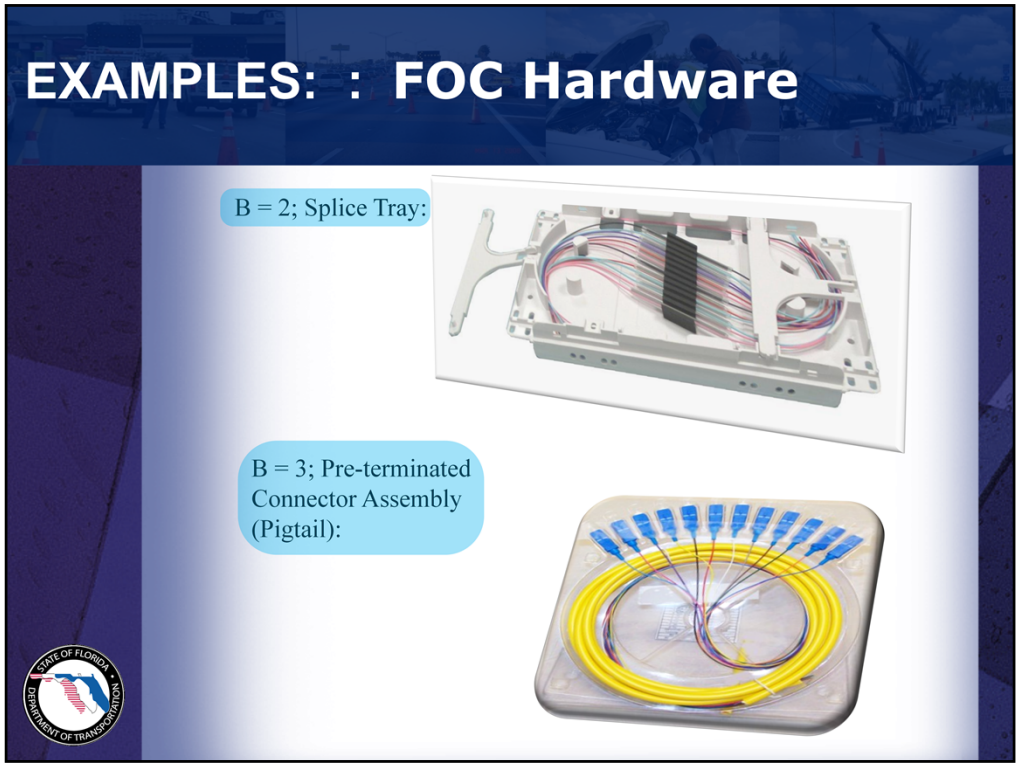
Also important to not is that FDOT intends these connections to be "per fiber" for cost tracking purposes. Therefore, if a project called for connecting every strand in one 72-count fiber cable to every strand in another 72-count cable, this should not be considered as "1" splice. It should be considered as "72" splices that connect the 2 cables at a single location.




The 633-3 series is where we now cover the hardware for FOC. This content is the same as what was in the old 783 pay item structure.

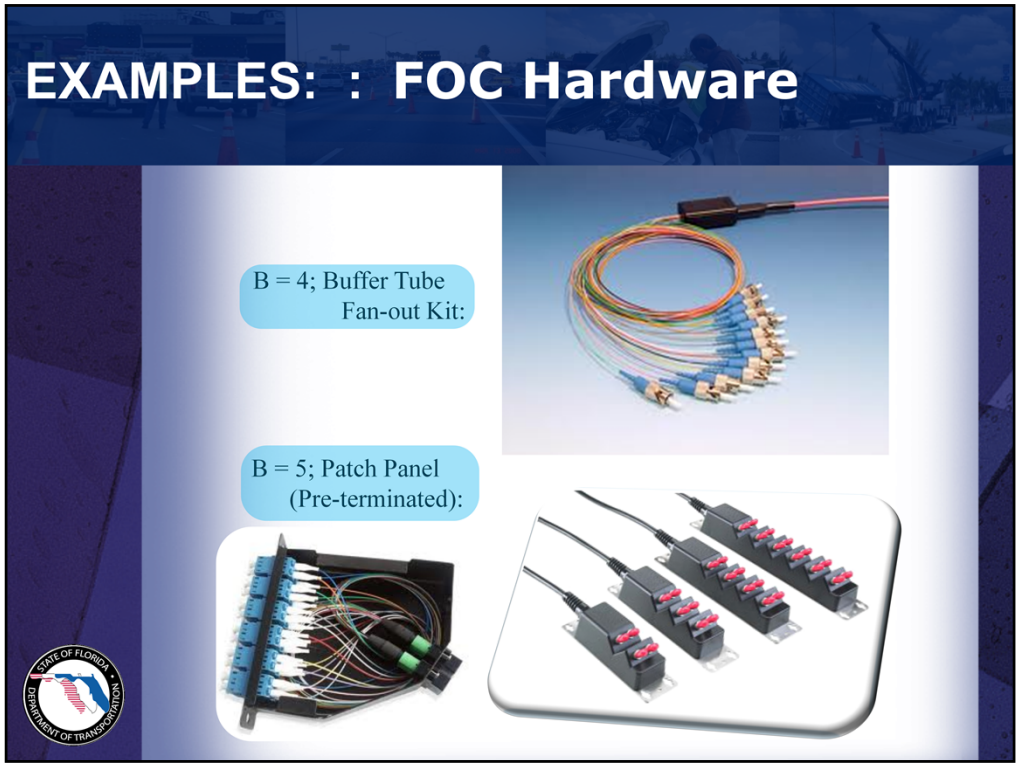
<click> This time we may very well use any of the numbers for the operation value because if you connect to existing fiber, you will need to pay for opening, modifying or relocating of closures or the splice trays within.

The component value, “B” <click> identifies a number of things which we will quickly cycle through. <click> For B=1, we have the splice enclosure (sometimes referred to as “closure”). The quick description of this hardware is a hardened device that houses splice trays and, in turn, splices. It is hardened to protect fiber from the elements and handling.



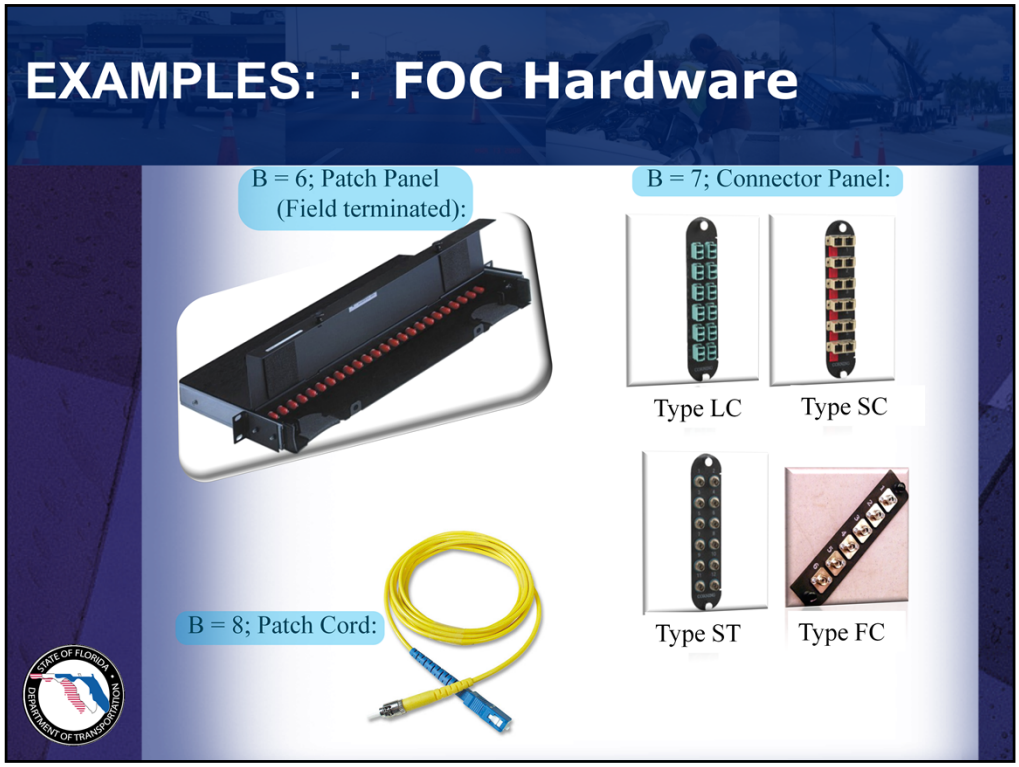

Splice trays <click> are simply that, trays to hold splices. They are another layer of protection and assist in physical fiber cable management

Pigtails <click> are optical fibers terminated on one end with a specified connector type and free on the other end to be spliced as needed.

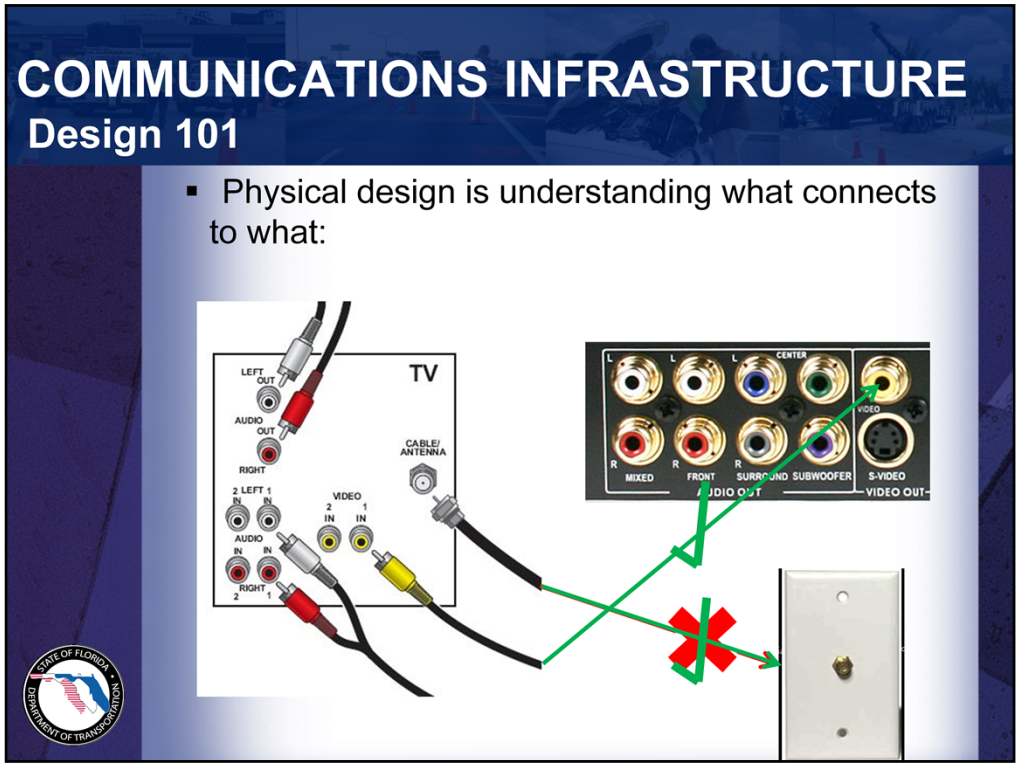



<click> Fan out kits are similar to pigtails except designed to terminate an entire buffer.

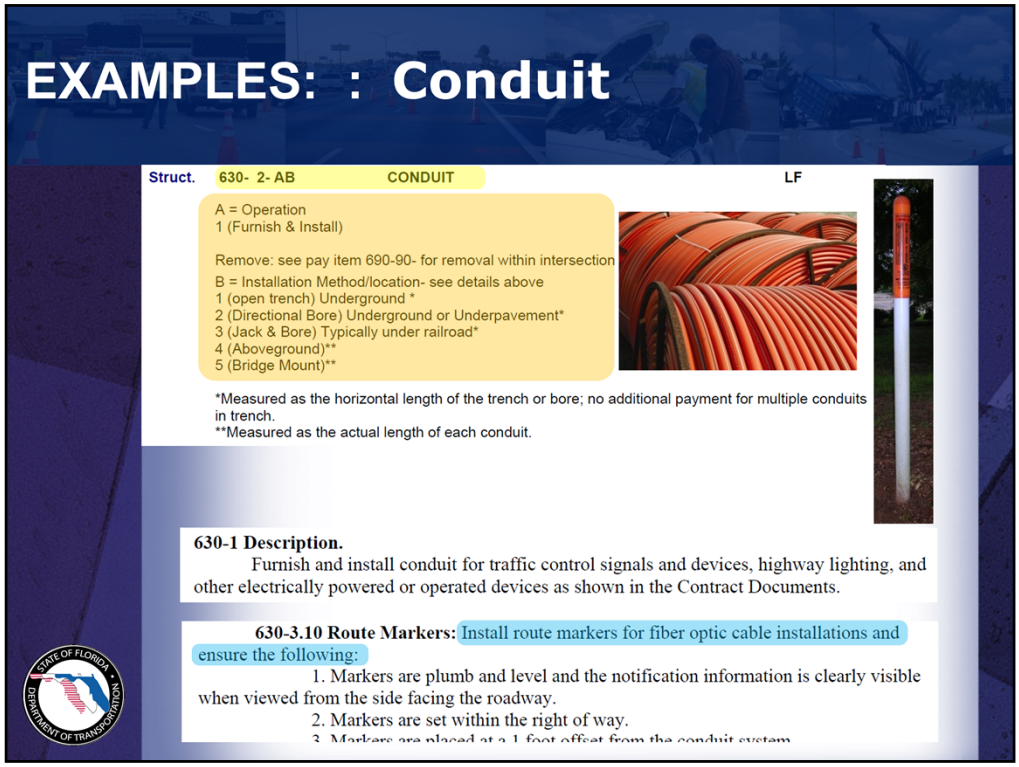
<click> Pre-terminated patch panels are patch panels preconfigured with a connector panel and fan-out kit factory installed.




Patch panels <click> are boxes of hardware designed to house splice trays, splices, and fibers internally along with terminations of those fibers to the back end of a connector panel <click>. They are also designed to mount to other hardware and also formed to attach connector panels to its face. <click> Connector panels are the face of a patch panel and where the fiber terminates on the back side and patch cords connect to those fibers on the face side. There are a plethora of connector types available in the market - each ideal for a given situation. The connector type and thus the panel are determined primarily by intended use and something that must be determined in design otherwise you end up with patch cords that won't connect up. <click> Patch cords are simply cords of optical fiber pre-terminated with specified connectors. Either end is configurable to jumper between connector panels of differing connector types and device ports.



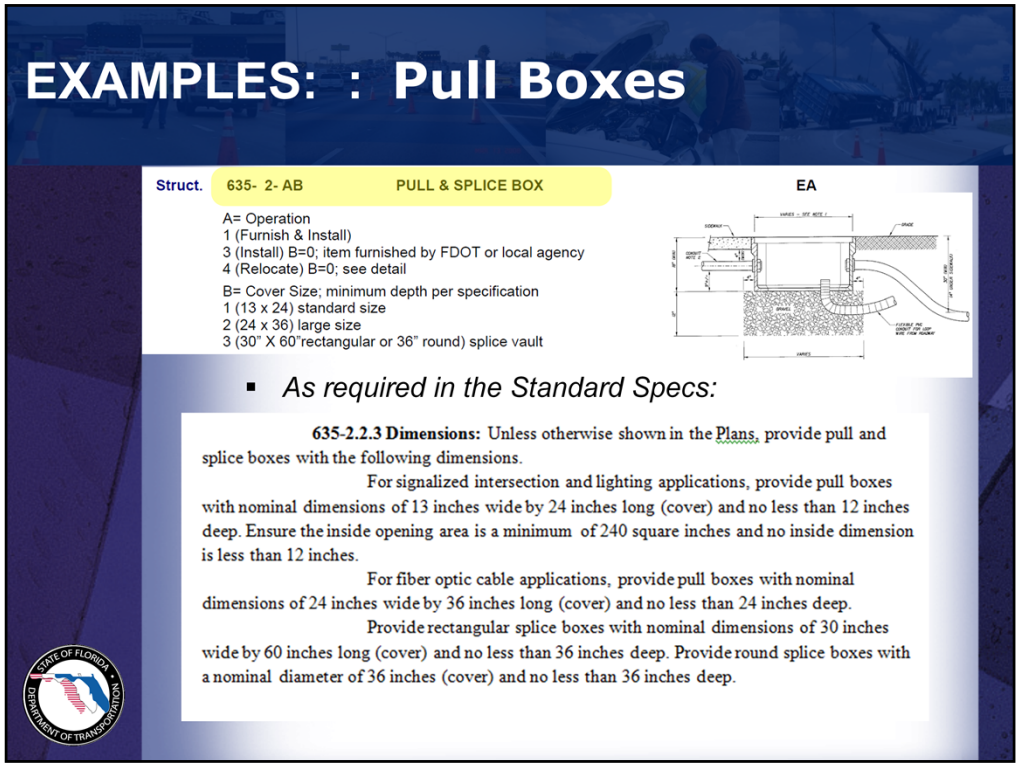

To emphasize this point, I've demonstrated here that specifying connectors is essential. <click> You would not attempt to connect your cable jack to your wall outlet thus, be sure you specify the right connectors less you find yourself unable to connect…



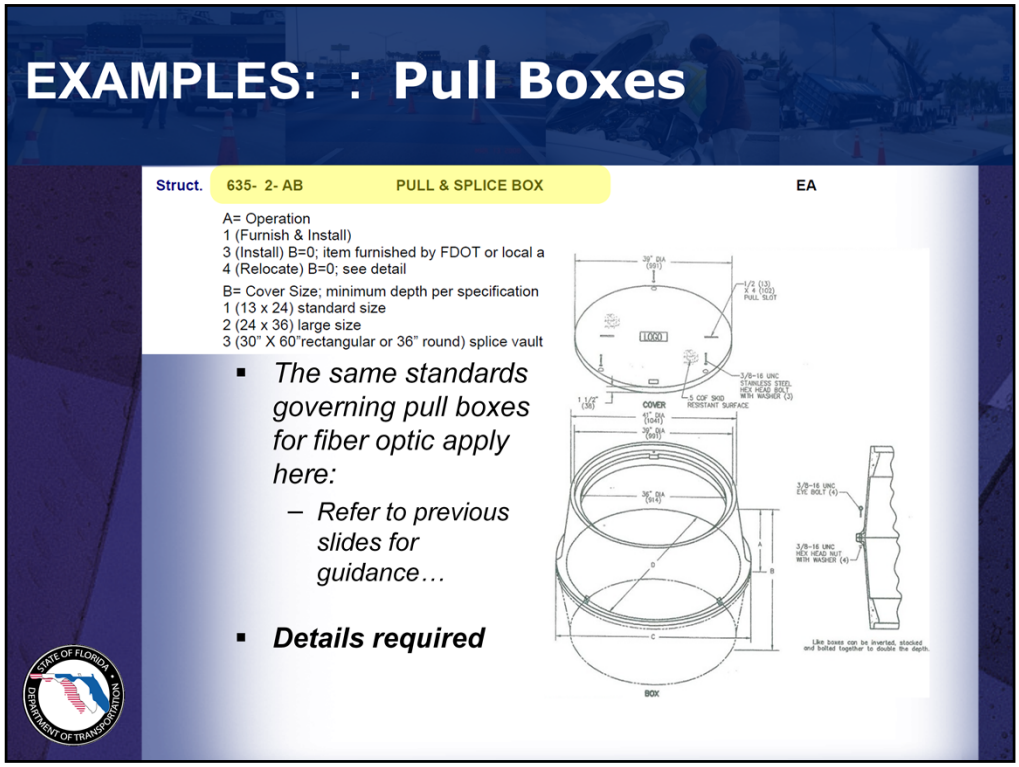

Moving out of directly related fiber optic cable components we get to conduit <click>. In the past, the Department had different pay items and specifications for conduit used for ITS, Signalization, and Lighting. This has now all been combined into the 630 Specification. An important thing to note about conduit for fiber optic cable installations is that standard route markers are expected to be included by default.

This has always been a typical requirement on past ITS projects utilizing conduit for fiber optic cable, but may be new to some. The markers are only required for fiber optic cable installations.

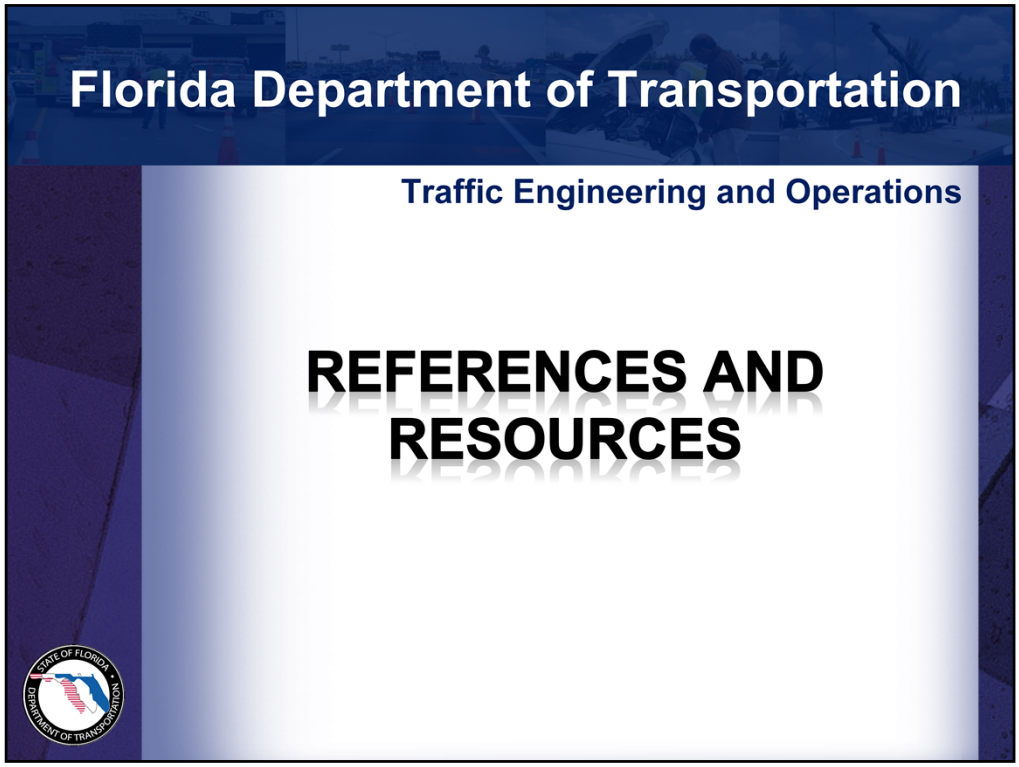
**DON'T FORGET GENERAL NOTE ON ROUTE MARKERS – WHAT DO THEY SAY**



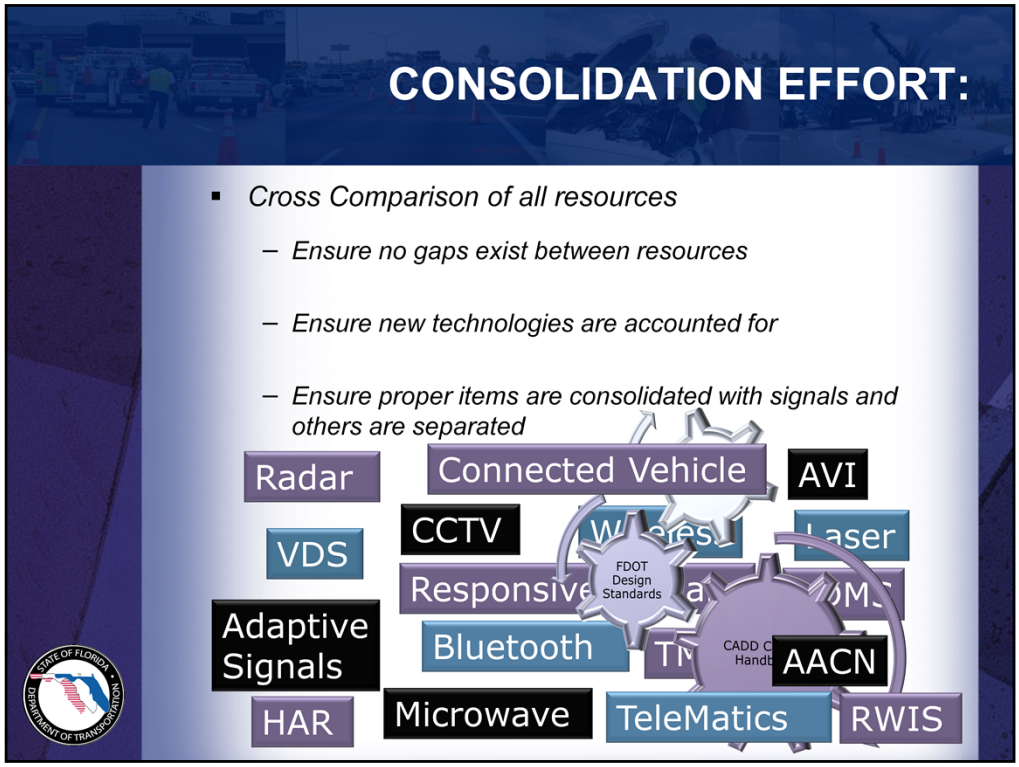

And lastly we get to pull boxes <click>. There are three available in the 635 series for various use cases. The specification gives some minimum dimensions for certain applications that are typical. Other sizes, or larger boxes can be shown in the plans when specifically required by a design. If there is no indication of atypical sizes or depths shown in the plans, then the minimum sizes and depths in the standards and specifications will govern.




It should be noted that the current specifications, pay items, and design standards allow for the use of round boxes as well as rectangular. The one depicted here <click> is for pulling, storage, and housing of connection hardware – enclosures and internal components of them. The obvious difference is size and I've somewhat plugged the round version because I am a big fan of them. I don't know about you all but I've opened my fair share of splice boxes and some of the lids can be upwards of 200 lbs. Aligning square and rectangle lids is hard enough, dropping them is – well, let's just say we invented round man-hole covers for a reason…




We're going to quickly discuss the consolidation efforts of the FDOT references and resources before we close up this module and open up for questions




Multiple efforts are underway within the department to consolidate many requirements that cross disciplines and are used in Signalization, ITS, lighting, and other applications. (Click)

These resources should all be working together acting as one whole resource for design… So future efforts hope to ensure that everything is parallel. In other words, every pay item has an associated specification, design standard, and cell (or line style).

(Click)

Being a field of technology, ITS is ever changing.

(Click) It will be crucial to make sure the resources account for the latest technologies, and provide enough generalities to allow for new technologies.

(Click)

Finally, proper consolidation and separation is key to ensuring seamless design. It will be critical to ensure proper consolidation… For example: a UPS for a signal cabinet will likely be quite different than that for an ITS cabinet… Whether that means having separate pay items completely, or using different categories within the UPS pay item number to differentiate.

All of these consolidation efforts will ultimately result in more consistent and efficient designs, higher clarity in the plans, and ultimately cost savings for both client and consultant.

The following two slides are simply the links to the general resources mentioned previously.

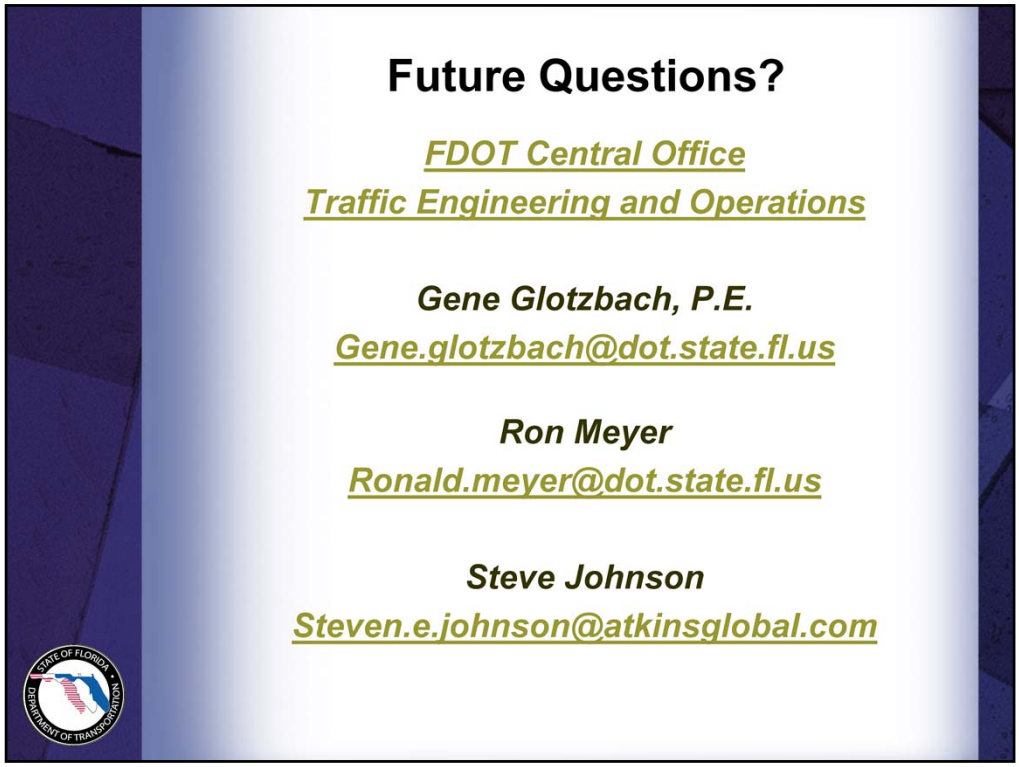
## Links / References

- FDOT Traffic Engineering and Operations
  http://www.dot.state.fl.us/trafficoperations/
- FDOT Specifications and Estimates
  http://www.dot.state.fl.us/specificationsoffice/
- FDOT Design Standards
  http://www.dot.state.fl.us/rddesign/DesignStandards/Standards.shtm
- Approved Product List
  http://www3.dot.state.fl.us/trafficcontrolproducts/
- Traffic Engineering Manual (TEM)
  http://www.dot.state.fl.us/trafficoperations/Operations/Studies/TEM/TEM.shtm

## Links / References

- Florida Intersection Design Guide
  www.dot.state.**fl**.us/rd**design**/FIDG-Manual/FIDG2007.pdf
- Plans Preparation Manual
  http://www.dot.state.fl.us/rddesign/PPMManual/PPM.shtm
- Master Pay Item List / WebGate
- FHWA Manual on Uniform Traffic Control Devices (MUTCD)
  http://mutcd.fhwa.dot.gov/pdfs/2009/pdf_index.htm

**You don't have to know it all ….**
**…. You just have to know where to find it**




And finally we have our last slide with contact information. Supported by a large team throughout central office including:

Gene Glotzbach (Glots-bock) and Ron Meyer with Traffic Operations

Me if questions about this presentation.

Now let's open the floor to questions. <after questions>

Thank you everyone and please contact ANY OF US for any follow-up.

# THANK YOU