



# Fiber Design for ITS and Signalization Projects

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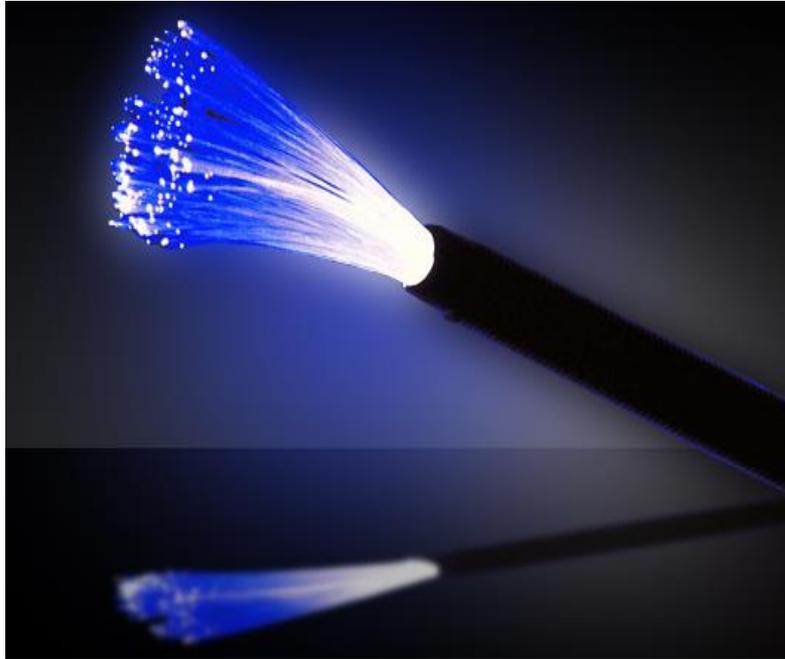
# PURPOSE

Provide insight into practices associated with fiber optic cable design including: specifications, pay-items, design standards, and industry practices.

- FDOT Standard Specifications for Road and Bridge Construction
- FDOT Design Standards
- Basis of Estimates (BOE)
- Plans Preparation Manual (PPM)

# AGENDA – Fiber Optic Cable

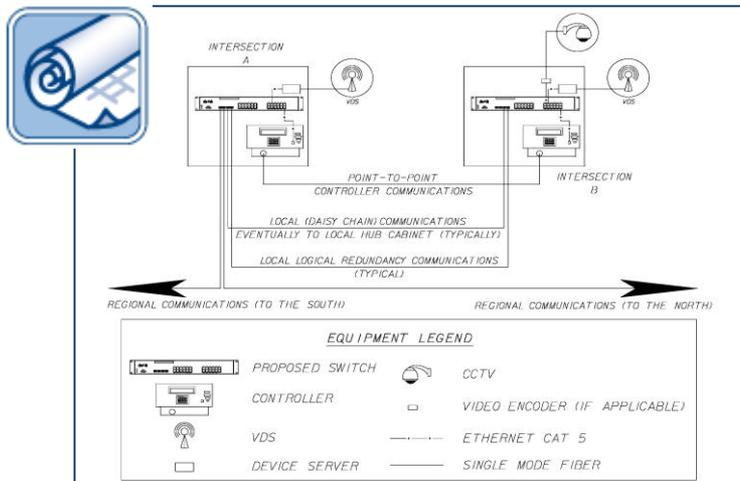
- What it is
- How it works
- Why we use it
- Standards
- Terminology



# AGENDA – Design Concepts

- High-level Design Concepts
- Layout for specific conditions
- Regulations important to our industry

## Plans



## Specifications

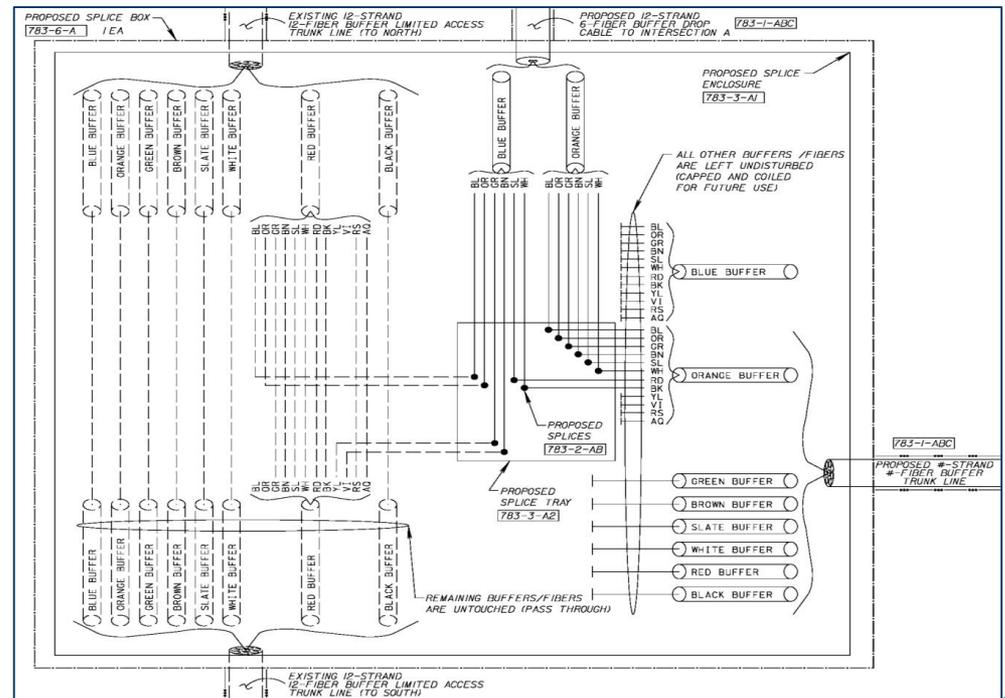


## Estimates



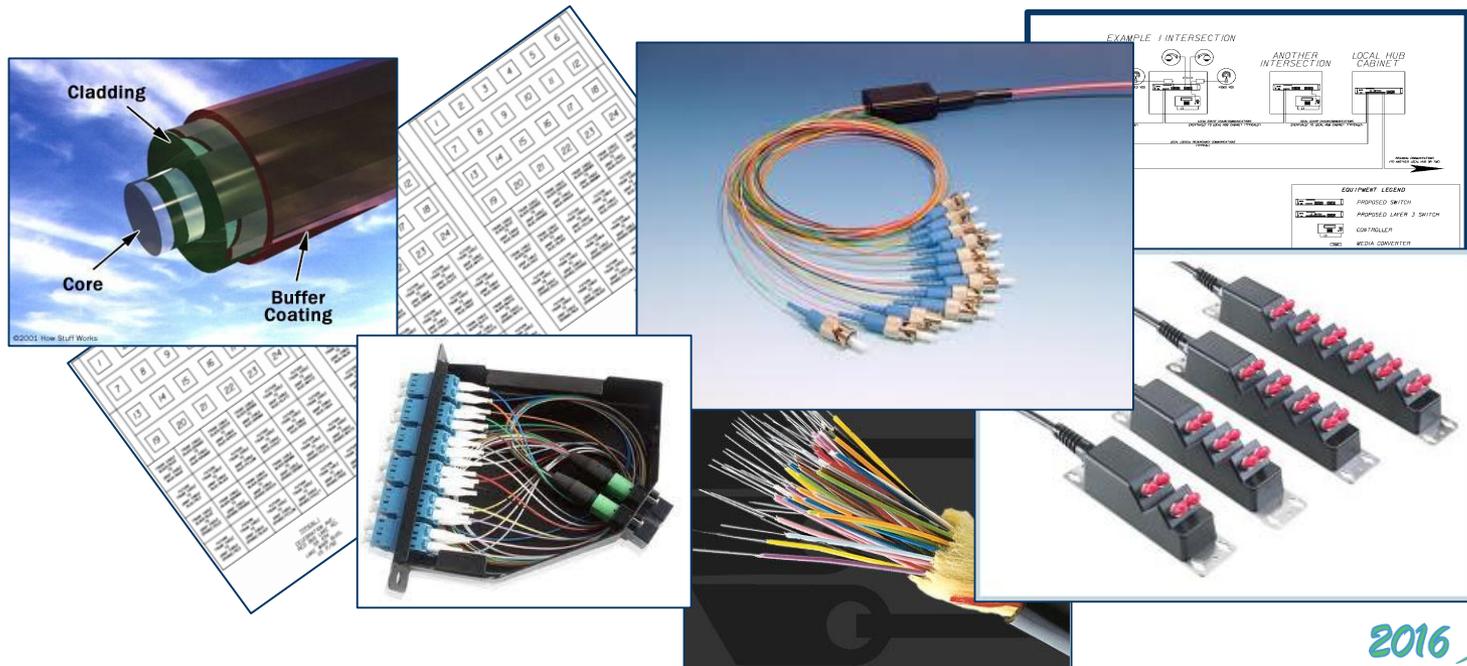
# AGENDA – Design Plans

- Plans layout
- Component parts (associated pay-items)
- Related details



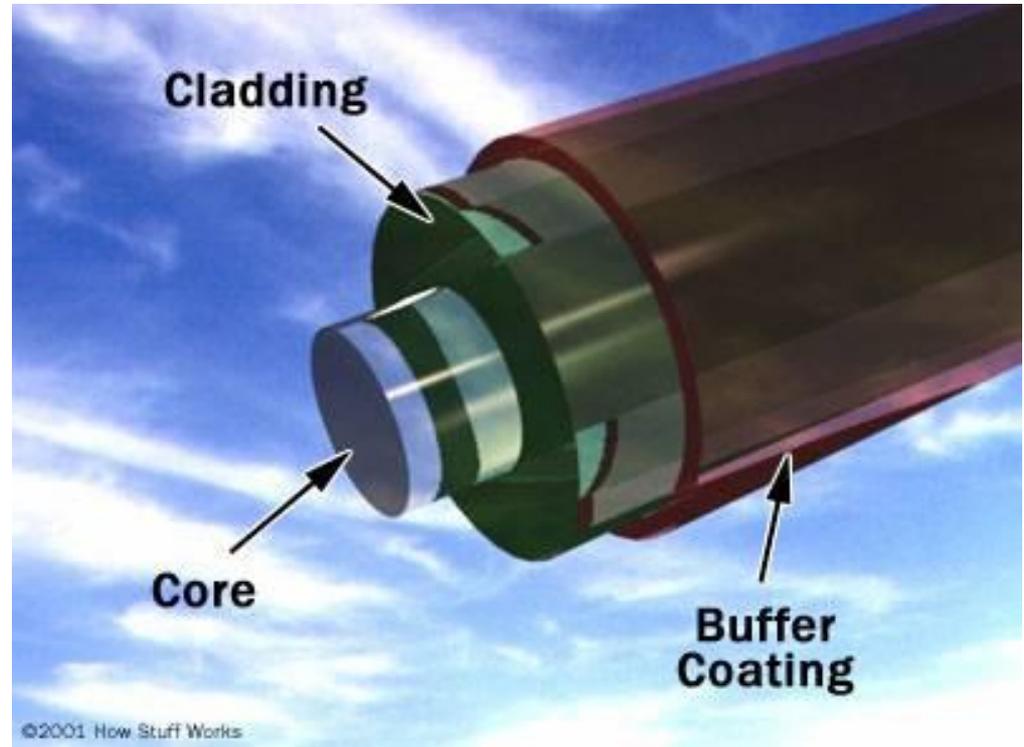
# AGENDA – Examples

- Various devices
- Connections to one another
- Associated pay-items (as applicable)

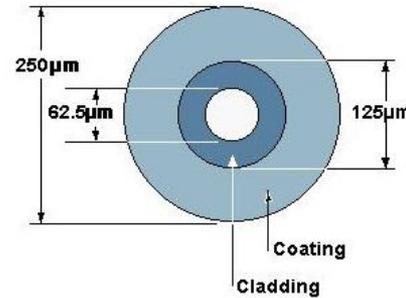
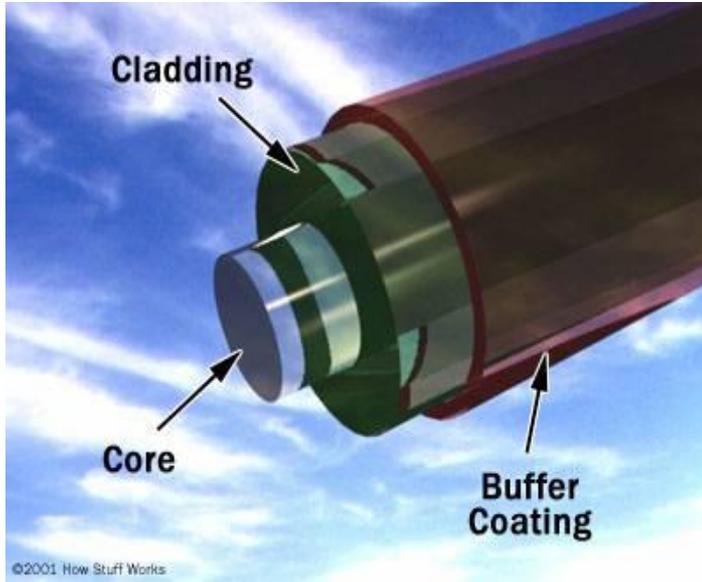


# FIBER OPTIC CABLE

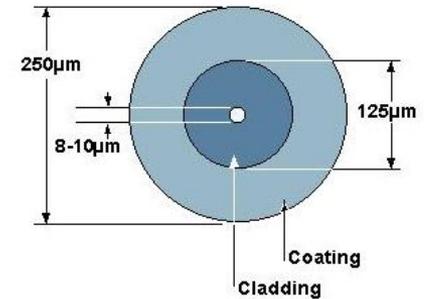
- What it is
- How it works
- Why we use it



# FIBER OPTIC CABLE: What is it?



TYPICAL MULTIMODE  
CROSS-SECTION



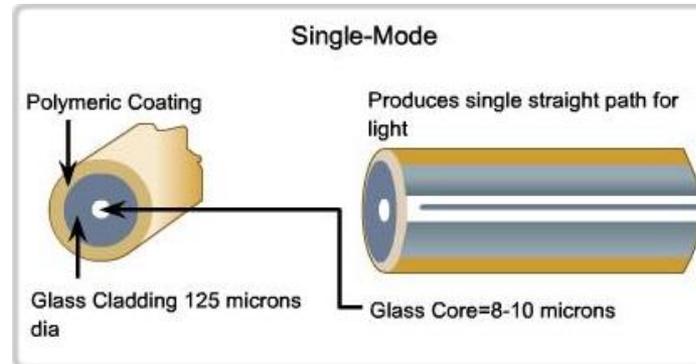
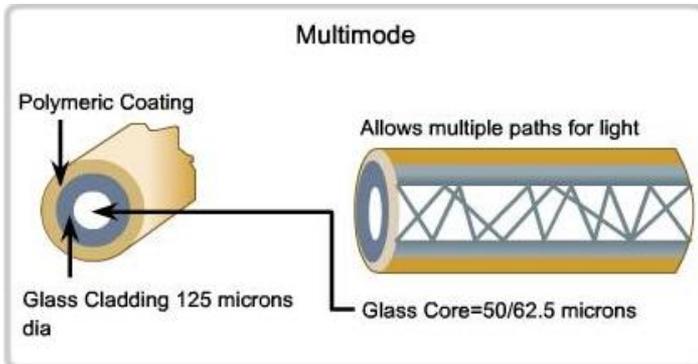
TYPICAL SINGLEMODE  
CROSS-SECTION

**Multi-Mode**

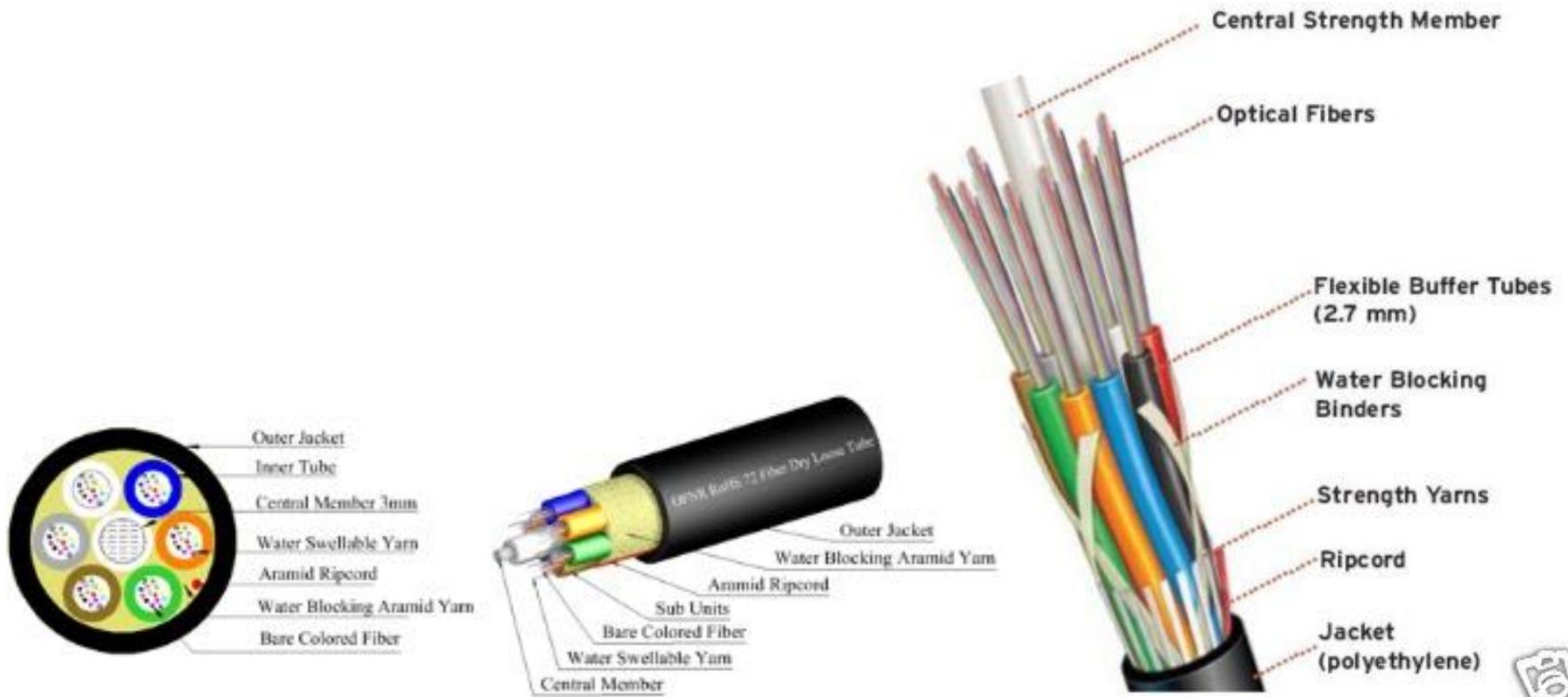
**Short-Haul Communications**

**Single-Mode**

**Long-Haul Communications**



# FIBER OPTIC CABLE: What is it?



# FIBER OPTIC CABLE: How does it work?



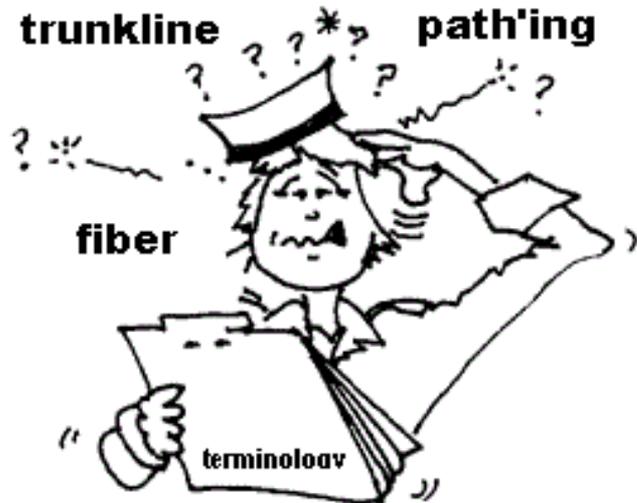
# FIBER OPTIC CABLE: Why do we use it?

- Extremely Low Loss
  - Transmit data over 120km without repeaters or regeneration
- Extremely High Bandwidth
  - 100 Gbps over a pair of fiber
- Data Security
- Resistance to EMI

# FIBER OPTIC CABLE: Standards

## □ TERMINOLOGY

Position	Jacket color
1	Blue
2	Orange
3	Green
4	Brown
5	Slate
6	White
7	Red
8	Black
9	Yellow
10	Violet
11	Rose
12	Aqua



## □ COLOR CODE

## □ RULE OF SEPARATION

# FIBER OPTIC CABLE: Terminology

- Backbone (or Trunk circuit)
  - Carries data from multiple network segments
  - 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
- Drops (or stub circuits)
  - Branches off of distribution and carries data at the local equipment cabinet level
- Splices/Terminations

# FIBER OPTIC CABLE: Color Code

Position	Jacket color
1	Blue
2	Orange
3	Green
4	Brown
5	Slate
6	White
7	Red
8	Black
9	Yellow
10	Violet
11	Rose
12	Aqua

## TIA-598-C STANDARD: "Optical Fiber Cable Color Coding"

144-Count Fiber Cable

	blue	orange	green	brown	slate	white	red	black	yellow	violet	rose	aqua
blue	1	13	25	37	49	61	73	85	97	109	121	133
orange	2	14	26	38	50	62	74	86	98	110	122	134
green	3	15	27	39	51	63	75	87	99	111	123	135
brown	4	16	28	40	52	64	76	88	100	112	124	136
slate	5	17	29	41	53	65	77	89	101	113	125	137
white	6	18	30	42	54	66	78	90	102	114	126	138
red	7	19	31	43	55	67	79	91	103	115	127	139
black	8	20	32	44	56	68	80	92	104	116	128	140
yellow	9	21	33	45	57	69	81	93	105	117	129	141
violet	10	22	34	46	58	70	82	94	106	118	130	142
rose	11	23	35	47	59	71	83	95	107	119	131	143
aqua	12	24	36	48	60	72	84	96	108	120	132	144

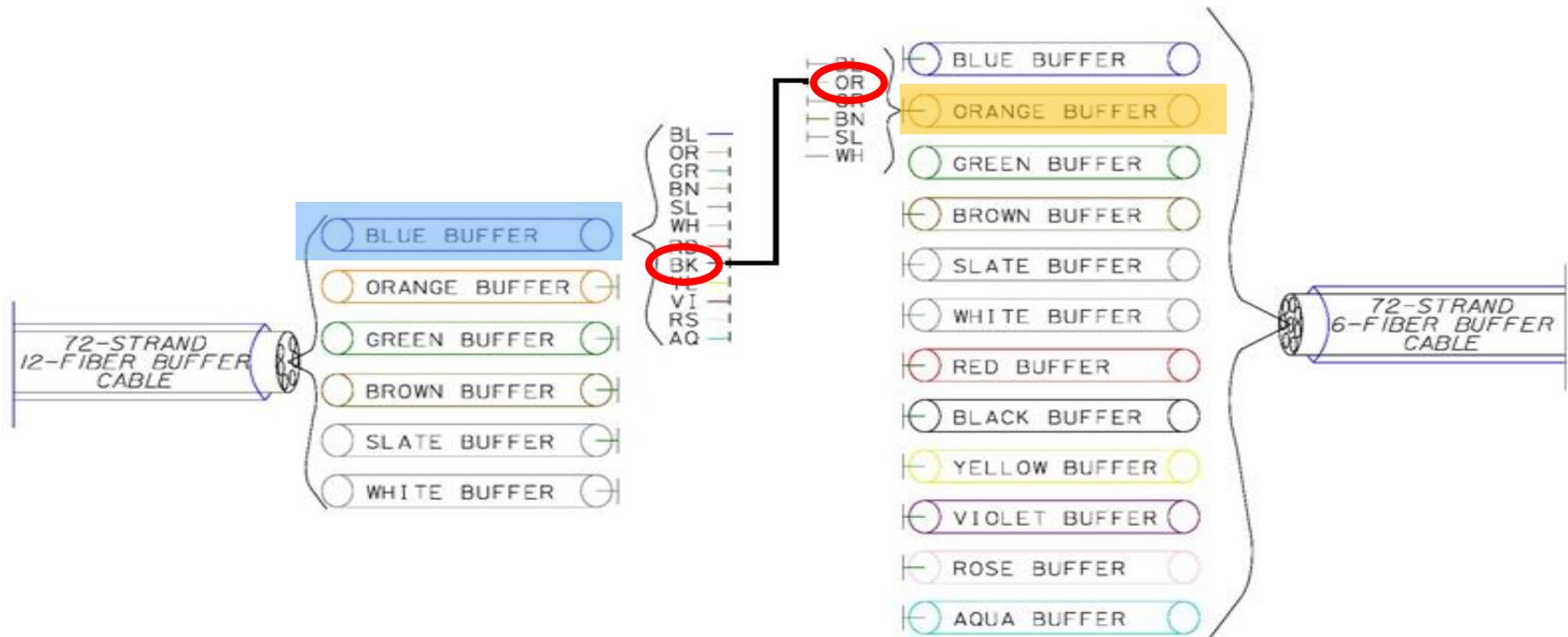
72-Count Fiber Cable

	blue	orange	green	brown	slate	white
blue	1	13	25	37	49	61
orange	2	14	26	38	50	62
green	3	15	27	39	51	63
brown	4	16	28	40	52	64
slate	5	17	29	41	53	65
white	6	18	30	42	54	66
red	7	19	31	43	55	67
black	8	20	32	44	56	68
yellow	9	21	33	45	57	69
violet	10	22	34	46	58	70
rose	11	23	35	47	59	71
aqua	12	24	36	48	60	72

72-Count Fiber Cable

	blue	orange	green	brown	slate	white	red	black	yellow	violet	rose	aqua
blue	1	7	13	19	25	31	37	43	49	55	61	67
orange	2	8	14	20	26	32	38	44	50	56	62	68
green	3	9	15	21	27	33	39	45	51	57	63	69
brown	4	10	16	22	28	34	40	46	52	58	64	70
slate	5	11	17	23	29	35	41	47	53	59	65	71
white	6	12	18	24	30	36	42	48	54	60	66	72

# FIBER OPTIC CABLE: Color Code



## 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		

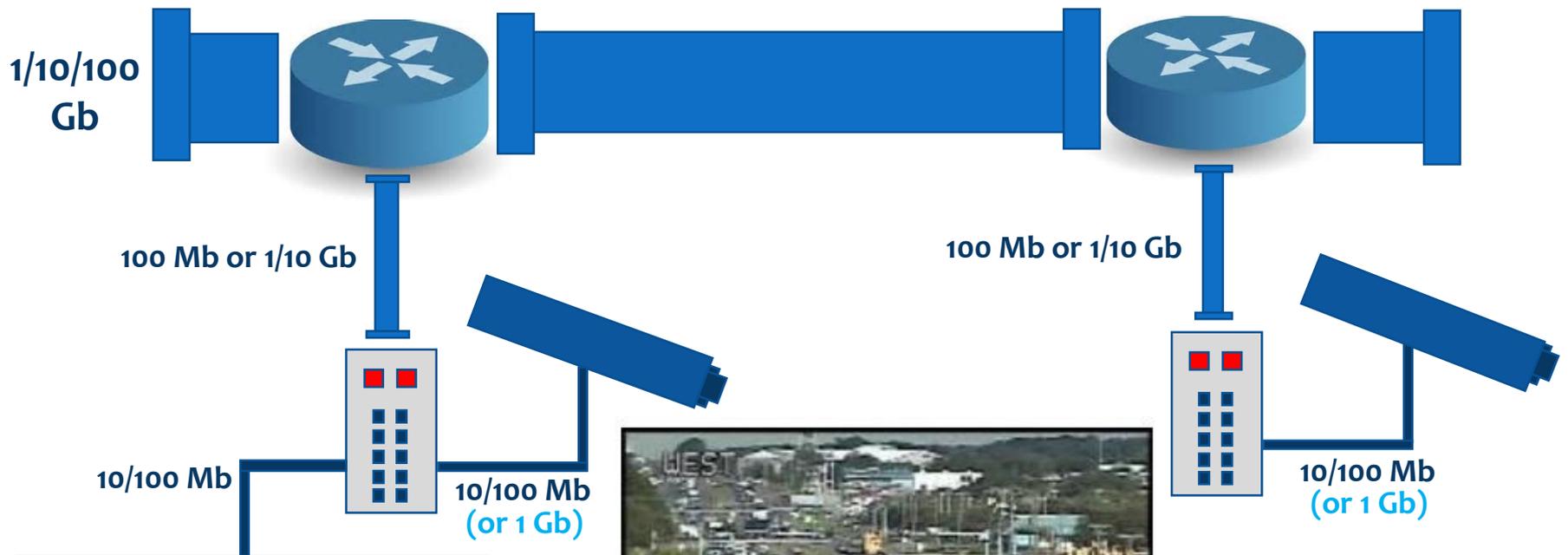
# Primary Fiber Design Concepts

- Minimize Exposure – Fiber Protection
- Capacity – Consider Future Growth & Scalability
- Design with Redundancy in Mind
- Link Budgets

# Protection of Backbone Cable



# Network Capacity



**CONGESTION AHEAD  
CLEARS PAST  
SR 60**

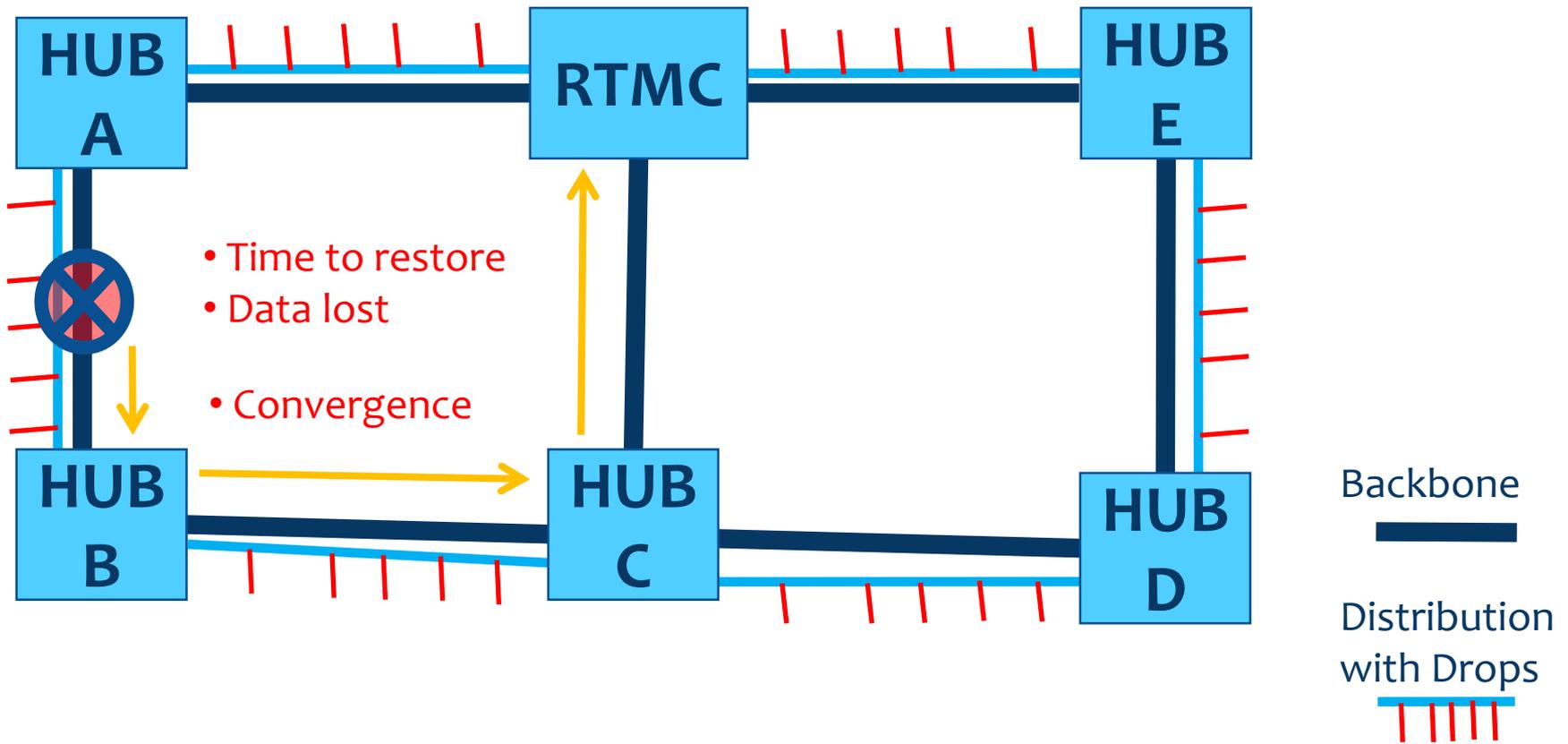


# Network Redundancy

- Redundancy is crucial in communication networks
- Natural enemies of fiber optic cable:



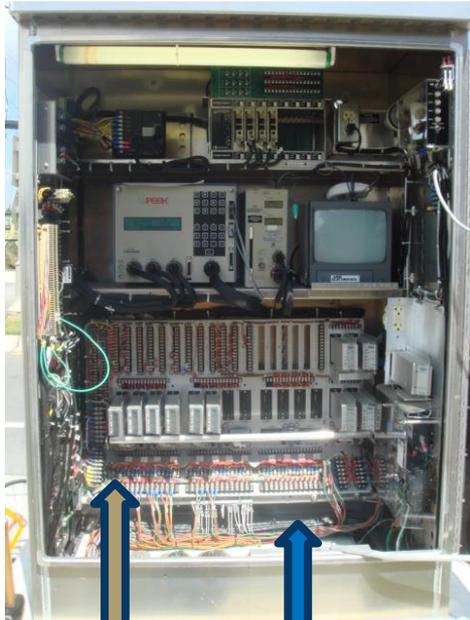
# Redundant Ring Topology



# Common Cable Disruptions



# Limit Exposure



Whole cable

**COPPER INTERCONNECT CABLE**

**FIBER INTERCONNECT DROP CABLES**

Piece of the whole cable

**FIBER NETWORK BACKBONE/DISTRIBUTION CABLE**

# Attenuation / Expected Loss

## 3 Primary Categories of Loss:

- Distance Traveled
  - 0.4 dB/km @ 1310nm
  - 0.3 dB/km @ 1550nm
- Fusion Splices **\*\*MINIMIZE AS MUCH AS POSSIBLE\*\***
- Connectors

**633-3.1.8.1 End to End Attenuation Testing:** Perform testing on all fibers to ensure that end to end attenuation does not exceed allowable loss (0.4 db/km for 1310 nanometer wavelength, 0.3 db/km for 1550 nanometer wavelength, plus 0.5 db for any connectors and 0.1 db for splices). Repair or replace cable sections exceeding allowable attenuation at no cost to the Department.

# Example Link Loss Table

- Distance: 5 km
- Qty of Splices: 3
- Qty of Connectors: 2

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

# Fiber Design Plans: Details

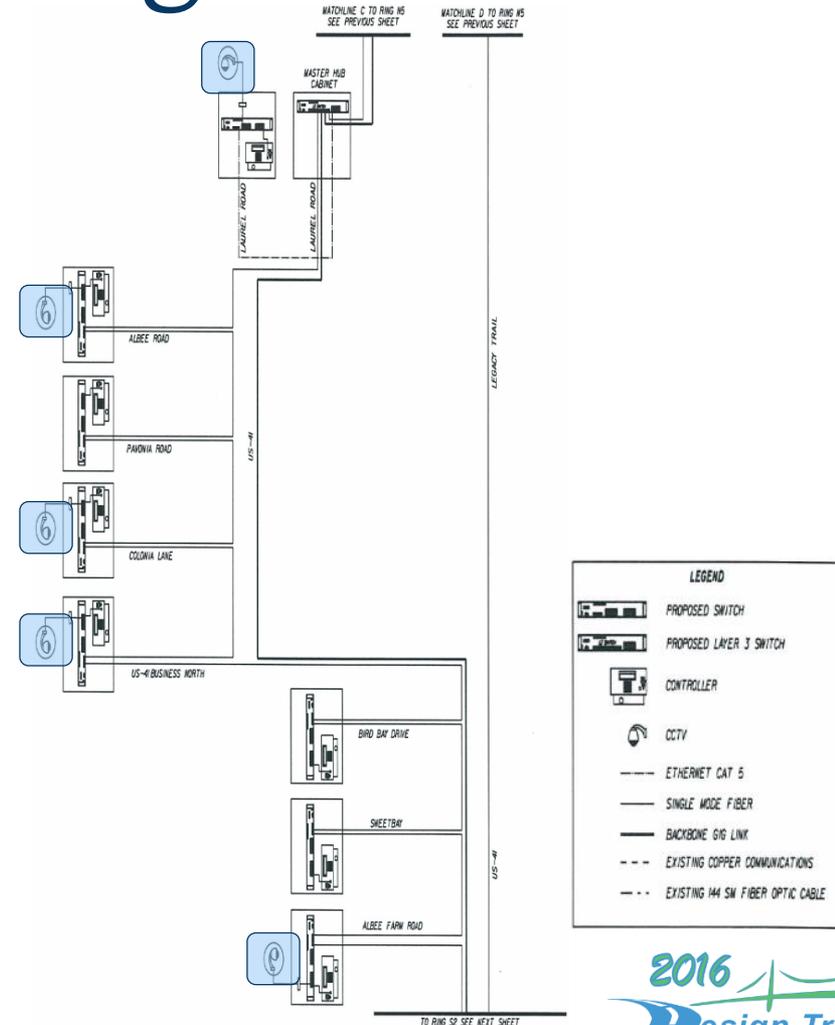
## 6 Primary Details (Best Practice):

- 1) Plan Sheets
- 2) Network Block Diagrams
- 3) Splicing Details
- 4) Port Assignments
- 5) Link Loss Budget
- 6) Wiring Diagrams

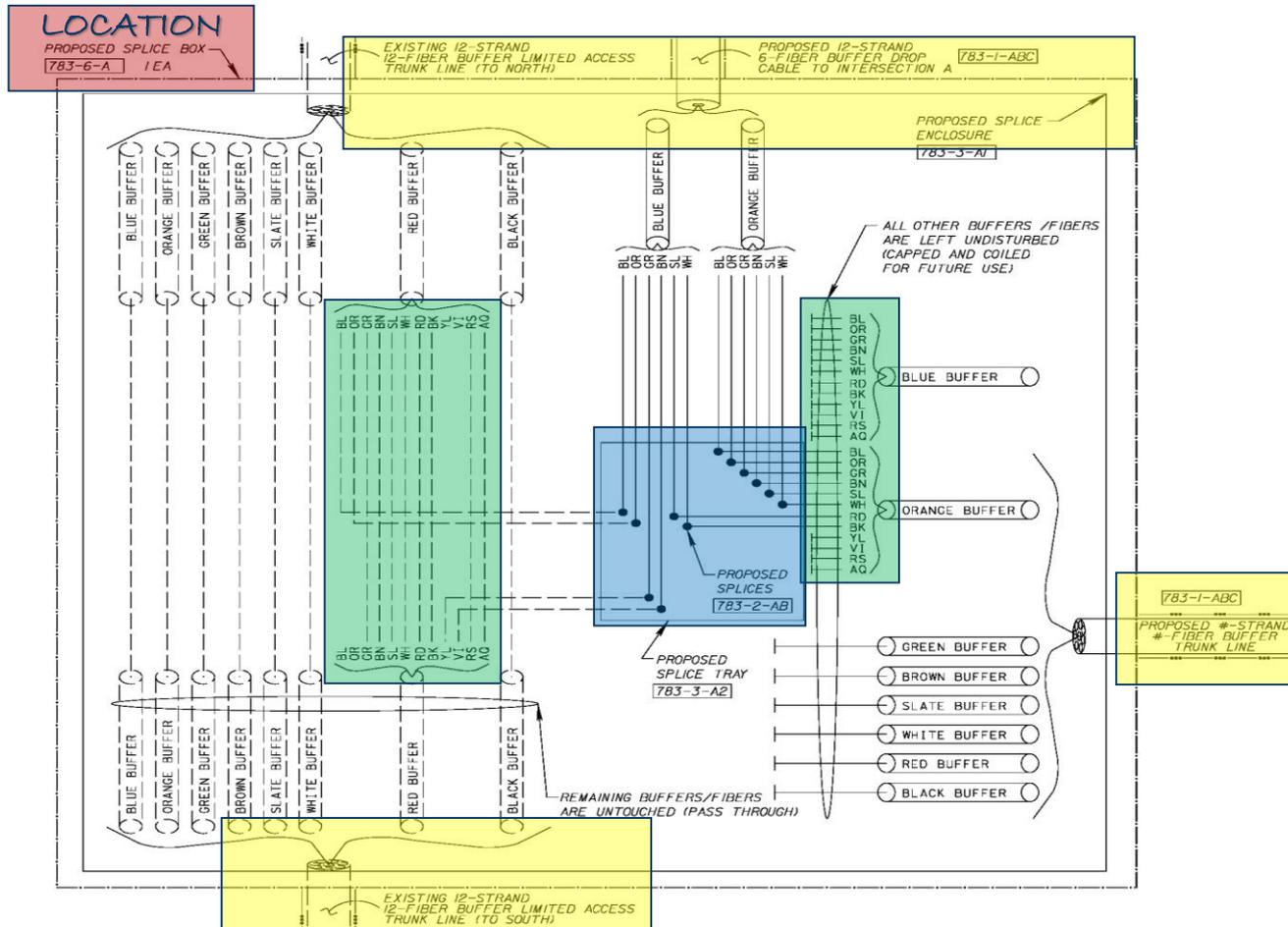


# Fiber Design Plans: Block Diagram

- Backbone
- Distribution
- Drops
- Local Hubs
- ITS/ATMS Devices
- Legend



# Fiber Design Plans: Splicing Detail



# Fiber Design Plans: Port Assignments



1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
7	8	9	10	11	12	7	8	9	10	11	12	7	8	9	10	11	12
13	14	15	16	17	18	13	14	15	16	17	18	13	14	15	16	17	18
19	20	21	22	23	24	19	20	21	22	23	24	19	20	21	22	23	24
TRUNK CABLE BLACK/ORANGE TO DROP CABLE BLUE/BLUE	TRUNK CABLE BLACK/ORANGE TO DROP CABLE BLUE/ORANGE	TRUNK CABLE BLACK/GREEN TO DROP CABLE BLUE/GREEN	TRUNK CABLE BLACK/BROWN TO DROP CABLE BLUE/BROWN	FUTURE TRUNK CABLE TO DROP CABLE BLUE/SLATE	FUTURE TRUNK CABLE TO DROP CABLE BLUE/WHITE	FUTURE TRUNK CABLE TO DROP CABLE BLUE/BLUE	FUTURE TRUNK CABLE TO DROP CABLE BLUE/ORANGE	FUTURE TRUNK CABLE TO DROP CABLE BLUE/GREEN	FUTURE TRUNK CABLE TO DROP CABLE BLUE/BROWN	FUTURE TRUNK CABLE TO DROP CABLE BLUE/SLATE	FUTURE TRUNK CABLE TO DROP CABLE BLUE/WHITE	TRUNK CABLE BLACK/BLUE TO DROP CABLE BLUE/BLUE	TRUNK CABLE BLACK/ORANGE TO DROP CABLE BLUE/ORANGE	TRUNK CABLE BLACK/GREEN TO DROP CABLE BLUE/GREEN	TRUNK CABLE BLACK/BROWN TO DROP CABLE BLUE/BROWN	TRUNK CABLE BLACK/SLATE TO DROP CABLE BLUE/SLATE	TRUNK CABLE BLACK/WHITE TO DROP CABLE BLUE/WHITE
FUTURE TRUNK CABLE TO DROP CABLE BLUE/RED	FUTURE TRUNK CABLE TO DROP CABLE BLUE/BLACK	FUTURE TRUNK CABLE TO DROP CABLE BLUE/YELLOW	FUTURE TRUNK CABLE TO DROP CABLE BLUE/VIOLET	FUTURE TRUNK CABLE TO DROP CABLE BLUE/ROSE	FUTURE TRUNK CABLE TO DROP CABLE BLUE/AQUA	TRUNK CABLE BLACK/RED TO DROP CABLE BLUE/RED	TRUNK CABLE BLACK/BLACK TO DROP CABLE BLUE/BLACK	FUTURE TRUNK CABLE TO DROP CABLE BLUE/YELLOW	FUTURE TRUNK CABLE TO DROP CABLE BLUE/VIOLET	FUTURE TRUNK CABLE TO DROP CABLE BLUE/ROSE	FUTURE TRUNK CABLE TO DROP CABLE BLUE/AQUA	TRUNK CABLE BLACK/RED TO DROP CABLE ORANGE/BLUE	TRUNK CABLE BLACK/BLACK TO DROP CABLE ORANGE/ORANGE	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/GREEN	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/BROWN	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/SLATE	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/WHITE
TRUNK CABLE BLACK/BLUE TO DROP CABLE ORANGE/BLUE	TRUNK CABLE BLACK/ORANGE TO DROP CABLE ORANGE/ORANGE	TRUNK CABLE BLACK/GREEN TO DROP CABLE ORANGE/GREEN	TRUNK CABLE BLACK/BROWN TO DROP CABLE ORANGE/BROWN	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/SLATE	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/WHITE	TRUNK CABLE BLACK/BLUE TO DROP CABLE ORANGE/BLUE	TRUNK CABLE BLACK/ORANGE TO DROP CABLE ORANGE/ORANGE	TRUNK CABLE BLACK/GREEN TO DROP CABLE ORANGE/GREEN	TRUNK CABLE BLACK/BROWN TO DROP CABLE ORANGE/BROWN	TRUNK CABLE BLACK/SLATE TO DROP CABLE ORANGE/SLATE	TRUNK CABLE BLACK/WHITE TO DROP CABLE ORANGE/WHITE	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/RED	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/ORANGE	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/GREEN	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/BROWN	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/SLATE	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/WHITE
FUTURE TRUNK CABLE TO DROP CABLE ORANGE/RED	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/BLACK	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/YELLOW	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/VIOLET	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/ROSE	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/AQUA	TRUNK CABLE BLACK/RED TO DROP CABLE ORANGE/RED	TRUNK CABLE BLACK/BLACK TO DROP CABLE ORANGE/BLACK	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/YELLOW	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/VIOLET	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/ROSE	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/AQUA	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/RED	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/BLACK	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/YELLOW	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/VIOLET	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/ROSE	FUTURE TRUNK CABLE TO DROP CABLE ORANGE/AQUA

# Fiber Design Plans: Link Budget

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

# Fiber Design Plans: Link Budget

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

**Optical Specifications**

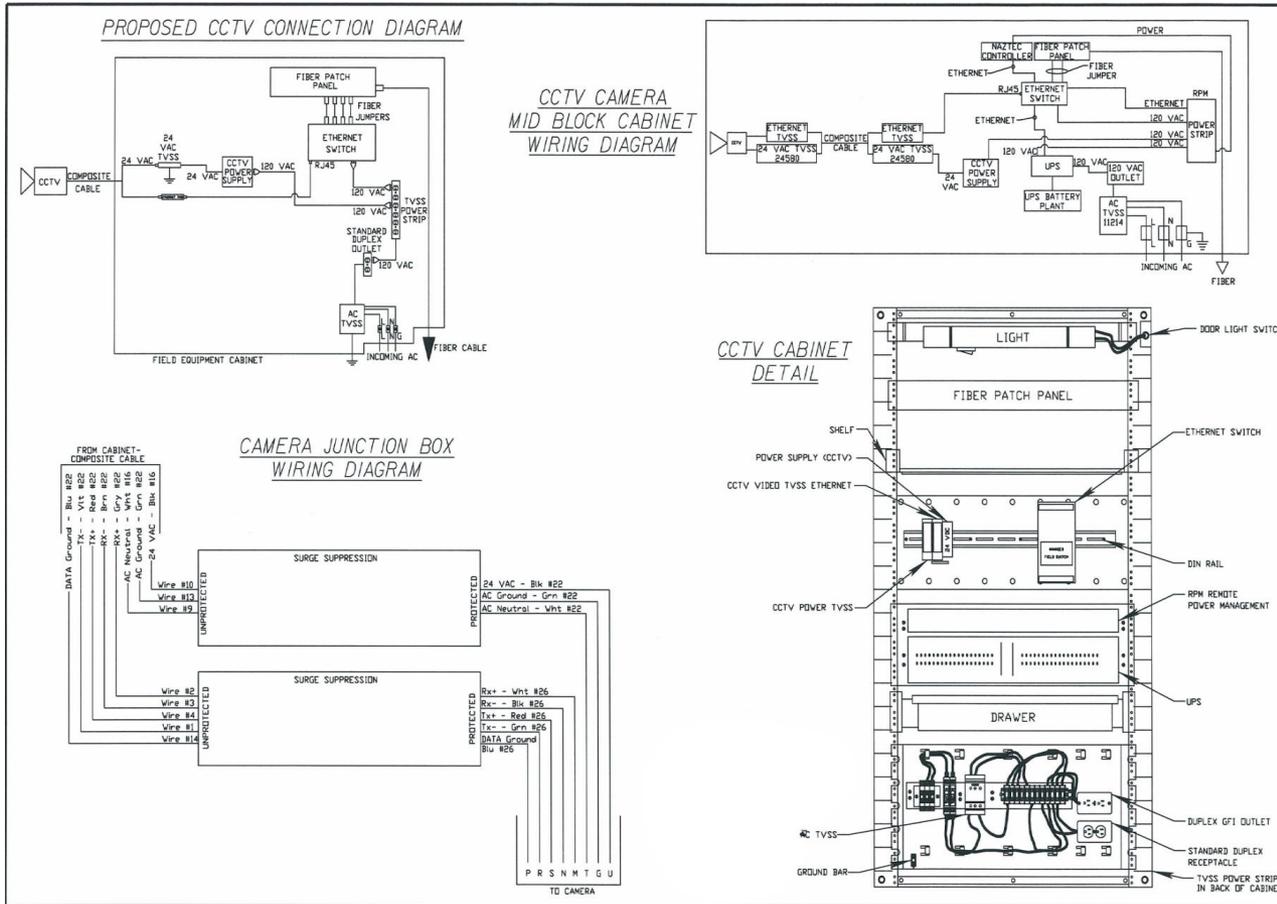
Table 2 specifies the optical parameters for the SFPs. Both receiver power and channel insertion loss specifications must be met for guaranteed operation.

**Table 2. Main Optical Parameters**

Product	Transmit Power Range (dBm)	Receive Power Range (dBm)	Maximum Channel insertion loss in dB (by fiber type)*	Transmit and Receive Wavelength Range (nm)
1000BASE-SX	-3 to -9.5	0 to -17	2.4 (FDDI-grade) 2.6 (OM1) 3.4 (400/400) 3.6 (OM2) 5 (OM3)	770 to 860
1000BASE-LX/LH	-3 to -9.5	-3 to -20	2.4 (any MMF) 6 (G.652 SMF)	1270 to 1355
1000BASE-EX	+3 to -1	+1 to -22	18 (G.652 SMF)	1290 to 1335
1000BASE-ZX	+5 to 0	-3 to -23	21 (any SMF)	1500 to 1580

$Tx_{(min)} - Rx_{(min)} \rightarrow$  Total Allowable Loss

# Fiber Design Plans: Wiring Diagrams



# Examples

- Fiber Optic Cable
- Connection Types
- Hardware for FOC
- Infrastructure for FOC

# Examples: Fiber Optic Cable Specifications

## SECTION 633 COMMUNICATION CABLE



### **633-1 Description.**

Furnish and install underground and aerial communication cable as shown in the Plans and Design Standards.

### **633-2.1 Fiber Optic Cable and Connections.**

#### **633-2.1.1 Single Mode Fiber Optic Cable.**

**633-2.1.1.2 Buffer Tubes:** ...Ensure that each fiber optic cable buffer tube contains 12 fibers per tube unless otherwise shown in the Plans.

# Examples: Fiber Optic Cable Pay Items

633-1-ABC

## Structure

A= Operation

1 (Furnish & Install)

3 (Install) Furnished by FDOT or local agency; C=0

4 (Relocate) C=0

6 (Remove) C=0

B= Location

1 (Overhead)

2 (Underground)

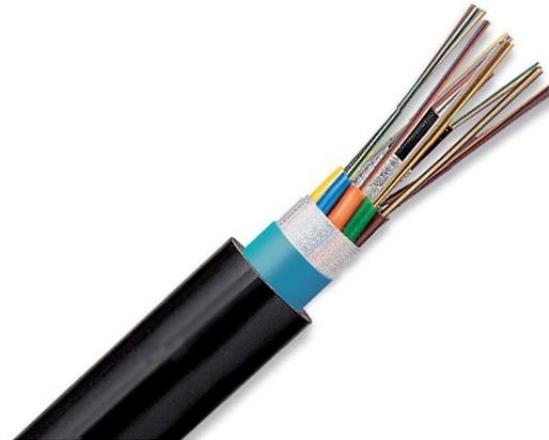
C= Number of Fibers in Cable

1 (2 to 12)

2 (13 to 48)

3 (49 to 96)

4 (97 to 144)



# Examples: Fiber Optic Connection

633- 2- AB

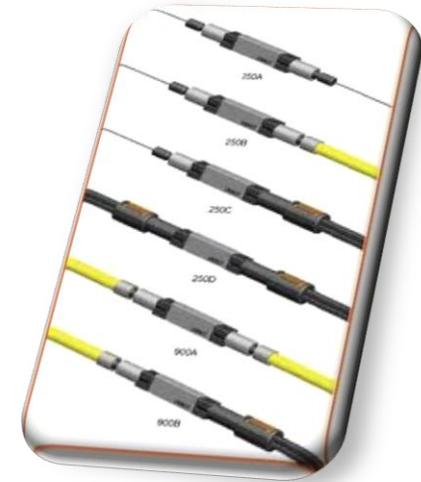
## Structure

A= Operation  
3 (Install)

B= Type  
1 (Splice)  
2 (Termination)

- *As required in the Standard Specs:*

**633-3.1.5 Fiber Optic Connection – Splicing:** Perform all optical fiber splicing using the fusion splicing technique, and according to the latest version of the manufacturer’s cable installation procedures; industry accepted installation standards, codes, and practices; or as directed by the Engineer.



# Examples:

## Fiber Optic Connection Hardware

633- 3- AB

### Structure

A= Operation

1 (Furnish & Install)

3 (Install)

4 (Relocate)

5 (Adjust /Modify)

B=Component

1 (Splice Enclosure)

2 (Splice Tray)

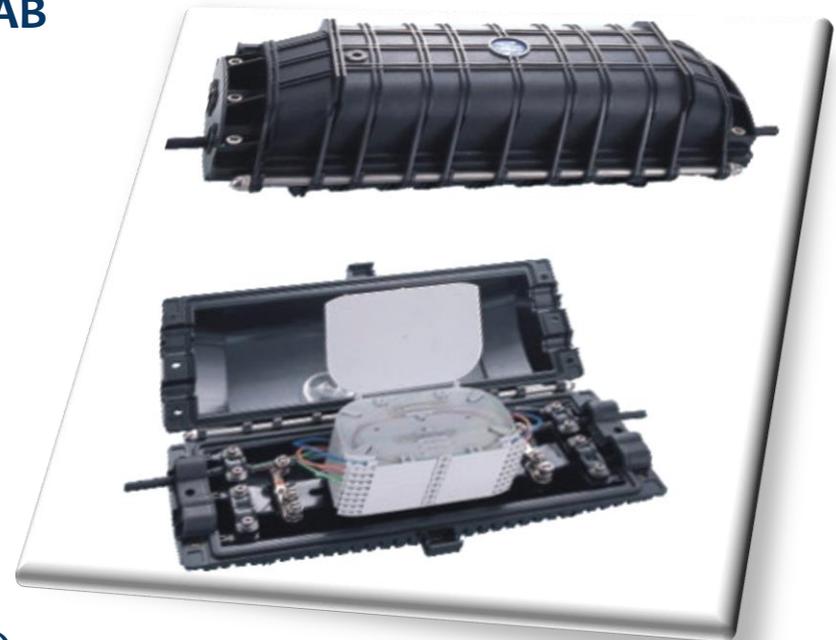
3 (Preterminated Connector Assembly)

4 (Buffer Tube Fan Out Kit)

5 (Patch Panel, Preterminated)

6 (Patch Panel, Field Terminated)

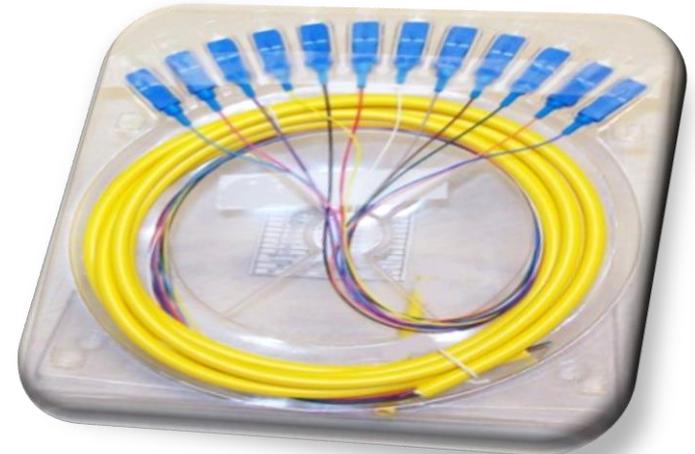
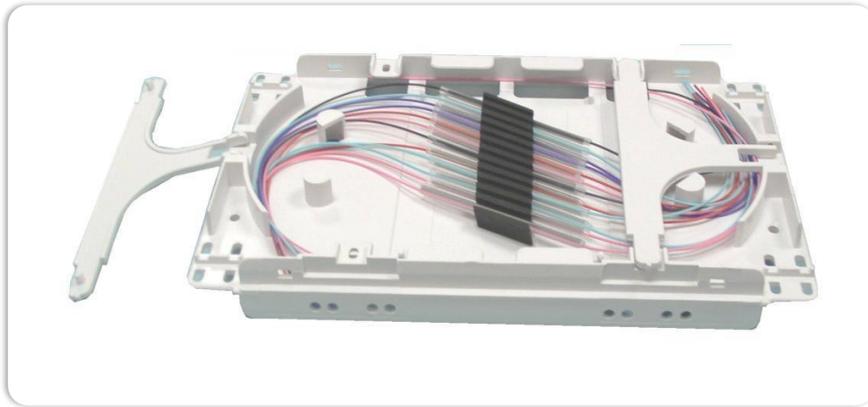
7 (Connector Panel)



B=1 (Splice Enclosure)

# Examples: Fiber Optic Hardware

B=2 (Splice Tray)



B=3 (Preterminated Connector Assembly)  
\* also known as a "Pigtail"



B=4 (Buffer Tube Fan-out Kit)

# Examples: Fiber Optic Hardware



B=5 (Patch Panel, Preterminated)



B=6 (Patch Panel, Field terminated)

Type ST, LC, SC



B=7 (Connector Panel)



B=8 (Patch Cord)  
\* or jumper

# Examples: Conduit

## SECTION 630 CONDUIT

### 630-1 Description.

Furnish and install conduit for traffic control signals and devices, highway lighting, and other electrically powered or operated devices as shown in the Contract Documents.

**630-3.10 Route Markers:** Install route markers for fiber optic cable installations and ensure the following:

1. Markers are plumb and level and the notification information is clearly visible when viewed from the side facing the roadway.
2. Markers are set within the right of way.
3. Markers are placed at a 1 foot offset from the conduit system.
4. The top of the marker post is a minimum of 5 feet and maximum of 6 feet above the finish grade
5. Markers are spaced a maximum of 500 feet apart.
6. A clear line of sight is maintained from one marker to the next.



# Examples: Conduit

630- 2 - AB

## Structure

A = Operation

1 (Furnish & Install)

6 (Remove) B=5 only

B = Installation Method/Location

1 (Open Trench) Underground \*

2 (Directional Bore) Underground or Under pavement\*

3 (Jack & Bore) Typically under railroad\*

4 (Aboveground)\*\*

5 (Bridge Mount)\*\*

\*Measured as the horizontal length of the trench or bore; no additional payment for multiple conduits in trench.

\*\*Measured as the actual length of each conduit.



# Examples: Pull Boxes

## SECTION 635

### PULL, SPLICE, AND JUNCTION BOXES

#### **635-1 Description.**

Furnish and install pull, splice, and junction boxes as shown in the Plans.

**635-2.2.3 Dimensions:** Unless otherwise shown in the Plans, provide pull and splice boxes with the following dimensions.

For signalized intersection and lighting applications, provide pull boxes with nominal cover dimensions of 13 inches wide by 24 inches long or larger and no less than 12 inches deep. Ensure the inside opening area is a minimum of 240 square inches and no inside dimension is less than 12 inches.

For fiber optic cable applications, provide pull boxes with nominal cover dimensions of 24 inches wide by 36 inches long or larger and no less than 24 inches deep.

Provide rectangular splice boxes with nominal cover dimensions of 30 inches wide by 60 inches long or larger and no less than 36 inches deep. Provide round splice boxes with a nominal cover diameter of 36 inches or larger and no less than 36 inches deep.

# Examples: Pull and Splice Box

## Structure

A= Operation

1 (Furnish & Install)

3 (Install)

4 (Relocate) B=0

5 (Repair) maintenance use only

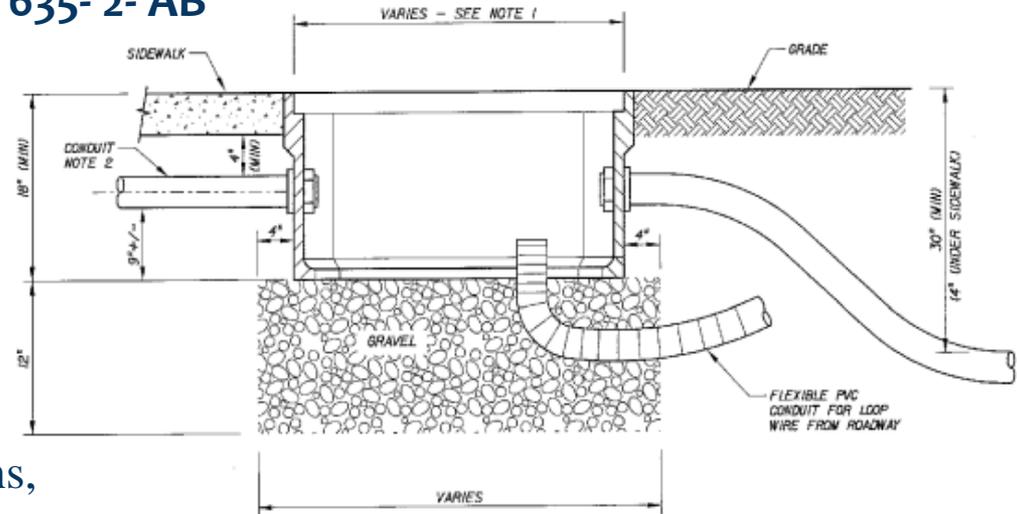
B= Cover Size; minimum dimensions,  
per specification

1 (13 x 24)

2 (24 x 36) large size

3 (30" X 60" rectangular or 36" round) splice vault

635- 2- AB



# Links / References

- FDOT Traffic Engineering and Operations  
<http://www.dot.state.fl.us/trafficoperations/>
- FDOT Program Management Office  
(Specifications and Estimates)  
<http://www.dot.state.fl.us/programmanagement/default.shtm>
- FDOT Design Standards  
<http://www.dot.state.fl.us/rddesign/DesignStandards/Standards.shtm>
- Approved Product List  
<https://fdotwp1.dot.state.fl.us/ApprovedProductList/Specifications>
- Traffic Engineering Manual (TEM)  
[http://www.dot.state.fl.us/trafficoperations/pdf/traffic\\_engineering\\_manual\\_revised\\_july\\_2011.pdf](http://www.dot.state.fl.us/trafficoperations/pdf/traffic_engineering_manual_revised_july_2011.pdf)

# Links / References

- Florida Intersection Design Guide  
<http://www.dot.state.fl.us/rddesign/FIDG-Manual/FIDG.shtm>
- Plans Preparation Manual  
<http://www.dot.state.fl.us/rddesign/PPMManual/PPM.shtm>
- Master Pay Item List / WebGate  
<http://www.dot.state.fl.us/programmanagement/Estimates/BasisofEstimates/Default.shtm>
- FHWA Manual on Uniform Traffic Control Devices (MUTCD)  
<http://mutcd.fhwa.dot.gov/>

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

# Questions?

**FDOT**

**State Traffic Engineering and Operations Office  
TSM&O Program**

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**Thank you**