PennState Applied Research Laboratory

Ingalls Shipbuilding

NAVY MANTECH manufacturing technology program

S2626 TEST ADAPTER EFFICIENCY IMPROVEMENT Emphasis on Fiber Optic Link Test

John Mazurowski
Penn State ARL -Electro-Optics Division
Jason Farmer
Huntington Ingalls - Ingalls Shipbuilding
Dr. Charles Kuznia
Ultra Communications

NSRP ALL-PANEL MEETING
March 22-25-2021

ONR Document Control Number: 43-7856-21

ISSUE DESCRIPTION

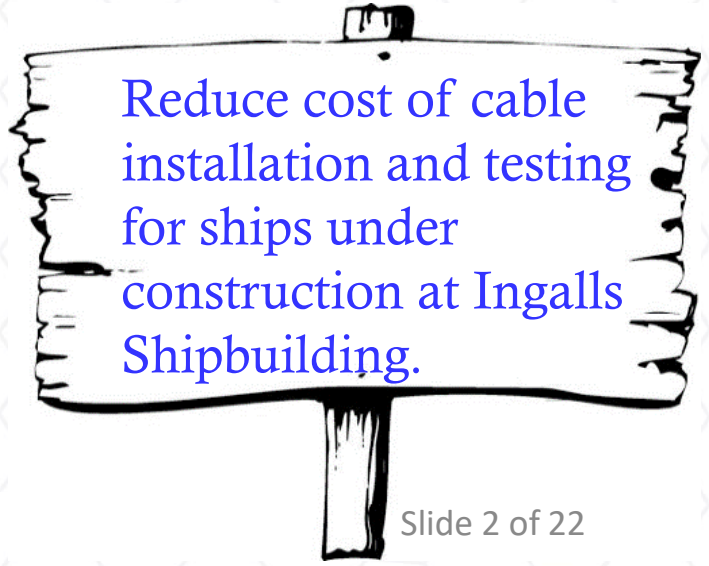
The complexity of electrical and optical connections in ships is also costly. Previous Navy ManTech, NSRP and SBIR projects have provided some methodology toward decreasing cable test costs. Of specific interest is testing of finished fiber optic links.

PROJECT OBJECTIVE

The project validated methods that reduce the cost of automatic cable testing, using the results of previous work. The new and improved methods will enable shipyards to address needs of new system requirements for ship manufacturing. Multi Channel Optical Time Domain Reflectometry (OTDR) was introduced for fiber optic link testing.

DEVELOPMENT EFFORTS

2006-2008 NAVAIR / Penn State Built-In Test Activity
2007-2017 SBIR / STTR work for OTDR Built-In-Test
2011-2015 ManTech S2306 Integrated Link Test System
2017-2020 ManTech S2437 Fiber Optic Installation on Ships
2016- 2021 NSRP Fiber Optic Testing Enhancement for Cost Reduction



PennState Electro-Optics Center

Ingalls Shipbuilding

DIT-MCO International

ULTRA COMMUNICATIONS

GENERAL DYNAMICS Land Systems

1) Integrate the Integrated Link Test System (ILTS) into Ingalls Shipyard.
2) Reduce number of electrical connectors and test adapters that must be acquired to measure electrical cable performance.
3) Mitigate sustainment risk for specific obsolete RF cable assemblies, and improve efficacy of diagnostic procedures for installed RF cables.
4) Develop fiber optic insertion loss / return loss tests with Optical Time Domain Reflectometry (OTDR) functionality and multi-fiber connections.

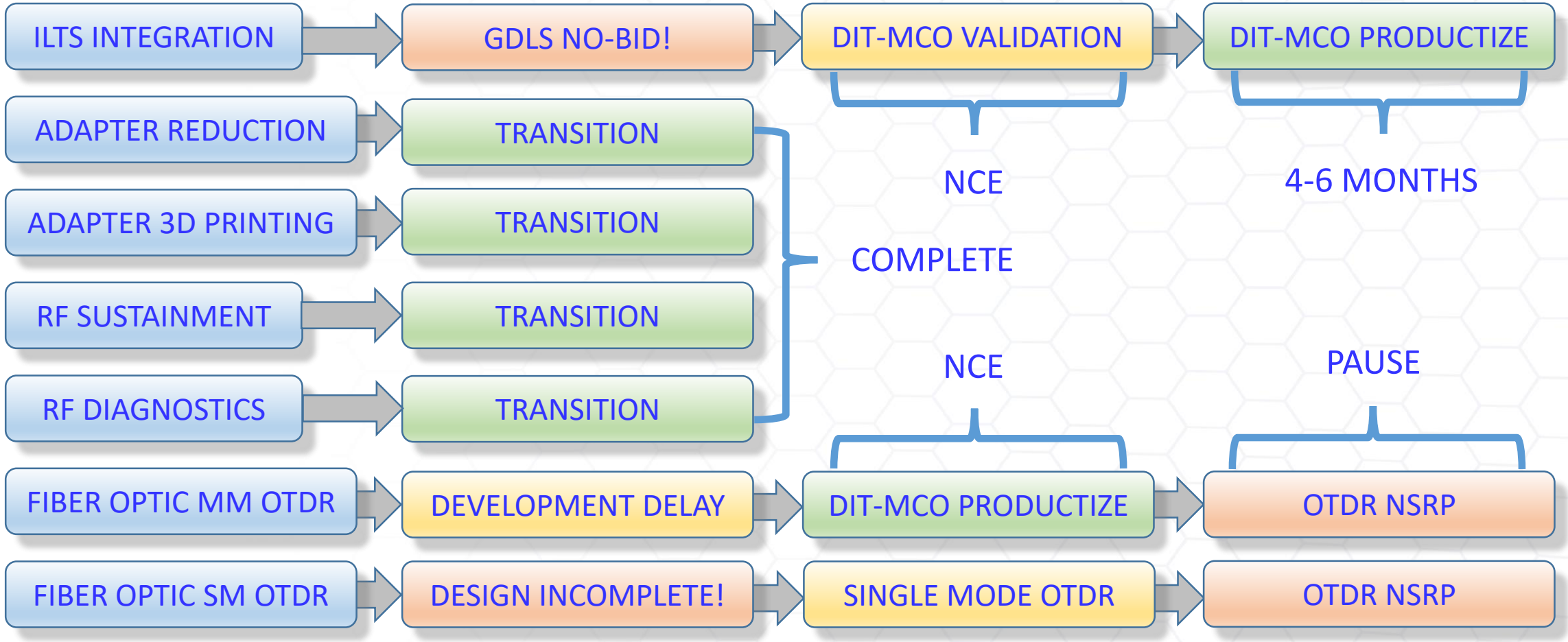
ILTS OVERALL PROJECT EVENTS

- Add 500 volt insulation resistance measurement.
- Counterfeit optical switch component.
- Implementation of NETS software.
- Adjust stimulus to drive steering diode.
- Connect system components without electrical test unit.
- Improve resistance accuracy.
- No bid on ILTS electrical production order.

ILTS TRANSITION CANDIDATES

- Ingalls Shipbuilding
- Newport News Shipbuilding
- NAVAIR Field Maintenance

NEAR TERM ACTIVITIES-



PennState Applied Research Laboratory

Ingalls Shipbuilding

NAVY MANTECH manufacturing technology program

1) Integrate ILTS into Ingalls Shipyard- Three Generations

Description of Issues

- Large, Heavy & Cumbersome System (Difficult to Move, Setup & Use)
- Time Consuming Programming (3rd Party Programming Dependency)
- Logistics Challenge (Many Custom Adapters & Loopbacks)
- Test Reports Generated in application (difficult Format to Edit)

Anticipated / Desired Improvements

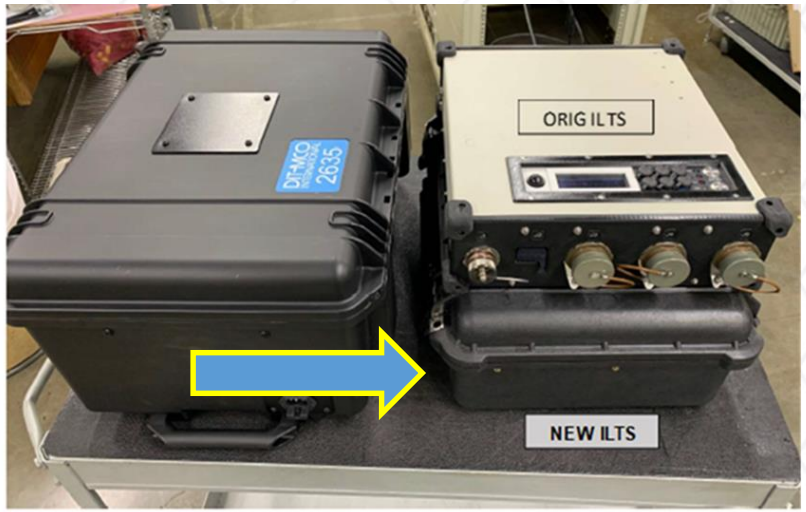
- Small, Efficient, Battery Powered (Improved Interfaces & Instructions)
- Simplify Generation of Cable Test Code (Automate & Interface w Databases)
- Expand to other Systems & Ship Classes (Possible w Improved & Efficient System)
- Open Report / Document Format (Easy to Reformat into Official Reports)

DIT-MCO- Modified Model 2635

- All features of original ILTS improvements
- Compatible with latest NETS management software
- Anticipated performance in shipyard environment (example: EMI tolerance)
- More compatible with shipyard specific loopback / diagnostic algorithms

DIT-MCO Model 2135 (Legacy)

Integrated Link Test System (ILTS)



DIT-MCO Modified Model 2635

2) Test Adapter Reduction

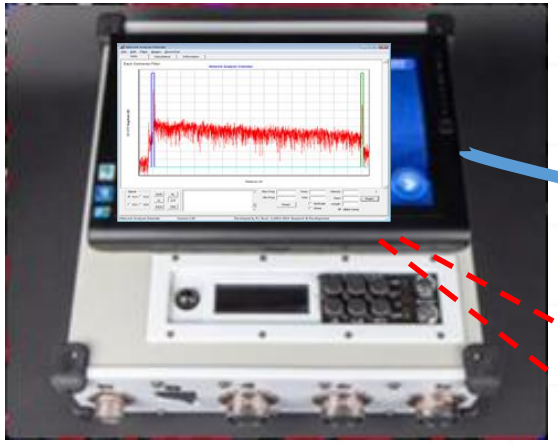
OVERVIEW:

Test adapters connect the ILTS to installed cables for testing.

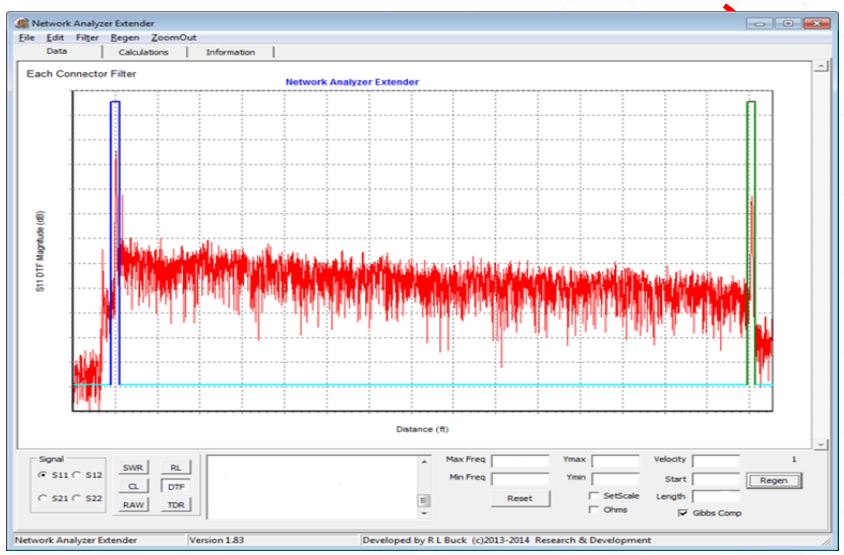
Connector variety reduced through geometry, pin configuration, keying etc.

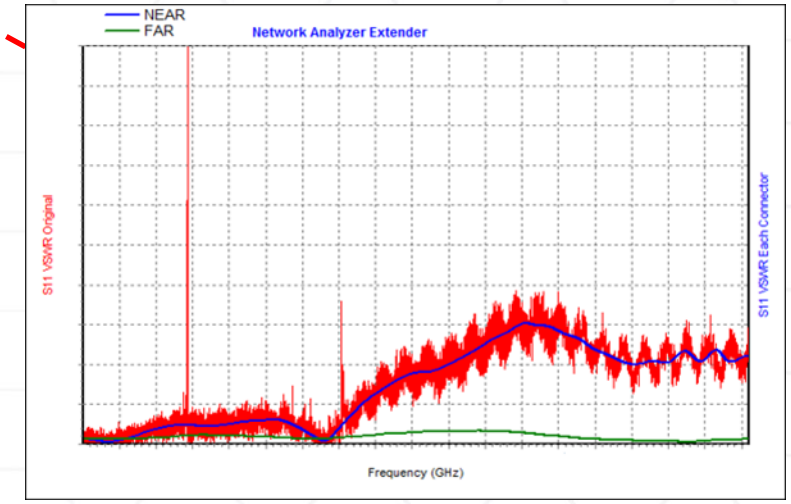
- ✓Adapter types reduced by 75%.
- ✓New ruggedized adapter design.
- ✓Additive manufacturing components reduces lead and replacement time.

3) Mitigate Risk- RF Cable Assemblies



Integrate and test special HII software on ILTS platform to have real time diagnostics capability to identify and isolate non-conforming components in RF cable assemblies (connectors, cable, defects, test equipment, etc.)





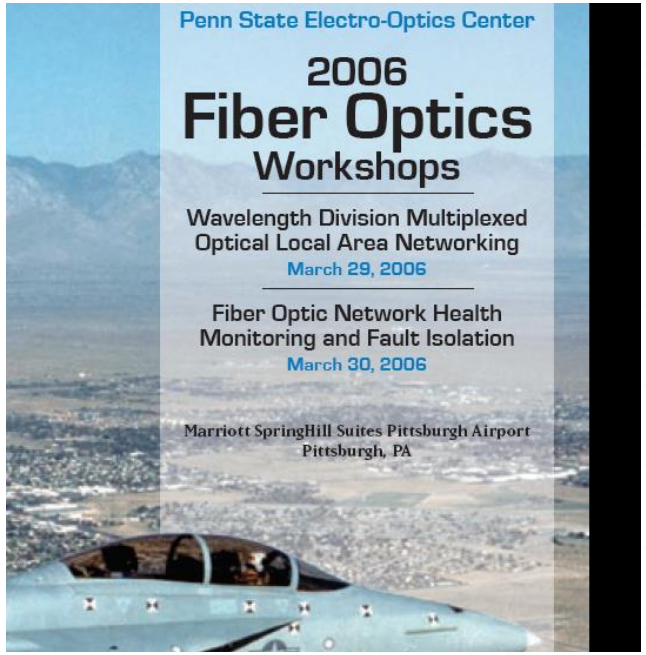
4) Develop Fiber Optic OTDR and IL / RL Capability

- Optical Time Domain Reflectometry- OTDR
- Narrow pulse stimulus- reflections separated in time
- OTDR diagnostic tests are very useful
- Present OTDR instruments are large
- Present OTDR instruments test one channel- not twelve

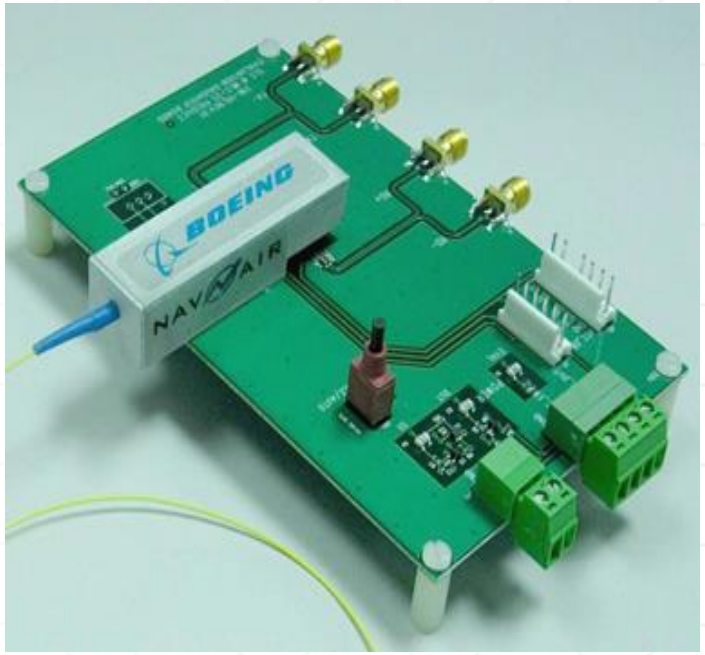
- Speed of light in optical fiber = roughly 204 meters per microsecond.
- Distance covered by one tenth nanosecond pulse = roughly 2 cm.
  This is enough to distinguish between physical features in a link!

Fiber Optic OTDR Built-In-Test (BIT) History- Feasibility

BIT Workshop March 2006



OTDR Transceiver Demo 2007



E.Y Chan, et al, "A novel Gb/s transceiver with OTDR built-in test (BIT) for health monitoring of local area networks," OFC, 2007

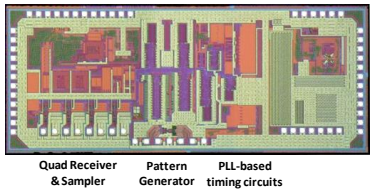
Link Test Trade Study 2007-2008

NAVAIR / Penn State
Harris- Subcontractor

- System Interface
- Diagnosis / Recovery
- OTDR Types-
- Miniaturize OTDR
- Coherent OFDR
- Incoherent OFDR
- Golay codes

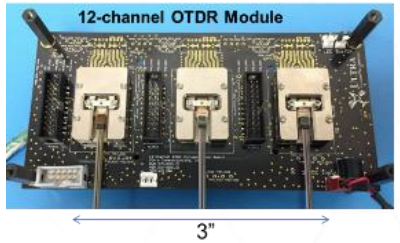
Fiber Optic OTDR Built-In-Test (BIT) History- Concept

OTDR ASIC for Built-in Test Transceiver with 1 cm resolution



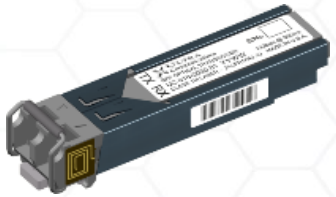
NAVAIR N05-T005

OTDR ASIC Enabled Fiber Optic Tester



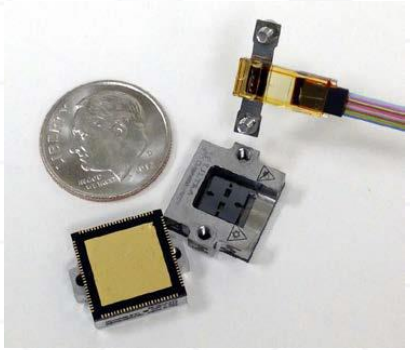
NAVAIR N112-117

OTDR ASIC Enabled Duplex "BITed"Transceiver



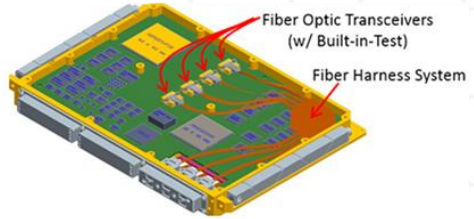
NAVSEA N112-134
NAVSEA N132-114

Dual-Quad Transceiver Form Factor Prototype with 1 cm resolution



C. Kuznia, et al, "Novel high resolution OTDR technology for multi-Gbps transceivers," OFC, 2014

OTDR ASIC Enabled Fiber Optic Tester



Air Force AF151-051

Demonstrated feasibility of using 1 gb/s transceiver pulses as OTDR stimulus- 1 cm resolution.

4) Develop Fiber Optic OTDR and IL / RL Capability

OVERVIEW

- SFP Transceivers, PCB Assembly, Software – Ultra-Communications.
- Packaging & Integration - Penn State ARL EO Division.
- System will test up to 12 circuits in one test operation.
- Streamlines data handling processes.

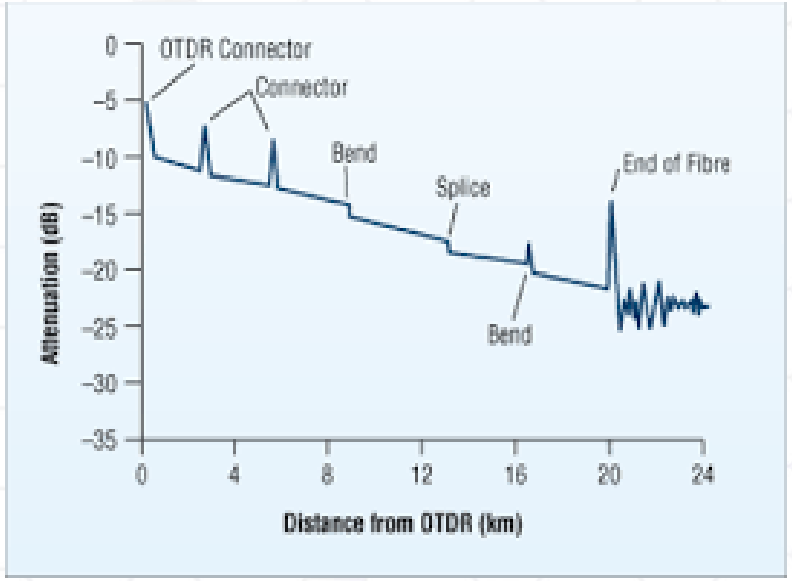
MULTIMODE

- 12 Channel Optical Time Domain Reflectometry (OTDR).
- Enabled by Small Form Factor Pluggable (SFP) Transceiver with embedded OTDR circuitry.
- Uses 4 pin and 8 pin fiber optic connectors, corresponding to most widely used cable types.

SINGLE MODE

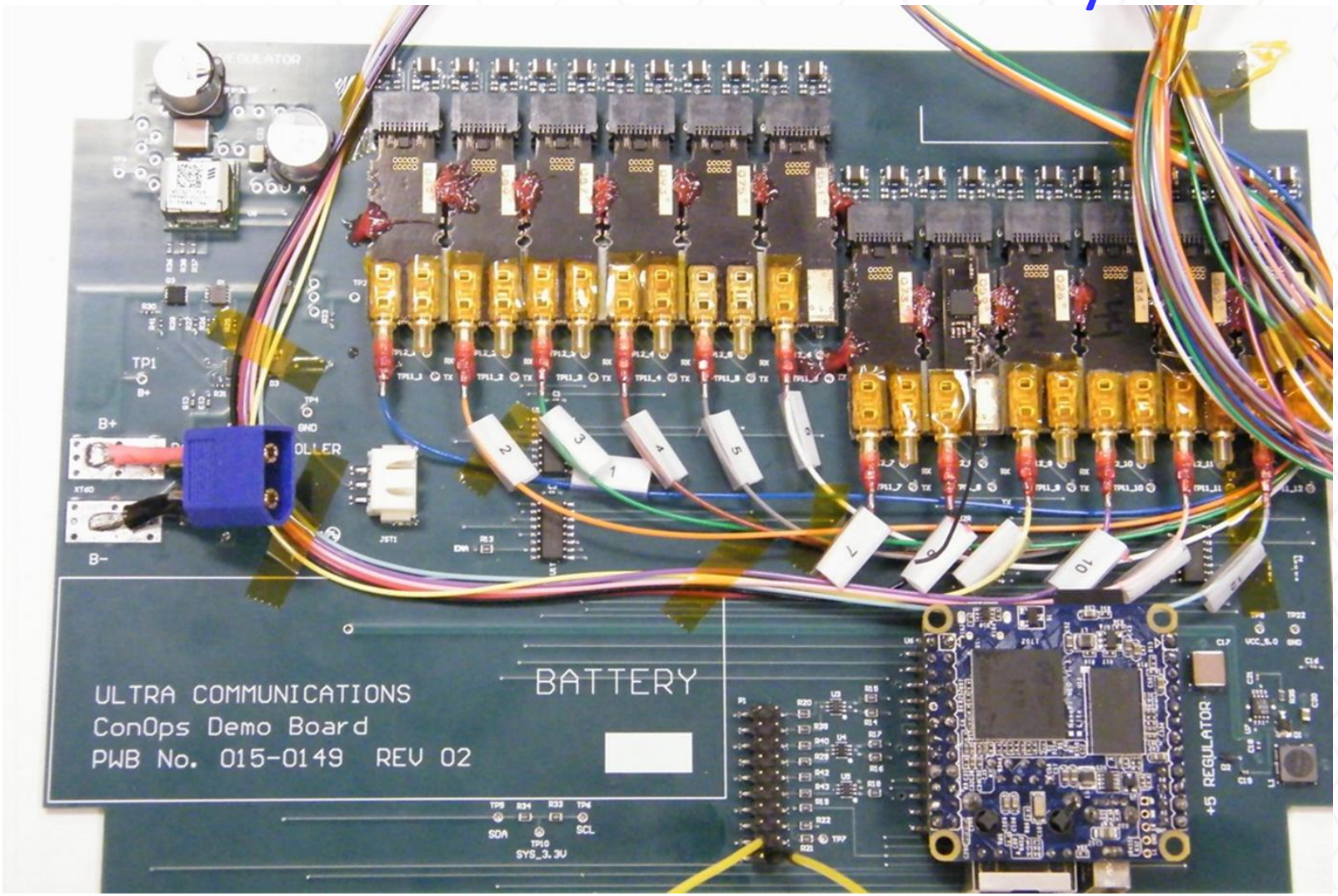
(Note: Embedded OTDR function is not yet available in single mode transceiver)

- 12 channel Insertion Loss (IL) Return Loss (RL).
- Enabled by Digital Diagnostic Monitoring Interface (DDMI).
- DDMI provides transmit power and receive power.
- Uses 4 pin and 8 pin fiber optic connectors, corresponding to most widely used cable types.



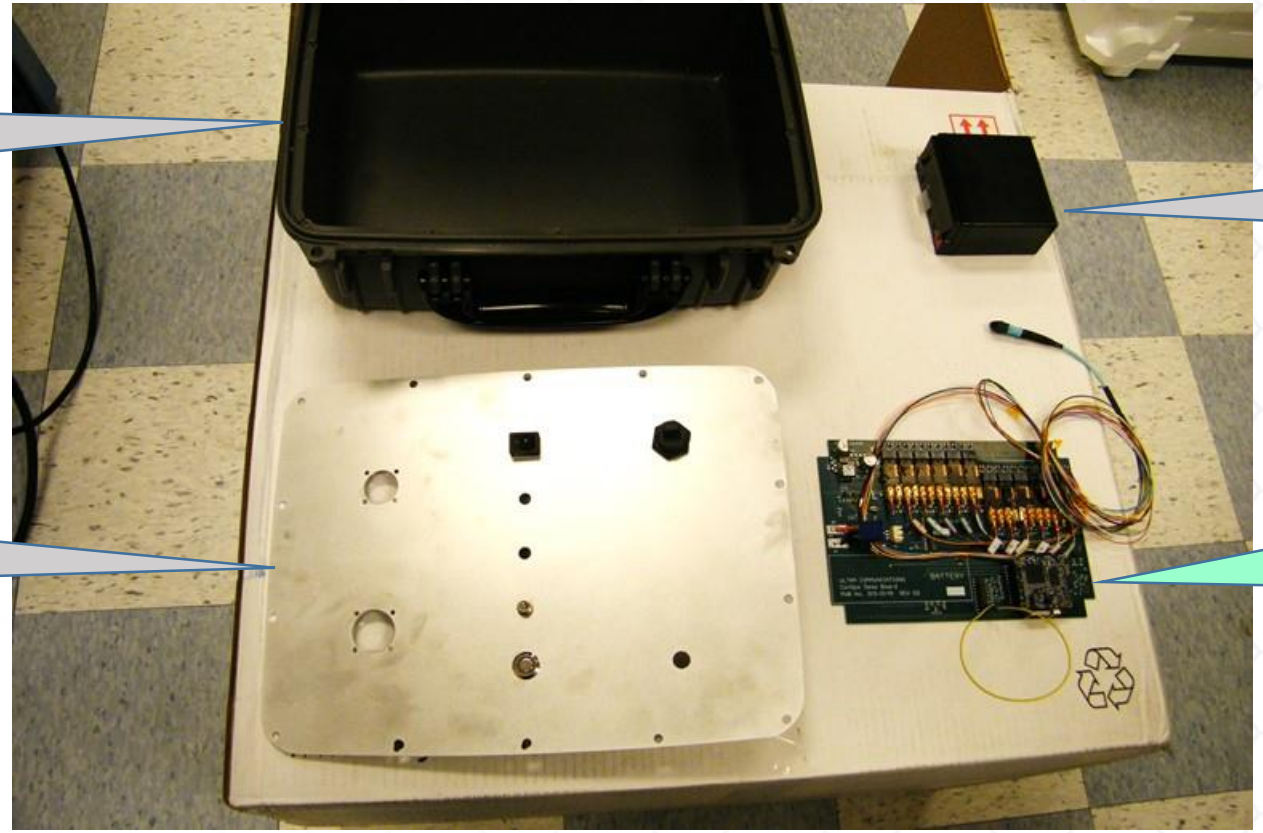
Typical OTFR spectrum
From: www.neophotonics.com

Fiber Optic Test Unit- Functional Assembly



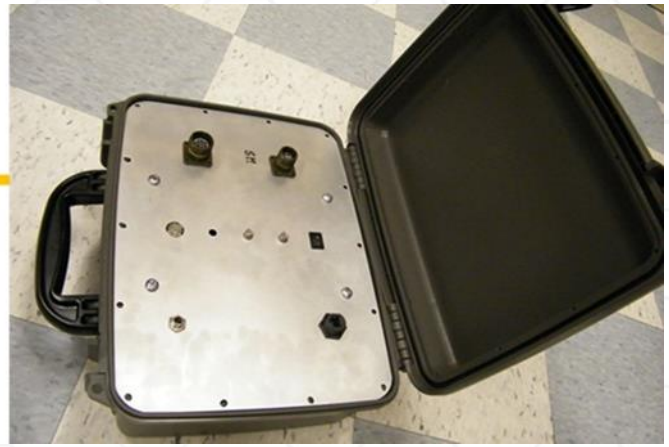
Fiber Optic Test Unit- Modular Design

- Both single mode and multimode units use a common package and faceplate.
- Printed Circuit Board Assembly (PCBA), fiber, and connectors are easily installed.



Fiber Optic Test Unit- All Together

Ethernet



Fiber Optic Test Unit- Measurement Mask Setup

Setup Table (Spreadsheet):

1) Server:

ServerId	Name	Address
19	ICP SLOT 19	10.4.131.16

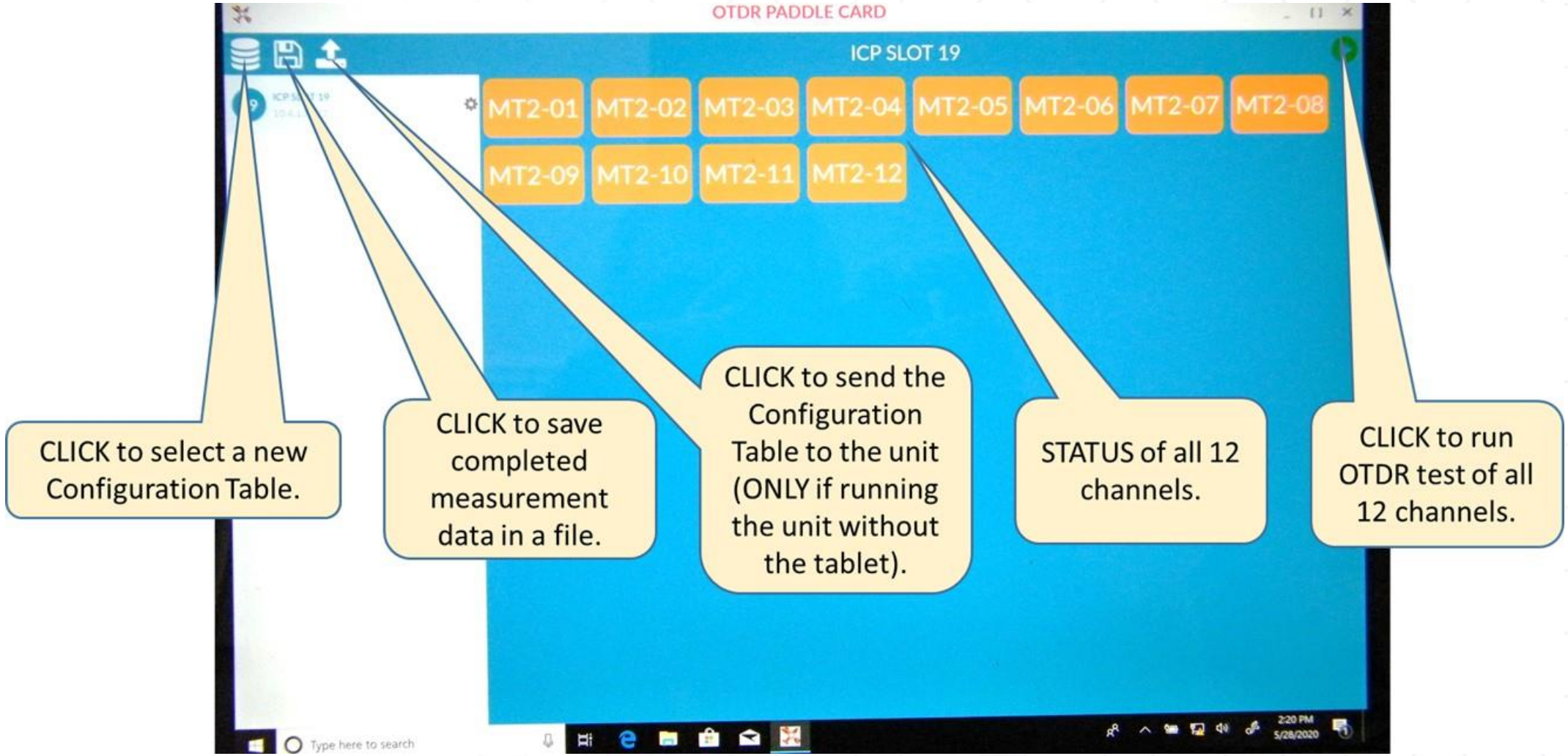
2) Link:

Name	Length	Length_Delta	R_Span_Min	R_Span_Max	R_End_Min	R_End_Max	R_Span_Value	R_End_Value
MT2-01	1	0.175	0	0.3	0	15	0	0
MT2-02	1	0.175	0	0.5	0	15	0	0
MT2-03	1	0.175	0	0.3	0	15	0	0
MT2-04	1	0.175	0	0.3	0	15	0	0
MT2-05	1	0.175	0	0.3	0	15	0	0
MT2-06	1	0.175	0	0.3	0	15	0	0
MT2-07	1	0.175	0	0.3	0	15	0	0
MT2-08	1	0.175	0	0.3	0	15	0	0
MT2-09	1	0.175	0	0.3	0	15	0	0
MT2-10	1	0.175	0	0.3	0	15	0	0
MT2-11	1	0.175	0	0.3	0	15	0	0
MT2-12	1	0.175	0	0.3	0	15	0	0

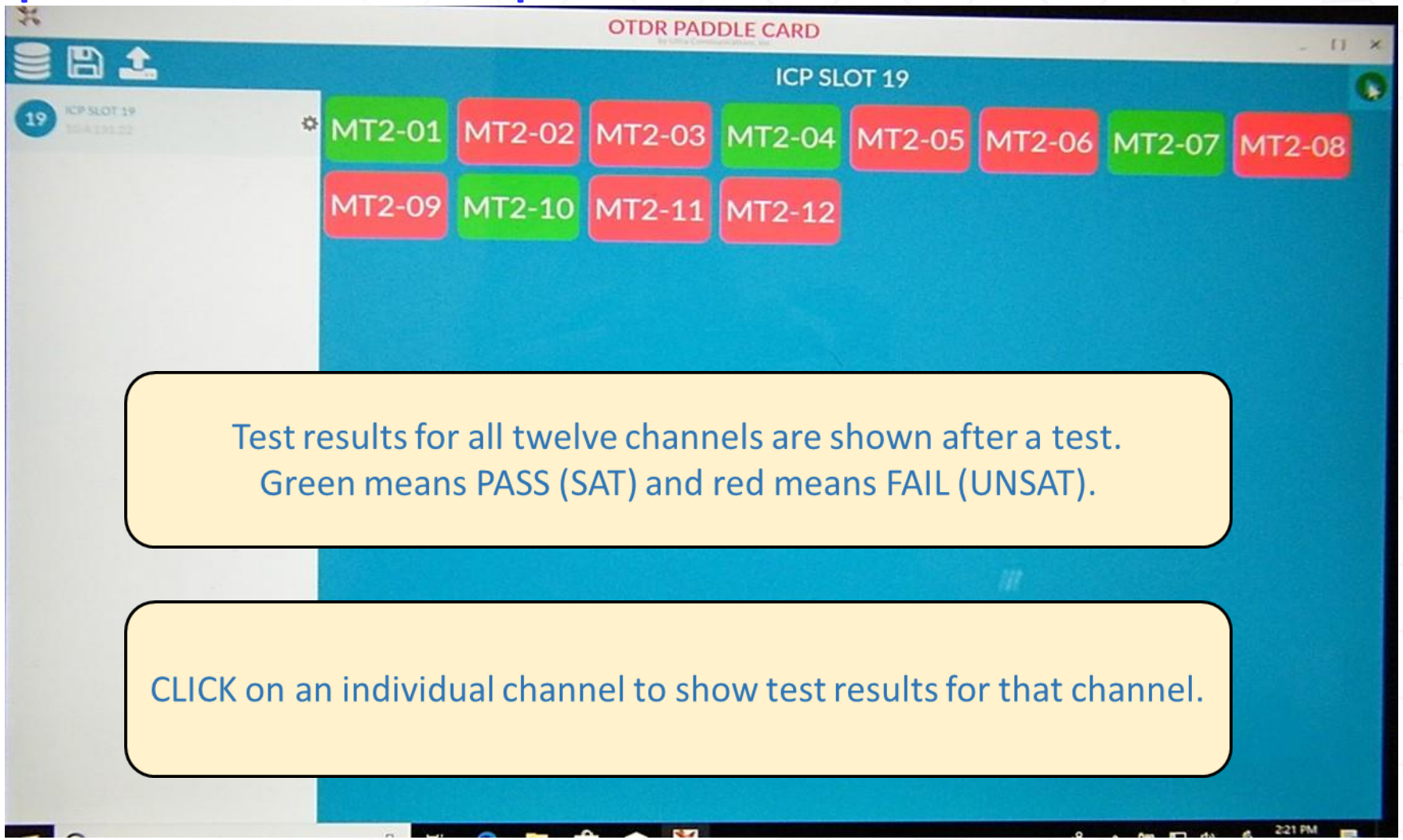
3) Segments:

LinkId	SegmentId	Length	Length_Delta	R_Span_Min	R_Span_Max	R_End_Min	R_End_Max	R_Span_Value	R_End_Value
1	1	1.55	0.175	0	0.3	0	1	0	0
2	1	1.48	0.175	0	0.5	0	4.5	0	0
3	1	1.55	0.175	0	0.3	0	4.5	0	0
3	2	5.23	0.175	0	0.3	0	4.5	0	0
3	3	4.3	0.175	0	0.3	0	4.5	0	0
3	4	0.93	0.175	0	0.3	0	4.5	0	0
4	1	1.54	0.175	0	0.3	0	1	0	0
5	1	1.55	0.175	0	0.3	0	1		
5	2	5.81	0.175	0	0.3	0	1	0	0
5	3	0.94	0.175	0	0.3	1	4.5	0	0
6	1	1.6	0.175	0	0.3	0	4.5	0	0
7	1	1.59	0.175	0	0.3	0	4.5	0	0
8	1	1.55	0.175	0	0.3	0	1	0	0
8	2	5.82	0.175	0	0.3	0	1	0	0
8	3	0.93	0.175	0	0.3	1	4.5	0	0
9	1	1.53	0.175	0	0.4	0	4.5	0	0
10	1	1.55	0.175	0	0.3	0	1	0	0
10	2	5.24	0.175	0	0.3	0	1	0	0
10	3	4.3	0.175	0	0.3	0	1	0	0
10	4	0.91	0.175	0	0.3	0.8	4.5	0	0
11	1	1.47	0.175	0	0.4	0	4.5	0	0
12	1	1.54	0.175	0	0.3	0	4.5	0	0

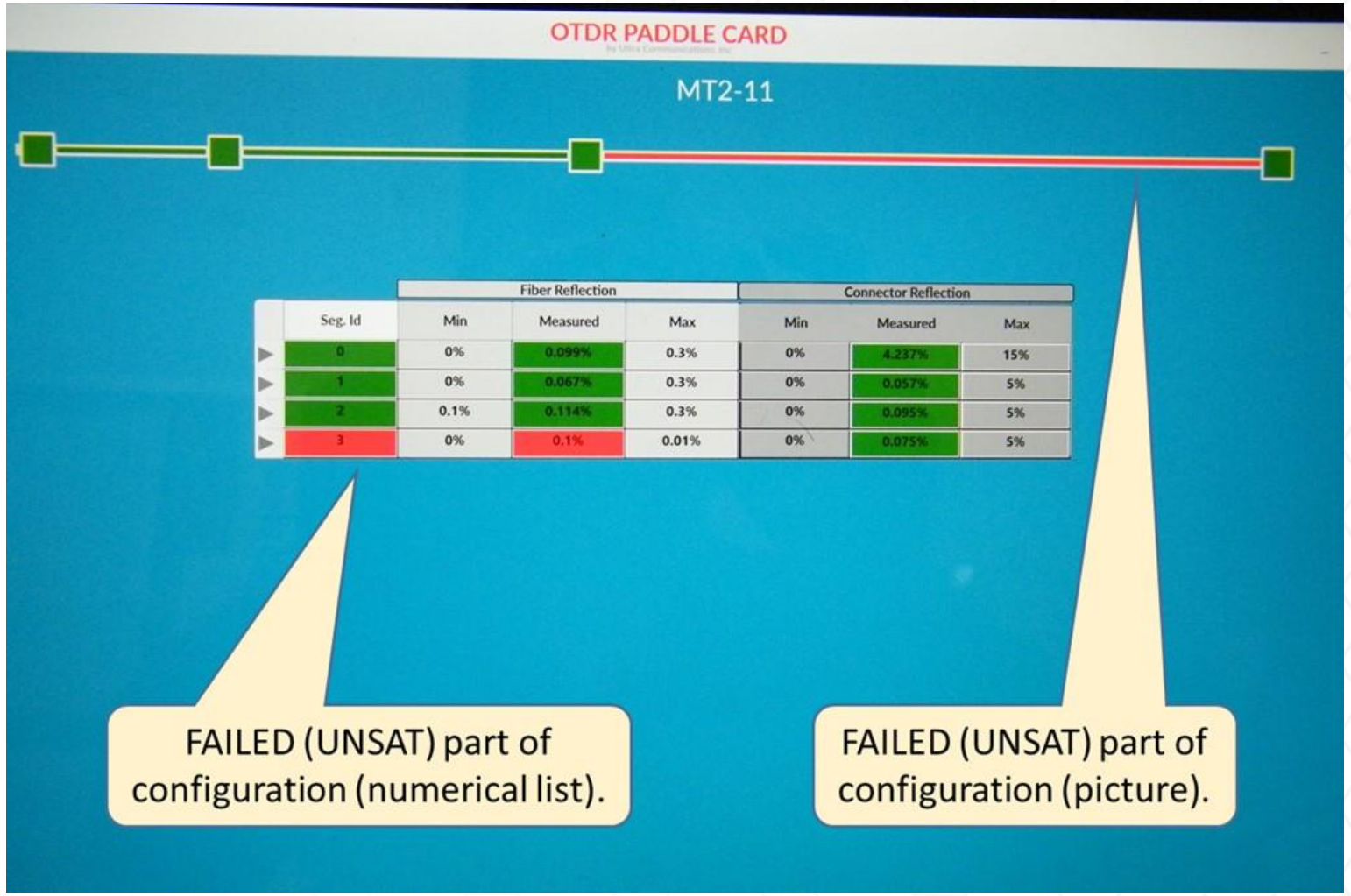
Fiber Optic Test Unit- Operation



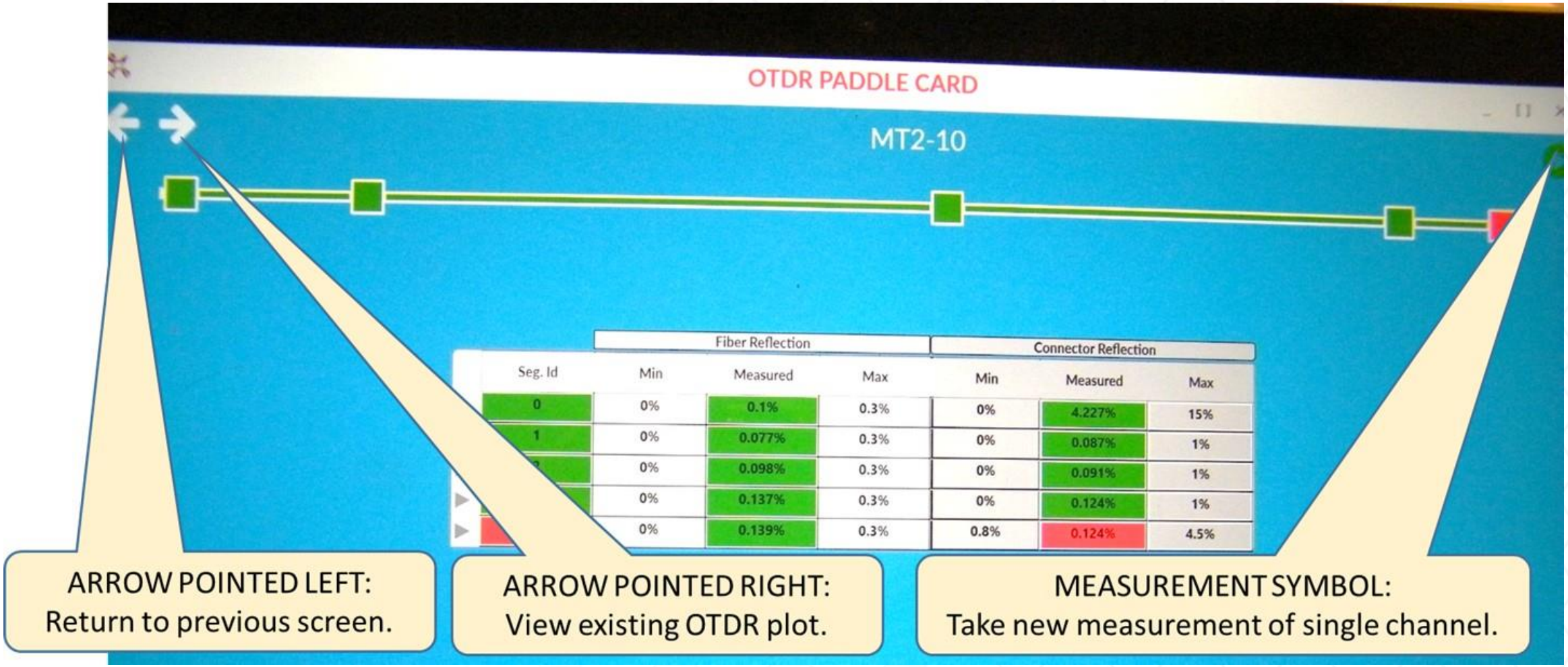
Fiber Optic Test Unit- Operation



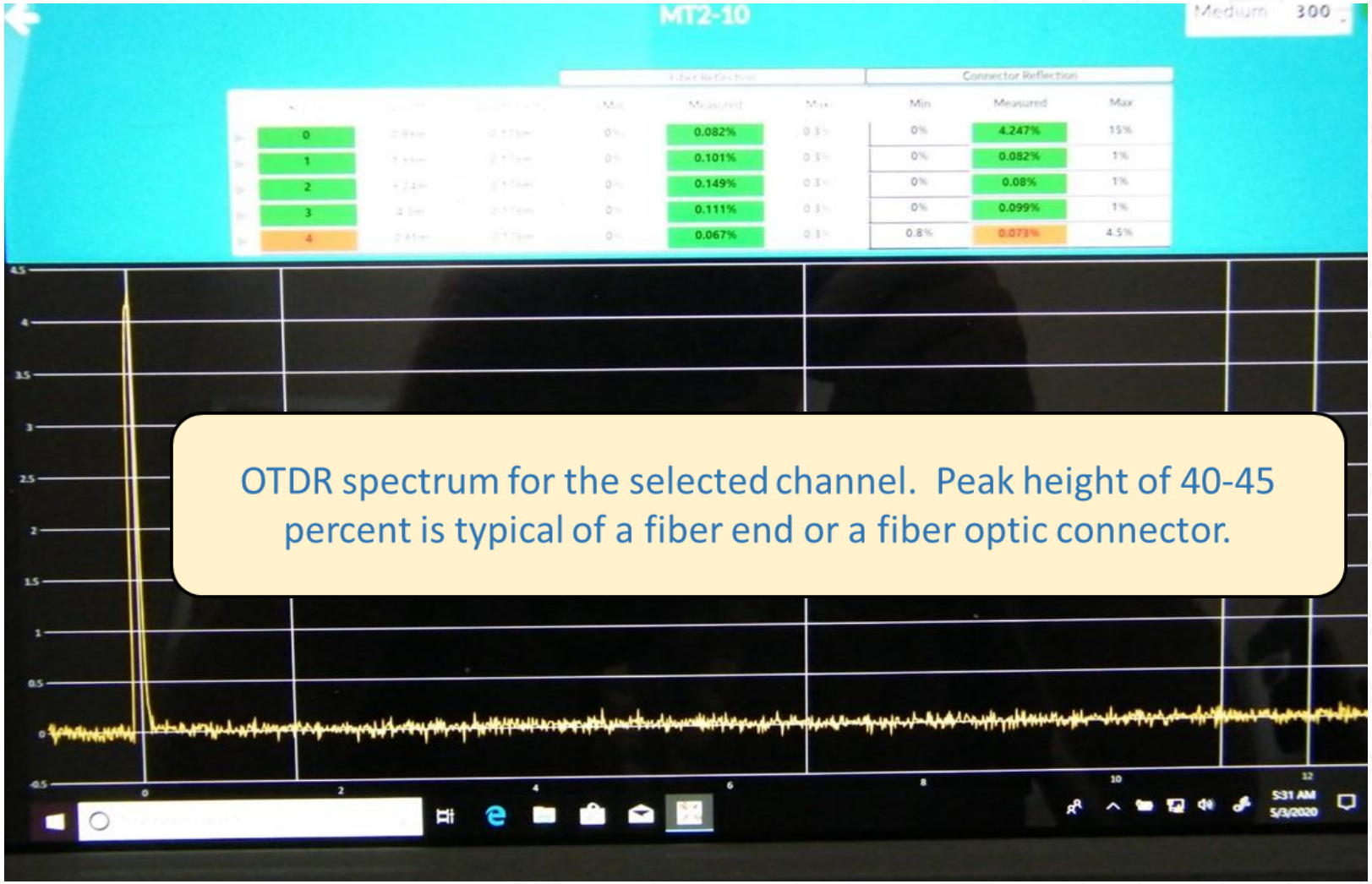
Fiber Optic Test Unit- Operation



Fiber Optic Test Unit- Operation



Fiber Optic Test Unit- Operation



John Mazurowski
jsm23@arl.psu.edu
724-295-7000 x7139

Jason Farmer
jason.farmer@hii-ingalls.com
228-935-7573

Dr. Charles Kuznia
ckuznia@ultracomm-inc.com
760-652-0011