

TELESCENT

Automation of the Physical Fiber Layer

Enabling On-Demand Interconnection Services and Remote Diagnostics using a Robotic Patch Panel

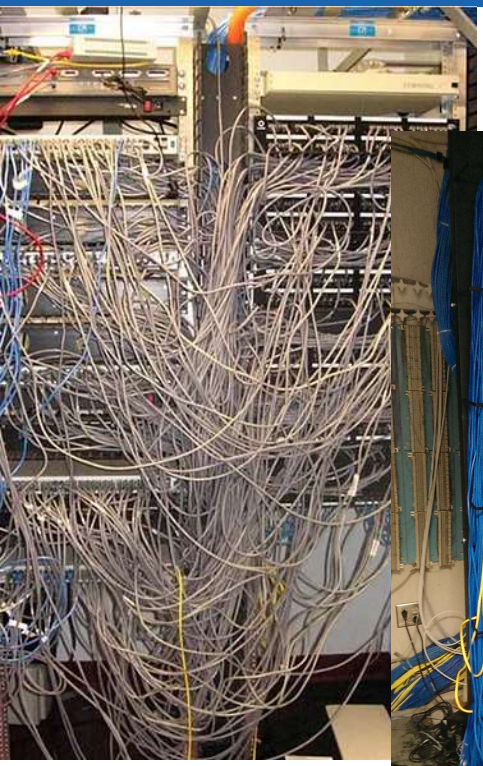
July 27, 2023

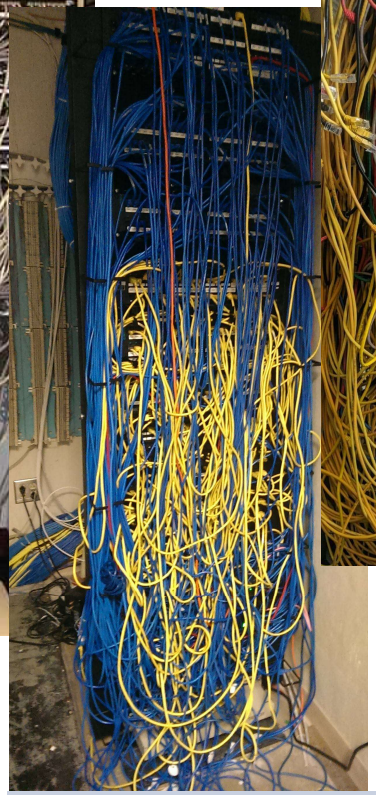
Agenda

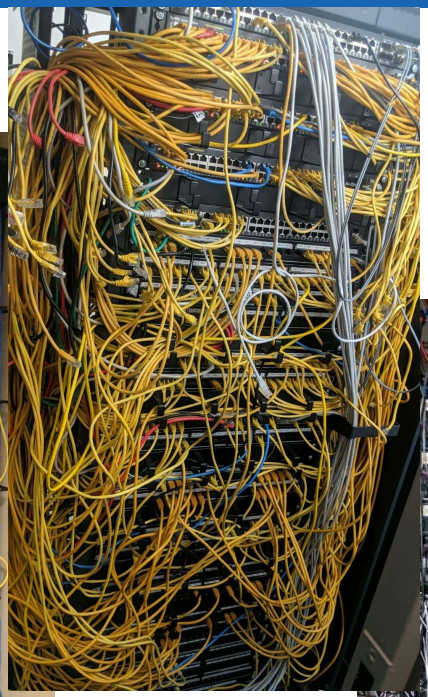
- Introduction – Need for Automation and Remote Diagnostics
- Service Provider Viewpoint – MOX Networks
- How it Works – Internal Design, Algorithm, Reliability
- RobUST™ Design Approach – Low Up-front Cost with Easy Scalability
- Software Integration
- Use Cases
- Roadmap and Future Improvements
- Summary

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Reddit Images from r/Cablefail and r/Cablegore

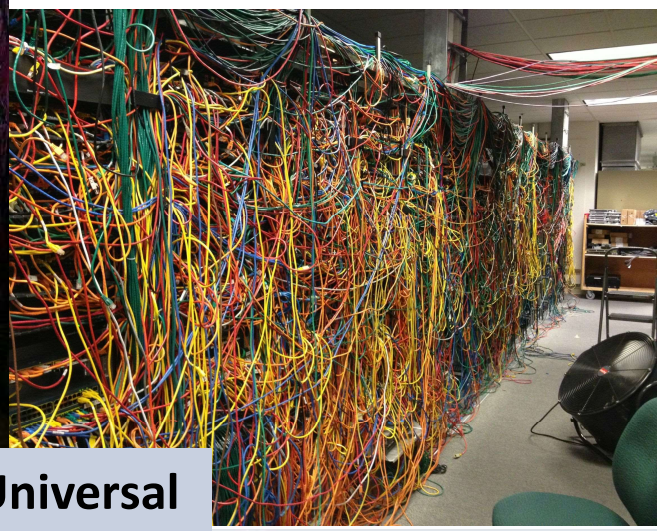








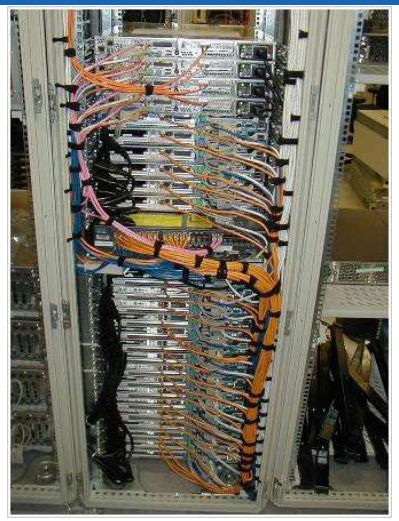




Cabling and Remote Diagnostic Challenges are Universal

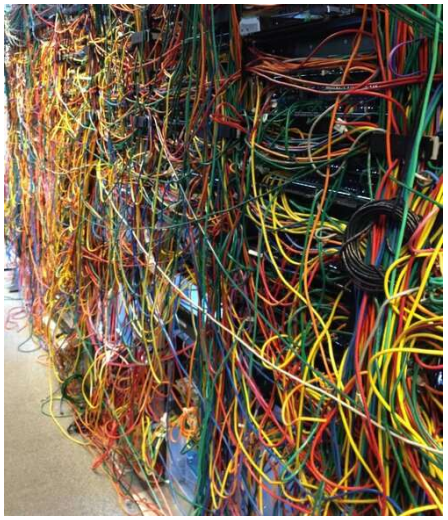
[Top 10 Cabling Fails | Data Center Frontier]

Preserve “Day One” Performance With Fiber Layer Automation



Years Later

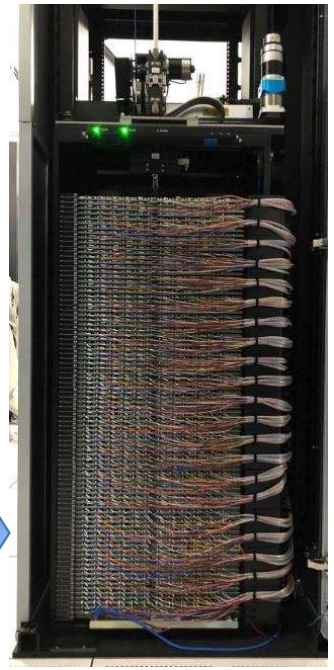
Manual Patch Panel – evolves to a mess





Years Later

Robotic System – No Touch after initial connections



How are Disconnects Managed?

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Robotic Fiber Management System in Action

- **Example of Customer Deployment**
  - Self contained Interconnect Management
- **>1,000 Duplex Ports per System**
  - Upgradeable, 96 duplex ports per fiber tray
  - Ability to offer asymmetric system (M ports x N patchcords) for low-cost implementation
- **Reconfiguration Made in 1 to 4 Minutes**
- **Excellent Optical Performance**
- **Perfect Inventory Records**
- **Latched Connections for Reliability**
- **Low Power Draw During Reconfiguration**

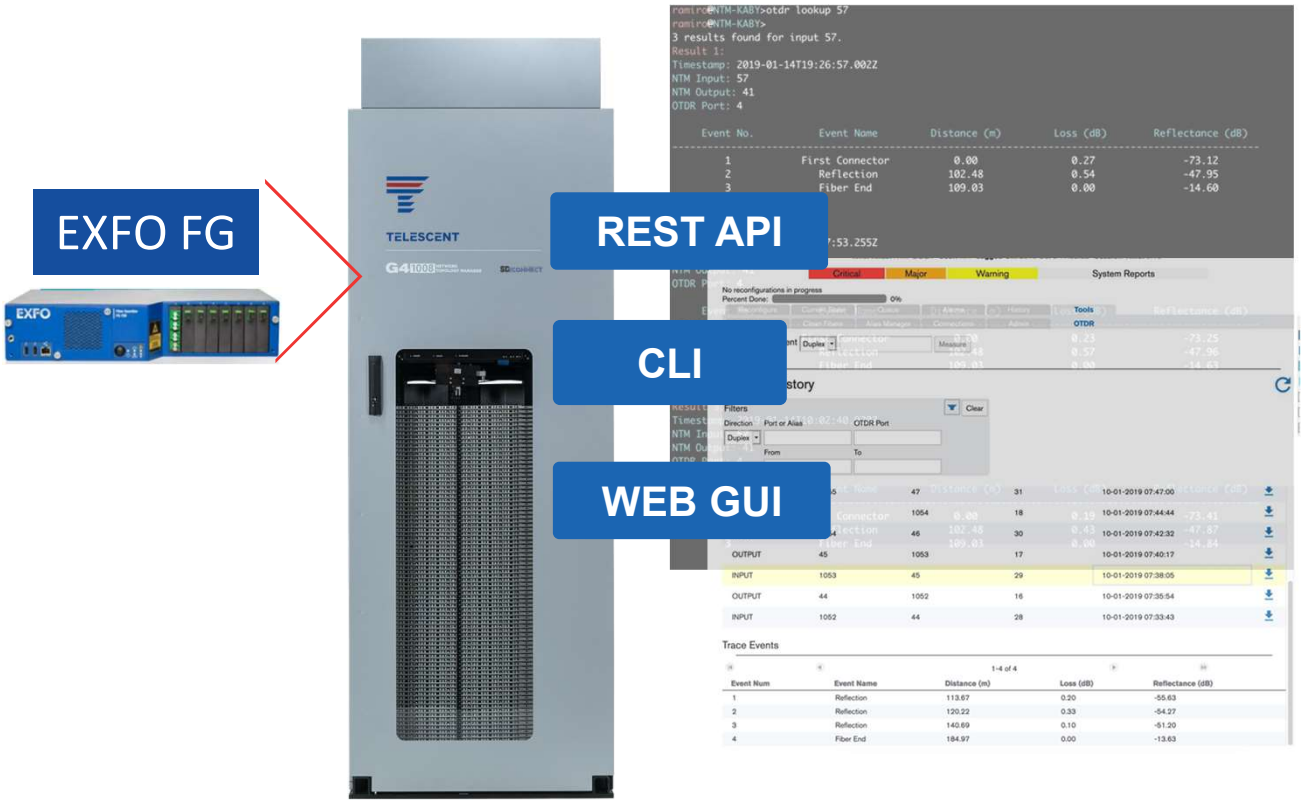
- **Operation Shown with Enclosure Doors Open**



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Remote Diagnostics with Integrated OTDR and Light Source

- **Readily available drivers for major platforms**
- **Open REST API, Command Line Interface, and WebGUI**
- **Historical OTDR traces**
- **SOR data for all traces**
- **Integrated OPM**



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Service Provider Viewpoint

MOX

INFINITE CAPACITY

Dave Bigelow

MOX
INFINITE CAPACITY

HOW DO YOU BUILD INFINITE CAPACITY FOR THE FUTURE?

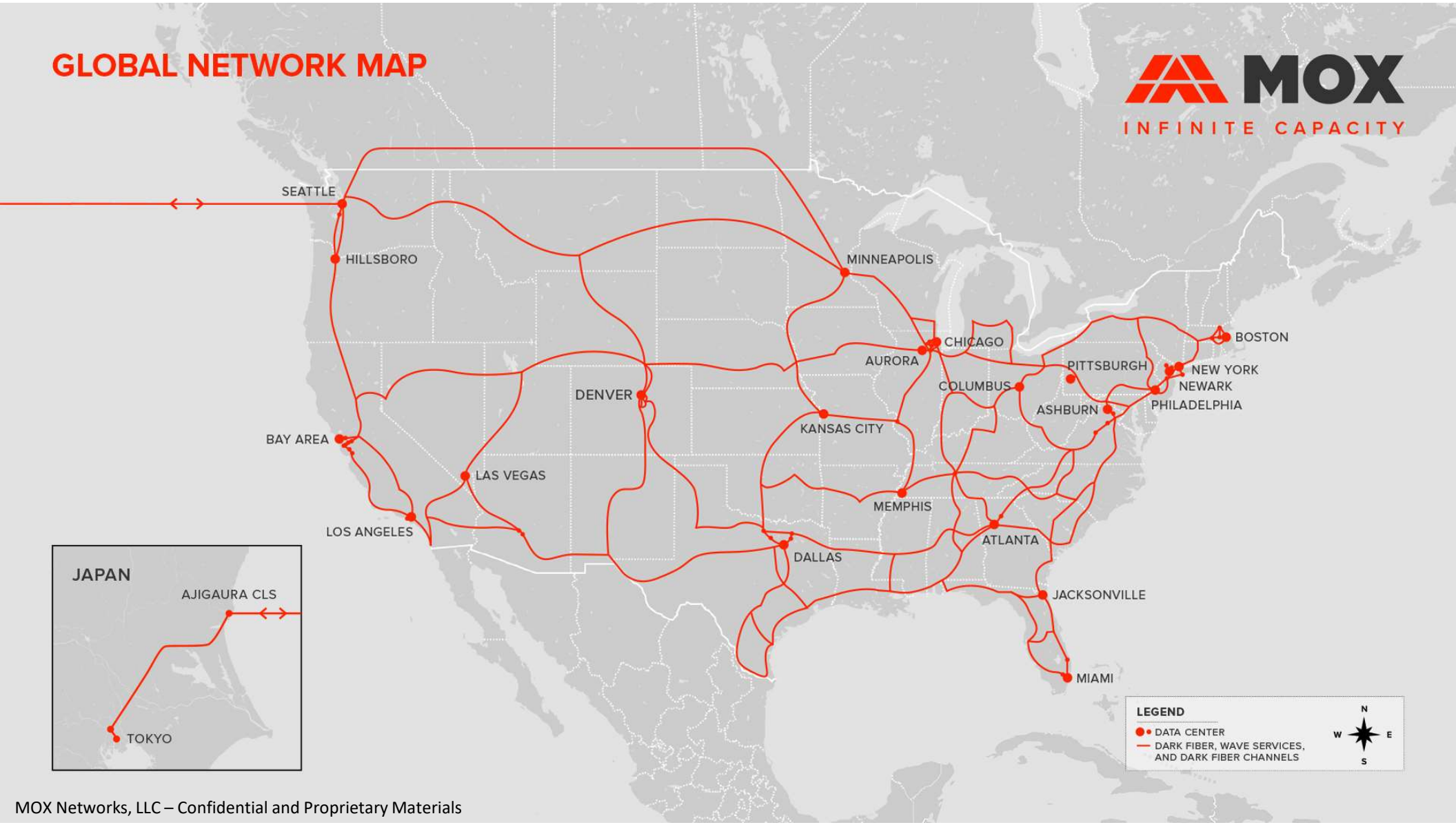
MOX NETWORKS & TELESCENT | JULY 27, 2023

Delivered By: DAVID BIGELOW, SVP, Engineering & Planning

The future will be shaped by infinite capacity to connect people, businesses, and information.



GLOBAL NETWORK MAP



MOX Networks, LLC – Confidential and Proprietary Materials

WHAT WE OFFER.

We offer a full range of lit fiber optic services, dark fiber, and our own unique dark fiber channels, from design to delivery.



WAVE SERVICES

Benefit from secure, scalable, high-capacity bandwidth powered by exclusive routes with unmatched low latency across North America and Asia.



DARK FIBER

Leverage highly diverse routes, unparalleled performance, and access to colocation. You manage and control your network while enhancing business performance through our leading fiber network routes.



DARK FIBER CHANNELS

Increase capacity without needing to purchase additional services. Self managed or fully managed, scale and control your upgrades.

WHY WE ARE DIFFERENT.

Trusted partner to the world's most powerful network users for its infinite capacity to solve business challenges.



INFINITE CAPACITY

Propelling business growth and transformation with leading fiber assets and performance.



CUSTOMER COUNSEL

Providing advice with agility, speed and efficiency to power our customers' objectives.

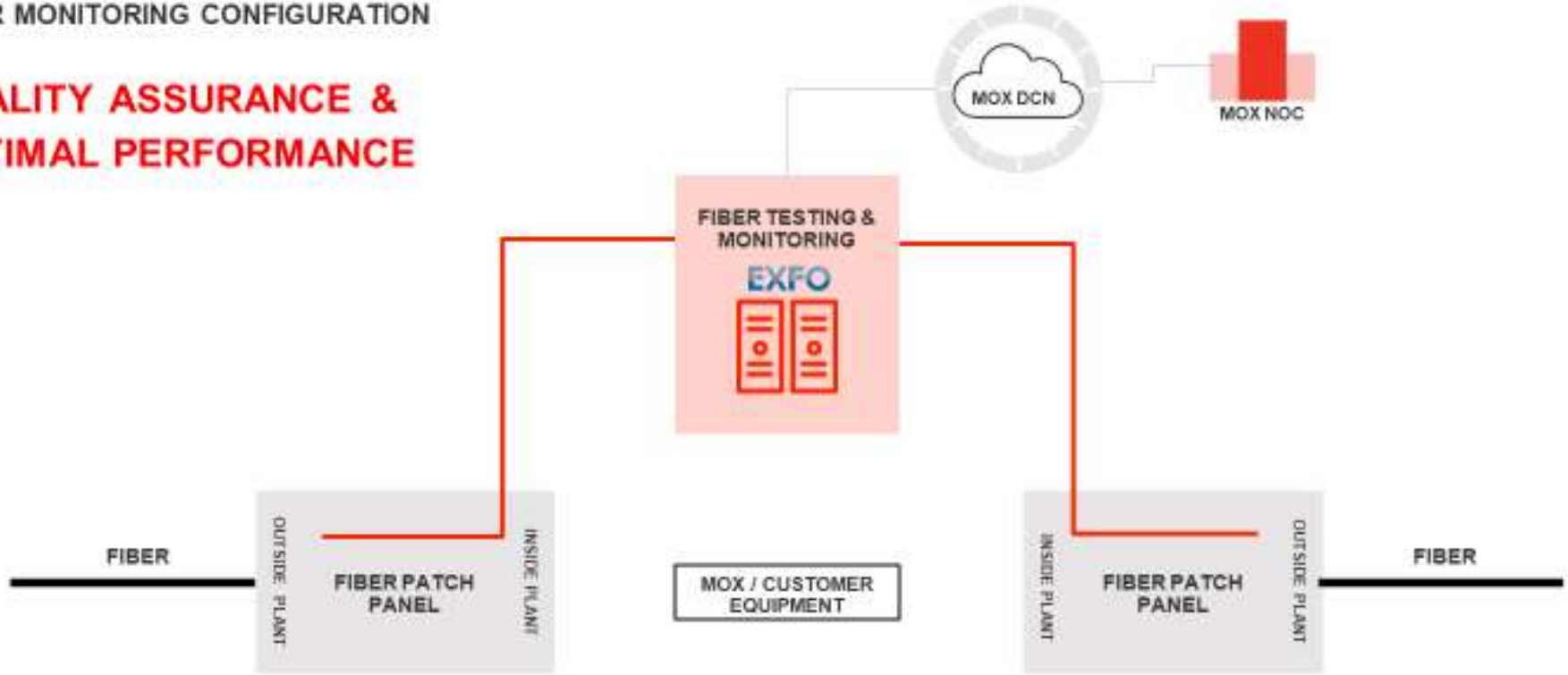


CUSTOMIZATION

Powering purpose-built infrastructure, network opportunities and relationships.

FIBER MONITORING CONFIGURATION

QUALITY ASSURANCE & OPTIMAL PERFORMANCE

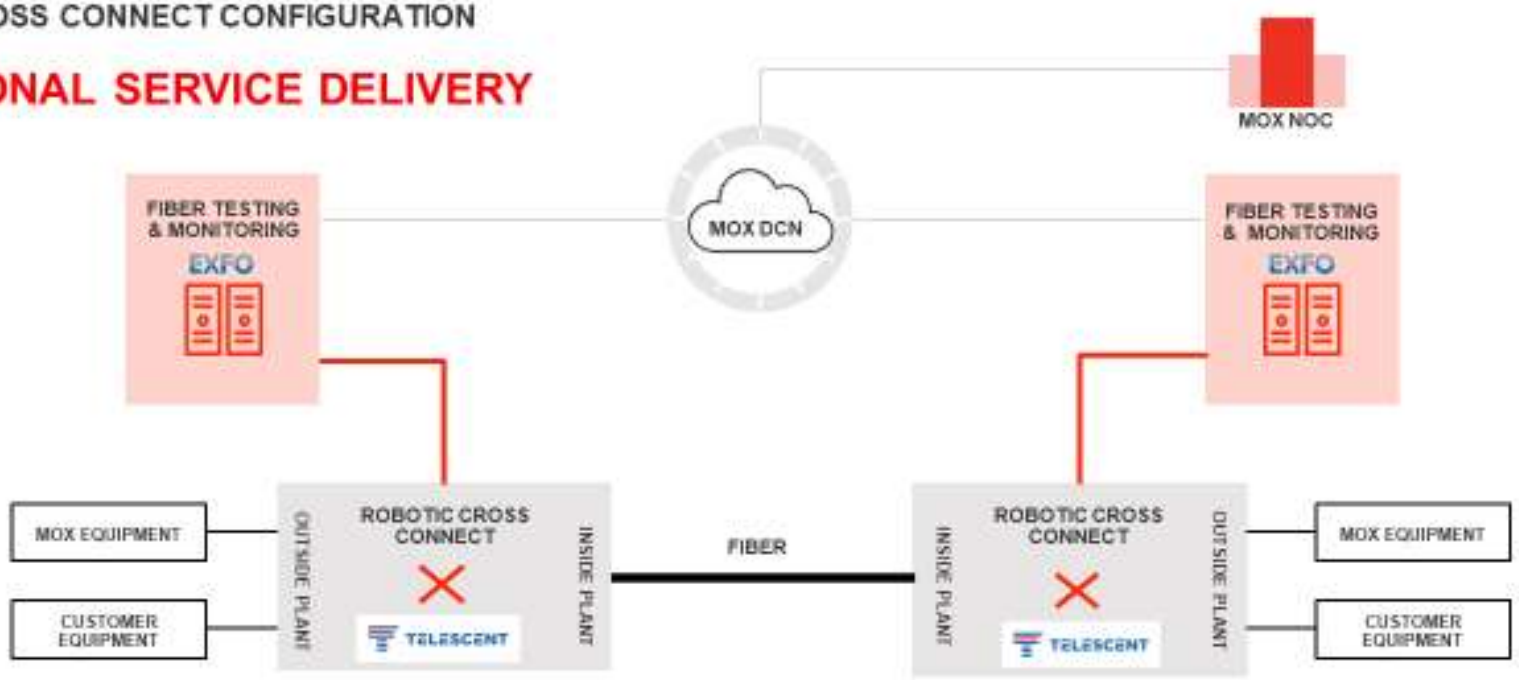


PERFORMANCE METRICS:

- ✓ CONTINUOUS FIBER TESTING AND MONITORING
- ✓ HISTORICAL RECORD OF ALL TEST RESULTS
- ✓ CABLE FAULT ISOLATION WITH GEOGRAPHIC LOCATION

ROBOTIC CROSS CONNECT CONFIGURATION

EXCEPTIONAL SERVICE DELIVERY



PERFORMANCE METRICS:

- ✓ REMOTE TEST AND PROVISIONING OF FIBER = EXCEPTIONAL SERVICE DELIVERY
- ✓ REMOTE TESTING WITH CUSTOMERS = RAPID CUSTOMER SUPPORT
- ✓ SERVICE RESTORATION = QUALITY ASSURANCE
- ✓ CONTINUOUS FIBER TESTING AND MONITORING = OPTIMAL PERFORMANCE
- ✓ HISTORICAL RECORD OF ALL TESTS = OPTIMAL PERFORMANCE
- ✓ CABLE FAULT ISOLATION WITH GEOGRAPHIC LOCATION = QUALITY ASSURANCE

SEATTLE TO PORTLAND TO HILLSBORO

DARK FIBER

Leverage highly diverse routes, unparalleled performance, and access to colocation. You manage and control your network while enhancing business performance through our leading fiber network routes.

WAVE SERVICES

Increase capacity without needing to purchase an entire network. Self managed or as a managed service, scale and control your upgrades.

Benefit from state-of-the-art communication services along a strategically placed network that's connected to world-class data centers and points-of-presence (PoPs) across North America and Japan.

DARK FIBER CHANNELS

Increase capacity without needing to purchase an entire network. Self managed or as a managed service, scale and control your upgrades.

MOX's new and diverse Pacific Northwest fiber routes offer Telescent's Gen 4 Network Topology Manager (G4 NTM), a leading remote and automated interconnect system.

TELESCENT



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MOX CAPABILITIES WITH TELESCENT

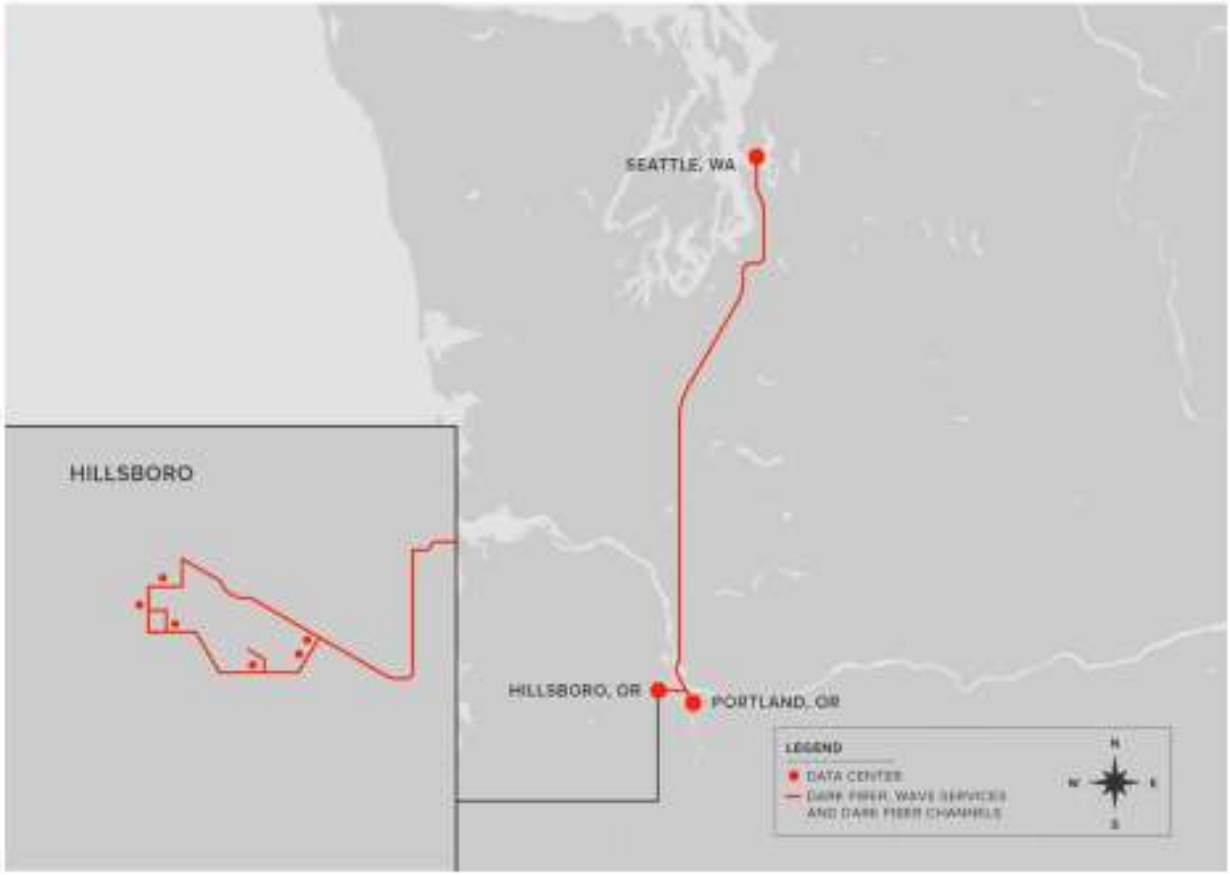
Telescent's GEN 4 Network Topology Manager (G4 NTM)

The G4 NTM technology provides MOX with a remote-controlled, reconfigurable fiber patch-panel and cross-connect platform to implement physical layer automation and diagnostics for MOX customers along deployment routes.

Notable Capabilities That MOX Has Realized Include:

- Reduced Service Delivery Intervals
- Real-time Implementation Capabilities
- Sophisticated Monitoring Tools
- Asset Inventory & Preservation
- Early Intervention & Diagnostics

TELESCENT



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We build the capacity to deliver on infinite possibilities in your industry.

Content Providers
Cable Companies
Enterprise
Financials
Government
Municipalities

MOX IS A LEADING FIBER OPTIC NETWORK SPECIALIST.

We build the capacity to deliver on the infinite possibilities for new paths, connections, and performance.

MOX responds to the increasingly complex requirements of hyperscalers, wireless service providers, government, municipalities, public and private partnerships, with exclusive, custom design and deployment of unmatched low latency networks.

Founded in 2013, MOX is a communications infrastructure company that owns and operates unique lit and dark fiber routes throughout North America and Asia.

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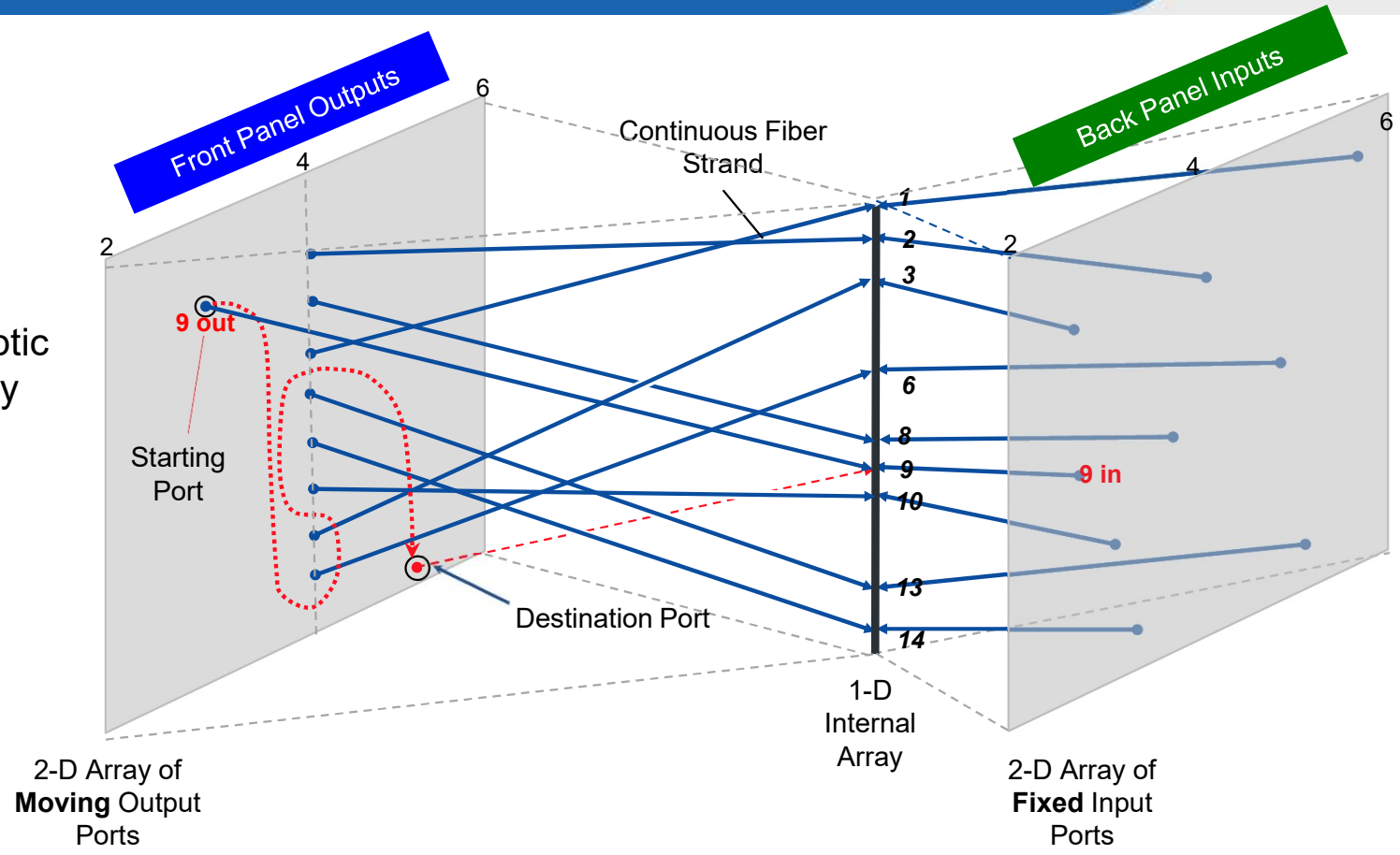
How It Works

Details of the System
Design, Algorithm, Reliability

Telescent's Proprietary KBS Algorithm – 1,008 Fibers

Key Features:

- Reconfigure ANY Fiber Optic Link Without Impacting Any Other Fiber Links
- Provision, Un-Provision, Re-Provision Connections



Algorithm Weaves Fiber through 1,007 Other Fibers

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Unique, Scalable Algorithm and Sophisticated Software

Telescent Knots, Braids, Strands (KBS) Algorithm

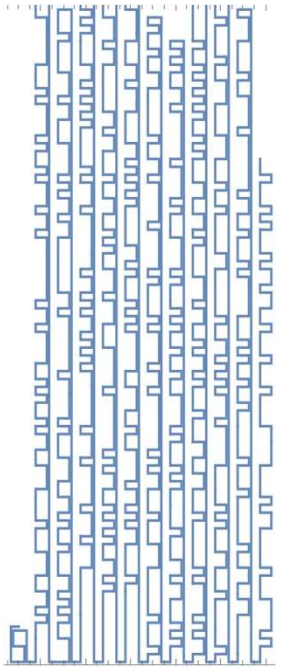
Mathematics Problem Thought to Have No Solution!

- **Truly Disruptive, Very High Barrier to Entry**
- **Protected by 56 Patents (32 Issued) and Trade Secrets**
  - KBS Algorithm, Machine Learning, Software Operating System, Compact Robotics, Tensioned Fibers, Cleaning Unit



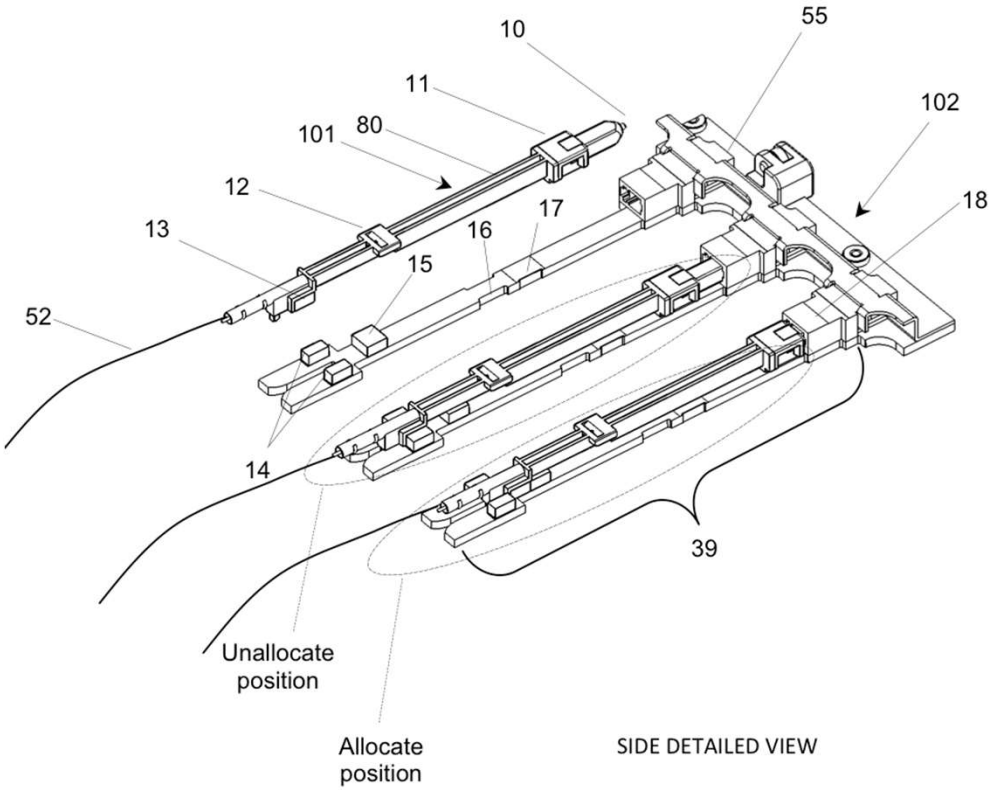
Miniature Interconnects Routed Without Entanglement

Computed Routing Path



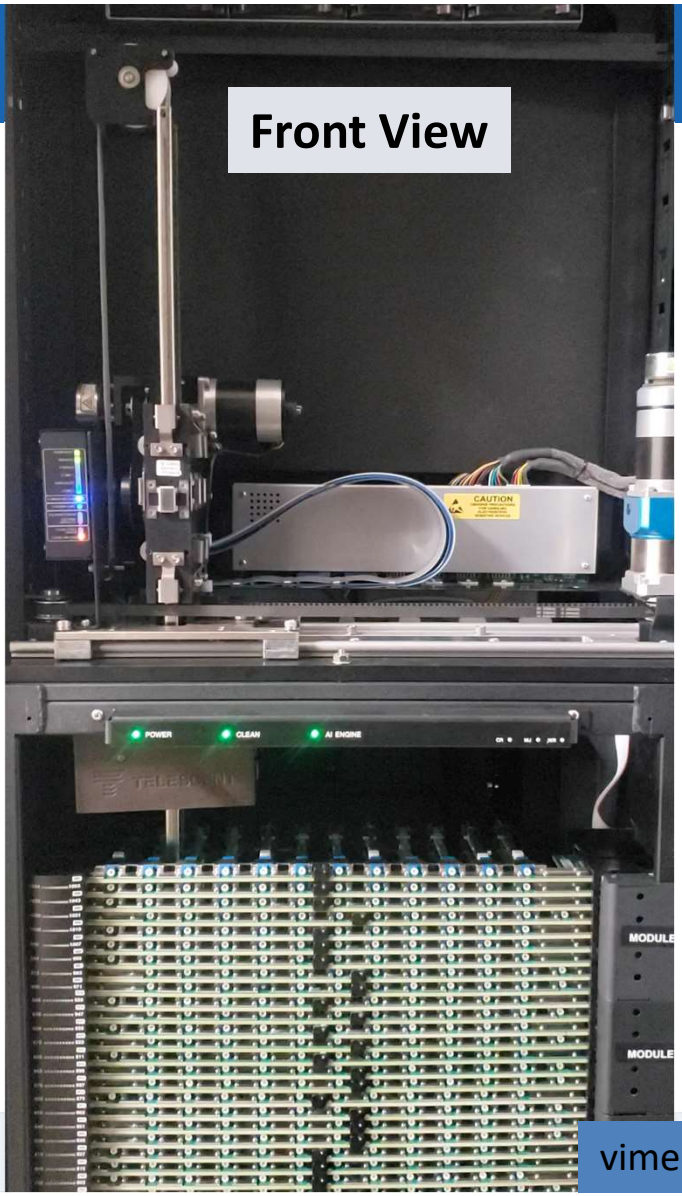
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Latched Fiber Connectivity

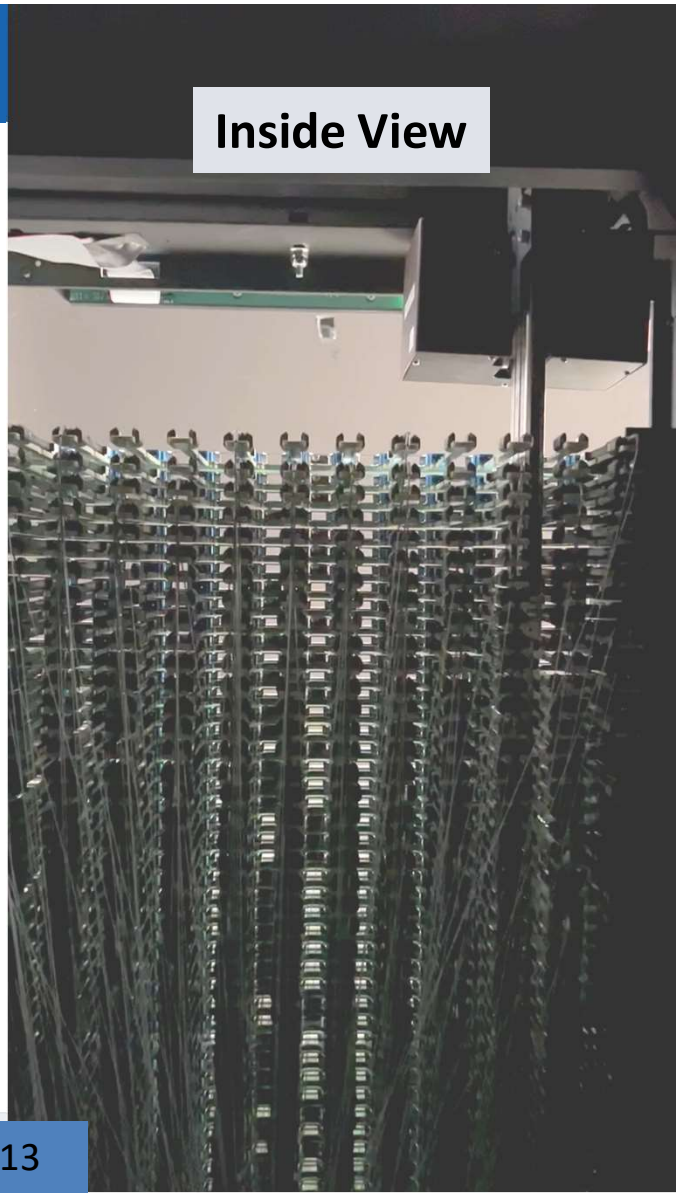


- Unplug State
  - Fiber connector is fully withdrawn from the mating sleeve (output port)
- Unallocate State
  - The fiber connector is partially engaged within the mating sleeve (output port)
  - IL > 30dB
- Allocated State
  - Fully engaged within the mating sleeve of the adaptor (output port)
  - Connection is provisioned

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- “Elevator Shaft” for Robot to Reach Down to Fiber
- Rows Shift Based on Algorithm Design
- Gripper Removes Connector from Magnetic Latch
- Fibers Never Make Contact / Rub against Each Others



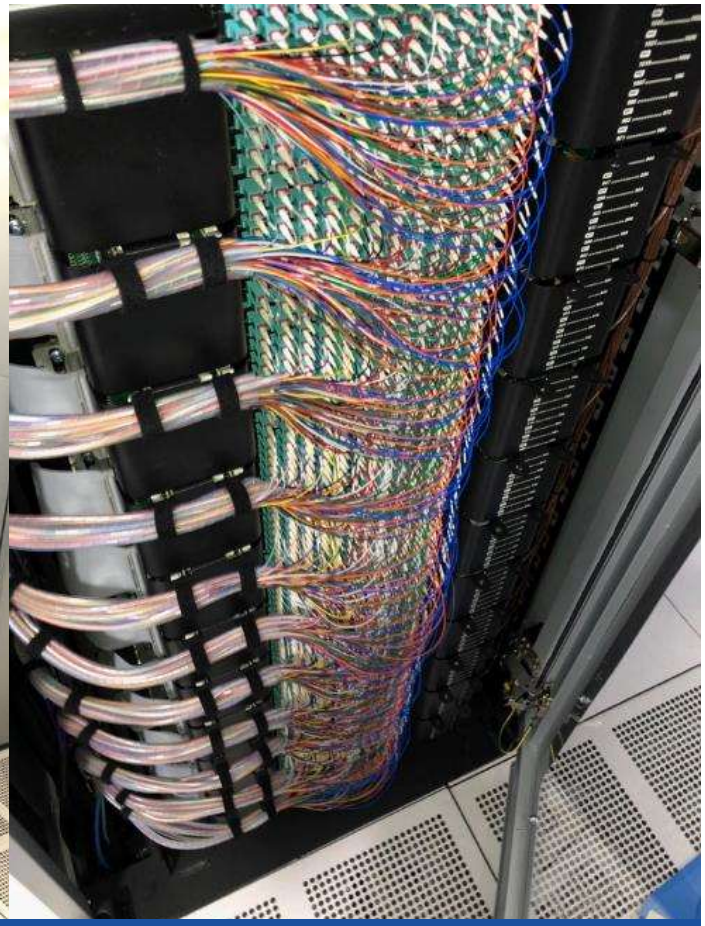
vimeo.com/manage/videos/848536506/f5d2224013

Fully Cabled System



G4 System Front - Without Cover





G4 Robotic Patch Panel Back - Without Cover

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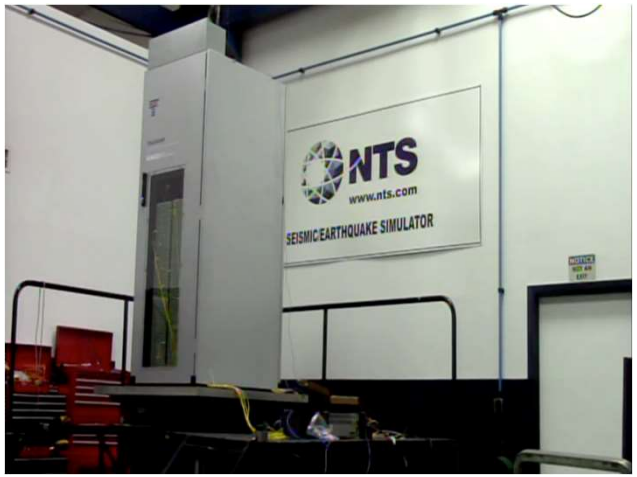
Focus on Reliability

- **Optical Connections are Mechanically Latching, Don't Require Power**
- **Redundant Power Supplies, Resilient Linux Server Hardware/SSD/software**
- **Cleaning Cartridge Ensures Consistent, Low Insertion Loss**
- **Robot is Maintenance-Free**
- **Flextronics (Contract Manufacturer) Producing High Quality Systems**
- **Passed All Industry Standard Tests**
  - NEBS Level 3, CE Mark (over 100 tests, 9 months)
- **Passed Tier 1 Telco (Japan) Field Trial**
  - Gold standard for product vetting
  - 166 tests, 3 months, 0 faults
- **Passed Multi-Tenant Data Center (MTDC) Field Trial, Won RFP and Deployed**
- **Passed Tier 1 Telco (USA) Field Trial and Deployed**
- **Deployed in Full Operation in Production Networks for > 3 Years, Demonstrating Reliability**

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NEBS Earthquake Zone-4 (8.2 Magnitude) and GR-63 Office Vibration

Robot was Performing Connections During Test Cycles,
IL Measured on 12 Ports with No Signal Degradation

Front - to - Back	Side - to - Side	Z - Axis
		
PASS	PASS	PASS

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MTBF of System Modules (Non-Service Interrupting)

Service Life of G4 NTM Modules		
Module	Replacement Time	Mean-Time-To-Failure (MTTF) by G4 NTM Modules (Non-Service Interrupting)
Gripper (Consumable)	15 mins	16k Simplex Reconfigurations (Random)
Cleaning Cartridge (Consumable)	15 mins	8k Cleanings
Server	2 hours	330k hours
Robot	30 mins	>32k Simplex Reconfigurations (Random)
Optical Power Monitor	1 hour	>100k hours (~200k hour estimate)
Power Management Module	2 hours	>100k hours (~200k hour estimate)
Ethernet Switch	1 hour	393k hours
Fiber Module (Active Electronics)	1hour	>100k hours (~200k hour estimate)
Fiber Module (Passive Fiber)	30 mins	>1k Reconfigurations (Random) Per Fiber

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RobUST™ Design Approach

Low Up-front Cost with Easy Scalability

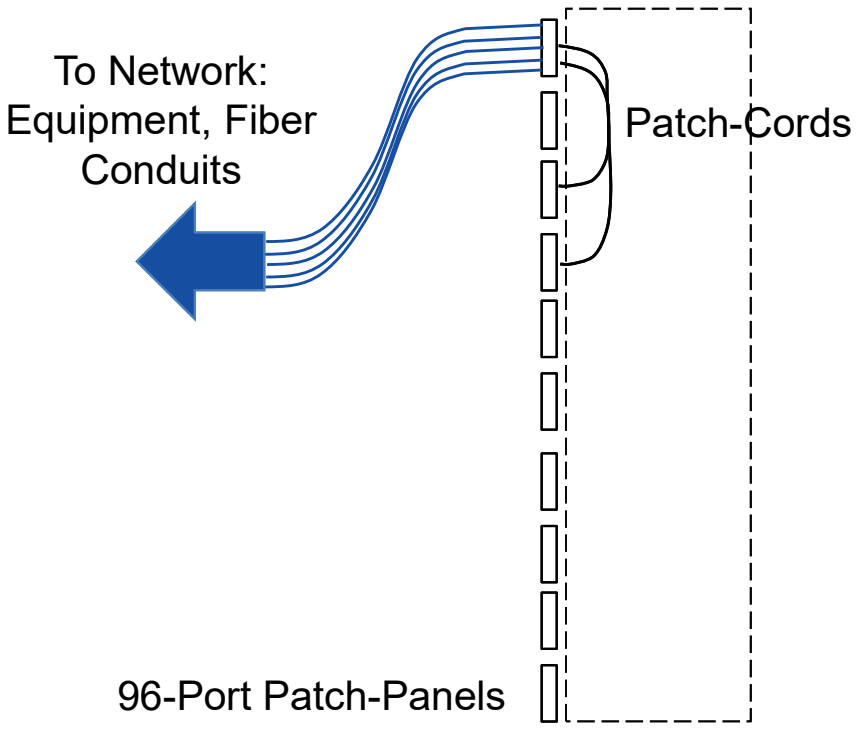
Cost Efficient Automation Using the Telescent System

- **Installation of Fiber with Decade Long Planning for Uptake**
  - High fiber count installation to offset high construction costs
- **Customers Only Activate a Portion of Fiber Capacity Initially**
  - Additional ports available when needed in future
- **Automation Needs to be Available for Any Fiber / Port**

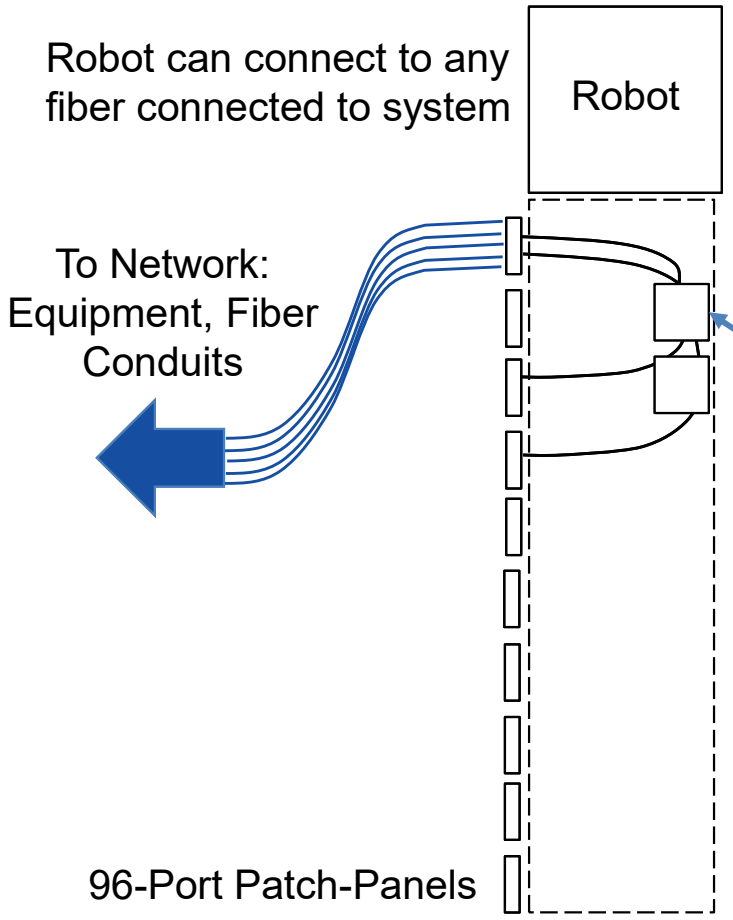
- **Challenges for Automation:**
  - Minimize up-front cost of the Automated System for unused ports
  - Allow automated connection of unused ports when ordered
  - Allow scalability to add automation as demand and revenue grows

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Manual and Robotic Patch-Panels and Patch-Cords



Robot can connect to any fiber connected to system



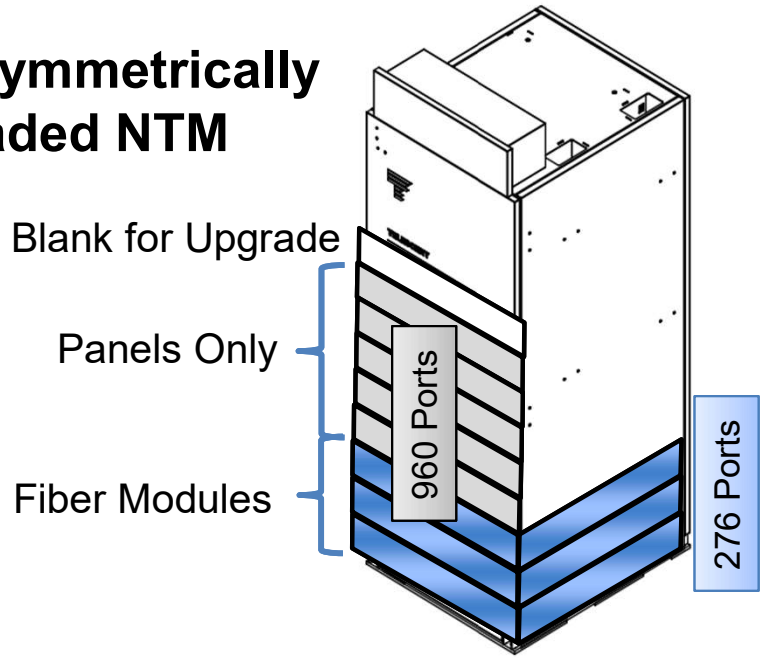
RobUST™ Architecture

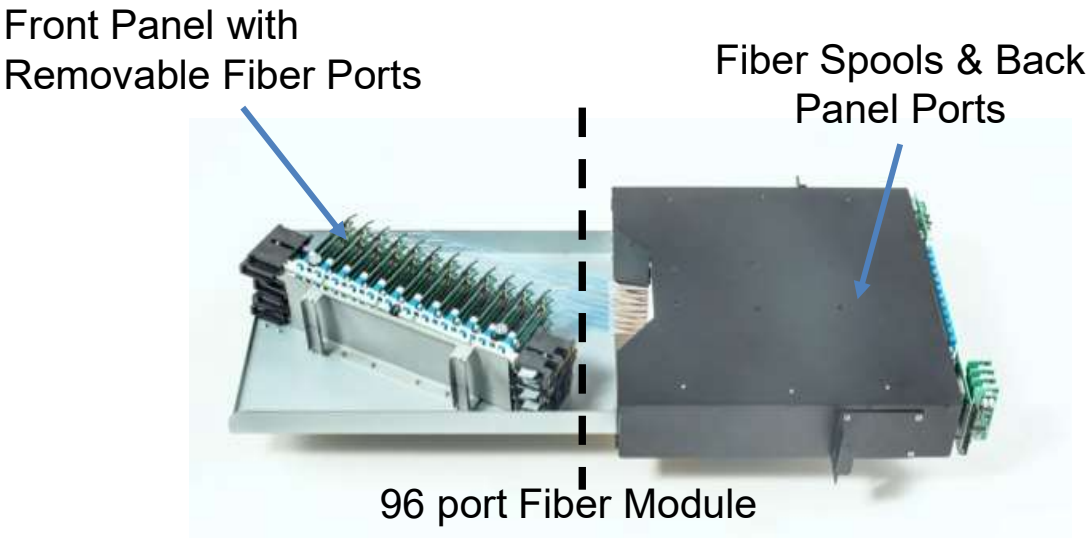
48-Reconfigurable Patch-Cord Modules

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Cost Efficient Pre-Cabling for Automated Fiber Management

Asymmetrically loaded NTM

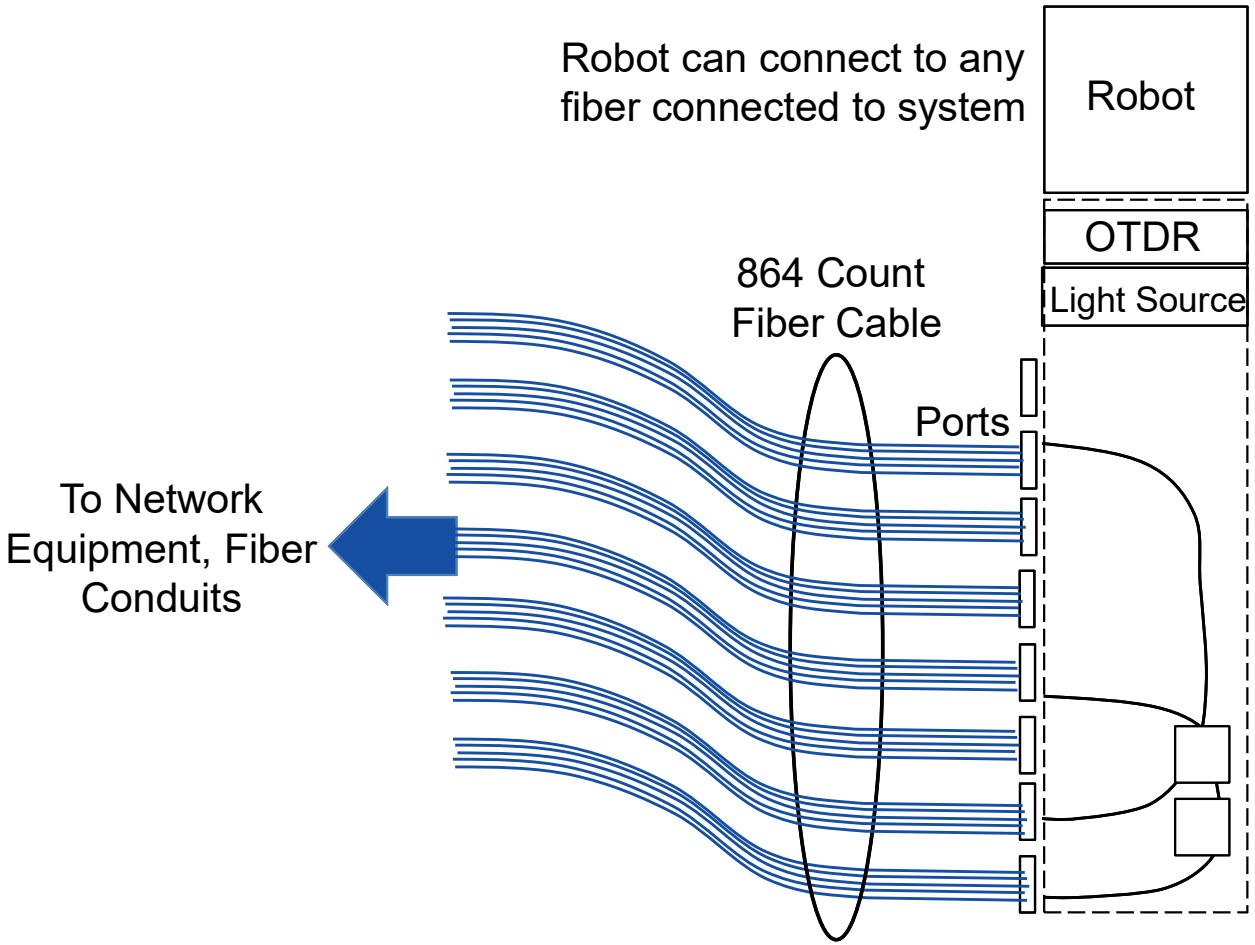




- Partially fill System with fiber modules (i.e. 276 duplex ports)
- Fill front of System with empty port front panels
- Connect all pre-wired fibers to front panel ports of System
- Robot can connect to any of pre-wired ports
- Expand system when needed by adding additional fiber patchcord modules

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Asymmetric Robotic Patch-Panels and Patch-Cords



RobUST™ Architecture

Asymmetric
'M' ports x 'N' Patch-Cords = Low Initial CapEx With Robotic Access to All Ports

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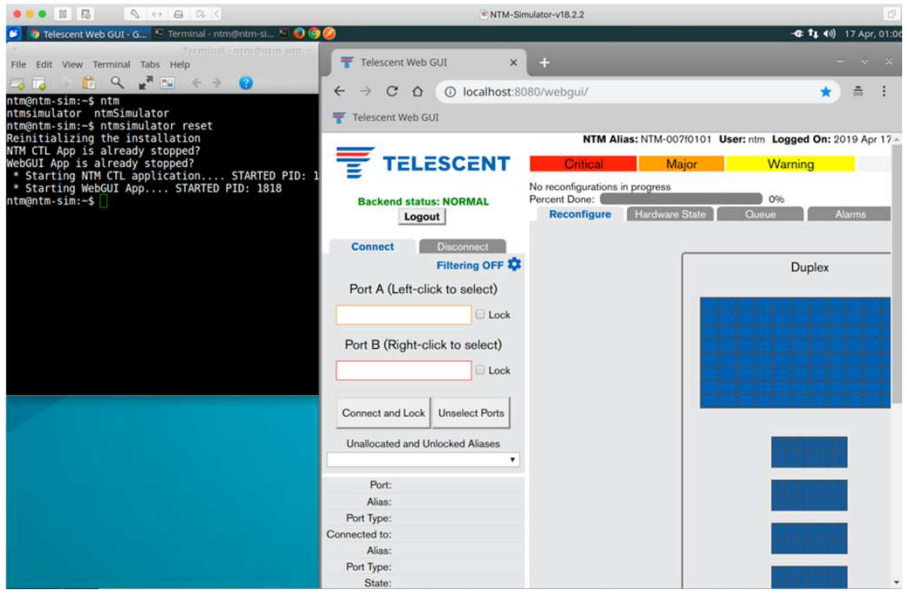
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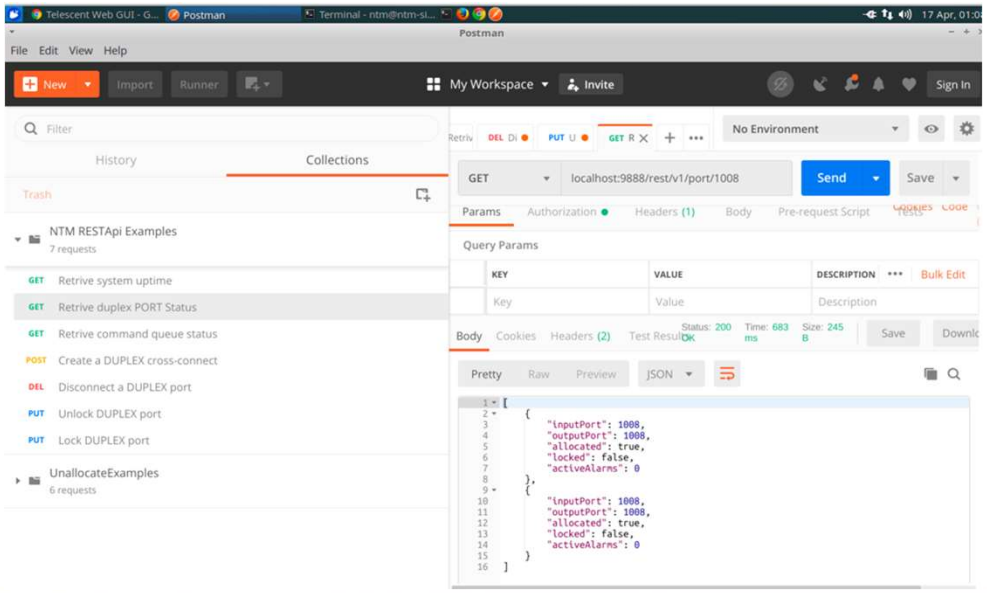
Implementation

Software Integration

Virtual Machine (VM): Excellent Development Tool

- VM image in Open Virtualization Archive (.ova) format
  - Same software distribution installed on the System
  - Simulated Hardware
  - Support major virtualization solutions – VirtualBox and VMware
- Docker image available

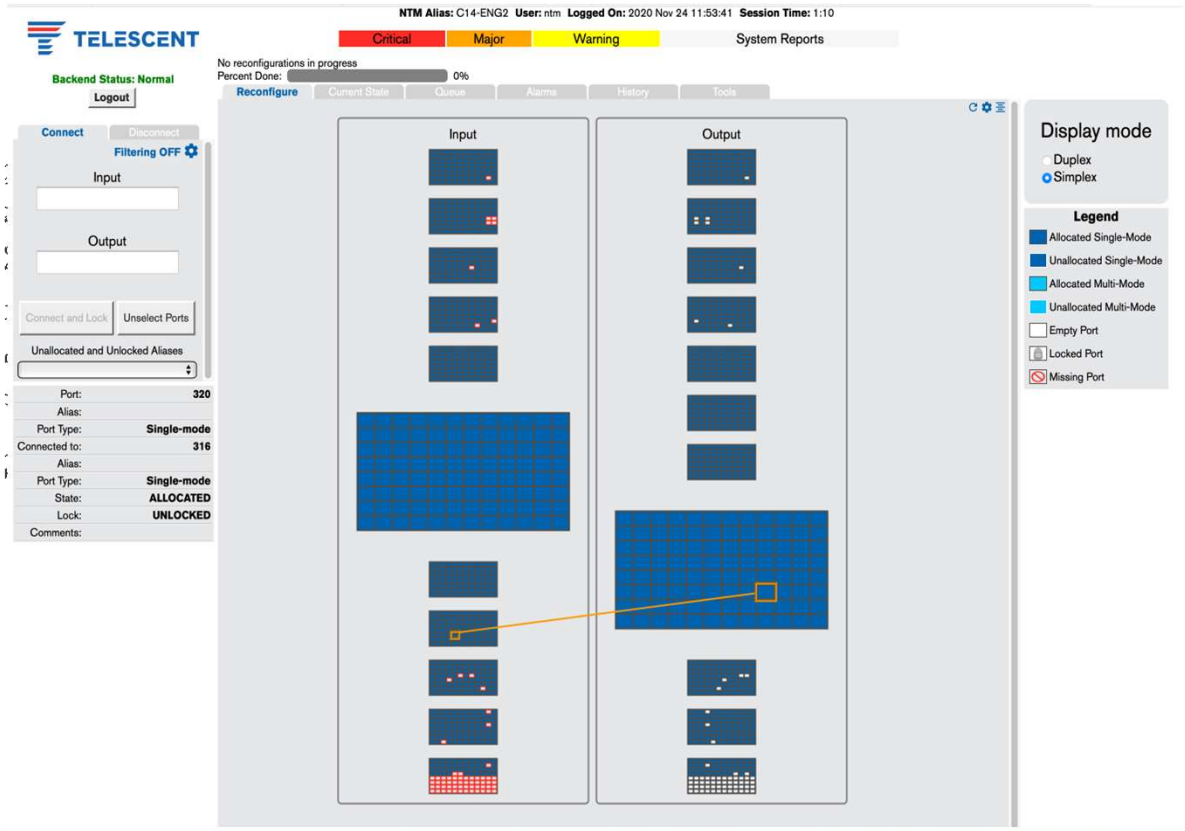




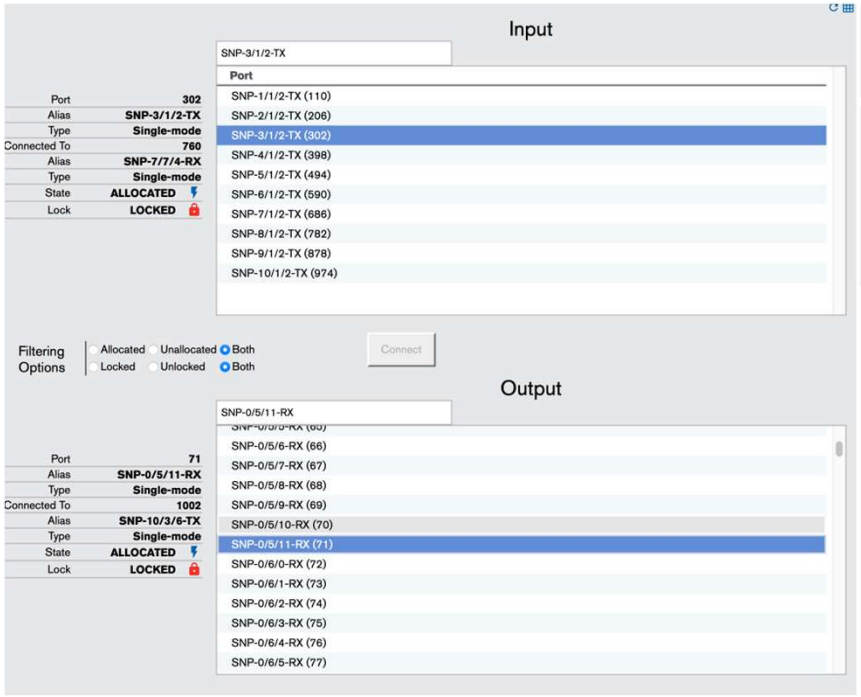
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WebGUI: Point & Click, Operational Focused

Click & Provision

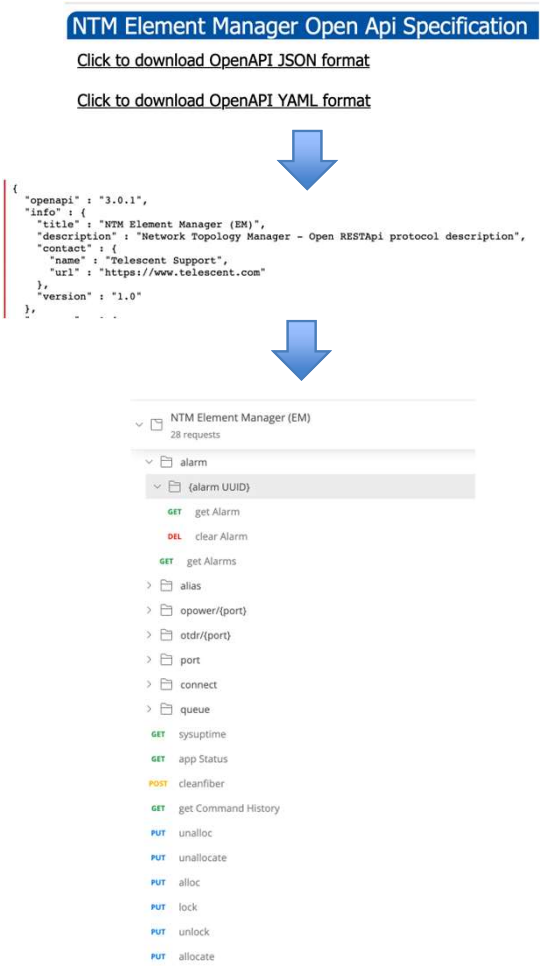


Type & Provision



RESTApi Integration

- **OpenAPI Specification OAS v3.0**
- **NTM Protocol specification in both YAML and JSON**
- **All Client RESTAPI calls ready accessible via tools like Postman**
- **Fast implementation**
  - **Code automatically generated for all major platforms**
  - **OpenAPI Tools readily available**



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Software Integration Example: Leading MTDC

- **NTM Simulator ("Virtual Machine") Used as Software Development Tool**
  - Open Virtualization Appliance (OVA) format. Easily imported into VMware, VirtualBox
  - Docker image already available at DockerHub.

- **Telescent REST API Speeds Integration**
  - Follows OpenAPI Specification (OAS)

- **MTDC Integrated NTM With OSS/BSS Using REST API:**
  - Salesforce.com (billing system)
  - ITRACS (interconnect inventory system)
  - MTDC customer facing web portal

- **MTDC Software Integration Process Took Only ~1 to 2 Man-Months**

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Use Cases

Example Use Cases

All Markets

- **Automation of Ubiquitous Fiber Management Tasks, Testing**

Multi-Tenant Data Center

- **Edge/Colo MMR and Cage Automation, Submarine Landing**
  - Zero-touch, Interconnect-on-Demand

Transport

- **Provisioning, Fiber Monitoring and Remote Fault Isolation**
  - Metro or Long-Haul Fiber Automation and Software Control

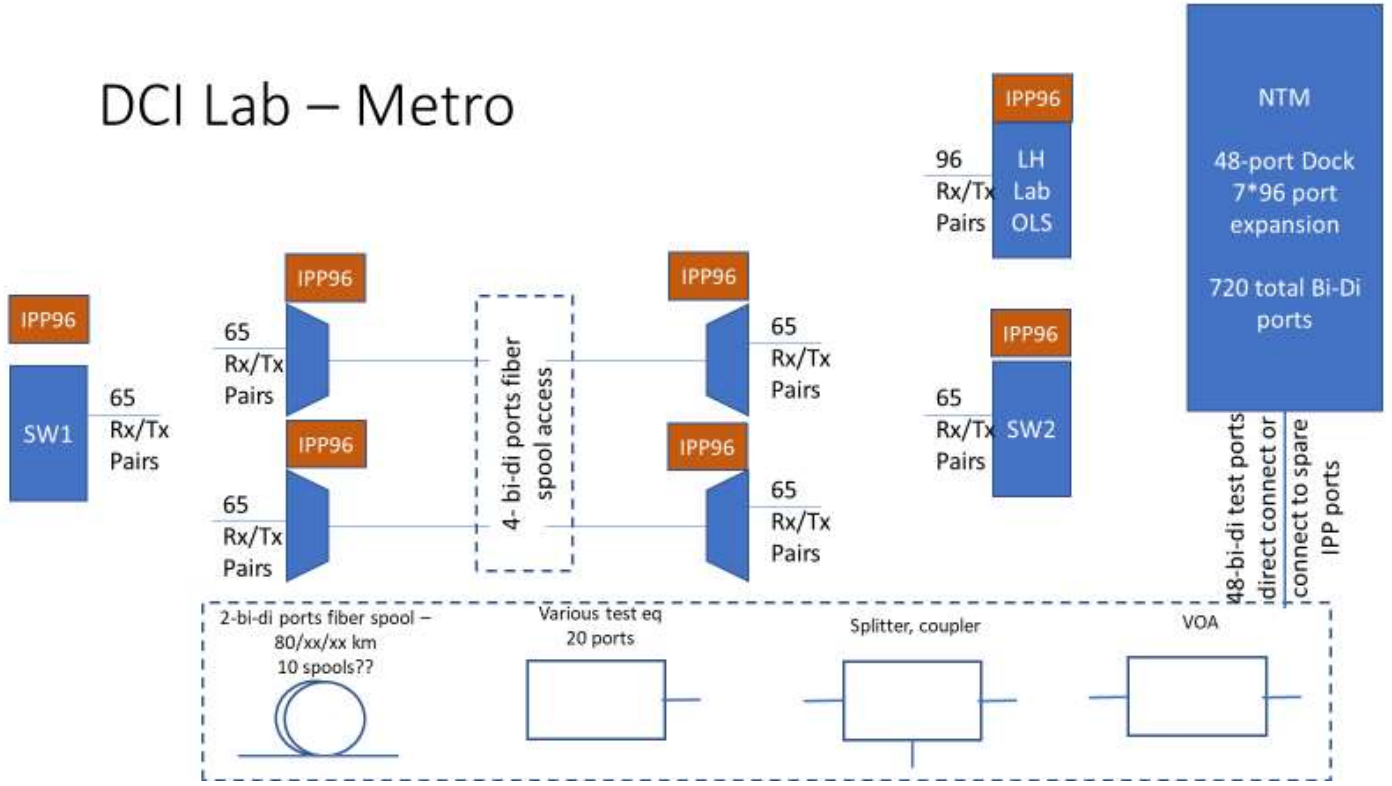
Cloud/Hyperscale

- **Graceful Scaling of Switching and Routing Fabric**
  - e.g. Re-striping during DC Expansion / Refresh
- **GPU Clusters for Machine Learning Workflows**
  - 2-4x Faster ML Training by Reconfiguring Fiber

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Lab Automation

- **Use NTM in Test Lab to Validate New Technology**

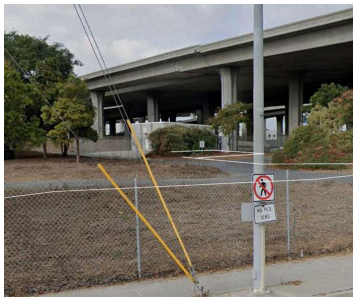


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Installed At 7 Los Angeles Metro Locations

Caltrans

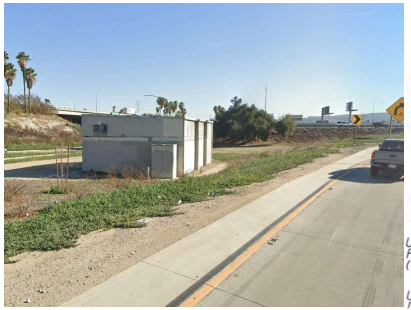
- **Monitoring/ Provisioning/ Control of large metro deployment**

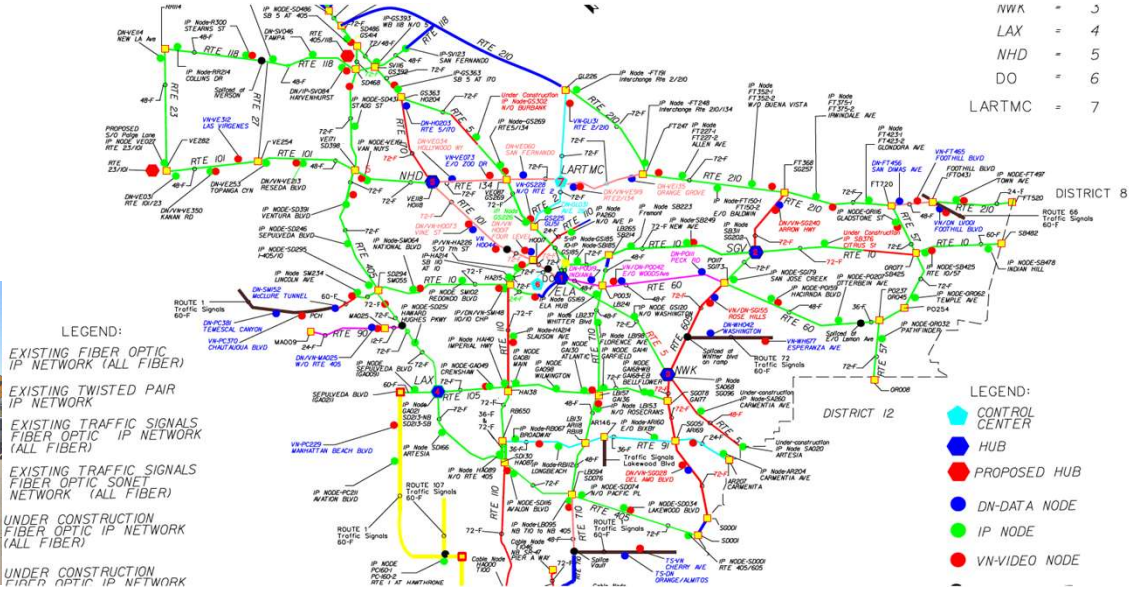


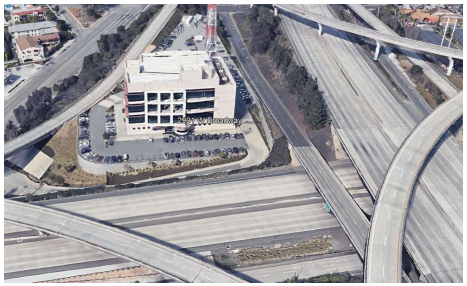








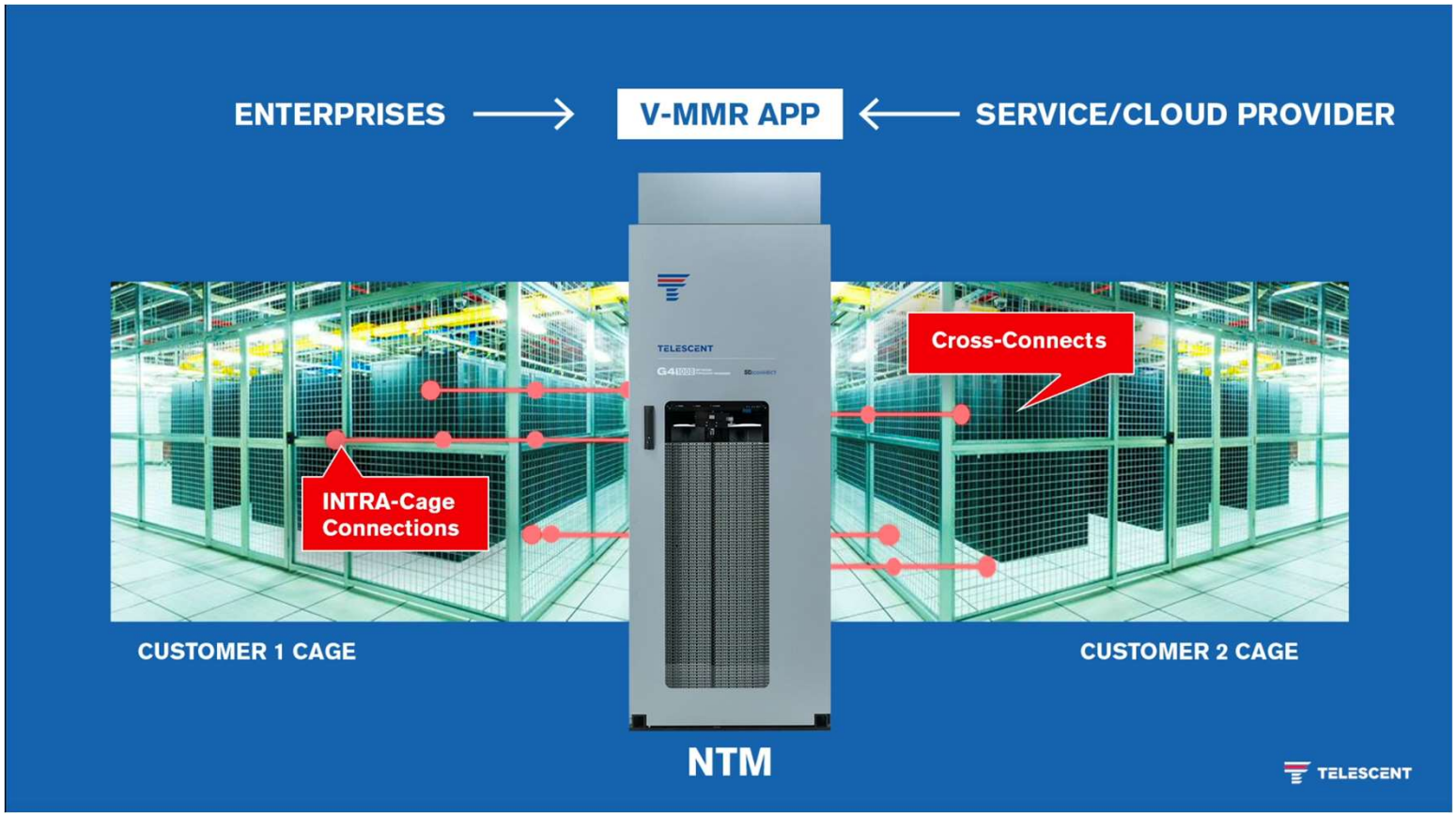






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Remote Meet-Me-Room (MMR)



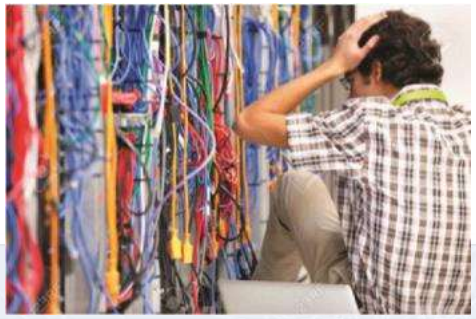
Telescent Video of MMR Portal: https://vimeo.com/368361486/3ea41f7e72

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Manual versus Automated Reconfiguration Process

Manual Process (3 – 14 day SLA)

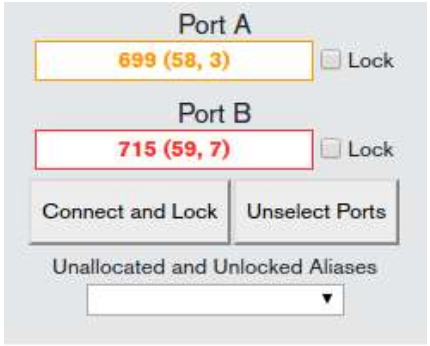
- Receive a work order
- Select and locate a cable from inventory
- Travel to and access the facility
- Locate the physical interconnection at patch-panels and network equipment
- Confirm records in work order are correct
- Clean all connector
- Install new interconnection
- Perform OPM and/or OTDR measurement to confirm installation was done properly
- Document change and manually input into database

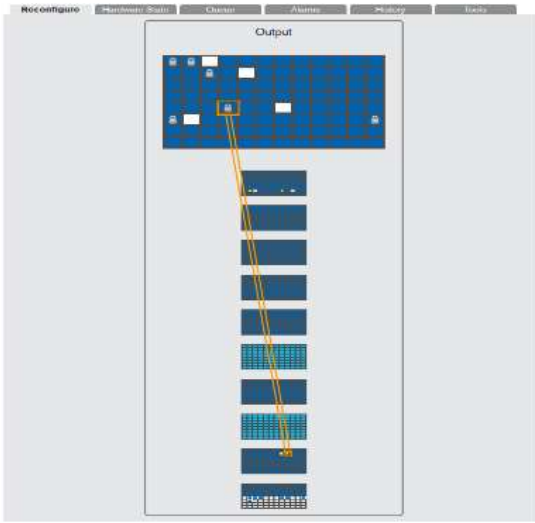


Automated Process (2 hour SLA)

- Enter port connections in online portal



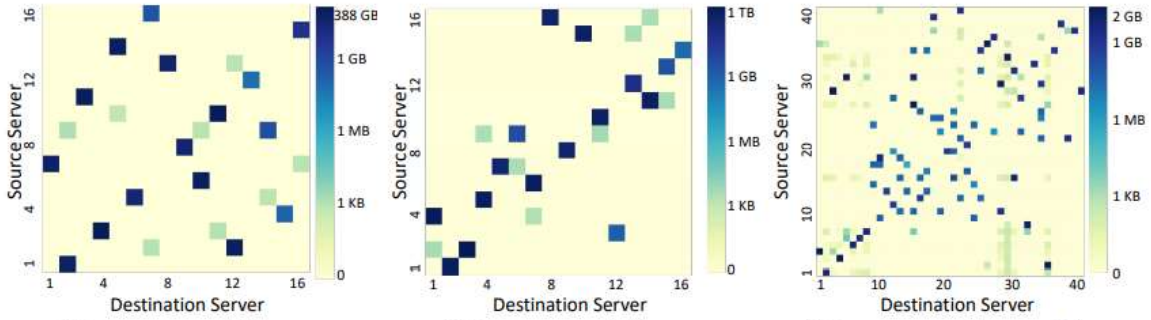




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Machine Learning Cluster Using Telescent Robotic System

Cost-Effective, Programmable Fiber Connectivity to Optimize Topology of GPU Cluster Enables 2X – 4X Faster ML Training!



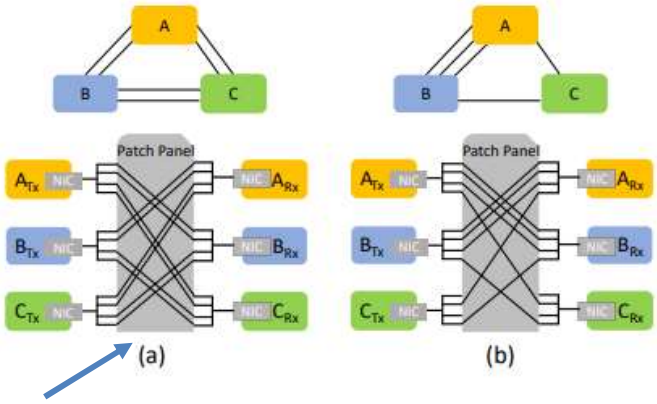
(a) Language model 1 data/model/pipeline parallel

(b) Language model 2 data/model/pipeline parallel

(c) Image recognition model data/model/pipeline parallel

Figure 3: Heatmap of communication pattern for three jobs running on multiple GPU servers in our cluster.

- **Server Communication Depends on ML Algorithm**
- **Stable & Predictable During Iterations**
- **Adjusting Link Bandwidth Significantly Impacts Speed**



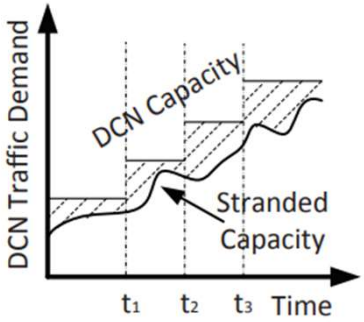
Robotic System

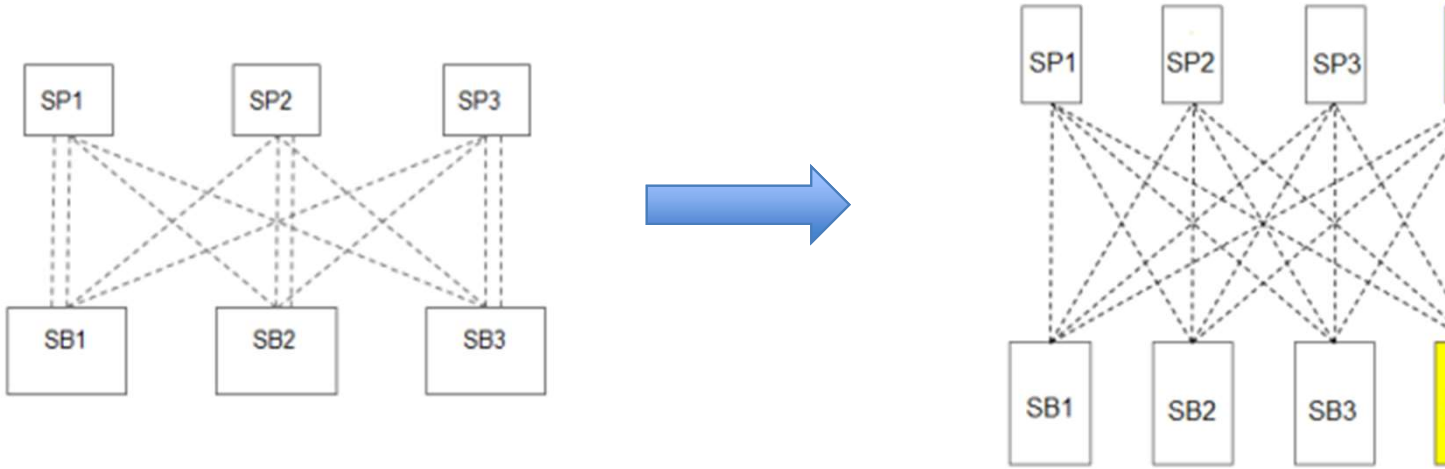
Reference: TOPOOPT: Co-optimizing Network Topology and Parallelization Strategy for Distributed Training Jobs

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Data Center Expansion – Adding Capacity

- **Data Center Capacity is Expanded over Time**
  - Balances investment, demand and technology
  - Typically 1 – 2 years to reach full capacity, then technology refresh cycle
- **Capacity Addition Requires Rewiring of Clos Network**
- **Minimal Rewiring Algorithms Still Require 10 – 25% of Connections to be Reconfigured during Each Expansion**





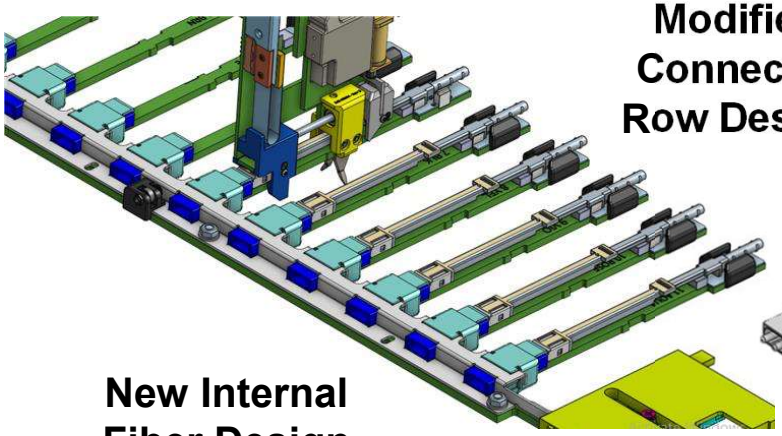
S. Zhao, "Minimal Restriping for Data Center Expansion," Technical Disclosure Commons

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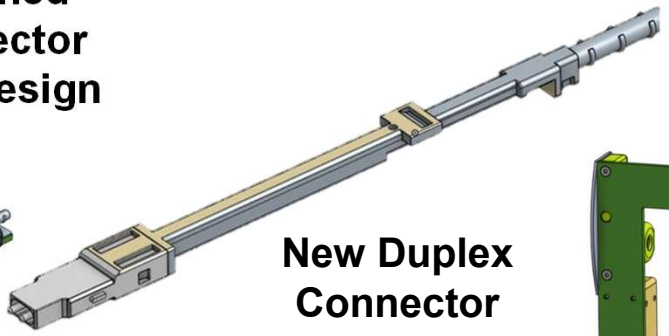
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Product Roadmap And Summary

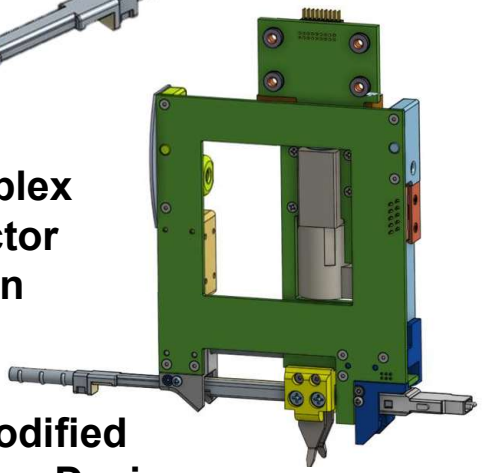
Expansion of Capability using Multiple Fibers per Connector



Modified Connector Row Design



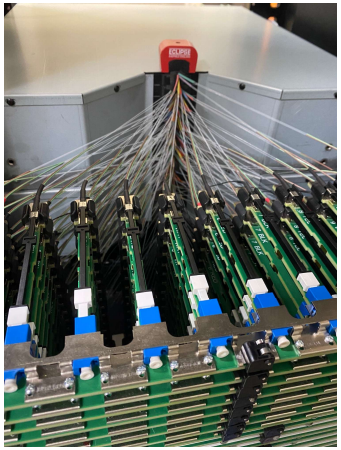
New Duplex Connector Design



Modified Gripper Design

New Internal Fiber Design





Prototype of System w/ Modified Connector
(2 fibers / connector)



Similar Rack Design

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Product Roadmap - Telescent's Scale Provides Unique Advantages

Hardware System

- **Gen 4 OCS (Today)**
  - 1,000 Ports; 1,000 Fibers
  - General Availability Since 2018
  - Introducing New Ribbon Spliced Option
- **Gen 5 OCS**
  - 1,000 Ports; 2,000 Fibers
  - General Availability Early 2024
- **Gen 6 OCS**
  - Up to 1,000 Ports and 32,000 Fibers
  - 8, 16, 32 Fibers per MT Connector
  - General Availability Late 2024

Software Applications

- **Rest API (Today)**
  - General Availability Since 2018
- **Inventory Database (Today)**
  - General Availability Since 2018
- **Optical Test & Validation (Today)**
  - General Availability Since 2021
- **Orchestrator (Today)**
  - General Availability Since 2022
- **Network Manager**
  - General Availability 2024

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Company Overview

- **Telescent Solution is Operationally Deployed**
  - Multiple production networks since Q4 2018
  - Estimated 1.3 million system hours to date, > 1 billion port hours
- **Fully Certified, Highly Reliable**
  - NEBS Level 3/Telcordia GR-63, GR-1089
  - Passed numerous successful Tier 1 customer certification trials (NTT, AT&T, etc.)
- **Production Outsourced to Flextronics in Austin, TX**
- **56 Patents Issued and Pending**
- **$40M Invested to Date**
- **Based in Irvine, California, USA (near Los Angeles)**
- **Unique Product with Compelling Price Point, Addresses Very Large Market, >100M Ports per Year**

Certified by Telcordia NEBS™ Level 3

flex

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Thank You

shine@telescent.com

gibbemeyer@telescent.com

info@moxnetworks.com

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