Distributed Environments evolution – the case of AMPATH/AmLight

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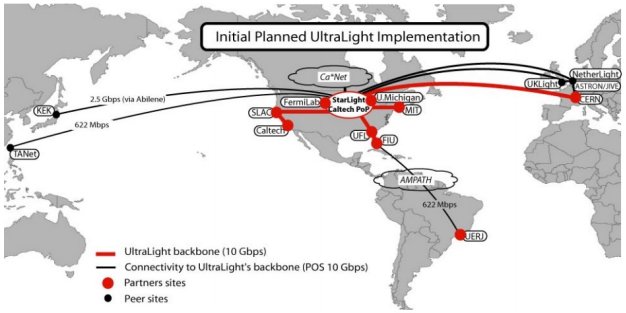
What is AMPATH?

AMPATH (Pathway of the Americas) (ASN 20080) is a high-performance Internet Open Exchange Point (OXP) in Miami, Florida, established in 2001. AMPATH facilitates peering and network research between U.S. and international Research and Education Networks (RENs) as well as direct links (e.g., UPR, UVI, NWS).

- Access to Internet2, Florida LambdaRail (FLR), Energy Sciences Network (ESnet)
- Access to AMPATH connectors and peers
- Access to the AtlanticWave Layer2 Transport service for national research networks
- Commodity Internet service through AMPATH's multi-homed connections to Tier-1 providers
- Settlement Free peering to more than 70 peers including Google, Akamai, Microsoft, Amazon, and NetFlix.
- Collocation Space
- Smart Hands and Engineering Service
- 120 Gbps of upstream bandwidth capacity via AtlanticWave and FLR

Back in the day…

Where it all started



2000

AMPATH PoP Operational

- ✓ 45 Mbps of bandwidth
- ✓ GSR 12012 router donated by Cisco Systems
- ✓ CBX-500 ATM switch donated by Lucent Technologies
- ✓ MOU for DS-3 capacity (9 countries for 3 years)
- ✓ Connectivity to I2 Abilene and StarLight

2001

AMPATH Inception

- ✓ Collaboration between FIU and Global Crossing
- ✓ REN interconnections
- ✓ Study current and emerging technologies
- ✓ Terremark and FIU signed RDA
- ✓ MOU signed with REUNA and RETINA

2002

AMPATH Service area

- ✓ First AMPATH™ International Conference
- ✓ Connected to Peru, Venezuela, Panama, Mexico, US Virgin Islands, and Colombia

2003

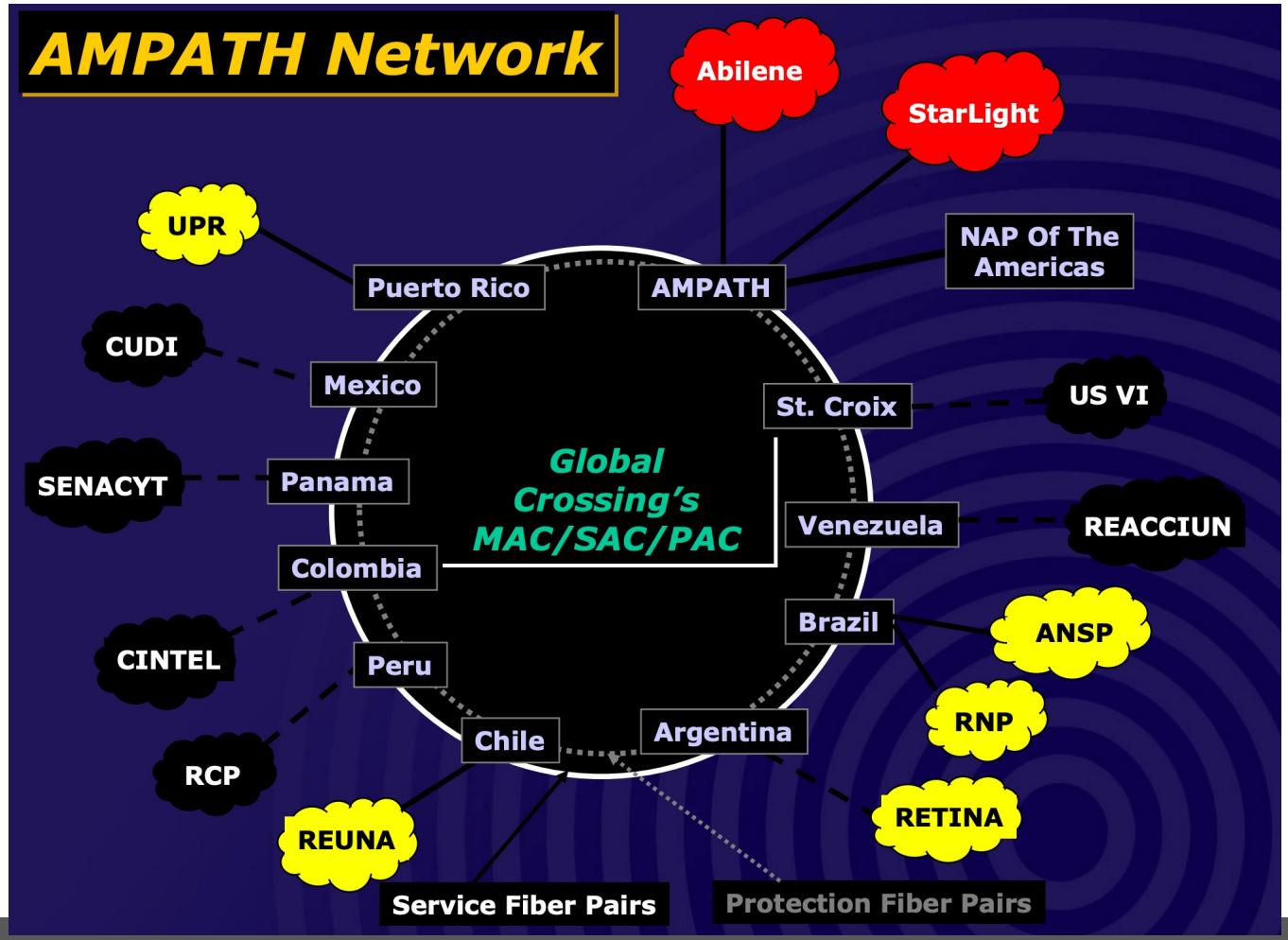
2004

- ✓ Working groups:
  - Astronomy
  - High-Energy Nuclear Physics (HENP)
  - Digital Data Collaboration
  - Atmospheric & Oceanographic
- ✓ CIARA was established at FIU
- ✓ RedCLARA established!
- ✓ Grid-enabled Center for High-Energy Physics Research and Educational Outreach (CHEPREO) at FIU
- ✓ Increased backbone capacity to 622 Mbps
- ✓ Supported the development and deployment of UltraLight

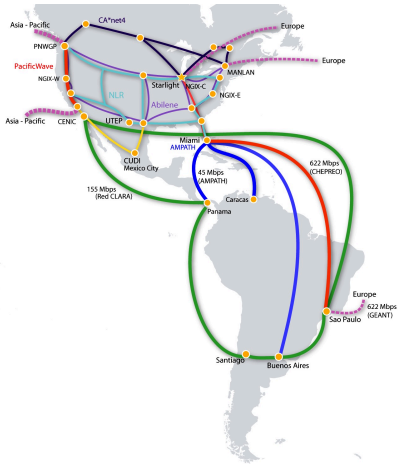
2002: First AMPATH™ International Conference - Universidad Austral de Chile, Campus Isla Teja Valdivia, Chile

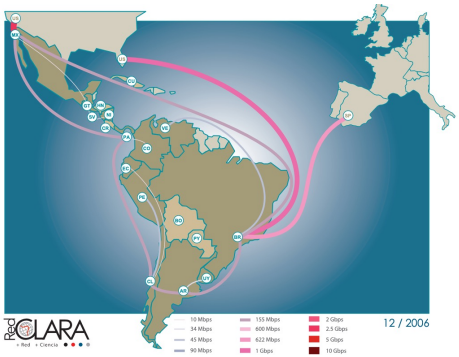
AMPATH Valdivia Group Report: https://ampath.net/ampath2/wp-content/uploads/2018/10/Valdivia_Report.pdf

2003: AMPATH Network



2005-2009





Increasing Discovery & Education Across the Americas
WHREN
Western Hemisphere Research & Education Networks

LILA
Links Interconnecting Latin America

2005

WHREN-LILA Initiatives

- ✓ 2x 1 Gbps San Diego to Tijuana
- ✓ 2.5 Gbps Miami to Sao Paulo
- ✓ 10 Gbps over 5 years
- ✓ Partnered with RedCLARA

Supported Pan American Advanced Studies Institute (PASI) Initiative

2006

Supported cyberinfrastructure for International Biodiversity Research Collaboration

2007

- ✓ Supported PLaNetS: Physics Lambda Network System
- ✓ Initiated the Global CyberBridges graduate fellowship program for science and engineering

2008

Florida LambdaRail joined Forces with CiscoWave and UltraLight/PLaNetS to enable the AtlanticWave and Brazil's CMS Tier2 facilities to participate in SC08

2009

AtlanticWave established a 10Gbps wave along the Atlantic rim, from NYC to Miami

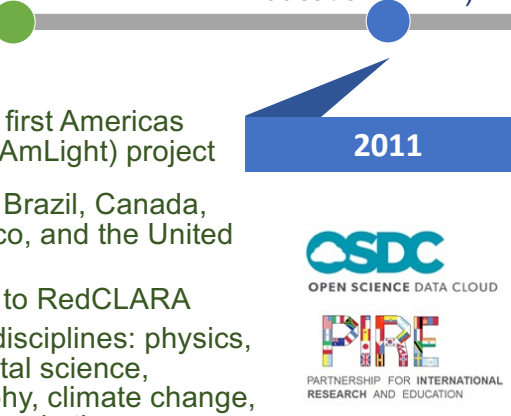
2010-2014

2010

- ✓ Initiated the first Americas Lightpaths (AmLight) project
- ✓ Connecting Brazil, Canada, Chile, Mexico, and the United States
- ✓ Connecting to RedCLARA
- ✓ Supported disciplines: physics, environmental science, oceanography, climate change, astronomy, and others

2011

- ✓ PrimoGENI coupled with AmLight network resources extends the GENI infrastructure to partnership programs in Brazil to prototype future Internet network architectures
- ✓ AMPATH to launched support for Dynamic Hybrid Networking
- ✓ Open Science Data Cloud (OSDC); Partnerships for International Research and Education (PIRE)



2012

- ✓ Initiated the FlowSurge project
- ✓ Experimented with OpenFlow and SDN
- ✓ South American Astronomy Coordination Committee (SAACC)

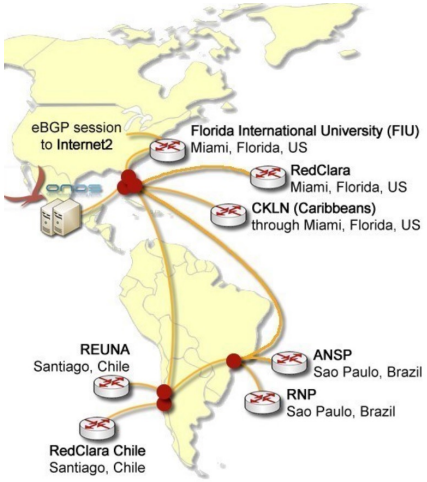
2013

- ✓ Upgraded the AmLight links between Brazil and U.S. RENs to 40 Gbps
- ✓ Deployed an experimental 100 Gbps alien wave between the U.S. and Brazil
- ✓ Dynamic virtual circuit service are available on AmLight

2014

- ✓ FIU awarded for AmLight to provide an advanced international network for the Vera Rubin Observatory
- ✓ AmLight network added Software-Defined Networking capability between the U.S. and Latin America

2015-2019



AtlanticWave SDX
INTERNATIONAL DISTRIBUTED SOFTWARE-DEFINED EXCHANGE

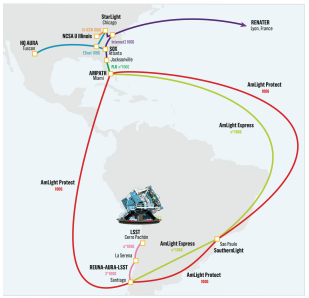
AmLight ExP
Americas Lightpaths Express & Protect

2015

- ✓ AmLight ExP activates first US - Latin America 100Gbps networking link
- ✓ Angola Cables and FIU signed of a memorandum of understanding (MOU)
- ✓ FIU implemented Science DMZ

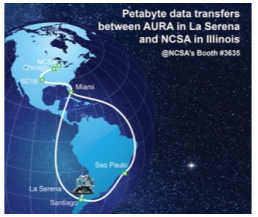
2016

- ✓ AtlanticWave-SDX: A Distributed Intercontinental Experimental Software Defined Exchange for Research & Education Networking
- ✓ AmLight deployed ONOS and SDN-IP software live on Next-Generation REN
- ✓ AmLight ExP project implements a hybrid network strategy that combines the use of optical spectrum (Express) and leased capacity (Protect)



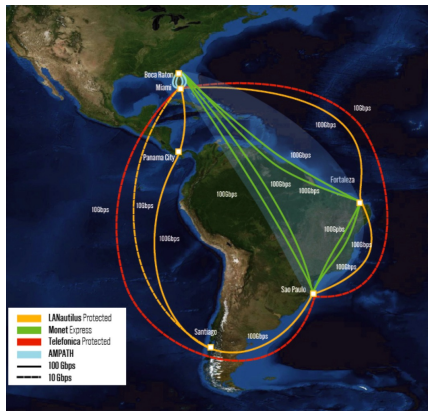
2017

- ✓ AmLight-Exp network demonstrated a large data-sets transfer at SC17
- ✓ Supported inter-domain coordination to leverage multiple academic network operators to support Vera Rubin Observatory data transfer



2018

- ✓ Vera Rubin Observatory's first light resulted in a successful transfer of digital data over International AmLight 100 Gbps fiber optic networks
- ✓ AmLight's SDN Looking Glass – An SDN centralized monitoring system



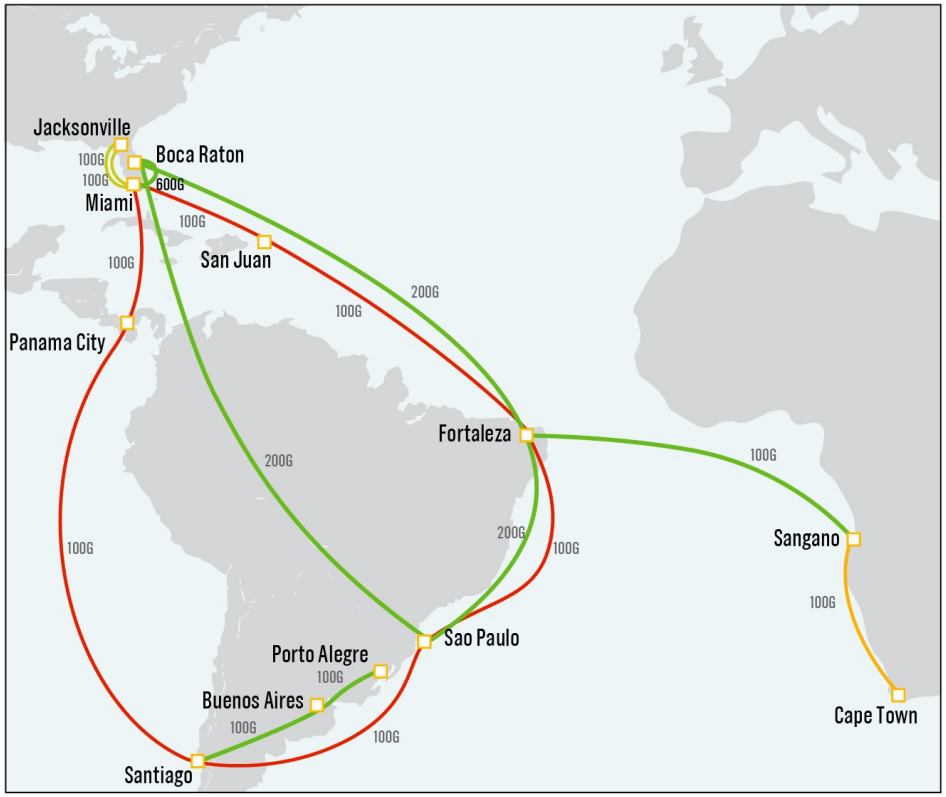
2019

- ✓ AmLight ExP project added 3x 200 Gbps optical waves for R&E between the U.S. and Brazil
- ✓ AmLight ExP introduced In-band Network Telemetry (INT)
- ✓ 630 Gbps of upstream bandwidth, network auto-recovery and dynamic provisioning, network programmability, integration with SENSE project's distributed orchestrator, and 100Gbps DTNs

2020-2021

2020

- ✓ AmLight ExP interconnected three continents by activating 100Gbps end-to-end links between the U.S., Brazil and South Africa (NSF award # 1451018)
- ✓ IRNC: Core Improvement: Americas-Africa Lightpaths Express and Protect (AmLight-ExP) (NSF award #2029283)
- ✓ IRNC: Core Improvement: AtlanticWave-SDX: A Distributed Experimental SDX Supporting Research, Experimental Deployments, and Interoperability Testing on Global Scales (NSF award #2029278)
- ✓ CC* Integration-Large: Q-Factor: A Framework to Enable Ultra High-Speed Data Transfer Optimization based on Real-Time Network State Information provided by Programmable Data Planes (NSF award #2018754)



2021

2021

AmLight ExP
Americas Lightpaths Express & Protect
(NSF Award # ACI-2029283)

Americas-Africa Lightpaths Express and Protect (AmLight-ExP)

The goal of the newly funded AmLight ExP project (NSF Award #2029283) is to operate and continuously improve production and experimental network connections between the USA, Latin America and Africa:

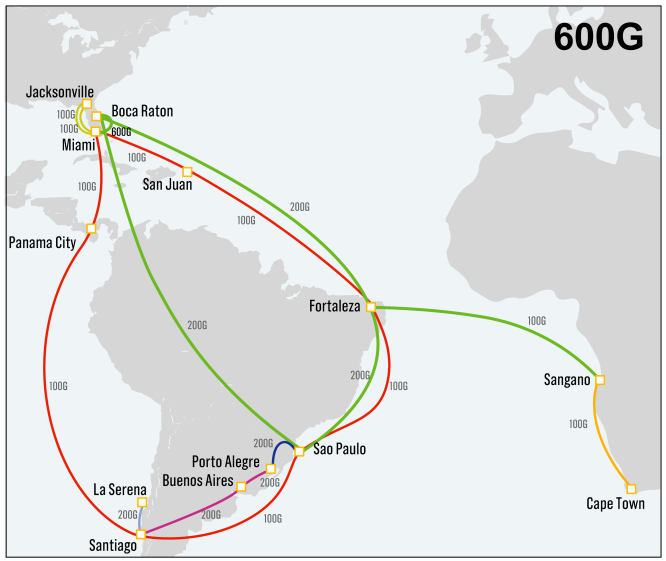
- ✓ **Evolving the AmLight-ExP physical infrastructure**: The upgraded network infrastructure will support new high-demand SLA-based science drivers.
- ✓ **Evolving the AmLight-ExP SDN Controller**: With the existing infrastructure, AmLight ExP has presence in 3 continents, 10 data centers, and a forwarding layer that includes 25+ 100Gbps links. On top of this complex infrastructure, many services are provided, such as L2VPNs, L3VPNs, cloud services, R&E IP Transit, including dynamic services and testbeds. The AmLight-ExP SDN Controller will be enhanced to increase automation of many network functions and improve resiliency.

2021

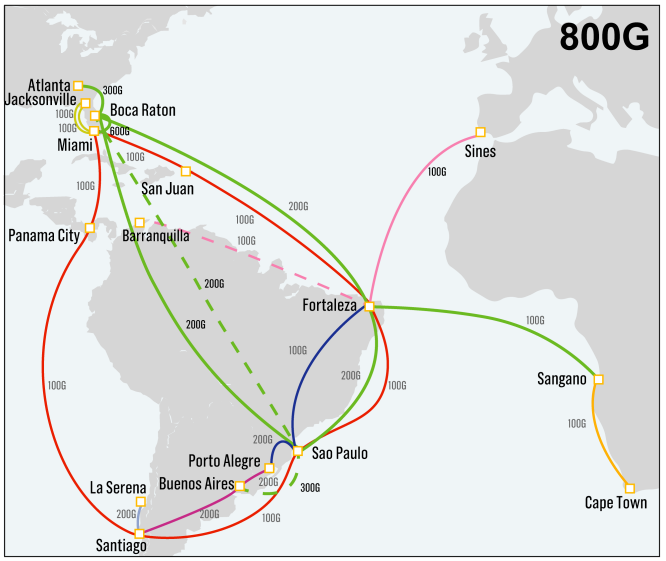
2021

AmLight ExP
Americas Lightpaths Express & Protect
(NSF Award # ACI-2029283)

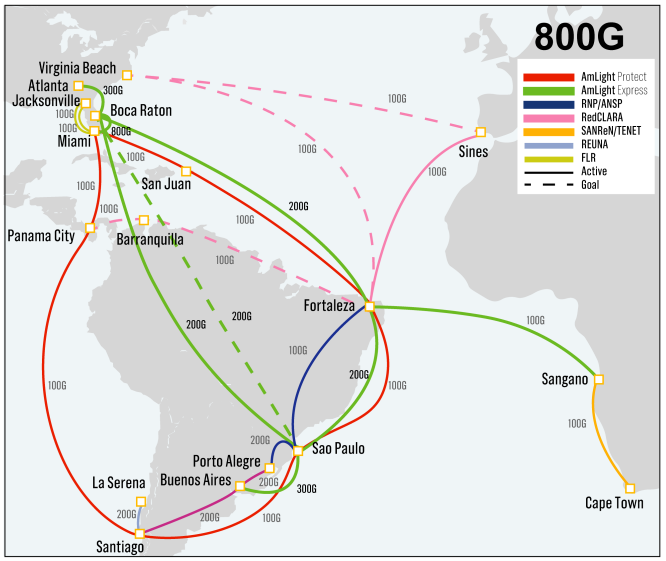
Americas-Africa Lightpaths Express and Protect (AmLight-ExP)



2020



2021-2023



2024-2026

2021

2021

AtlanticWave-SDX 2.0

A Distributed Experimental SDX Supporting Research, Experimental Deployments, and Inter operability Testing at Global Scale

(NSF Award #2029278)

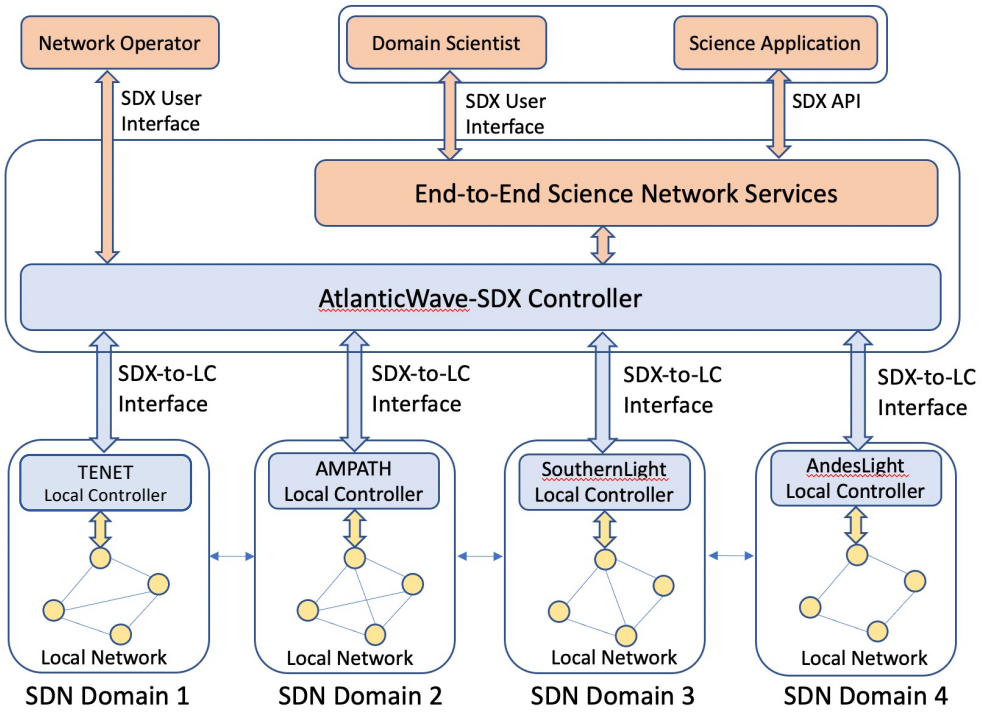
GOALS:

To build a distributed SDX between the Americas and Africa (NSF award #2029278)

- ✓ Building a distributed intercontinental experimental SDX by leveraging Open Exchange Points (OXPs) connected to AmLight ExP
- ✓ The project also includes collaboration with the Open Science Grid (OSG) and Pegasus workflow management system.

To enable domain scientists to reserve network resources through a multi-domain SDX by

- ✓ Simplifying the interface for domain scientists to request network resources
- ✓ Providing interfaces to program the forwarding plane to respond to application requirements



Over 34 National Science Foundation (NSF) Awards

Over 20 years of service to the research communities

600GB links connecting 3 continents

Conclusion

We covered 20 years of evolution starting from a PoP in Miami to a distributed Open Exchange Point Infrastructure that:

- ✓ Connected three (3) continents: South America , North America, and Africa
- ✓ Increased bandwidth capacity from 45 Mbps to multiple 100/200 Gbps links, total upstream capacity of 600 Gbps
- ✓ Evolved a rational international infrastructure through collaborations with RENs and global R&E community
- ✓ Evolved a production and experimental international backbone infrastructure based on SDN technology
- ✓ Connected six (6) OXPs
- ✓ Deployed an international backbone using a hybrid environment of optical spectrum and leased capacity
- ✓ Supported varieties of science drivers
- ✓ Involved researchers and students
- ✓ …. and we are not finished yet

Over 81 academic publications

209 students involved via various programs and internships

Over 200 Conference presentations

Over 34 National Science Foundation (NSF) Awards

Over 20 years of service to the research communities

600GB links connecting 3 continents

THANK YOU!

vchergar@fiu.edu

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Acronyms

AmLight - Americas Lightpaths
AmLight ExP - Americas-Africa Lightpaths Express and Protect
AMPATH -Pathway of the Americas
ANSP- Academic Network of Sao Paulo, currently named REDNESP
AutoGOLE - Automated GLIF Open Lightpath Exchanges
CHEPREO - Grid-enabled Center for High-Energy Physics Research and Educational Outreach
CIARA - Center for Internet Augmented Research and Assessment
ESnet - Energy Sciences Network
FIU - Florida International University
FLR - Florida LambdaRail
GENI -Global Environment for Network Innovations
GLIF - Global Lambda Integrated Facility
HENP - High-Energy Nuclear Physics
HEPGRID - High Energy Physics GRID Rio de Janeiro
INT - In-band Network Telemetry
LHC - Large Hadron Collider
MOU - Memorandum of Understanding
NWS - New World Symphony
OSDC - Open Science Data Cloud
OSG - Open Science Grid
OXP - Open Exchange Point
PASI - Pan American Advanced Studies Institute
PIRE - Partnerships for International Research and Education
PLaNetS- Physics Lambda Network Services
QoS - Quality of Service
RDA - Research and Development Agreement
RedCLARA - Regional Research and Educational Network for Latin America
REN - Research and Education Network
RETINA - Argentinian Research and Educational Network
REUNA - Chileans Research and Educational Network
RNP - National Education and Research Network of Brazil
SAACC - South American Astronomy Coordination Committee
SDN - Software Defined Networking
SENSE - SDN for End-to-End Networking @ Exascale
SNMP - Simple Network Management Protocol
SouthernLight GLIF Open Lightpath Exchanges Sao Paulo
SPRACE - Sao Paulo Research and Analysis Center
UPR -University of Puerto Rico
UVI - University of the Virgin Islands
WHREN-LILA - Western Hemisphere Research and Networking and the Links Interconnecting Latin America