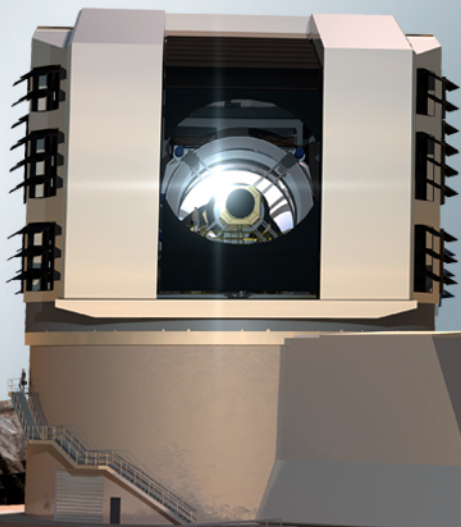




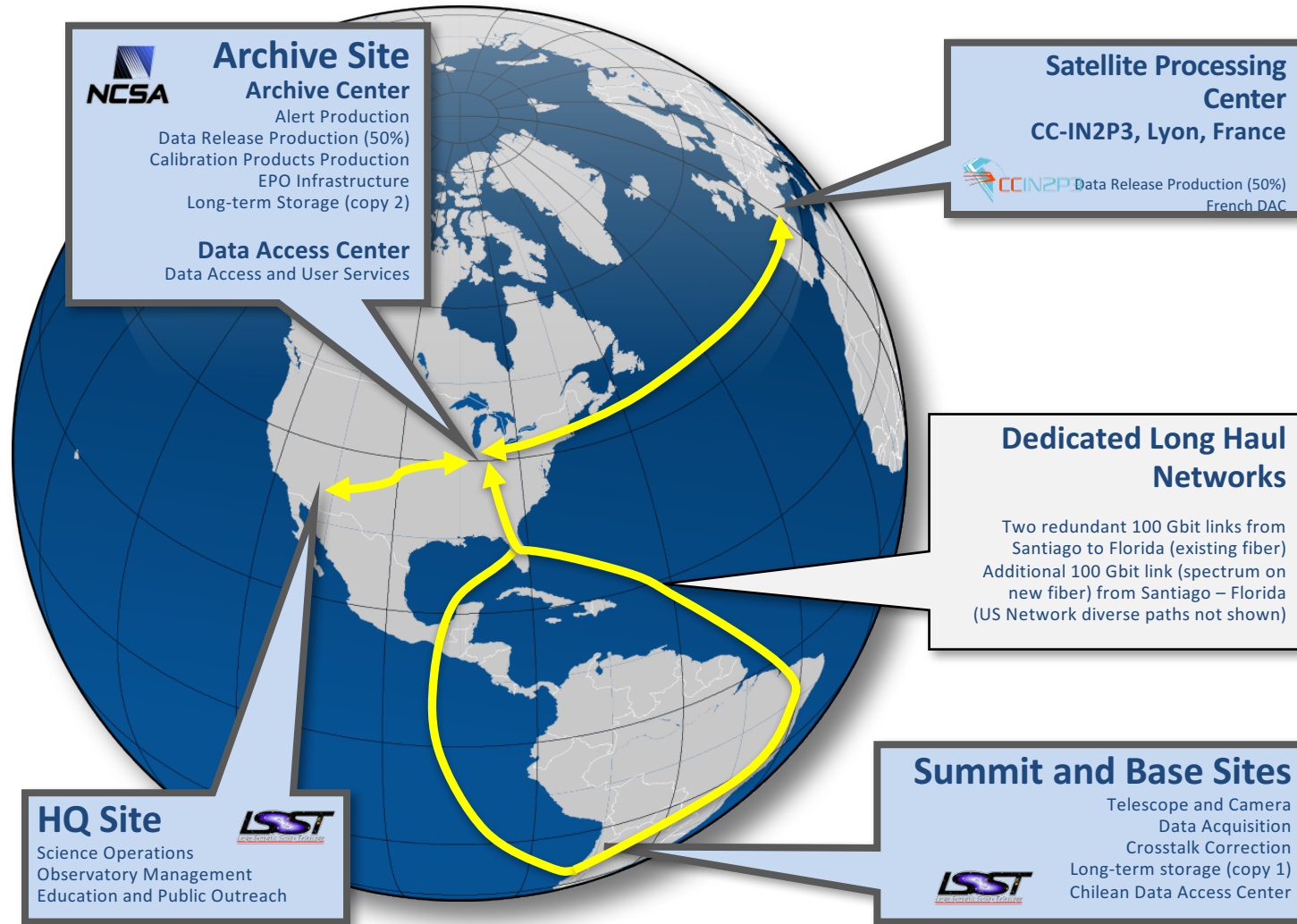
Networking for the Large Synoptic Survey Telescope (LSST)

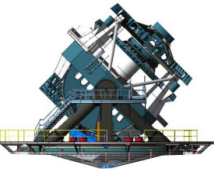
Jeffrey Kantor
Technical/Control Account Manager



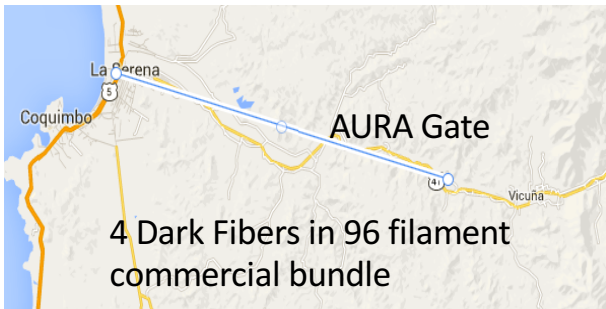


LSST Sites and Connections

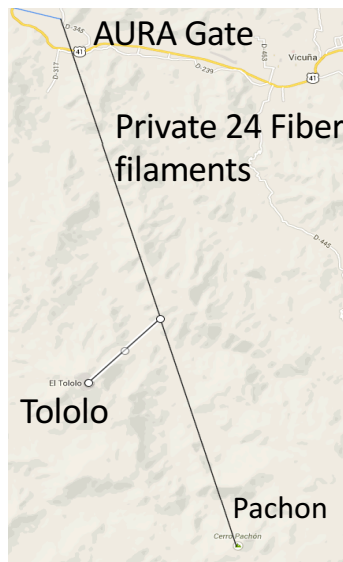




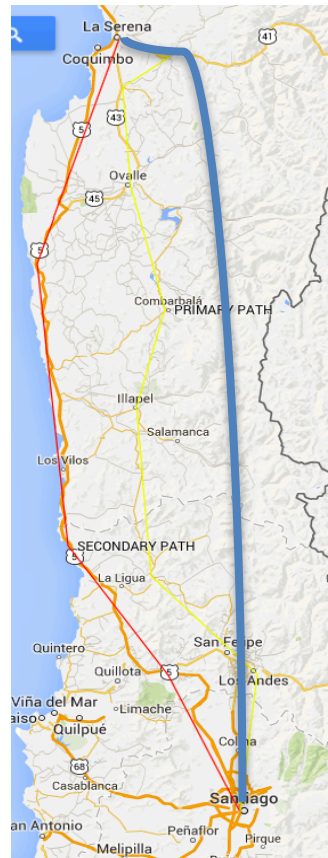
Chilean National WAN



Three main Telecoms investing in a fiber bundle for an alternate route from La Serena to Vicuña and Santiago. AURA will have an 18 year IRU (2016-2034) with REUNA for 4 dark fiber filaments in this bundle.



Telefonica will install a private 12 fiber pair bundle for the sole use of LSST and AURA.



Blue line indicates the path in which REUNA will have a dark fiber pair.

AURA/LSST and REUNA will each utilize a 100G circuit. LSST will occupy one 100Gbs circuit. Other AURA traffic will flow over the REUNA 100G circuit.

AURA will have an optional additional 9 x λ s within this pair, each of which can be 10,40,100Gbs

Red line indicates the legacy Pan American route where LSST will have 4Gb between 2016 and 2019 which will increase ≥ 40 Gb as a diverse path

LSST Long-Haul Networks are contract-dominated



- 02C.08.03.01 Chile National WAN
 - 02C.08.03.01.01 Contract 1 La Serena - Santiago Network
 - 02C.08.03.01.01A Contract 1a La Serena - Gatehouse Network
 - 02C.08.03.01.02 Contract 2 Liello Consultancy
 - 02C.08.03.01.03 Contract 3 Gatehouse - Summits Network
 - 02C.08.03.01.04 Contract 4 DWDM Equipment
 - 02C.08.03.01.05 Contract 5 Operating
- 02C.08.03.02 International Chile - US WAN
 - 02C.08.03.02.01 Contract 1 100 Gbps Managed Ring
 - 02C.08.03.02.02 Contract 2 FIU-CIARA Management
 - 02C.08.03.02.03 Contract 3 Spectrum
 - 02C.08.03.02.04 Contract 4 US National WAN

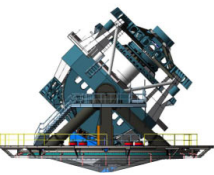


Chilean Network Milestones



- La Serena – Santiago secondary path operational at 4 Gbps by April, 2016 (complete)
- La Serena – AURA Gatehouse path operational by November, 2016
- Summits – Gatehouse path operational by January, 2017
- LSST DWDM Network Equipment complete by April, 2017
- La Serena – Santiago primary path operational by March, 2018
- La Serena – Santiago secondary path operational at 40 - 100 Gbps by October, 2019

LSST November 2016 Month End Baseline			FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024	FY2025
Activity Name	Start	Finish	2014-10-01	2015-10-01	2016-10-01	2017-10-01	2018-10-01	2019-10-01	2020-10-01	2021-10-01	2022-10-01	2023-10-01	2024-10-01
Total	28-Sep-15	15-Oct-19											
Chilean Contract 1 La Serena-Santiago Fiber	28-Sep-15	15-Oct-19											
La Serena to Santiago Path Design Ready	28-Sep-15	28-Sep-15		La Serena to Santiago Path Design Ready									
Technical Implementation plan of fiber connection (primary link) - Complete		15-Dec-15		Technical Implementation plan of fiber connection (primary link) - Complete									
Fiber Delivery Ready		16-Dec-15		Fiber Delivery Ready									
Delivery of "functional Pre-operations Link" (at least 4Gbps), Ready		15-Apr-16		Delivery of "functional Pre-operations Link" (at least 4Gbps), Ready									
Delivery of 4Gbps link from La Serena to Santiago Ready - Complete		15-Apr-16		Delivery of 4Gbps link from La Serena to Santiago Ready - Complete									
3T Fiber Installation Certification and Acceptance Test - Complete		02-Jan-17		3T Fiber Installation Certification and Acceptance Test - Complete									
La Serena – Santiago link Ready		15-Mar-17		La Serena – Santiago link Ready									
Equipment Installation and Acceptance Test - Complete		15-Mar-17		Equipment Installation and Acceptance Test - Complete									
La Serena to Santiago with test traffic flowing over LSST Lambda Ready		29-Dec-17		La Serena to Santiago with test traffic flowing over LSST Lambda Ready									
Intermediate traffic testing and report - Complete		29-Dec-17		Intermediate traffic testing and report - Complete									
La Serena to Santiago with live traffic and uptime over LSST Lambda Ready - Compl		15-Mar-18		La Serena to Santiago with live traffic and uptime over LSST Lambda Ready - Compl									
Report on functional fiber, including uptime, 1st year functional milestone - Complete		02-Jan-19		Report on functional fiber, including uptime, 1st year functional milestone - Complete									
Technical Implementation Plan for 40Gbps diverse path - Complete		15-Mar-19		Technical Implementation Plan for 40Gbps diverse path - Complete									
Full Capacity over Diverse path Ready		15-Oct-19		Full Capacity over Diverse path Ready									
Full capacity La Serena to Santiago over Primary link AND Secondary link - Complete		15-Oct-19		Full capacity La Serena to Santiago over Primary link AND Secondary link - Complete									
Chilean Contract 1A La Serena-Gatehouse Fiber	15-Dec-15	05-Apr-17											
La Serena-Gatehouse path design Ready		15-Dec-15		La Serena-Gatehouse path design Ready									
Gatehouse to La Serena path design Ready - Complete		16-Dec-15		Gatehouse to La Serena path design Ready - Complete									
Fiber delivery - Complete		15-Mar-16		Fiber delivery - Complete									
Report on functional fiber connections, including AURA equipment - Complete		15-Aug-16		Report on functional fiber connections, including AURA equipment - Complete									
End of commissioning, Acceptance of fiber connection - Complete		05-Apr-17		End of commissioning, Acceptance of fiber connection - Complete									
Chilean Contract 3 Summits-Gatehouse Fiber	15-Jan-16	01-Jun-17											
Mountain - Base Fiber Path Ready		15-Jan-16		Mountain - Base Fiber Path Ready									
Gatehouse to Summit contract signed; Design Ready - Complete		15-Jan-16		Gatehouse to Summit contract signed; Design Ready - Complete									
Summits-Gatehouse Fiber Ready		28-Feb-17		Summits-Gatehouse Fiber Ready									
Fiber delivery by Telefonica - Complete		28-Feb-17		Fiber delivery by Telefonica - Complete									
Summits-Gatehouse Initial Capability Ready		01-Jun-17		Summits-Gatehouse Initial Capability Ready									
End of commissioning and Acceptance - Complete		01-Jun-17		End of commissioning and Acceptance - Complete									
Chilean Contract 4 Network Equipment Purchase/Contract	01-Jun-16	05-Apr-17											
Vendor selection Ready		01-Jun-16		Vendor selection Ready									
Final Selection of equipment vendor - Complete		01-Jun-16		Final Selection of equipment vendor - Complete									
Mountain - Base LSST DWDM End Node Installation and Test Ready		04-Apr-17		Mountain - Base LSST DWDM End Node Installation and Test Ready									
REUNA La Serena - Santiago DWDM equipment - Complete		04-Apr-17		REUNA La Serena - Santiago DWDM equipment - Complete									
LSST and AURA summit to base DWDM equipment - Complete		05-Apr-17		LSST and AURA summit to base DWDM equipment - Complete									

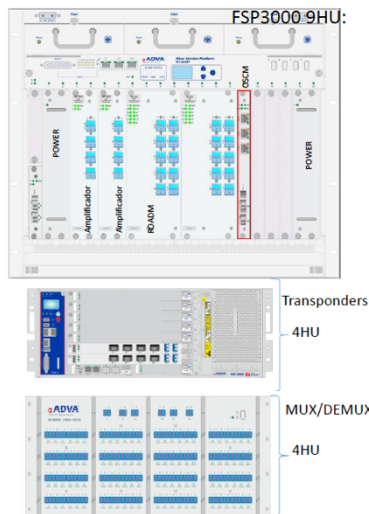


DWDM Equipment



- Conducted 9 rounds of bids with 9 vendors
- Separate purchases (REUNA and AURA)
 - La Serena – Santiago with line item for replacement
 - Base – Summit with line item for replacement
- Procurement in process

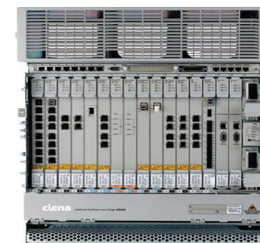
ADVA



PADTEC



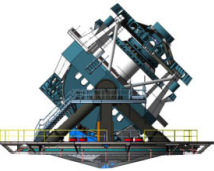
CIENA 6500



INFINERA



- Simple Rack and Stack Design
- 1 Tb/s of Line + Client Capacity
- Client: 10GbE, 40GbE, 100GbE
- Line: 500Gb/s WDM Super-channel
- Instant Bandwidth
- CLI, NMS or SDN Control
- 2 RU, 19 inch rack, AC or DC power 450W



- 100G Ethernet ring until 2032
- Subcontractor to FIU includes LATIN AMERICAN NAUTILUS (Telecom Italia)
- LSST 2018-2032 ring



- Spectrum on new fiber
- Combination of investors
- Provides primary, exclusive LSST path Santiago-Boca Raton

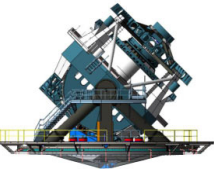


International and US Network Milestones



- 100 Gbps Ring is operational end of FY17
- Spectrum link is operational end of FY18
- US National network is operational end of FY19
- Subsequent deliveries improve reliability and services

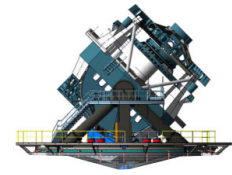
LSST November 2016 Month End Baseline			FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024	FY2025
Activity Name	Start	Finish	2014-10-01	2015-10-01	2016-10-01	2017-10-01	2018-10-01	2019-10-01	2020-10-01	2021-10-01	2022-10-01	2023-10-01	2024-10-01
Total	01-Oct-15	18-Aug-21											
International Contract 1 100G managed ring	01-Oct-15	28-Sep-20											
First Data passed on 100G ring without errors - Complete		01-Oct-15		First Data passed on 100G ring without errors - Complete									
100G ring operating at 95.0% availability - Complete		28-Sep-16			100G ring operating at 95.0% availability - Complete								
Santiago - Miami Early Integration Ready		26-Sep-17				Santiago - Miami Early Integration Ready							
100G ring operating at 97.0% availability - Complete		26-Sep-17					100G ring operating at 97.0% availability - Complete						
100G ring operating at 98.0% availability - Complete		26-Sep-18						100G ring operating at 98.0% availability - Complete					
100G ring operating at 99.0% availability - Complete		27-Sep-19							100G ring operating at 99.0% availability - Complete				
100G ring operating at 99.99% availability - Complete		28-Sep-20								100G ring operating at 99.99% availability - Complete			
International Contract 2 FIU-CIARA Management	30-Sep-16	18-Aug-21											
International Contract 3 Spectrum Contract	30-Jun-17	29-Jun-18											
Agreement with Monet Cable Partner signed Complete		30-Jun-17				Agreement with Monet Cable Partner signed Complete							
First light test report - Complete Contract		29-Sep-17				First light test report - Complete Contract							
Santiago - Boca Raton Early Integration Ready		29-Jun-18					Santiago - Boca Raton Early Integration Ready						
Data passing test report - Complete		29-Jun-18					Data passing test report - Complete						
International Contract 4 US National Network	24-Apr-17	30-Sep-20											
VLAN design finalized Miami-NCSA - Complete		24-Apr-17			VLAN design finalized Miami-NCSA - Complete								
Miami - Chicago Early Integration Ready		26-Sep-18					Miami - Chicago Early Integration Ready						
Boca Raton - Chicago Early Integration Ready		26-Sep-18						Boca Raton - Chicago Early Integration Ready					
ESNet Request - Complete		26-Sep-18						ESNet Request - Complete					
ESNet Implementation Phase 1 - Complete		30-Sep-19							ESNet Implementation Phase 1 - Complete				
Miami - Chicago Full Integration Ready		30-Sep-19							Miami - Chicago Full Integration Ready				
Boca Raton - Chicago Full Integration Ready		30-Sep-19								Boca Raton - Chicago Full Integration Ready			
ESNet Implementation Phase 2 - Complete		30-Sep-20								ESNet Implementation Phase 2 - Complete			



FY16 Accomplishments



- La Serena – Santiago primary fiber installed, waiting on Ministry paperwork to activate
- La Serena – Santiago secondary path configured, tested, and accepted (at 4 Gbps)
- La Serena – AURA Gatehouse fiber installed up to Highway 41 turnoff to AURA Gatehouse, “last mile” to be installed at same time as AURA – Gatehouse – Summits fiber
- AURA Gatehouse – Summits fiber contract split out and awarded to Telefonica, first phase (survey route) complete, installation complete by January, 2017
- DWDM equipment procurement
- 100 Gbps Ring East and West side fibers in place and operating at 95.0% availability, Santiago peering for Santiago – Sao Paulo and LSST DWDM equipment by April, 2017



“Bang for the Buck”



- Leveraging joint, multi-national investments in fiber optic networks yielded 10x cost reduction to LSST
 - “3T” fiber in Chile from La Serena – Santiago
 - 100 Gbps ring Santiago – Miami
 - Monet Cable Sao Paulo – Boca Raton
 - Net to LSST 140 – 200 Gbps diverse paths in Chile
 - Net to LSST 300 Gbps (100 Gbps spectrum) diverse paths Chile – US
 - LSST MREFC investment ~\$20M
 - Net Value ~\$200M (if leased commercially)



Summary



- LSST Networks support distributed operations across 3 continents
- LSST is employing a high degree of leverage in joint, multi-institution investments in high-speed fiber optic networks
- LSST remains on track to achieve unparalleled level of network bandwidth and services for South American – North American astronomical research