Airglow (green) above Cerro Pachón, Chile; Credit: International Gemini Observatory/NOIRLab/AURA/NSF/M. Paredes

South American- African Astronomy Coordination Committee (SA3CC) Meeting Report

April 19-20, 2022

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Executive Summary

This report documents the proceedings of the AmLight SA3CC Meeting, on April 19-20, 2022, from the astronomy community and the Research & Education Networks (REN) of the AmLight project. Researchers from universities, organizations and research institutions from the USA, Latin America, Africa, and Europe participated. The SA3CC Meeting was comprised of two sessions: Science Requirements & Activities Updates, and Providers updates.

The Science Requirements & Activity updates session started with welcome remarks and introductions by the Co-Chairs (Julio Ibarra and Robert Blum followed by presentations from Vera C. Rubin Observatory, NOIRLab, NRAO, ALMA, CCAT, GMTO, Simons Observatory, CMB-S4, ngVLA, ngEHT. A lively open discussion followed. The Providers updates session included network presentation updates including AmLight-ExP, REUNA, RedCLARA, RNP, TENET/SANReN, ESnet, Internet2, SLAC and concluded with Open Discussion and Coordination.

1. Introduction

The South American-African Astronomy Coordination Committee (SA3CC) is comprised of representatives from the various astronomy projects that conduct science and operate observatories in the Americas and Africa. The SA3CC meeting was hosted virtually by Florida International University (FIU) on April 19-20, 2022, from 11am to 4 pm to accommodate the different time zones. The meeting program can be found here: https://www.amlight.net/?p=4820. A Zoom registration was used to document participation and a SA3CC 2022 Participant Guide was created to better accommodate the virtual meeting presentations and discussions. The guide can be found here:
https://docs.google.com/document/d/18mJZJKe-Vz58yj0tWKEA4h0wkHV_LKOwYpzK_tCWenQ/edit

The two-day meeting gathered 72 astronomy researchers and network engineers (See Appendix A & C for the agenda and participants list). Presentations and lively discussion took place among representatives from the astronomy community and representatives from National Research and Education Networks. The following organizations attended:

- AMPATH International Exchange Point in Miami
- Association of Universities for Research in Astronomy (AURA)
- Atacama Large Millimeter/submillimeter Array (ALMA)
- Brazilian National Research and Educational Network (RNP)
- Center for Astrophysics, Harvard & Smithsonian
- Cerro Chajnantor Atacama Telescope (CCAT)
- Cherenkov Telescope Array (CTA) Observatory
- Chilean Research and Educational network (REUNA)
- Cosmic Microwave Background Stage 4 (CMB-S4)
- Council for Scientific and Industrial Research (CSIR) South Africa
- Energy Science Network (ESnet) at Lawrence Berkeley National Laboratory
- European Research and Educational network (GEANT)
- European Southern Observatory (ESO)
- Fermi National Accelerator Laboratory (Fermilab)
- Florida International University (FIU)
- France Research and Educational network (RENATER)
- Giant Magellan Telescope Observatory (GTMO)

- Indiana University
- Information Sciences Institute (ISI) University of Southern California (USC)
- International Center for Advanced internet Research Northwestern University
- Internet2
- Korea Institute of Science and Technology Information (KISTI/KREONET)
- Laboratorio Interinstitucional e-Astronomia (LIneA) Brazil
- Laboratório Nacional de Astrofísica (LNA)
- Latin American Advanced Networks Cooperation (RedCLARA)
- Lawrence Berkeley National Laboratory (Berkeley Lab)
- National Radio Astronomy Observatory (NRAO)
- National Science Foundation (NSF)
- NSF's National Optical-Infrared Astronomy Research Laboratory (NOIRLab)
- Research and Education Network at Sao Paulo (rednesp)
- São Paulo Research Foundation (FAPESP)
- Simons Foundation
- SLAC National Accelerator Laboratory
- Smithsonian Astrophysical Observatory (SAO)
- South African National Research Network (SANReN)
- South African Radio Astronomy Observatory (SARAO)
- Square Kilometre Array (SKA) Organization
- Tertiary Education and Research Network of South Africa (TENET)
- University of California at San Diego (UCSD)
- University of Sao Paulo (USP)
- Vera C. Rubin Observatory

Spring 2022 Vera Rubin Observatory Network Engineering Team (NET) Meeting
The Network Engineering Taskforce (NET) annual meeting took place on April 21-22, 2022, from 11 am to 4 pm following the SA3CC meeting. The NET meeting was by invitation only and focused on objectives of continuing the planning, development, and deployment of a collaborative network to support the needs of the Vera Rubin Observatory in Chile.

The two-day meeting gathered 37 network engineers from REUNA, AmLight/FIU, SLAC, ESnet, I2, IN2P3, REDNSP, RNP, Vera Rubin Observatory, AURA, RENATER, GEANT, In2p3, TENET/SANReN, and technical astronomy engineers (See Appendix B & D for the agenda and participants list). An online guide was created to guide the participants discussions and contributions during the virtual meeting. The guide can be found here:
https://docs.google.com/document/d/12anyMY-dMlUFIt_vF3WlYlJQK555TNcM/edit

2. Goals and Objectives of the AmLight SA3CC Meeting

AmLight-ExP builds upon the results of the WHREN-LILA project, Award# OCI-0441095, and the AmLight IRNC project, Award# ACI-0963053. Over the last 15 years, these projects have effectively built and supported a cooperative and collaborative consortium among R&E network providers and users in the Western Hemisphere. The success of previous U.S. & Latin American networking activities has led to a groundswell of change for research instruments. Data-intensive instruments and data dependent instruments are being located in South America. The Vera Rubin Observatory is a significant example of a data-dependent instrument and has from the beginning been part of the planning for AmLight-ExP (NSF award # 1451018 and #2029283). The focus of AmLight-ExP is an open instrument for collaboration that interconnects open exchange points. AmLight-ExP provides a means to leverage collaborative provisioning and network operations that effectively maximizes the benefits to all members of the consortium. AmLight-ExP manages the NSF investment in the context of leveraging international partnerships to attain the greatest benefits for all participants. See Appendix A for the agenda.

A key goal of the SA3CC meeting is to gather input and collect information from participants about the activities of the astronomy projects and the R&E networks supporting them. Questions and comments posed during each presentation were recorded using Zoom. The recordings can be found here:
https://www.youtube.com/watch?v=IGtnJ14vC5k&list=PLqEq6vGwyln_9i_Lin70L1KMyY9UrGGYV

3. Activities of the SA3CC Meeting

The meeting was organized in two sessions and presentations (See appendix A) from the following institutions were included:

Science Requirements & Activities Updates

- Vera C. Rubin Observatory Operations (Bob Blum, Christian Silva)
- NOIRLab – ITOPS (Chris Morrison / Mauricio Rojas / Eduardo Toro)
- NRAO, ngVLA (David Halstead, Adele Plunkett)
- ALMA (Christian Saldias, Nicolas Ovando)
- Simons (Simone Aiola)
- CMB-S4 (Eli Dart)
- MeerKAT (Bradley Frank)
- CCAT (Mike Nolta)
- GMTO (Sam Chan)
- US-ELT (Marie Lemoine-Busserolle)

R&E Providers Updates

- AmLight1: International links (Jeronimo Bezerra)
- AmLight2: Monitoring and Measurement Improvements (Renata Frez)
- SANReN/TENET (Shukri Wiener)
- REUNA (Albert Astudillo)
- REDNESP (Joao Eduardo Ferreira)
- RedCLARA (Luis Eliécer Cadenas)
- RNP (Aluizio Hazin)
- USDF infrastructure (Mark Foster)
- USDF data movement and multi-site processing (Richard Dubois)
- Internet2 (Chris Wilkinson)
- ESnet (Paul Wefel)

4. Science Requirements & Activities Updates

4.1 Vera Rubin Observatory Construction (Robert Blum, Rubin Observatory Senior Manager & Cristian Silva, Rubin Observatory IT Manager Chile)

Vera Rubin Observatory's vision and mission support the science priorities for the community.

Vision: By acquiring, processing, and making available the vast dataset collected with the Vera C. Rubin Observatory, the Legacy Survey of Space and Time (LSST) will provide the community with the data to address some of the most fundamental questions in astrophysics, advance the field of astronomy, and engage the public in the discovery process.

Mission: Produce an unprecedented astronomical data set for studies of the deep and dynamic Universe, make the data widely accessible to a diverse community of scientists, and engage the public to explore the Universe with us.

Figure 1 Vera Rubin Observatory

Four driving science themes define the Vera Rubin Observatory system and operations plan:

- Probing Dark matter & Dark Energy
- Inventory of the Solar System
- Mapping the Milky Way
- Exploring the Transient Optical sky

Vera Rubin Observatory operates as an integrated system that includes: the Summit & Base sites, US data facility (SLAC California, US), Headquarter Site (AURA, Tucson, Arizona, US), Dedicated Long Haul Networks, UK data facility (IRIS network, UK), and French Data Facility (CC-IN2P3 Lyon, France).

The current first light and survey schedule includes:

- Engineering First Light, mid-2023
- LSSTCam First Light, late 2023
- Rubin Operations is planning for full survey operations on April 1, 2024

The dates have an appropriate uncertainty, following the effect of the lockdown from the COVID-19 pandemic, and the interruption of the supply chain for the last two years. Currently, the Dome facility is completed in the Chilean mountain, and ongoing work on the control system and software facility tests are in progress. In addition, the camera (currently in SLAC) is integrated and tested and expected to be shipped to Chile by the end of the year 2022. Current progress on the network infrastructure includes Installation of the Tucson Test Stand (TTS), Internal network review, NSCA Test Stand (NTS) dismantled and soon to become Base Test Stand (BTS), backup link to Summit is in progress, and cybersecurity improvements.

There are simulated data releases in collaboration with Dark Energy Science that aim to prepare the community by providing an early dataset for science through Data Preview. Vera Rubin Observatory data sets and tools will be ideal for reaching new audiences and engaging underserved communities without the resources to join astronomy research fully. All algorithms, pipelines, and tools will be open source.

4.2 NSF's National Optical-Infrared Astronomy Research Laboratory (NSF's NOIRLab) (Christopher Morrison, Head of IT operations NOIRLab; Mauricio Rojas, Eduardo Toro, CTIO NOAO)

The mission of NOIRLab is to enable breakthrough discoveries in astrophysics by developing and operating state-of-the-art ground-based observatories and providing data products and services for a diverse and inclusive community.

The NOIRLab programs include Mid-scale Observatories (MSO), Community Science and Data Center (CSDC), GEMINI Observatory, Kitt Peak National Observatory (KPNO), and Vera Rubin Observatory. NOIRLAb also has Tenant services, including summit base connectivity and research and commodity internet access. AURA operates these facilities and NSF's NOIRLab under a cooperative agreement with NSF.
The network connectivity has 10Gbps burstable to 40Gbps on Pacific and Atlantic links (via AmLight), and a 10Gbps shared backup link provided by REUNA via RedCLARA. From La Serena to Santiago through the valleys, a 40Gbps fiber link serves as a primary path and 4Gbps as a backup along the coast. From Cerro Pachon to La Serena, there is a 20x10Gbps DWDM primary link and multiple backup links. DWDM equipment has been installed to accommodate redundancy from La Serena to Cerro Pachon. Additionally, Las Cumbres Observatory (LCO) has been using 23 years old single mode fiber from La Serena to the Base Datacenter. NOIRLab has been working to improve this connectivity by installing a second switch for redundancy and eventually moving to a new fiber.

IT operations improvements during 2021 included installation of Next Generation Firewalls, upgrade on NX-OS Backbone devices, network services & collaborative tools, and collaboration and integration with Vera C. Rubin Observatory. NOIRLab networking upgrades project includes LAN design upgrade in all locations (La Serena, Cerro Pachón, Cerro Tololo, Hilo, Mauna Kea, Tucson, Kitt Peak), WiFi upgrade, and WAN design.

4.3 National Radio Astronomy Observatory (NRAO) and Atacama Large Millimeter/ Submillimeter Array (ALMA) (David Halstead, CIO, Assistant Director at NRAO & Adele Plunkett, Astronomer at NRAO)

The Atacama Large Millimeter/submillimeter Array (ALMA) is currently the largest astronomical project, composed of 66 high-precision antennas located on the Chajnantor Plateau. ALMA is a multinational project with many partners, and three ALMA Regional Centers (ARCs), which contain a single copy of the data:

- NA: NRAO, Charlottesville, VA, USA
- EU: ESO, Garching (Munich), Germany
- EA: NAOJ, Mitaka (Tokyo), Japan

Cycle 7 of observations restarted in March 2021 and Cycle 8 will run through September 2022. An MOU is signed between Associated Universities Inc. (AUI) and REUNA to provide local connectivity to Santiago. From Santiago to ARCs, there are multiple contracts with REUNA and other NRENs. There is a joint AURA-AUI agreement for 1Gbps committed (burstable to 10 Gb/s capacity) from Santiago to US NREN via Latin America's Nautilus Point of Presence. The link from NRAO to Internet2 through UVa is 10Gbps. The typical rate obtained during peak data transfer periods is 2-300Mbps, with bursts up to 600Mbps. Recently most of the data processing being done in Santiago then archived at the North American ALMA Science Center (NAASC). ALMA was a key contributor to the Event Horizon Telescope (EHT) imaging the Black Hole. However, due to bandwidth constraints from geographically distributed telescopes, data was shipped on disk for correlation.

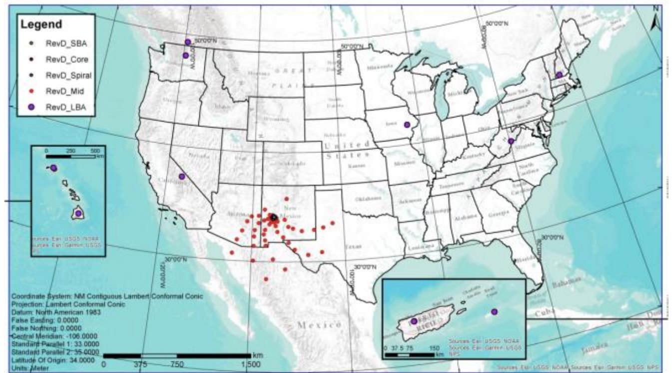
4.4 Next Generation Very Large Array (ngVLA) (David Halstead on behalf of Rob Selina, ngVLA Project Engineer)

The Next Generation Very Large Array (ngVLA)[1] is a development project the National Radio Astronomy Observatory (NRAO) for thermal imaging at a milli-arcseconds resolution which aims to bridge the Square Kilometer Array (SKA) and ALMA capabilities. The Astro2020 Decadal Survey on Astronomy and

[1] Next Generation Very Large Array (ngVLA) https://ngvla.nrao.edu/system/media_files/binaries/130/original/ngVLA-Project-Summary_Jan2019.pdf?1548895473

Astrophysics[2] identified the ngVLA as a high-priority large, ground based facility whose construction should start this decade. The Canadian Astronomy Long Range Plan (LRP2020)[3] recommended that Canada provide $130 million toward ngVLA construction and $6 million per year for operating the facility.

Current used antenna are 48 years old. The new antenna designs contract has been awarded with preliminary design review in 2022, delivery in late 2023, and interferometric testing in 2024. The construction of the antennas will begin from 2025 to 2035. The first operation will start in 2028 and full operation in 2035. The Main Array (MA) locations are planned USA (New Mexico, Texas, Arizona) and Mexico. The Large Baseline Array (LBA) locations (Figure 2) are planned for the USA (California, Washington state, Virginia, Iowa, Virgin Islands, Puerto Rico, Hawaii) and Canada (Penticton).



Long Baseline Antenna Locations

Qty	Location	Notes	Qty	Location	Notes
3	Puerto Rico	Arecibo Site	3	Green Bank, WV	GBO
3	St. Croix	VLBA Site	3	Brewster, WA	VLBA Site
3	Kauai, HI	Kokee Park Obs.	3	Penticton, BC	DRAO
3	Hawaii, HI	Not MK Site	3	North Liberty, IA	VLBA site
3	Hancock, NH	VLBA Site	3	Owens Valley, CA	VLBA site

Figure 2 Long Baseline Antenna Locations

The data rate of 723Gbps per antenna will aggregate to 800Gbps links on ngVLA installed fiber. For example, ~3 antenna LBA site will equal ~1Tbps link. All sites can be connected via leased fiber, spectrum, or bandwidth. The data rates are estimated to average 8Gbps to peak 128Gbps and computing ~60PFLOPS/s. The data archiving will follow ALMA-like distributed archiving and re-processing among international partners. The ngVLA will require a significant investment in new fiber-optic infrastructure in the Southwest USA, with connections across North America.

The ngVLA project will focus on science ready data products. The full science operations are projected to be in 2035. Planning, construction of new science instrument takes a long time. For example, ALMA was proposed in the 80s, the proposals were ingested in 90s, construction began in 2000, and operations in 2011.

4.5 Atacama Large Millimeter/Submillimeter Array (ALMA) connectivity (Christian Saldias, IT Manager ALMA, and Nicolas Ovando, Network Specialist ALMA)

The ALMA antennas are located at the Array Operations Site (AOS) on the Chajnantor plateau of the Chilean Andes at an altitude of 5000 meters. The Operation Support Facility (OSF) and the AOS are connected with dark fiber (Figure 3). There is a pair of dark fiber connection between AOS and Calama (about 150km). From Calama to REUNA PoP in Antofagasta there is a dedicated Lambda 2x10G (about 200 km). There is a dedicated sub-Lambda from REUNA PoP to Vitacura Campus in Santiago (Evalso/ESO) in Santiago. A backup link from AOS to Santiago is in progress. From Santiago, the data is transferred to the three archiving facilities via REUNA and international research and educational networks.

Currently, there is an ongoing effort to upgrade the Padtec DWDM equipment at AOS, Calama, and Antofagasta. In addition, the European Southern Observatory (ESO) is upgrading the Ciena DWDM equipment at Antofagasta, Santiago, and Vitacura.

[2] Astro 2020 https://www.nationalacademies.org/our-work/decadal-survey-on-astronomy-and-astrophysics-2020-astro2020
[3] LRP2020 https://casca.ca/?page_id=11499

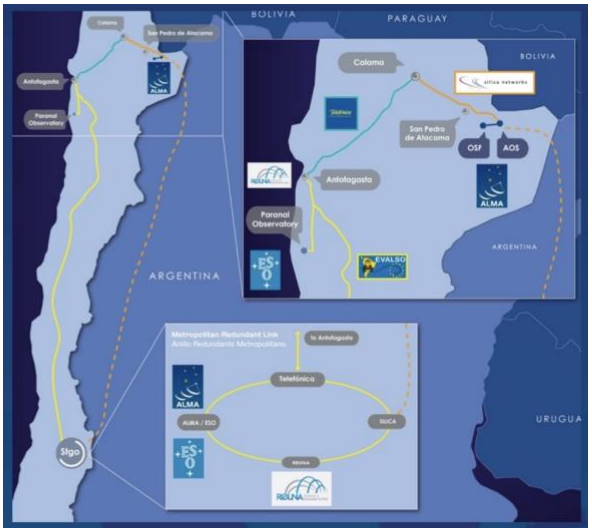


Figure 3 ALMA Communication Infrastructure

ALMA will have 3x1G links once the upgrade is completed. The next step includes moving from 1G to 10G links. Additional observatories in the Chajnantor Plateau (e.g., CCAT, TAO) can be connected to the REUNA PoP and benefit from the upgrades as well. ALMA Control Room Extension (CRE), located in Santiago, continues to support remote operations.

A correlator upgrade is being developed and will be implemented in 2030. The expected data rate will be ~1PT/year. In addition, there is a project for a new OSF-AOS FO cable for Wideband Sensitivity Upgrade (WSU) evaluating the installation of a new fiber optic cable (48 fibers) for direct communications between the antennas and a new correlator in OSF-TF.

4.6 Simons Observatory (SO) (Simone Aiola, Data and Pipeline Project Lead)

The Simons Observatory (SO)[4] is a forthcoming polarization-sensitive Cosmic Microwave Background (CMB) experiment located in the high Atacama Desert (Cerro Toco) in northern Chile inside the Chajnantor Science Preserve. The survey will last five years, from 2023 to 2028, and will include data from the CLASS, ACT, and PolarBear/Simons Array telescopes in Chile (Figure 4). Although the project is privately funded, some of the final data products will be released to the science community.

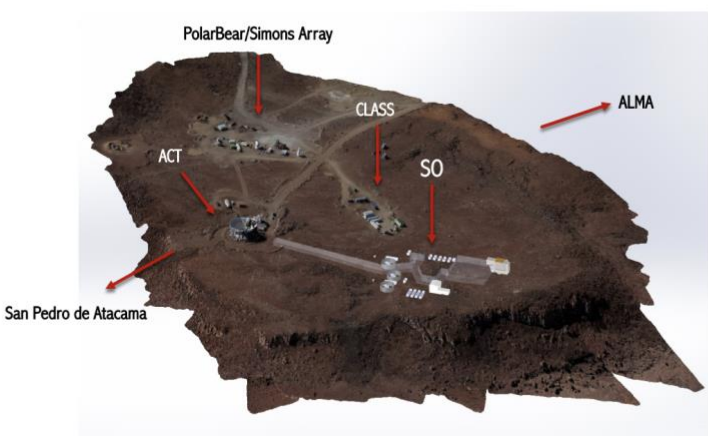


Figure 4 Simons Observatory sites

The instrumentation includes a Large-Aperture Telescope (LAT), three Small-Aperture Telescopes (SATs), and 70 000 detectors. The SATs platforms are being tested and shipped from Germany to Chile. The LAT is currently being tested. The Simons three telescopes' foundations are poured, and computer installation at the site will be connected in the summer of 2022.
The first light (SAT and LAT) is expected in 2022, the first science observation by 2023, and the full science observation by 2024. The data rate is estimated to be ~132Mbps during the day, with 40-50TB data volume per month by 2024. The raw data for the 5-year survey will be ~3PB.

The data management infrastructure includes an observatory control system to monitor and acquire data, hardware infrastructure for computing at the Simons site, a software library to process raw time-ordered data, a simulator of time-ordered data, simulations of observed sky maps, software to perform quality cuts and calibrations, and software to turn time-ordered data into maps[5]. Two one-month copies of the data will be stored at Simons, and three full copies at the US. SneakerNet (shipping discs) and fiber links are

[4] Simons Observatory https://simonsobservatory.org/
[5] https://github.com/simonsobs

implemented in data management. The fiber connection should be operational before June 2023. The data will be sent via disks within 24h to UCSD, SDSC, National Energy Research Scientific Computing Center (NERSC), and later to Princeton. There are no strict requirements on data getting to the USA. Two copies of the data will be stored at the site until three copies appear in the US.

The Atacama Astronomical Park (Parque Astronómico de Atacama PAA) will be providing fiber connectivity from ALMA to Simons. An MoU between Simons and ALMA to allow fiber connection is under revision. In addition, an MoU between Simons and REUNA to utilize the service needs to be finalized. Simons' connection path follows SILICA PoP >>REUNA PoP ALMA via PAA fiber>> Calama >>Antofagasta>> Santiago>>Miami>>San Diego. Testing has been performed from ALMA PoP to NESC (>700Mbps for over a month).

4.7 Cosmic Microwave Background (CMB) -S4 (Eli Dart, LBNL & ESnet, Data Management L3 Lead for Data Movement)

CMB-S4 is the 4th generation ground-based CMB experiment[6]. CMB-S4 is supported by the Department of Energy Office of Science (DOE/HEP) and the National Science Foundation (NSF: Astronomy & Physics & Polar programs). The experiment will use instruments located at the South Pole and the Atacama Desert in Chile. CMB-S4 precursors include South Pole Observatory, Simons Observatory & CCAT-prime for seven years. There will be three LATs (two in Chile, one in the South Pole), six SATs (the South Pole with possible relocation), and 500 000 detectors.

The primary science goals include creating a test model of inflation (tensor-to-scalar ratio), determining the role of light relic particles in fundamental physics, measuring galaxy clusters' emergence, exploring the mm-wave transient sky, and measuring the rate of transient events. The construction will occur until 2027, deployment at the sites until 2029, and operations will begin from 2029 to 2036. The COVID-19 Pandemic has caused some delays, but the projects are continuing to move forward. The data from Chile will be transferred over the REUNA/AmLight links to NERSC and Argonne Leadership Computing Facility (ALCF). There is no physical network connection at the South Pole, and the reduced data will be shipped using disks to the USA. The current site design does not include the reuse of Simons site facilities or telescopes, but this is a possible option for the future, which was discussed.

The compressed data rate is ~1.2Gbps with real-time transfer to NERSC and a few hundred transient alerts per year (which could be analyzed using FABRIC nodes). A big buffer will be provisioned to address network failure. At the Atacama site, one-month data will be stored on-site (~400TB). Cerro Toco fiber optic connection being built from REUNA at ALMA to Simons and CMB-S4. There is an ongoing collaboration with Simons and REUNA on services design.
Prototyping of the data distribution based on NERSC's Modern Research Data Portal was completed[7] and used for preliminary data distribution service for Data Challenge 1. Data transfer from the portal currently runs at 1.1Gbpsec, 8.8Gbps (4TB/hour), and from NERSC and ALCF, high-speed data transfer clusters work at 8.2Gbps or 65Gbps (30TB/hour).

4.8 More Karoo Array Telescope (MeerKAT) (Bradley Frank, Senior Developer & Researcher, SKA South Africa, Fernando Camilo, Chief Scientist SKA, Simon Ratcliffe, Technical Lead for scientific computing, SKA)

[6] CMB-S4 project https://cmb-s4.org/
[7] CMB-S4 data portal https://data.cmb-s4.org/

MeerKAT is a radio telescope consisting of 64 antennas in the Northern Cape of South Africa[8]. MeerKAT (Figure 5) was incorporated into the first phase of the SKA in 2003 and was launched in 2018. There is an extension of 16 SKA1-MID dishes on baselines up to 17 km, with a new correlator and science processor. There is ongoing testing of the SKA1-MID hardware. The incorporation of MeerKAT into SKA will begin after 2022. Full polarization, band, and synthesis observation total to ~24TB. Current operations include Large Science Projects (LSPs) and available time projects. Over 50% of the time is used for science, and another eight LSPs are underway. There is imaging in 4k, 32k, narrowband, and pulsars observations. Currently, S-band is being commissioned, and Ultra High Frequency (UHF) observations have started. There are commercial users such as MeerTRAP and MeerLICHT. Further developments include SETI backend and some VLBI capability. MeerKAT is now operationally oversubscribed. Many datasets are no longer proprietary and are available through the archive interface[9]. Over 81 refereed publications cite MeerKAT data[10].

Figure 5 MeerKAT South Africa (SKA precursor)

Currently, quality control includes comparing the quality of archived images to real-time images. Cross calibration can produce a significant bottleneck in the entire imaging process. If the need for calibration is removed, it will significantly lower the image process time. After calibration and imaging, the data is transmitted to the data archive in the Centre for High-Performance Computing (CHPC Cape Town/CSIR). Data is transferred to the Inter-University Institute for Data Intensive Astronomy (ILIFU Cape Town/UCT) vi GridFTP for science analysis and can be accessed from an astronomer via Globus. The ILIFU Cloud host about ~4PB MeerKAT data.

4.9 Fred Young Submillimeter Telescope (FYST a.k.a. CCAT-prime) (Mike Nolta, FYST Software Lead)

The Fred Young Submillimeter Telescope (FYST), formerly known as CCAT-prime (Figure 6), will be a 6-meter diameter telescope with a surface accuracy of 10 microns, operating at submillimeter to millimeter wavelengths and sited at 5612 meters elevation on Cerro Chajnantor in the Atacama Desert of northern Chile[11]. The partnership includes Cornell University as the lead organization with Arizona State University, Cardiff University, NIST, University of Chicago, and the University of Pennsylvania; a German consortium led by the University of Cologne (Cologne, Bonn, Max Planck Inst. for Astrophysics); Canadian Atacama Telescope Corp (CATC), Canadian consortium led by the University of Waterloo (Waterloo, Toronto, British Columbia, Calgary, Dalhousie, McGill, McMaster, Western Ontario), CATC

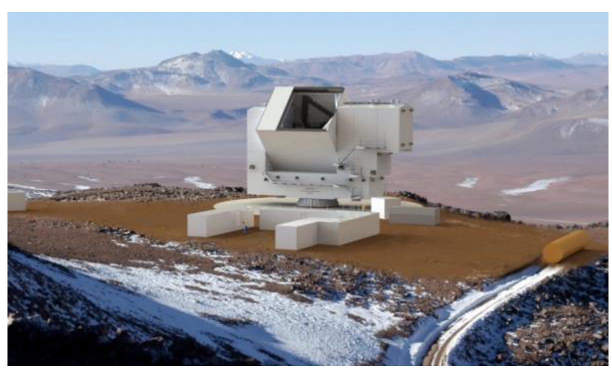


Figure 6 Fred Young Submillimeter Telescope (FYST a.k.a. CCAT-prime)

[8] SARAO MeerKAT https://www.sarao.ac.za/science/meerkat/about-meerkat/
[9] https://apps.sarao.ac.za/katpaws/archive-search
[10] MeerKAT ADS Library: https://ui.adsabs.harvard.edu/public-libraries/wmc9yO6IQ3mUZCPx7MQRxg
[11] Fred Young Submillimeter Telescope (FYST): http://www.ccatobservatory.org/index.cfm/page/about-ccat.htm

"observers"/partners (St. Mary's, Manitoba, Lethbridge, Alberta, National Research Council) and Chilean Universities (University of Chile, UCSC, PUC).

The expected first light in mid-2024, with a data rate of ~3-8TB/day. There are two first-light instruments: CHAI (multi-pixel heterodyne receiver) and Prime-Cam (7 optic tubes, each tube with a field of view of ~1.3 degrees). The CHAI surveys will include the Galactic Ecology project (GEco) (galactic mid-plane, nearby molecular clouds, Magellanic clouds, and nearby galaxies) and science track (cloud structure formation, star formation, microphysics & chemistry of the interstellar medium). The Prime-Cam science goals include epoch of reionization (first stars), tracing galaxy evolution, characterizing CMB foregrounds, galactic magnetic fields, galaxy clusters, Rayleigh scattering, and time-domain phenomena.

A scaled-down version of the Prime-Cam module, holding a single optics tube, will be shipped to Chile if Prime-Cam is not ready in 2023. Because its location is at a high altitude, FYST faces different regulations (e.g., additional medical tests are required). In addition, fuel companies won't make regular deliveries, so generators need to be located at the CCAT&TAO service area and, from there, connect power and fiber to the telescopes. There is an agreement to connect two dark fiber cables from the CCAT&TAO service area to ALMA pad 409 (~20% completed).

During CHAI observation, the data will be sent to Cologne, Germany (~685Mbps/day) and Toronto, Canada (~13Mbps/day). During pre-Cam observation, the data will be sent to Cornell University, USA (~386Mbps) and Toronto, Canada. A preliminary iperf3 network test has been done from ALMA to the Toronto network. The summit has been leveled, and the part of the foundation has been precast and ready to be assembled at the summit. The CHAI & likely Mod-Cam will be completed and shipped from Germany to Chile in 2023 and the Prime-Cam in 2024. Science observation will start in late 2024.

4.10 Giant Magellan Telescope Observatory (GMT) (Sam Chan, GMT Head of Information Technology)

Figure 7 GMTO Primary Mirror Segment

The GMT[12] will be the largest Gregorian telescope in the world located in within the Las Campanas Observatory (LCO) in Chile. The GMT's 24.5-meter primary mirror will be comprised of seven 8.4-meter diameter segments. Two of the mirrors are completed, three are in production queue, and one is casting. The telescope is expected to have a resolving power ten times greater than the Hubble Space Telescope. The GMTO corporation is an international consortium consisting of Arizona State University, Carnegie Institution for Science, Harvard University, Smithsonian Institution, Texas A&M University, The University of Texas at Austin, University of Arizona, University of Chicago, Astronomy Australia Limited, Australian National University, São Paulo Research Foundation (FAPESP), Korea Astronomy and Space Science Institute, a Weizmann Institute of Science. GMT and the Thirty Meter Telescope (TMT) International Observatory in Hawaii are part of the US Extremely Large Telescopes (ELT)[13] program.

[12] Giant Magellan Telescope Observatory https://www.giantmagellan.org/
[13] US ELT program https://www.noao.edu/us-elt-program/

The pandemic halted the construction of GMT, and the first light is scheduled to be in 2028. The team hopes to leverage fiber links from the summit to La Serena and NSF RENs connections for the data transfer process. Data archiving facility(s) have not been selected yet. The produced data is estimated to be ~10-40 TB per night. Backup options (e.g., AWS, Pasadena data center, summit data facility) are currently discussed.

4.11 US Extremely Large Telescope Program (US-ELT) (Marie Lemoine-Busserolle, Systems Scientist US-ELTP & NSF NOIRLab)

The US Extremely Large Telescope program is a joint endeavor between the NSF's NOIRLab, Thirty Meter Telescope (TMT) in Hawaii, and the Giant Magellan Telescope (GMT) in Chile. US-ELT objectives include access for all US astronomers and support for large-scale, systematic, and collaborative research. The Astro2020 decadal survey ranked the US-ELT program as the highest ground-based priority in *Pathways to Discovery*[14]. The mode of investigation includes data products with high archival reuse value, smaller PI-class proposals allocated more frequently, and community research using all archived data from TMT and GMT. The community developed Key Science programs (KSP), including research in extrasolar planets and the search for extraterrestrial life, dark universe, extreme gravity, resolving the physics of galaxy evolution, solar system, stars & stellar evolution, explosive transients, and more.
NOIRLab will provide user services, documentation, and training, to support the entire research life cycle (e.g., developing KSPs, submission of proposals, time allocation evaluation, observation planning, tracking, retrieving data, and long-term archiving).

4.12 Summary Science Instruments

The following table summarizes the information on intstruments reported in section 4. It contains the name of the instrument with a link to its website, its location, sites where data is archived, what stage the instrument is in (planning, construction, operation), the estimated start and end date, and data flow characteristics from the instrument to archive.

Instrument	Location	Data archive	Stage	Start - End date	Data flow characteristics
Vera Rubin Observatory	La Serena, Chile	US: SLAC, EU: In2p3, UK	construction	Oct 2023-2033	20TB per night, Image must be transferred within 6 seconds from the Base to the USDF. The telescope will produce 10 million transient events per night, which will be distributed in real time within 60 seconds to community brokers. Data flow from Chile to USA and EU. US partners: NSF, DOE, IN2P3; Managed by AURA

[14] https://nap.nationalacademies.org/resource/26141/interactive/

Next Generation Very Large Array (ngVLA)	New Mexico, Texas, Arizona, Mexico, California, Washington state, Virginia, Iowa, Virgin Islands, Puerto Rico, Hawaii	Distributed archive	planning	2025-2035	The data rate of 723Gbps per antenna will aggregate to 800Gbps links on ngVLA installed fiber. For example, ~3 antenna LBA site will equal ~1Tbps link. The LBA sites (UPR, U Central Florida, Arecibo Observatory) proposed to NSF a 100Gbps link to I2. US partners: NSF; Managed by NRAO, NSF, and AUI
Atacama Large Millimeter/submillimeter Array (ALMA)	San Pedro de Atacama	NRAO, Charlottesville, VA, USA; EU: ESO, Garching (Munich), Germany; NAOJ, Mitaka (Tokyo), Japan	operation	2011-present	1TB per day, total volume will be ~220TB; Typical rate obtained during peak data transfer periods is 2-300Mb/s, with bursts up to 600Mb/s. A new correlator will increase the data to 1PT/year in 2030. Data come from Chile to USA, EU, and Japan. US partners: NRAO; Managed by Associated Universities, Inc. (AUI)/NRAO
Simons Observatory	Chajnantor, Chile	USA: NERSC, UCSD/SDSC, Princeton	construction	2023-2028	The data rate is estimated to ~132 Mbps during the day with 40-50 TB data volume per month. The raw data for the 5-year survey will be ~3PB. There is NO strict requirement on data getting to the US. Data flow from Chile to Princeton USA
Cosmic Microwave Background (CMB-S4)	Chile and at the South Pole	NERSC	planning	2029-2036	The compressed data rate is ~1.2Gbps with real time transfer (transient events) to NERSC using FABRIC nodes; 1 month data will be at on-site storage ~400TB connected with 10Gbps and it will take 4 days to clear a month-long backlog. Managed by DOE & NSF
MeerKAT	South Africa	SARAO, Cape Town/CSIR, South Africa	operation	2018-present	Data is archived at Centre for High Performance Computing (Cape Town/CSIR). Academic research and computing are done at Inter-University Institute for Data Intensive Astronomy (Cape Town/UCT) and Ilifu Cloud

FYST (a.k.a. CCAT)	Cerro Chajnantor, Chile	Cologne, Germany Toronto, Canada Cornell University, Ithaca, NY, USA	construction	2024	~3-8 TB/day; connecting to dark fiber at ALMA Pad 409 Dark Fibers; During CHAI observation, the data will be sent to Cologne, Germany (~685Mbps) and Toronto, Canada (~13Mbps). During pre-Cam observation, the data will be sent to Cornell University, USA (~386Mbps) and Toronto, Canada. Data flow from Chile to Germany, Canada, and USA.
US ELT: GMT & 30m Hawaii telescope	Chile and Hawaii	TBD	construction	2028	Projected 10-40 TB per night. Data flow from Chile and Hawaii; Managed by NSF & NOIRLab

5. R&E Provider Updates

5.1 AmLight: International Links project (Jeronimo Bezerra, IT Associate Director FIU and Chief Network Engineer AmLight)

AmLight ExP project (NSF Award #2029283) operates as a distributed academic open exchange point, built to enable collaboration among Latin America, Africa, and the US. The 2021-2025 project goals are to continue enabling collaboration among researchers and network operators by providing reliable, sustainable, scalable, and high-performance network connectivity and services. Current focus of the project is to suppor Service Level Agreement (SLA)-driven science applications, improving network visibility and management, enabling integration between AmLight and network-aware science drivers, adding new network and cloud services, and minimizing the human role in network operation.

Current network connectivity has 600Gbps of upstream capacity between the US and Latin America and 100Gbps to Africa. In 2022 AmLight is expanding to Atlanta, Georgia, with 400Gbps of total capacity. An additional 200Gbps from Brazil to the US will be added in 2023. The AmLight SDN architecture from 2014 to 2020 included a data plane, control plane, management plane, and application. From 2021 to 2025, the team will add new specialized components per SDN Plane, a new management plane (In-band Network Telemetry), a brand-new intelligence plane focused on learning the network state and creating a sub-second closed-loop control, brand-new control plane (Kytos-ng), and new data plane based on a programmable network device (NoviFlow P4 switches).

Kytos-ng is the next generation of the Kytos SDN open-source platform, maintained by FIU and rednesp. The project focuses on the AmLight operation requirements that include support for multiple metrics implementation and restrictions (e.g., number of hops, minimum delay, max bandwidth, ownership, reliability, priority, average bandwidth utilization), per-packet telemetry (e.g., INT), support for bandwidth reservation, and support for multiple southbound protocols (e.g., OpenFlow 1.3+ and gRPC P4Runtime).

Additional updates were made at the Data plane, packet and optical layers. At the packet layer, legacy switches were replaced by NoviFlow switches (Tofino ASIC 32x100G ports per switch), virtual machines were embedded, OpenFlow 1.3+1.4 & P4Runtime for southbound were enabled, and INT for per-packet telemetry was implemented. Ciena Waveserver Ai transponders are used at the optical layer level, with Point-to-point circuits with API license, streaming telemetry-capable devices, and REST API for monitoring.
The changes in mindset compared to the previous AmLight-ExP project include creating the SDN closed-loop control to include policies to be prepared for sub-second reaction and debugging. For example, policies

can include restriction/reservation of 80+% BW utilization >= 2s, 50+% [Queue Occupancy] >= 2s, or a number of path changes >= 5 in 2h.

The 2021-2025 AmLight-ExP plan to support SA3CC includes redundancy, SLA-driven services, and automation. AmLight has many links and multiple paths connecting its sites (e.g., from Chile to Jacksonville, there are more than 25 possible paths to take). AmLight will handle any SLA-driven packet-loss-intolerant and sub-minute-response-time-expected science application. Additionally, the AmLight engineering team prefers to focus on engineering and new services over manual activities (e.g., closed-loop control).

5.2 AmLight: Monitoring and Measurement Improvements (Renata Frez, RNP/AmLight Network Analyst)

AmLight has a rich set of tools to monitor its infrastructure and measure its performance. The benefits to the SA3CC community from the Measurement & Monitoring Tools used at AmLight include complete network visibility, historical data, identifying and resolving outages, identifying security threats, monitoring SLAs, and recognizing points for improvement. The current list of implemented tools include sFlow, perfSONAR, telemetry, INT, Zabbix, and security tools. sFlow is used for traffic analysis in AmLight routers and switches. PerfSonar runs scheduled tests (Throughput, Latency, Loss). Telemetry from the Juniper routers (JTI) provides data streams periodically (up to two seconds). For INT, there are P4 applications exporting reports directly from the Data Plane. Zabbix is AmLight's central monitoring solution that collects CPU, memory, disk, and network interface usage data from a device. Custom scripts are combined with Zabbix to collect data using Netconf, gRPC, and REST. Other integration plugins (e.g., Prometheus, Slack, visualizations app) are also integrated.

AmLight’s security strategy includes implementation of a honeypot, BGP global routing table monitoring, DoS/DDoS monitoring, and threat intelligence. Additionally, AmLight/AMPATH is part of the MANRS initiative to improve the security and resilience of today's Internet routing methods (e.g., filtering, anti-spoofing, coordination, validation). Combining all monitoring tools enables AmLight to track any performance issue and user request.

5.3 South Africa National Research and Educational Network (SA NREN) (Shukri Wiener, Executive Officer Technical and Operations)

SA NREN is comprised of TENET and SANReN. The roles and responsibilities of the South African NREN (SA NREN) are distributed between the South African National Research Network (SANReN) group at the Council for Scientific and Industrial Research (CSIR) and the Tertiary Education and Research Network of South Africa (TENET)[15]. The international connectivity of SA NREN includes capacity on several submarine cable systems: SACS 100G, WACS 60G (100G), SAT3 20G, EASSy 20G, and SEACOM 60G (100G); and connect to four International R&E Exchange points: ZAOXI Cape Town, AMPATH Miami, GEANT London, and Netherlight Amsterdam. SA NREN interconnects with the three regional African networks UbuntuNet Alliance, WACREN, and ASREN. The SA NREN backbone includes multiple 10G links, which are being gradually upgraded to 100G or 200G, including 100G IP/MPLS Links. All universities and research councils are connected. The national connectivity DWDM backbone includes 96 channels (gridless and directionless optical line system), a 100G DWDM transport long haul network and a 200G DWDM transport metro network.

Several astronomy instruments are located in the South African regions. The South African Radio Astronomy Observatory (SARAO) manages the MeerKAT (pathfinder to SKA) in the Karoo desert, approximately 700km from Cape Town. Current connectivity includes an existing fiber and new fiber optic

[15] SA NREN https://sanren.ac.za/south-african-nren/

cable to the SKA core site that has completed the environment impact assessments that will be followed by wayleave negotiation.
All backbone nodes on the 100G backbone are being upgraded. Alternate fiber routes and 100G managed links are used to provide resiliency.

5.4 Chilean Academic Network (REUNA) (Albert Astudillo, Chief Technology Officer at REUNA)

REUNA supports over 45 organizations that conduct 80% of the research in Chile. The network infrastructure spans over 9000 km and connects over 400,000 students and academics. The backbone network includes multiple100G and 10G paths, 18 PoPs, and resilient backup. REUNA has completed improving the Las Campanas' connectivity from instruments located in Las Campanas using existing infrastructure in 2021. REUNA also has increased its capacity in the metropolitan ring by using lambda alien waves over the metropolitan ring and implementing RedCLARA DWDM equipment in Huechuraba and Compañía. New services available to the science communities include a 100Gbps link for Vera Rubin from Argentina, 200Gbps traffic for RedCLARA from Argentina, and 200Gbps traffic between REUNA and RedCLARA. In southern Chile, upgrades include a new direct 10G link from Santiago to Concepción, a new ethernet node installation at Curicó, an upgraded a 10G protected link (Chillán to Concepción to Temuco), and an upgrade from 1G to 10G protected link form (Temuco - Valdivia - Osorno - PMontt). The backup link to Argentina has been upgraded too.

REUNA is planning to support multiple new projects. For example, the Patagonia project over FOA (Fibra Óptica Austral) plans to integrate the rest of Chile into the REUNA backbone infrastructure by connecting multiple PoPs. Currently, the links to Coyhaique and Punta Arenas are under construction. The initial operation time frame is from 2022 to 2027.

Another project includes creating a PoP in Chanjantor Valley to provide connectivity to multiple astronomical projects in the area (e.g., TAO, FYST formerly known as CCAT). The agreement between ALMA and REUNA is in the final stage, and the initial capacity will be 1G scalable over time with an intended implementation date of the end of 2022. The physical connection to Cerro Toco (e.g., Simons, CMBS-4, PolarBear, ACT, CLASS, SMB-54) is also in progress. Preliminary tests between FYST Array Operations Site (AOS) in Calama to the CANARIE network/University of Toronto via REUNA and RedCLARA network shows stable results.

REUNA partners with important international initiatives such as the RedCLARA expansion, the BELLA project, and AmLight-ExP. Additionally, multiple fiber optic cables will reach Chile in a few years. The Chilean government is leading the effort on the installation of a new submarine cable to connect Chile with Oceania. REUNA is planning to have a spectrum on the cable. Moreover, the Chilean government has promoted the Punta Arenas as a gateway for the Antarctic Programs of more than 20 countries to make the southern Chilean zone a world science point.

5.5 Research and Education Network de São Paulo (rednesp) (Joao Eduardo Ferreira, Executive Director rednesp)

The formerly known Academic Network of Sao Paulo (ANESP) evolved into two parts: Research and Educational network at Sao Paulo (rednesp) that includes a committee from the University of Sao Paulo (USP), Sao Paulo State University (UNESP), the State University of Campinas (UNICAMP), and the Academic Committee comprised of astronomy and physics team from Sao Paulo Research Foundation (FAPESP) science board. Rednesp has three primary efforts. The first effort is to maintain financial investment to support and improve the academic research network in Sao Paulo, including collaboration on Atlantic and Pacific links with AmLight, and support from the FAPESP. International links are connected via submarine cables, such as Monet and SACS. The second effort includes several technical collaborations.

First is the management of international links (e.g., 40Gps alternative links, 100Gbps resilient links, 2x100Gbps Monet links). Next is the integration of important research institutes and universities throughout the state of Sao Paulo. Another technical collaboration is the development of the Kytos-ng SDN software with the AmLight team. The goal of Kytos-ng development is to provide additional network functionality. Last technical collaboration includes support for international persistent multisource infrastructure implementation of AutoGOLE/SENSE with the Global Network Advanced Group (GNA-G). Finally, the third effort is maintaining and improving the n x 100Gbps network backbone in the state of Sao Paulo to provide supercomputing functionality to the connected university along with the network.

5.6 Latin American Cooperation of Advanced Networks (RedCLARA) (Luis Eliécer Cadenas, Executive Director RedCLARA)

The mission of RedCLARA is to contribute to the development of science, education, technology and innovation in Latin America and the Caribbean through the articulation, connection and strengthening of their national research and education networks. The vision of RedCLARA is to be a key actor, facilitator of connectivity between the National Research and Education Networks (RNIE), and enabler of the digital transformation processes of education, science, technology and innovation in Latin America and the Caribbean.

Today's RedCLARA infrastructure consists of multiple 100Gbps links in South America extending to Central and North America, Europe, and Africa. The Bella Cable was successfully deployed and activated June 2021, with an initial capacity of 100 Gbps. Currently ~40Gbps are in use, but the number is expected to grow as more countries are connected via the Bella T project. Bella-T phase two also includes strengthening and expanding the Latin American digital ecosystem to multiple carriers in Latin & Central America and the Caribbean. Currently, the n x 100Gbps paths Fortaleza-Porto Alegre-Buenos Aires-Santiago, and the path from Ecuador to Panama and Columbia and Panama to Fortaleza are completed. Next step is to connect to the Dominican Republic where a cybersecurity center will be built with collaboration of the European Union. With the Bella project, RedCLARA acquired 45 optical channels for 25 years from Latin America to Europe and six optical channels within Latin America.
Bella 2030: A digital alliance between Europe, Latin America and the Caribbean plan include connecting 16 additional Latin American countries in connectivity with Europe, North America, and Africa. Current discussions are in place for using the Humboldt cable system to support Antarctic projects and connection to Australia.

5.7 Brazil's academic network - Rede Nacional de Ensino e Pesquisa (RNP) (Aluizio Hazin, Engineering and Operation at RNP)

The RNP backbone is in its 7th generation network deployment with partnerships with electric power companies (Chesf, Eletrosul, Furnas, TAESA, IE Madeira, Argo), Telebras, and other private ISPs. RNP's strategy includes no leased lines or IRU payments for interstate dark fibers except the redundancy for Boa Vista/RR. Most of the investments are in electric infrastructure, optical equipment, and in some cases, hardware/software support. Jointly with rednesp, RNP participates in international projects, such as the AmLight ExP, the Bella project, and RedCLARA. Dark fiber links in Fortaleza connect to the most important companies (e.g., TiSparkle, Telxius, Angola Cables) and data centers (e.g., Equinix SP2, SP3, SP4, RNP PoPs). RNP also operates two Global Exchange Points (GXP), one in Fortaleza (SAX) and one in Sao Paulo (SOL).

Over 13 new 100G circuits are planned to be activated in 2022. RNP intends to deploy the subsequent phases of the Eletrosul and Furnas projects in 2022. The Eletrosul project includes links from Londrina to Curitiba to Porto Alegre and the Furnas project includes links from Campinas to Araraqura, São Paulo to Brasília and Belo Horizonte, Brasília to Belo Horizonte, and Belo Horizonte to Vitória to Teixeira de

Freitas. Additionally, RNP is finishing a swap process of optical channels in its backbone. Currently, 13 routes have completed the negotiation, and seven are in progress.

RNP is continuing to seek new long-term partners to develop its new network. There are ongoing conversations with some current partners that could add new routes in the future. Scalable solutions are still preferable, but the swap strategy will become a pivotal point to the success. RNP is making all the efforts to honor the commitments made with the Academic partners (LSST/Amlight and RedCLARA/Bella).

5.8 Rubin Observatory US Data Facility SLAC National Accelerator Laboratory (Mark Foster, Director IT Infrastructure at SLAC)

The SLAC National Accelerator Laboratory is a US Department of Energy (DOE) Office of Science laboratory operated by Stanford University[16]. In 2020, SLAC was selected as the US Data facility (USDF) designated for Rubin Observatory data processing, archiving, and data access. The raw images will be transferred from the Base site in Chile to the USDF (24-30TB/night, 6.4GB per image, and 18-bit uncompressed compressed at the Base site). The data must be transferred to SLAC in seven seconds and the generated alerts in one minute. The data flow (up to 39Gbps) includes northbound (raw images, wavefront images, and raw calibration images) and southbound (prompt data products and telemetry). From the USDF, 10M alerts per night will be available to the brokers within 60 seconds. There are multiple non-Rubin Community alerts brokers as well. From the base site, calibration products and L2 data products will be transferred to a Chilean Data Archive. From the USDF, 50% of the annual data release (raw images, ½ of the L2 data products, calibration products, coadds, catalogs, SDQA) will be processed in French Data Facility at IN2P3, and another 25% of the annual data release will be processed at a UK data Facility. ESnet will handle the traffic to Europe.

The SLAC Shared Data Facility (S3DF) has storage, and computational recourses shared among multiple projects. The S3DF is expanding storage and archiving capacity to accommodate the future incoming data from the Rubin Observatory. Primary and backup optical waves will connect to the continental US using AmLight links to ESnet in Atlanta. From Atlanta, the traffic will go over the ESnet backbone (VPRN similar to LHCONE) to SLAC. Currently, SLAC can support 200Gbps aggregate capability between SLAC and other sites with multiple ESnet 100Gbps links (ability to scale Nx100Gbps in 2022, Nx400Gbps in 2023). In addition, ESnet6 has installed two optical nodes on SLAC premises (part of the Bay Area optical ring with multi-Tbps optical capacity) to accommodate the Vera Rubin Observatory traffic. The Stanford Research Computing Facility (SRCF) building has been physically expanded to accommodate more equipment.

5.9 Vera Rubin Observatory Multi-Site Processing (Richard Dubois, Senior Staff Scientist at SLAC)

The Vera Rubin Observatory will produce sequential images every 30 seconds covering the entire visible sky every few days (20TB/ day of raw data). The prompt data products include up to 10 million alerts per night (delivered in 60 seconds and later distributed via community brokers and alert filtering services). Results of different image analyses or transient and variable sources, and solar system objects will be delivered via prompt products database in 24h and later to the Rubin Observatory and independent data facilities. The data release products will be a final ten-years data release (images 5.5 million x 3.2 GB and 15PB catalog of 37 billion objects). The Rubin science platform will provide access to Rubin data products and services for all science users and project staff. However, access to proprietary data and the science platform will require Rubin's data rights.

Vera Rubin Observatory has multiple data facilities. The United States Data Facility (USDF)/SLAC will have ~10% of computing available to users and 25% of data release processing. The French Data Facility

[16] SLAC https://www6.slac.stanford.edu/

at CC-IN2P3 will have 50% of data release processing. The UK Data Facility will have 25% of data release processing. Other independent data access centers (about 15) will serve only a subset of data; Cloud services are also included. A prototype interim data faculty science platform is currently using Google cloud.

Rubin data products are ambitious and still have some uncertainty in computing needs. SLAC envisions ~1700 cores for the first year and an increase to ~20,000 cores until year ten for ~200 days annual turnaround. Prompt Processing (nightly alert generation, daily solar system processing) is sized to consume ~1200 cores continuously when observing begins. About 100PB will be transferred by around year ten. Projected network transfer rates are estimated to have a multi-side processing model where SLAC outbound will be dominated by feeding the IDACs and brokers, assuming the Data Rate Processing (DRP) transfer can be processed in parallel. Current technologies already adopted for multi-side Processing include PanDA (workflow management), Rucio (data movement), and cvmfs (code distribution). Initial testing using Rucio has been performed between SLAC and IN2P3. Multisite testing of the links and network throughput is on the way. However, Rucio is not appropriate for low latency transfers, and a custom solution will be used to provide the seven seconds data movement from Chile to SLAC. An estimated billion files per year (primarily small files but a lot of them) will be transferred as they are made. The team is working closely with the pipeline developers to ensure the files are transmitted over the Atlantic. Rucio will be combined with an existing internal metadata handling tool called Butler for data orchestration. Currently, SLAC is installing new hardware and conducting test processing.

5.10 Internet2 (I2) (Chris Wilkinson, Director of Network Planning and Architecture Network Services at I2)

The I2 Next Generation Infrastructure (NGI) program is a complete set of activities to review and update the services, value, and supporting technology of the Internet2 infrastructure portfolio (and relationships in the larger ecosystem). The objectives of the NGI include infrastructure that supports data-intensive research, cloud access, software-driven infrastructure, sustainability, and sharing. The NGI capabilities update include an upgrade in capacity (400Gbps backbone), full automation, improved measurement (perfSonar nodes, high degree of visibility), an entirely new security layer, operating cost reset (70% less space / 70% less power), extended engineering and new software teams, and cloud capacity enhancements (1.6TB). Commercial peering capacity has grown from 980Gbps in 2019 to 5,640Gbps in 2021.
Network services activities for 2022 include delivery of member-facing self-service software-driven network products, updated router proxy, new routing and routing security portal, updated cloud-connect portal, more enhanced role-based access/authorization for services via InCommon, platform services agreement, rallying routing security across the community, telemetry sharing projects, operations RFP award (NOC services), and supporting community interests in federal infrastructure programs.

Next, transatlantic capacity upgrades on Amitié cable include 1 x 400G link in partnership with CANARIE (Boston to Bordeaux) and 2 x 400G links in association with ESnet (Boston to London, Boston to Bordeaux). Future steps include deploying new hardware at the MANLAN and WIX exchange points, automation to support the FABRIC project, and protocols (move to EVPN). I2 also supports the Open Science Grid (OSG) objective of creating an open national cyberinfrastructure that allows the federation of CI at over 3,900 higher education institutions. I2 currently hosts five OSG nodes and will host five additional OSG caches in the network this year. Last, I2 is developing a new network services web portal and API set to provide access to the I2 stack (L2 and L3) and other software-controlled services.

5.11 Energy Science Network (ESnet) (Paul Wefel, Network Engineer at Lawrence Berkeley National Laboratory)

ESnet is the US Department of Energy High-Performance Network. ESnet interconnects DOE national sites, research, and commercial networks internationally. The DOE Office of Science's mission is to deliver scientific discoveries and major scientific tools to transform our understanding of nature. The mission of ESnet is to interconnect science network user facilities designed to accelerate scientific research and

discovery. The annual aggregated traffic carried by ESnet is estimated to grow ten times every four years. The science applications are taking full advantage of the well-engineered networks.
Several significant updates on the ESnet backbone took place in 2021. Over 74 Ciena 400G circuits have been deployed at the optical layer, and 3 Infinera CHM2T circuits have been upgraded to 400G. The use of mixed vendor equipment reduces the risk of software updates complication. Additionally, deploying and transitioning 42 ESnet6 routers into service has been completed. Currently, routed traffic of almost all core 100G links has been upgraded to 400G. Most ESnet router provisioning activities now use the automation stack to deploy services. Services such as Edges & BGP peers on 42 routers have been migrated to orchestrated and automated services. Currently, the orchestrator is managing over 1882 service subscriptions.

A new platform called Stardust has been implemented in ESnet for network measurement and analysis. Stardust is an extensible open architecture with multiple access methods, can use multi data sources from the network, and has flexible aggregation. In addition, a visualization dashboard is available for the engineers to provide insights on the network, flow information, data traffic, and more. Currently, the ESnet team is working on implementing optical information (e.g., metrics across networks, port statistics, circuit statistics) in the platform. Currently, ESnet manages 4x100G international links to Europe and planning to acquire its first 400G transatlantic additions spectrum on the Amitié cable system along with Internet2/CANARIE by 2023.

Appendix A. Program for the SA3CC Meeting

Tuesday, April 19, 2022
11:00 – Welcome – Julio Ibarra

Session I: Science Requirements & Activities Updates
11:10 – Vera C. Rubin Observatory Operations (Bob Blum, Christian Silva)
11:30 – NOIRLab – ITOPS (Chris Morrison / Mauricio Rojas / Eduardo Toro)
12:00 – NRAO & ngVLA (David Halstead, Adele Plunkett)
12:30 – ALMA (Christian Saldias, Nicolas Ovando)
12:50 – Simons (Simone Aiola)
13:10 – *Refreshment Break*
13:40 – CMB-S4 (Eli Dart)
14:00 – MeerKAT (Bradley Frank)
14:20 – CCAT (Mike Nolta)
14:40 – GMTO (Sam Chan)
15:00 – US-ELT (Marie Lemoine-Busserolle)
15:20 – Open Discussion/Coordination
15:40 – Adjourn

Wednesday, April 20, 2022
11:00 – Welcome – Julio Ibarra

Session II: Providers updates
11:10 – AmLight1: International links (Jeronimo Bezerra) | Download presentation
11:30 – AmLight2: Monitoring and Measurement Improvements (Renata Frez) | Download presentation
11:50 – SANReN/TENET (Shukri Wiener) | Download presentation
12:10 – REUNA (Albert Astudillo) | Download presentation
12:30 – REDNESP (Joao Eduardo Ferreira) | Download presentation
12:50 – *Refreshment Break*
13:20 – RedCLARA (Luis Eliécer Cadenas) | Download presentation
13:40 – RNP (Aluizio Hazin) | Download presentation
14:00 – USDF infrastructure (Mark Foster) | Download presentation
14:20 – USDF data movement and multi-site processing (Richard Dubois) | Download presentation
14:40 – Internet2 (Chris Wilkinson) | Download presentation
15:00 – ESnet (Paul Wefel) | Download presentation
15:20 – Open Discussion/Coordination
15:40 – Adjourn

Appendix B. Program for the Vera Rubin Observatory NET Meeting

Thursday, April 21, 2022

11:00 - Welcome and Introductions

- Goals and Objectives – Phil Demar, Cristian Silva and Julio Ibarra (5 minutes)
    - What are the goals and objectives, and responses to questions, of the 2022 NET meeting?
        - Scope of the meeting is to focus on the LHN to transition from Construction to Operations
        - Goal: To demonstrate to Sponsors and Vera Rubin management that the network will not miss a data transfer window.
        - Other questions or statements to add?
- Planned Outcome over the next two days (5 minutes)
    - How does the NET demonstrate/show that the network is not the cause of a problem?
    - What is the impact if data transfer windows are missed? What does Rubin do to recover?
- Rubin Observatory Network Status Overview – Cristian or Bob Blum (10 minutes)

11:20 - *Session 1*: LHN Specifications and Design Documents Catalog - Cristian Silva moderator.

Objective: Catalog for documents to transition from Construction to Operations.
Catalog document: https://ittn-044.lsst.io/ITTN-044.pdf

Actions:

- Cristian to provide an update on where catalog and documents will be stored and available to the NET. Update catalog with status of documents in 2022.

Outcome:

- Identify documents that will guide NET activities on to Operations.
- Cristian to transfer Dropbox contents and catalog to a Google Drive.
- Identify document owners.

11:40 - *Session 2a*: Updates about the physical networks in Chile and Brazil – Cristian Silva moderator

Report on the physical networks since the 2021 Rubin Observatory NET meeting. A representation of the portion of your physical network that supports the Rubin Observatory is requested; anything else is outside the scope.

Objective: The outcome of Session 2 is to document what the Rubin Observatory NET has deployed at the physical layer since the 2021 Rubin Observatory NET meeting. Each physical network representative will present 1 - 2 slides and take questions.

- Rubin Observatory Network – Cristian Silva (10min)
- REUNA – Albert Astudillo (10min)
- RedCLARA – Marco Teixeira (10min)
- RNP – Fabio Okamura (10min)

Outcome: Diagrams and description to be made available for LSE-78 and LSE-479.

12:20 - *Session 2b*: Updates about the physical networks International and CONUS - Phil DeMar moderator

- FIU-AmLight – Jeronimo Bezerra (10min)
- SLAC - Mark Foster (10min)
- ESnet - Paul Wefel (10 min)
- GEANT – Richard Hughes Jones (10 min)
- RENATER – Frederic Loui (10 min)
- UK/JANET - (Duncan Rand) (10 min)
- IN2P3 – Jerome Bernier (10 min)

Outcome: Diagrams and descriptions to be made available for LSE-78 and LSE-479.

13:20 - *Scheduled Break (30 minutes)*

13:50 - *Session 3*: Updates to LSE-78 Rubin Observatory Network Design Document and LSE-479 Rubin Observatory Network Technical Document – Cristian Silva and Julio Ibarra moderators.

Objective: Review LSE-78, with emphasis on CONUS and transatlantic networks due to the selection of SLAC as the US Data Facility for Operations, and the addition of a UK processing site and Data Access Center(s).

Review the significant changes to LSE-479, with emphasis on CONUS and transatlantic networks due to the selection of SLAC as the US Data Facility for Operations, and the addition of a UK processing site and Data Access Center(s). Also, cover Huawei Avoidance new path in Brazil. Document when changes in the network are planned, e.g., 20G to 100G on ESnet. (Note: planned activities will also be documented in the Baseline Milestones for LHN document.

Supporting documents:

- Observatory Network Design (LSE-78)
- Network Technical Document (LSE-479)

Outcome:

- LSE-78 was submitted to the Change Control Board (CCD). Determine if LSE-78 should be revised and resubmitted.
- LSE-479 session is to review LSE-479 document and prepare to submit to the Rubin Observatory Change Control Board (CCB). Identify gaps in the updated document and to assign for updates.

14:20 - *Session 4*: Review and update the NET activities and milestones as Rubin Observatory approaches Operations - Julio Ibarra moderator

Objective: Identify activities and milestones to accomplish before the start of Operations.
Supporting documents: Vera Rubin Baseline Milestones for LHN document
Outcome: Update the Baseline Milestones for LHN project plan

15:00 - Wrap up and Actions
15:10 - Adjourn

Friday, April 22, 2022

11:00 - Welcome – Cristian Silva, Phil Demar, Julio Ibarra (10 minutes)

- Overview of Day 1 meeting and Roadmap for Day 2

11:10 – *Session 5*: End-to-end Test and Performance Measurement Plan – Julio Ibarra moderator

Purpose: To understand what the Rubin Observatory NET must accomplish to satisfy ourselves that we can demonstrate that the networks are ready for Verification and acceptance, and can be measured and monitored.

Context:

- Primaries are dedicated by end of FY22 (except Boca – Atlanta in FY23). By definition, no need for QoS on the dedicated primary (only Vera Rubin traffic)
- Secondary: SLA Expectation: By the start of FY22 , there is a 40G minimum (during observing 10 hours per night) required on your secondary.

Supporting documents:

- End-to-End Test Plan:
- Long-Haul Network Design FY2020 and FY2023.docx

Objectives: In 3-4 slides, present the following:

- The methodology implemented on your network to provide the 100G dedicated on the primary path, and the 40G minimum bandwidth commitment on the backup path
- Persistent End-to-end Monitoring and Measurement Infrastructure: Your network's measurement infrastructure (PerfSonar, etc):
  - Summit to Base – Vera Rubin (Cristian)
  - Base to Santiago – REUNA (Albert)
  - Santiago to Atlanta – AmLight (Renata)
  - Atlanta to SLAC – Esnet (Paul)
  - US Data Facility – SLAC (Mark)
- What bandwidth guarantees are required from USDF to IN2P3? and UK facility?

The outcome of session 5 is to:

- Update the End-to-end Test and Performance Measurement Plan with the information provided by each network operator
- Prepare the End-to-End Test plan document for submission to the Rubin Observatory CCB for baseline.

12:10 - *Session 6*: Rubin Observatory Networks Verification - Phil Demar moderator

Purpose: To understand what must be accomplished to demonstrate to funding agencies and to Rubin Observatory management that by FY2022 the Rubin Observatory Network has met its requirements. Review the Vera Rubin Observatory Network Verification plans and schedule.

Context:

- SLAC is not yet ready.
- Verification is a one-time activity, performed as a workflow in Jira. It's not possible to complete in FY22 to test against official paths and tools.
- Need to know when network paths and computers in SLAC will be operational.
- Cannot verify until we have somewhere to land in SLAC.
- Perform informal verification run on the current 20G infrastructure?

Supporting Documents: Vera C. Rubin Network Verification Document (LDM-732)

Objective: Rubin Observatory Network Verification (planning for formal tests/demonstrations) – Cristian Silva

- Responses to the 2020 Pre-Verification Review.
- LDM-732 Rubin Observatory Networks Verification Baseline (Cristian Silva)
    - LDM-732 describes the methodology used (how) the Rubin Observatory NET demonstrated that requirements were met.

Outcome: Review is to provide comments that will be useful for the improvement of the Network Verification plan.

13:10 - *Scheduled Break (30 minutes)*

13:40 - *Session 7*: Operations Contracts, SLOAs, MOAs, baselining the O&M plan, and establishing the Virtual NOC - Phil DeMar moderator

Supporting Documents:

- Global NOC Assessment questionnaire
- Network Operations and Management Plan

Objectives:

- An update on the plans, budgets, requests for FY22 and FY23 (including VNOC) - Cristian Silva
- An update on Operations Contracts, SLOAs, and MOAs, including comments on SLOA template - Julio Ibarra
- Discussion and comments on O&M plan - Phil DeMar

Outcome: Collect comments to the drafts of SLOAs and O&M plan provided to Cristian.

14:10 - Closure and Next Steps
14:30 - Adjourn

Appendix C. List of Participants SA3CC Meeting April 19-20, 2022

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