Rubin Observatory July 2023.; Credit: RubinObs/NSF/AURA/L. Guy

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

August 1-2, 2023

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Executive Summary

This report documents the proceedings of the AmLight SA3CC Meeting, on August 1-2, 2023, 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, Solan Digital Sky Survey, CMB-S4, SO, EHT, US-ELT, GMTO, ngVLA. A lively open discussion followed. The Providers updates session included network presentation updates including AmLight-ExP, Vera Rubin Observatory Network, UK & France Data Transfer, REUNA, RedCLARA, RNP, rednesp, USDF, Internet2, ESnet 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 in-person and virtually by Florida International University (FIU) on August 1-2, 2023, from 10 am to 5 pm to accommodate the different time zones. The meeting program can be found here: https://www.amlight.net/?p=5187.

The two-day meeting gathered 54 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)
- Cherenkov Telescope Array (CTA) Observatory
- Chilean Research and Educational network (REUNA)
- Cosmic Microwave Background Stage 4 (CMB-S4)
- Energy Science Network (ESnet) at Lawrence Berkeley National Laboratory
- European Research and Educational network (GEANT)
- Florida International University (FIU)
- France Research and Educational Network (RENATER)
- Five-hundred-meter Aperture Spherical Telescope (FYST) (a.k.a. CCAT)
- Giant Magellan Telescope Observatory (GMTO)
- Internet2
- Latin American Advanced Networks Cooperation (RedCLARA)
- MIT Haystack Observatory
- 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)
- Simons Foundation
- SLAC National Accelerator Laboratory
- Sloan Digital Sky Survey (SDSS)
- Tertiary Education and Research Network of South Africa (TENET)
- University of Pennsylvania (UPenn)
- University of Southern California Information Sciences Institute
- University of Texas (UT)
- Vera C. Rubin Observatory

Fall 2023 Vera Rubin Observatory Network Engineering Team (NET) Meeting
The Network Engineering Taskforce (NET) annual meeting took place on August 3-4, 2023, from 10 am to 5 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 40 network engineers from REUNA, AmLight/FIU, SLAC, ESnet, IN2P3, RNP, Vera Rubin Observatory, RENATER, GEANT, RedCLARA, FNAL, GlobalNOC, Internet2, Vera Rubin Observatory: UK, NSF, and technical astronomy engineers (See Appendix B & D for the agenda and participants list).

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 fostered 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 operate in South America and South Africa, with new projects in the pipeline. 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 maximize 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.

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 (Mauricio Rojas, Eduardo Toro)
- ALMA NRAO (David Halstead, Adele Plunkett)
- ALMA Network Infrastructure (Jorge Ibsen)
- CCAT (Mike Nolta)

- Sloan Digital Sky Survey (Guillermo Blanc)
- CMB-S4 (James Aguirre)
- Simons (James Aguirre)
- EHT (Jason SooHoo)
- US-ELT (Lucas Macri)
- GMTO (Sam Chan)
- ngVLA (David Halstead)

R&E Providers Updates

- AmLight1: International links (Jeronimo Bezerra)
- AmLight2: Monitoring and Measurement Improvements (Renata Frez)
- Vera Rubin Observatory Network (Cristian Silva)
- UK & France Data Transfer (Richard Hughes-Jones)
- REUNA (Albert Astudillo)
- RedCLARA (Marco Teixeira)
- RNP (Ari Frazão)
- rednesp (Joao Eduardo Ferreira)
- USDF Data Movement and Multi-Site Processing (Richard Dubois)
- USDF Infrastructure (Mark Foster)
- Internet2 (Chris Wilkinson)
- ESnet (Joe Metzger)

4. Science Requirements & Activities Updates

4.1 Vera C. Rubin Observatory Operations (Bob Blum, Senior Manager, Christian Silva, IT Manager Chile)

Figure 1 Vera Rubin Observatory 2023

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 (*Figure 1*), 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.

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 schedule includes:

- Engineering First Light, October 2024
- Arrival of LSSTCAm on the summit, October 2023
- LSST Starts in FY25

In March 2023, formal control of the TMA was obtained, marking a significant milestone in the construction progress. The construction of the Dome is progressing well, with expectations for it to continue into the following year. Meanwhile, the LSST camera is undergoing its final testing phase at SLAC and is scheduled for shipment to Chile in October 2023. The Data Management team has already entered the commissioning phase, with some operations already underway. The Integration team is actively monitoring schedule updates to optimize resource utilization and space allocation. Similarly, the commissioning team is concentrating on refining the observatory validation plan to enhance efficiency both on and off the sky.

The construction progress for the Rubin Observatory includes planning for the survey start in mid-2025. Data Preview 0 (DP0) is advancing successfully, enhancing the Operations team and community involvement, and now includes the addition of a Solar System catalog in DP0.3. Challenges persist in assessing the impact of satellites, with direct impact appearing manageable but systemic effects still not well understood. The in-kind program is in active growth, albeit with slow progress in Data Release Analysis (DRA) development. Efforts also continue to develop the Sustainability program for both the Rubin Observatory and NOIRLab. Additionally, the Education and Public Outreach (EPO) efforts remain active within the Operations phase.

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

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.

NOIRLab IT Operations have seen significant advancements, including the implementation of Next Generation Firewalls and a focus on hardware and software standardization. They have expanded the number of limited Tunnel Profiles for Remote Observing at CTIO and SOAR and implemented 2FA/MFA using PingOne Cloud Service. The ResearchSOC Initiative is underway, and SecureX has been implemented for enhanced security. Network backbone devices have undergone OS upgrades, and new topology planning with HA implementation is in progress. Additionally, there are efforts to implement virtualization and storage clusters at various NOIRLab locations (CTIO, GN, Tucson) and to deploy a unified productivity suite for all NOIRLab staff.

The NOIRLab Networking Upgrade Project is currently ongoing with several key focus areas. The LAN design is still in progress, with a priority on Tucson Base facilities where design and equipment purchase are in the works. The WiFi upgrade is actively being implemented at the La Serena Center. Additionally, there are plans for WAN design, including updates to the VPN Site-to-Site matrix and the standardization of Next Generation Firewalls (NGFW) and Border routers with a focus on high availability (HA). The implementation strategy is based on standard technologies, particularly at the La Serena Center, employing traditional Multi-Tier design and Fabric L2 Leaf-Spine architecture with Multi-Link Aggregation (MLAG). This encompasses Core-Distribution-Access topologies, and preparations are underway for the setup in BDC La Serena, involving Optics Hardware and Unified Management Tools.

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 (*Figure 2*):

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

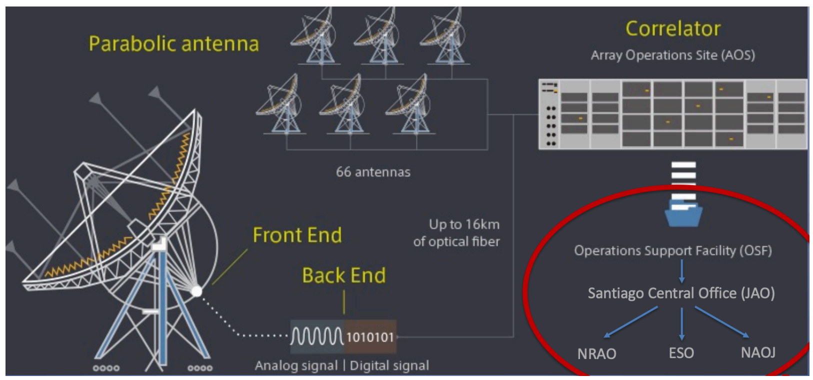

Figure 2 ALMA Telescope Data Flows

In terms of Expected Data Transfer, transferring data from Santiago Central Office (SCO) to the ARCs is not expected to be problematic, even with the anticipated increase in data volume from WSU. The majority of data processing and user data transfers are expected to proceed smoothly, with a focus on accommodating larger datasets that fully leverage the enhanced capabilities. In 2022, the average downloaded dataset size was 20 GB, with a maximum of 2.5 TB. However, during the upgrade, data sizes are projected to range from 1 TB to 125 TB. The assumed average data rate will be (in the 2030s) of the order of 3.6 PB/year - 6.6 PB/year. The ALMA project is actively considering the user experience and computational resources, particularly the Science Platform, to facilitate scientific output in light of these larger datasets.

The ramp-up of the ALMA data rate has been slower than initially expected, which has allowed us to remain proactive in managing data flows. Currently, data predominantly flows from the Joint ALMA Observatory (JAO) to ALMA Regional Centers, with most data processing occurring at the JAO. We are closely monitoring network performance while transferring approximately 10 terabytes per day across multiple parallel streams. It is imperative that we establish a dedicated 10Gb/s bandwidth link within the next 1-2 years to enhance transfer speeds to and from Chile, particularly for bulk reprocessing and handling occasional large data and metadata transports such as database exports. Furthermore, it appears that most upcoming developments, such as the next-generation correlator, can likely be accommodated without increasing the data rate by more than a factor of approximately four.

4.4 Atacama Large Millimeter Array (ALMA) Network Infrastructure (Jorge Ibsen, Head of Computing)

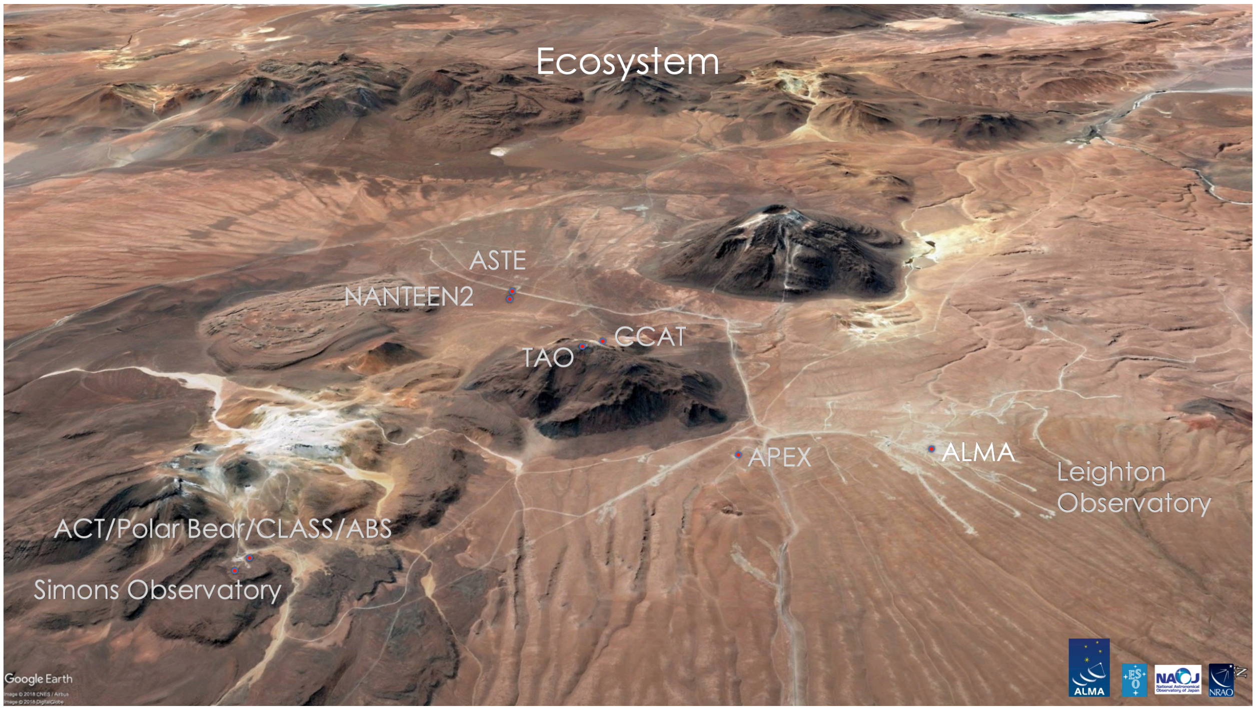

Figure 3 Chajnantor plateau of the Chilean Andes

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. 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.

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.

4.5 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, will be a 6-meter diameter telescope with a surface accuracy of 8 microns, operating at submillimeter to millimeter wavelengths and sited at 5612 meters elevation on Cerro Chajnantor in the Atacama Desert of northern Chile[1]. 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 "observers"/partners (St. Mary's, Manitoba, Lethbridge, Alberta, National Research Council) and Chilean Universities (University of Chile, UCSC, PUC).

The expected first light in 2025, 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, the foundation hole has been dug, the foundation is installed, the summit has been also fenced, the trenching is in progress (98% complete) and the telescope is still being constructed in Germany. 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.

The schedule for the telescope project involves assembling the telescope in Germany by November of the current year, with plans for shipment to Chile in mid-2024. The final acceptance phase is expected to be completed by mid-2025. Additionally, CHAI and Mod-Cam are scheduled for shipment in late 2024, while Prime-Cam is set to ship in late 2025. The commencement of science observations is anticipated to begin in late 2025.

4.6 Sloan Digital Sky Survey (SDSS-V) (Guillermo Blanc, Associate Director of Strategic Initiatives)

SDSS-V is the first facility providing multi-epoch optical & IR spectroscopy across the entire sky, as well as offering contiguous integral-field spectroscopic coverage of the Milky Way and Local Volume galaxies.

[1] Fred Young Submillimeter Telescope (FYST): http://www.ccatobservatory.org/index.cfm/page/about-ccat.htm

This panoptic spectroscopic survey continues the strong SDSS legacy of innovative data and collaboration infrastructure.

SDSS-V operates through a collaborative effort involving 66 academic institutions. This ambitious project receives support from esteemed entities such as the Sloan Foundation, the Heising-Simons Foundation, and the U.S. National Foundation for Science (NSF), highlighting the collective commitment to advancing astronomical research and exploration.

The Milky Way Mapper (MWM) survey, an integral part of SDSS-V, employs both BOSS low-resolution optical and APOGEE medium-resolution near-IR spectroscopy to target over 5 million objects, creating a detailed stellar map across the entire sky with a focus on low Galactic latitudes. By utilizing high signal-to-noise ratio (S/N) spectra, the survey aims to deduce stellar parameters and surface chemical composition, shedding light on the Milky Way's formation mechanisms. Additionally, MWM conducts multi-epoch observations of multi-star and planetary systems, unraveling their formation and evolution. The survey explores a high-dimensional parameter space, including stellar mass, age, composition, rotation, and internal structure, contributing to a comprehensive understanding of diverse stellar objects.

The Black Hole Mapper (BHM) within SDSS-V conducts a multi-object spectroscopic survey, focusing on optical spectra, often with multiple epochs, for over 300,000 quasars. The survey aims to collectively comprehend the masses, accretion physics, and the growth and evolution of supermassive black holes over cosmic time. Leveraging the existing BOSS spectrographs, BHM utilizes the 2.5m telescopes at both Apache Point and Las Campanas Observatories, providing wide optical spectral coverage with a resolution of R~2000.

The Local Volume Mapper (LVM) is an optical integral-field spectroscopic survey targeting the Milky Way, Small and Large Magellanic Clouds, and other galaxies in the Local Volume. Utilizing new telescopes and recently constructed spectrographs covering the wavelength range of 3600-10000 Å, with a spectral resolution of R~4000, the LVM instrument is designed based on the DESI spectrograph. Operating from Las Campanas Observatory, Chile, within SDSS-V, it aims to collect approximately 20 million contiguous spectra over 2,500 square degrees of the sky, including the midplane of the Milky Way, Orion, and the Magellanic Clouds, with potential expansion to cover the Northern Milky Way, M31, and M33, contingent on funding.

4.7 Cosmic Microwave Background (CMB) -S4 (James Aguirre, Associate Professor of University of Pennsylvania)

CMB-S4 is the 4th generation ground-based CMB experiment[2]. 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 scientific objectives of CMB-S4 are organized into four primary goals. First, it aims to scrutinize models of inflation by measuring or establishing upper limits on "r," the ratio of tensor fluctuations to scalar fluctuations. Second, CMB-S4 seeks to unravel the role of light relic particles in both fundamental physics and the structure and evolution of the Universe. The third goal involves measuring the emergence of galaxy clusters, understanding their formation, and quantifying the evolution of both clusters and the intracluster medium during this pivotal period in galaxy formation. Lastly, CMB-S4 aims to explore the millimeter-wave transient sky, employing the rate of mm-wave Gamma-Ray Bursts (GRB) to constrain GRB

[2] CMB-S4 project https://cmb-s4.org/

mechanisms and providing mm-wave variability and polarization measurements for stars and active galactic nuclei. These goals collectively contribute to advancing our understanding of the Universe's history, evolution, and contents.

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[3] 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).

The Atacama Data strategy for CMB-S4 involves a steady-state data rate of approximately 1 Gbps, with the potential to reach up to 5 Gbps in catch-up mode. In contrast to SO, CMB-S4 will not conduct its initial data processing on-site but will stream the data back to the U.S. for processing. This processing will include generating quick-look maps for data quality checks and transient detections. The primary goal is to issue transient alerts rapidly enough to facilitate timely follow-up observations, with a current requirement of around a day and a planned target of hours, possibly even minutes. The data processing options encompass national computing resources such as NERSC, dedicated project hardware like the U.S. cluster, and ideally, FABRIC in-network computing.

4.8 Simons Observatory (SO) (James Aguirre, Associate Professor of University of Pennsylvania)

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 four years, from 2024 to 2029/2030, 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.

Major Developments from 2022 to 2023 include the official funding of $52.66 million from the NSF[5] for the Advanced Simons Observatory (ASO) Photovoltaic power station. The expansion of the complement of optics tubes for LAT from 7 to 13, resulting in a doubling of mapping speed, has been achieved. A significant effort has been devoted to Data Management to ensure the public and timely distribution of science data. All telescope platforms (SATP, LAT) and LAT receiver (LATR) are on-site and undergoing testing, with one SAT already on-site and others expected shortly. Additionally, SO:UK funding has been secured during this period.

In the current timeline as of mid-2023, the Simons Observatory is actively engaged in the deployment and commissioning of SAT (Small Aperture Telescopes). Anticipated milestones include the first light for SAT in late 2023, followed by the first light for LAT (Large Aperture Telescope) in early 2024. The observatory aims to commence its first science observations in early 2024 and expects to be in full swing with science observations by mid-2024. The overall project encompasses construction from 2016 to 2024, with

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[3] CMB-S4 data portal https://data.cmb-s4.org/
[4] Simons Observatory https://simonsobservatory.org/
[5] Detecting faint traces of universe's explosive birth is aim of NSF-supported Advanced Simons Observatory- https://new.nsf.gov/news/detecting-faint-traces-universes-explosive-birth

operations slated to begin in 2024 and extend to 2029/2030, incorporating a four-year survey followed by Advanced Simons Observatory (ASO) operations.

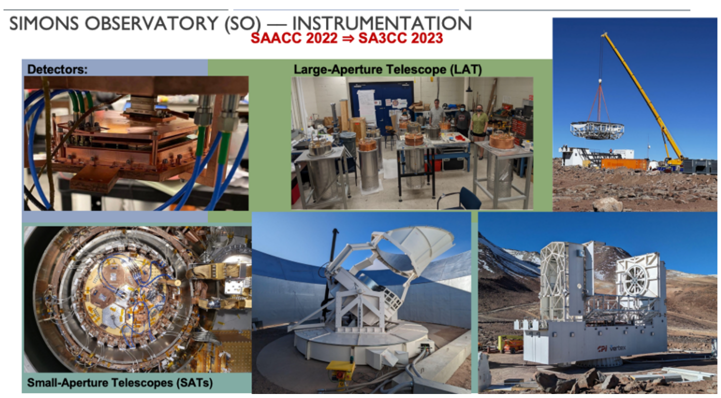

Figure 4 Simons Observatory

The data movement plan from the Simons Observatory (SO) site to the U.S. involves several key developments. The design of the site network has been completed and is currently under review. Additionally, SO has secured a fiber connection from the site to the ALMA REUNA PoP, with an update indicating that the connection near pad W208 has been updated to PAA (Possibly Alternate Access), ensuring fiber connectivity from ALMA to the site. An MoU (Memorandum of Understanding) between SO and ALMA to permit the fiber connection is in the preliminary revision stage, now updated to PAA x ALMA MoU. Furthermore, there is ongoing work on an MoU between SO and REUNA to finalize the utilization of services in this context. These steps collectively contribute to the robust data movement strategy of the Simons Observatory.

4.9 Event Horizon Telescope (EHT) (Jason SooHoo, IT Manager)

Figure 5 EHT 2023 Observing Campaign

The Event Horizon Telescope (EHT) is an array of millimeter and sub-millimeter wavelength telescopes using Very Long Baseline Interferometry (VLBI). The array spans the world creating a telescope with an effective Earth-sized aperture. Each pair of stations within the array creates a baseline covering the effective Earth-size aperture. Phased array stations like ALMA makes noticeable improvements to the observation coverage. The EHT VLBI backend receives the broadband signal, digitizes it, and records onto data modules. The data is then shipped to the MIT Haystack Observatory Correlator in Massachusetts, USA and the Max-Planck Institute for Radio Astronomy Correlator in Bonn, Germany for processing.

After the initial correlation, the data undergoes calibration algorithms to refine the data products. Subsequently, imaging techniques are applied to the calibrated data, resulting in the generation of images, which may include phenomena like supermassive black holes.

The EHT is evolving its observation strategy from annual to more frequent intervals, aiming for monthly or weekly snapshots. This shift allows for dynamic tracking of celestial targets like the M87 black hole, capturing short-term changes and creating continuous visual records. However, this ambitious plan comes with challenges, particularly due to the diverse nature of participating stations, each facing unique hurdles.

Addressing these challenges involves a focus on enhancing network and data transport capabilities. Faster networks and increased storage capacities at correlators are crucial for processing the growing data volumes efficiently. The EHT is also working on network quantification, running tests from stations to correlators to identify bottlenecks and deploying network test nodes for comprehensive monitoring. Additionally, streamlining station setup procedures and providing local staff training are ongoing efforts to reduce uncertainties and enhance the efficiency of EHT operations.

The future of EHT campaigns hinges on robust, high-speed Research Networks to sustain international operations. The EHT2023 Observing Campaign in April 12 - 23, 2023 (*Figure 5*), observed 6 of the nights at 10 sites (Chile: ALMA, Atacama Pathfinder EXperiment (APEX) [6]; Greenland Telescope (GLT)[7]; USA: Kitt Peak National Observatory (KPNO)[8]; France: NOrthern Extended Millimeter Array (NOEMA)[9]; Mexico: Large Millimeter Telescope Alfonso Serrano (LMT)[10]; Hawaii: James Clerk Maxwell Telescope (JCMT)[11], Submillimeter Array (SMA)[12], UArizona ARO Submillimeter Telescope (SMT) [13], and South Pole Telescope (SPT) [14]). The long-term aspiration is to overcome challenges in data transport on larger scales, necessitating improvements in high-speed networks extending to both remote stations and correlators. Collaboration with Research and Education Networks (RENs) on an international level is vital for optimizing these networks. In the short term, the practice of sending partial data back to correlators for swift validation remains crucial, especially with the anticipated increase in observation cadences. Streamlining operational processes and procedures is a key focus for achieving quicker turnarounds, while network quantification and station monitoring play pivotal roles in tracking performance changes and optimizing data transport.

4.10 US Extremely Large Telescope Program (US-ELT) (Lucas Macri, Project Director)

The US ELT Program sets forth several key objectives to facilitate transformative scientific endeavors through American access to a bi-hemispheric Extremely Large Telescope (ELT) system. The program aims to empower large-scale, systematic, and collaborative research, particularly through designated Key Science Programs. Additionally, the program commits to delivering exceptional user support in alignment with the proposed investment in the US-ELTP. It strives to enhance participation in science initiatives associated with the Thirty Meter Telescope (TMT) and Giant Magellan Telescope (GMT), fostering inclusivity in research. The program also emphasizes active engagement and representation of the entire US scientific community in the governance, scientific planning, and instrumentation development of GMT and TMT. The National Science Foundation provided support to further the design and development of advanced optical technologies and user services of US-ELT program[15].

The US-ELTP's commitment to research inclusion stands at the forefront of its mission, focusing on broadening participation in TMT and GMT science for all astronomers. A special emphasis is placed on researchers from smaller and under-resourced institutions, ensuring accessibility and equitable opportunities. The provision of science-ready data products will enhance the accessibility of GMT and

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[6] Atacama Pathfinder EXperiment (APEX) - http://www.apex-telescope.org/ns/
[7] Greenland Telescope (GLT)Project - https://www.cfa.harvard.edu/greenland12m/
[8] Kitt Peak National Observatory (KPNO) - https://www.noao.edu/kpno/
[9] NOEMA (NOrthern Extended Millimeter Array) -https://iram-institute.org/observatories/
[10] Large Millimeter Telescope Alfonso Serrano (LMT) - http://www.lmtgtm.org
[11] James Clerk Maxwell Telescope (JCMT) - http://www.eaobservatory.org/jcmt/
[12] Submillimeter Array (SMA)- http://sma1.sma.hawaii.edu/
[13] UArizona ARO Submillimeter Telescope (SMT) - https://aro.as.arizona.edu/
[14] South Pole Telescope (SPT) - https://aro.as.arizona.edu/
[15] US Extremely Large Telescope Program Receives $15.3 Million from the National Science Foundation https://noirlab.edu/public/announcements/ann23029/?lang

TMT to observers across the spectrum. The incorporation of archival research not only expands scientific opportunities but also engages researchers from a diverse range of institutions. The US-ELTP Data Science Suite is poised to play a pivotal role by offering an open platform for user training in data analysis, promoting inclusivity in scientific exploration. Furthermore, the collaborative models employed in organizing Key Science Program teams reinforce the commitment to an open and inclusive research environment, with research inclusion becoming a key element in the merit review of Key Science Programs.

The TMT's location strategy in Hawaii is designed with a division between sea-level headquarters and the summit. The sea-level headquarters, situated 50 km away, serves as the primary hub for science operations control and accommodates most staff, excluding those involved in on-site maintenance or major interventions. The summit, dedicated mainly to telescope operators during nighttime operations, could potentially see an increased level of automation and safety measures that might allow for the relocation of all nighttime staff to sea-level in future operational stages. Additionally, TIO partners may establish their Remote Operations Centers to support their community in areas such as science program preparation, optimization, data reduction, and even remote observations.

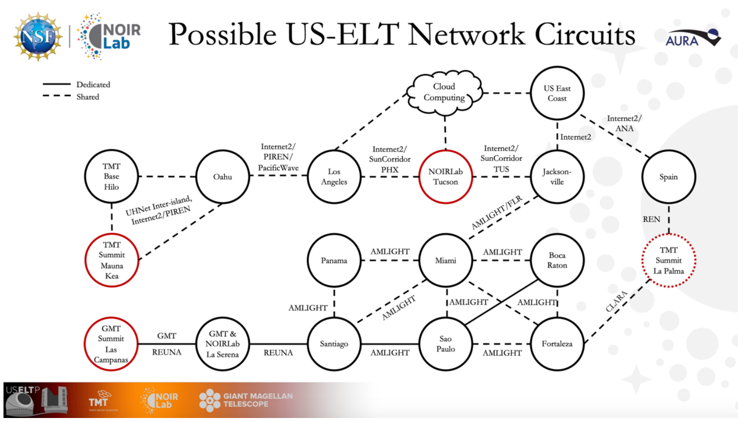

Figure 6 Possible US-ELT Network Circuits

The TMT Data Management System (DMS) and Data Processing System (DPS), key components of the UPP (Upper Project Platform), play crucial roles in handling science exposures and processing instrument data. The DMS focuses on reliably storing and tracking science exposures and ancillary files, ensuring seamless collaboration with NOIRLab, developing data transfer policies, and verifying the integration with the US-ELTP Science Archive. Possible US-ELT network circuits will be using an existing REN connection (*Figure 6*). On the other hand, the DPS maintains commonality and standards for processing all science instrument data, engaging in collaborative design efforts with NOIRLab for Explore Integration Time Calculators (Explore-ITC) tools, validating interfaces to instrument specifications, and supporting the integration of TMT's data processing tools into the UPP environment. Testing and validating UPP tools for data processing are integral tasks for both the DMS and DPS components.

The US-ELTP is poised to revolutionize astronomical research by providing open access to the GMT and TMT, empowering US astronomers for transformative scientific endeavors. With a dedicated commitment to outstanding user support, the program seeks to facilitate researchers in achieving their scientific aspirations. The US-ELTP's user services aim to extend the reach of science, fostering collaboration with TMT and GMT and expanding the research community. In tandem, NOIRLab is set to work closely with the scientific community throughout development and construction, ensuring the creation of systems that align seamlessly with researchers' needs.

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

The GMT[16] 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)[17] program.
The Giant Magellan Telescope Observatory (GMT) is anticipating the generation of approximately 31 terabytes of scientific data each year. GMT's "First Light" milestone is planned for around the year 2029. To support the management and analysis of this extensive data output, the project intends to utilize a nearby data center, likely the NSF research/education network, to enhance data processing and storage capabilities.

4.12 Next-generation Very Large Array (ngVLA) (David Halstead, NRAO CIO)

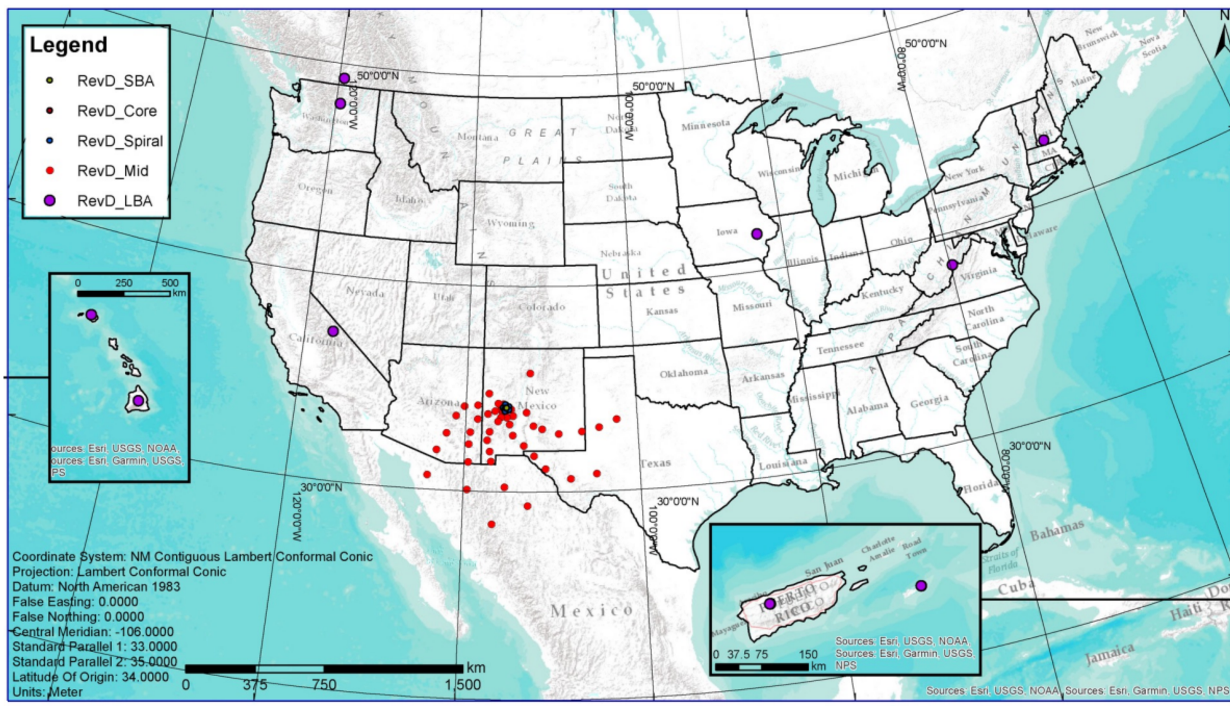

Figure 7 Long Baseline Antenna Locations

This envisioned VLA aims to push the scientific frontier by offering thermal imaging at milli-arcsecond resolution, providing a substantial improvement in sensitivity by a factor of 10 and a remarkable increase in resolution ranging from 10 to 100 times compared to the existing VLA. Its operational frequency range spans from 1.2 to 116 GHz, positioning it as a bridge between the Square Kilometre Array (SKA) and ALMA projects. This proposal-driven, pointed telescope would focus on deep single fields and small area mapping. The proposed location is centered around the present VLA location in the Southwest USA.

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

Importantly, the project is currently under evaluation as part of the Astro2020 Decadal Survey, highlighting its potential significance in the field of astronomy.

The Prototype Antenna contract progress is as follows: The Preliminary Design Review (PDR) phase was successfully completed in December 2022. Currently, fabrication is in progress, with plans for factory acceptance tests scheduled for late 2023. The next step involves site acceptance testing, which is expected to commence in mid-2024.

The Antenna Data Rates for the ngVLA project include the following specifications: Real-time correlation of all 244 18m array elements with up to 20 GHz of instantaneous bandwidth per polarization and 8-bit digitization at all frequency bands. Each antenna can handle data at a rate of 723 Gbps, which is transmitted over 8 links at 100 Gbps and 2 links at 400 Gbps on ngVLA installed fiber infrastructure. The data is then requantized and formatted for transmission on packet-switched networks. For approximately three antenna Low-Band Array (LBA) sites (*Figure 7*), the goal is to achieve a combined link capacity of around 1 Tbps (to be confirmed).

4.13 Summary Science Instruments

The following table summarizes the information on instruments 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
Next Generation Very Large Array (ngVLA)	Puerto Rico (Arecibo Site), St. Croix (VLBA Site), Kauai, HI (Kokee Park Obs.), Hawaii, HI (Not MK Site), Hancock, NH (VLBA Site), Green Bank, WV (GBO), Brewster, WA (VLBA Site), Penticton, BC (DRAO), North Liberty, IA (VLBA site), Owens Valley, CA (VLBA site)	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, Chile	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	Cornell University, Ithaca, NY, USA, Cologne, Germany Toronto, Canada	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 & TMT	Chile and Hawaii (or La Palma, Canary Island)	Tucson AZ	construction	2029	Projected 10-40 TB per night. Data flow from Chile and Hawaii; Managed by NSF & NOIRLab
EHT	ALMA, APEX, GLT, JCMT, KP, LMT, NOEMA, SMA, SMTO, and SPT	MIT Haystack Observatory Correlator in Massachusetts, USA and the Max-Planck Institute for Radio Astronomy Correlator in Bonn, Germany	operation	varies	2023 Campaign notes: Observations were at 230GHz & 345GHz, Dual pol and double side band, Station recorders at 64Gb/s, Collecting about ~2PB raw data per station. The data is then shipped to the MIT Haystack Observatory Correlator in Massachusetts, USA and the Max-Planck Institute for Radio Astronomy Correlator in Bonn, Germany for processing.

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 support 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).

Since 2022 and into 2023, AmLight has been primarily focused on several key initiatives. These include the replacement of legacy network devices with fully programmable P4 switches, enhancing network resilience through the addition of new links, reducing operational expenses by addressing power consumption and rack space utilization, expanding the availability of 100G access interfaces for both users and science drivers, and enhancing overall network visibility.
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.

Between 2021 and 2025, AmLight is intensifying its Software-Defined Networking (SDN) framework with notable developments. They are introducing a new data plane using programmable network devices, specifically NoviFlow/EdgeCore P4 programmable switches, while also enhancing network visibility through P4/In-band Network Telemetry (INT) and Juniper JTI for routers. Additionally, they are pioneering an Intelligence Plane with the Behavior, Anomaly, and Performance Manager (BAPM) designed for sub-second closed-loop control, as detailed in a 2023 IEEE NOMS paper. Lastly, AmLight is implementing the Kytos-ng SDN controller as part of the new Control Plane. These initiatives underscore their commitment to advancing network capabilities and management within the SDN framework.

In the year 2023, AmLight is set to expand its production infrastructure by incorporating 10 new switches across various locations. Specifically, Miami will receive 3 new switches, Boca Raton will have 1, Santiago will have 1, Jacksonville will have 1, Atlanta will see the addition of 2 switches, and Buenos Aires will have 2 new switches. This strategic expansion aims to enhance network capabilities and support the growing demands of these respective locations within the AmLight network (*Figure 8*).

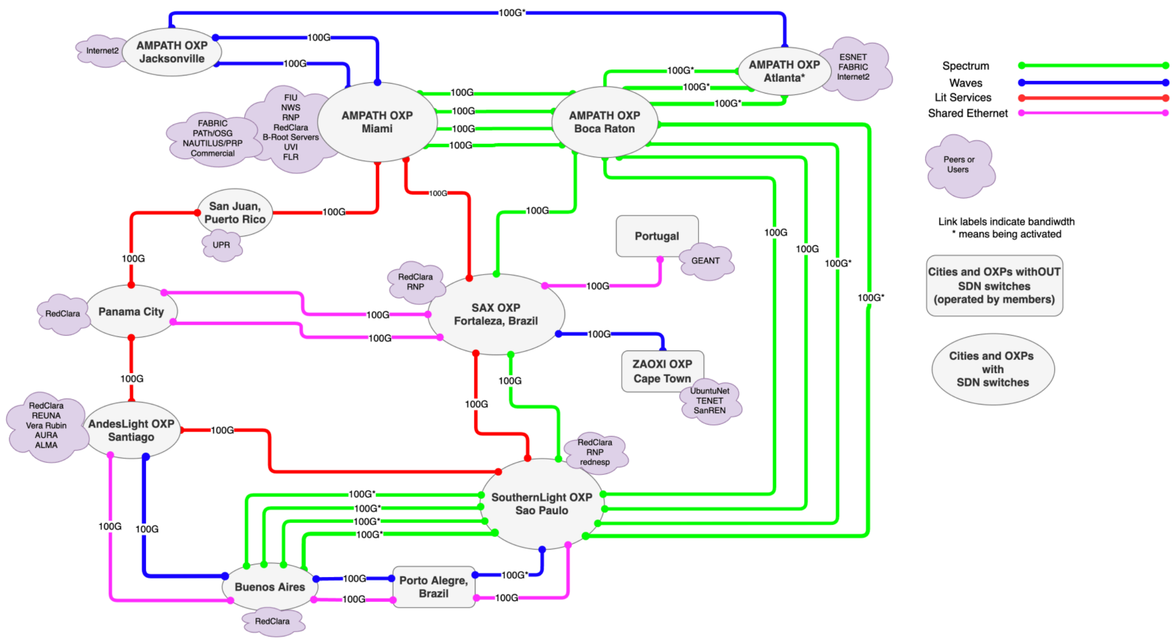

Figure 8 AmLight SDN Long-haul Links - 2023/2024

AmLight is actively supporting SA3CC through its complex network topology and substantial bandwidth capacity. With more than 25 potential paths between Chile and Jacksonville, they are striving to optimize network services by ensuring proper load balancing while meeting user constraints and requirements. AmLight is well-prepared to accommodate science applications that are intolerant of packet loss and demand sub-minute response times. Leveraging per-packet telemetry and sub-second network profiling capabilities, AmLight can rapidly respond to network conditions in under a second. Their focus is on proactive engineering and automation, utilizing closed-loop control to carry out time-consuming operational tasks without the need for human intervention. This approach ensures the network remains robust and responsive to support SA3CC's objectives effectively.

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, antispoofing, coordination, validation). Combining all monitoring tools enables AmLight to track any performance issue and user request.

Between 2021 and 2025, AmLight is dedicated to advancing its Software-Defined Networking (SDN) framework with comprehensive enhancements. A new Data Plane is being established based on programmable network devices, specifically leveraging NoviFlow/EdgeCore P4 programmable switches. The introduction of a new Management Plane aims to augment network visibility through P4/In-band Network Telemetry (INT) for programmable switches and Juniper JTI for Juniper routers. A novel Intelligence Plane, represented by the Behavior, Anomaly, and Performance Manager (BAPM), is currently under development to learn network states and establish a sub-second closed-loop control. This innovation aligns with a goal described in the 2023 IEEE NOMS paper titled "An Adaptive and Efficient Approach to Detect Microbursts Leveraging Per-Packet Telemetry in a Production Network." Additionally, a brand-new Control Plane is being implemented through the Kytos-ng SDN controller. These initiatives collectively underscore AmLight's commitment to advancing network capabilities and efficiency within the SDN framework.

In conclusion, AmLight has achieved remarkable advancements in network monitoring and visibility. The implementation of In-band network telemetry (INT) has enabled the monitoring of every packet, exceeding expectations in enhancing network visibility. The introduction of JTI has expanded visibility into Juniper devices, while perfSONAR tests provide critical insights into user experiences. Recognizing that each monitoring tool has its strengths and weaknesses, AmLight combines these tools to effectively track performance issues and address user complaints. The importance of monitoring for security purposes is emphasized, and ongoing efforts to explore new monitoring methods continue. AmLight welcomes specific monitoring requests, encouraging open communication for optimizing their monitoring capabilities.

5.3 Vera Rubin Observatory Network (Cristian Silva, Rubin Observatory IT Manager Chile)

The Vera Rubin Observatory Network spans an impressive ~105,000 kilometers of fiber, with a significant portion (~46,000 kilometers) running underwater. The fiber network traverses six countries and encompasses 16 Points of Presence (PoPs) in its primary path. This expansive network involves the collaborative efforts of approximately 15 engineers from different Research and Education (R&E) organizations, highlighting a multi-organizational approach to its design and maintenance. The scale, global reach, and collaborative nature underscore the significance and complexity of the Vera Rubin Observatory Network.

The decision to remove the Network ACI from the Rubin Observatory was driven by several key factors. Firstly, its removal addressed a 10-gigabit bottleneck, enhancing overall network performance. Adopting a vendor-neutral approach provided more flexibility and compatibility. The transition to a highly scalable solution facilitated the network's growth and adaptability. The decision was also motivated by the desire to simplify troubleshooting processes, reduce costs, and streamline the overall network architecture. This strategic move reflects a commitment to optimizing efficiency, scalability, and cost-effectiveness in the Rubin Observatory's network infrastructure.

Several updates have been implemented in the network infrastructure. The Base Test Stand (BTS) is now operational at the base, connected to the LHN (Low-Level Network). The Summit Production cluster is also connected to the LHN, along with a dedicated commissioning cluster at the summit. A wireless backup link from Summit to Base has been enabled. Notably, the Summit to Base link, initially 40x10gb, has been upgraded to 4x100GB for improved capacity. Additional updates include the enabling of Summit to USDF (Utility & Support Facilities Division) replication in various workloads, the establishment of the Large File Annex (LFA) and Engineering Facilities Database (EFD) with Postgres support. These utilize Kubernetes resources, involve single streams, and operate at low bandwidth (~6MB/s). The Vera Rubin Observatory Network is pending various tasks, including end-to-end testing, encryption, security measures, avoiding the use of Huawei equipment, and ensuring observability. The ongoing effort involves continuous building of components like LFA, Comm Cluster, among others, resembling building blocks for a robust network infrastructure.

5.4 UK & France Data Transfer (Richard Hughes-Jones, Senior Network Advisor)

GÉANT serves as a crucial entity providing infrastructure and services to advance research, education, and innovation globally. It operates as a membership association comprising Europe's National Research & Education Networks (NRENs), including 38 European NRENs and NORDUnet (representing 5 Nordic NRENs). GÉANT's reach extends to over 10,000 institutions and 50 million academic users. The current project, GN4-3N, aims to integrate 30 countries into its infrastructure, with an estimated investment cost of €49 million. This infrastructure is expected to be viable for 15 to 21 years, with substantial contributions from NRENs. Notably, the Western ring is running at a remarkable 800 Gbit/s. In addition, the RENATER Network, based on dark fiber and DWDM hardware, spans 12,000 km of optical fiber, featuring 72 points of presence and supporting 150 wavelengths ranging from 10 to 200 Gbit/s.

In the disk-to-disk concurrent flows between Paris and Cambridge using davix-put and xrootd (HTTP), the setup includes CamDTN1 running xrootd version 5.6.1 and DTNlon executing davix-put. Each davix-put client is assigned to a different core. The tests involve transferring varying numbers of files concurrently, and the results are plotted to showcase total transfer rates. Notably, the flows exhibit smooth behavior over time, and the occurrence of very few TCP re-transmits is observed. The scalability of the system is evident as it successfully scales from 1 flow at 8 Gbit/s to 5 flows at 26 Gbit/s, highlighting the efficiency and effectiveness of the concurrent flow configuration.

5.5 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 11,000 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.

The Chajnantor Point of Presence (PoP), a collaborative project between REUNA and ALMA Observatory, stands as a pioneering initiative to offer fast, reliable, and secure connectivity to international astronomical projects situated on the Chajnantor Plateau. This PoP operates at an extraordinary altitude of more than 5,000 meters, making it the highest PoP for Research and Education (R&E) globally. The project facilitates the connection of 12 astronomical initiatives, enabling high-speed data transmission and supporting remote operation of telescopes and other critical functionalities. This infrastructure marks a significant advancement in providing essential networking capabilities for astronomical endeavors in one of the world's most challenging terrains. 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.

The collaborative physical connectivity initiative involves REUNA entering into a collaboration agreement with ALMA, allowing access to a portion of the connectivity infrastructure. This access enables REUNA to install its Point of Presence (PoP) within the ALMA data center in AOS (Array Operations Site). To extend the connectivity to various hills where telescopes or the Park are located, agreements have been established with ALMA for last-mile connectivity. The proposed solution for this connectivity is a Coarse Wavelength Division Multiplexing (CWDM) system. The first telescope connection is anticipated to be completed in the first half of 2024, marking a significant milestone in enhancing connectivity for astronomical projects in the region.

The establishment of a PoP in Punta Arenas is underway, with plans to achieve this milestone before the end of the year. Recognizing the global distribution of the astronomical research community, international connectivity plays a pivotal role in facilitating data transmission and remote management of instruments. In this context, the organization is actively engaged in collaborative efforts, serving as founders of RedCLARA, members of BELLA, and partners with Amlight. These affiliations underscore the commitment to fostering international reach and cooperation in support of advancing astronomical research and collaboration around the world.

The next challenge on the horizon involves the ambitious goal of connecting Antarctica. Recognizing the significance of Punta Arenas as a gateway city to Antarctica, where over 20 countries utilize its services, the challenge is to establish reliable and effective connectivity to support the diverse scientific and logistical operations in Antarctica. Overcoming the unique geographical and environmental challenges of Antarctica to enable seamless communication and data transmission represents a pivotal step in advancing international collaboration and research efforts in this remote and critical region.

5.6 Latin American Cooperation of Advanced Networks (RedCLARA) (Marco Teixeira, Director for Technical Infrastructure)

RedCLARA serves as a critical infrastructure that interconnects the National Research and Education Networks (NREN) of several Latin American countries, including Argentina, Brazil, Colombia, Costa Rica, Chile, Ecuador, Guatemala, Mexico, and Uruguay. Its primary mission is to connect these networks to advanced academic networks globally, fostering the development of science and academia. By providing connectivity, RedCLARA supports intraregional and transcontinental research across all fields of knowledge, contributing to the elimination of geographical borders. The collaborative nature of RedCLARA extends as more countries, such as Panama, Peru, and El Salvador, are actively working on developing their own NRENs and are expected to join forces with RedCLARA in the near future. This expansion reflects a commitment to enhancing research capabilities and collaboration across the region.

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.

The BELLA II Project is a regional initiative with a primary goal of diminishing the digital divide and fostering the development of essential infrastructure to consolidate and expand a digital ecosystem in the realms of science, technology, education, and innovation. This initiative is designed to reinforce and broaden the digital landscape in Latin America and the Caribbean. Its focus is on facilitating connections and exchanges among companies, research centers, educational institutions, and national research and education networks. The overarching aim is to align these efforts with the strategic objectives in education, science, technology, and innovation in the Latin American and Caribbean region. Through the BELLA II Project, there is a concerted effort to advance the digital capabilities and collaboration opportunities in these critical domains.

The project's financial requirements are outlined as follows: the total estimated initial investment is 28 million euros. The European Commission is set to contribute 13 million euros toward this initiative. The remaining counterpart funds are expected to be contributed by governments, development banks, investment funds, and other relevant entities. This financial structure reflects a collaborative effort with diverse stakeholders, leveraging resources from both public and private sectors to meet the project's financial needs and ensure its successful implementation.

5.7 The Brazilian Research and Educational Network (Rede Nacional de Ensino e Pesquisa RNP) (Ari Frazao, Manager of the Engineering and Operations Center)

RNP's backbone infrastructure is currently in its 7th generation, and the deployment is ongoing. The strategy involves investments in lightening optical fibers from electrical power companies and, in some cases, hardware/software support. There's an emphasis on channel swaps with Internet Service Providers (ISPs), and RNP aims to minimize the use of leased lines, except for specific cases in the Amazon Region.

The upcoming plans for the backbone include the deployment of nine more 100G circuits, some of which are redundant for added reliability. Additionally, there are plans to expand the Eletrosul and Furnas projects. Eletrosul focuses on connecting cities like Londrina, Curitiba, and Porto Alegre, while Furnas aims to establish connections from São Paulo to Teixeira de Freitas.

RNP has established international connections through partnerships with academic initiatives such as Bella (RedCLARA + GÉANT) and AmLight. Points of connection include Fortaleza (connected to RedCLARA and AmLight), São Paulo (connected to RedCLARA and AmLight), and Porto Alegre (connected to RedCLARA). Dark fibers are strategically used, connecting essential sites in Fortaleza and São Paulo.

RNP actively contributes to SA3CC, supporting data movement between observatories in Chile and South Africa. This connection is crucial for research and education communities in South America, Africa, the U.S., Europe, and other destinations of interest. Specifically, RNP has established a 100G link between Porto Alegre and São Paulo exclusively for the LSST (Large Synoptic Survey Telescope) Project.

RNP is actively engaged in several relevant projects aimed at advancing research and education through robust network infrastructure. The eCiber project focuses on creating a resilient infrastructure with 100G circuits, connecting key research institutions such as INPE, LNCC, and CNPEM. In parallel, Infovia 00, part of a comprehensive eight-phase program, spans from Macapá to Santarém, laying optical cables across the Amazon River and operating as a fully functional neutral operator with the involvement of 12 ISPs and telcos. Simultaneously, Infovia 01 is under experimental operation, connecting Santarém to Manaus and serving as a crucial initiative to enhance research infrastructure in the Amazon region. These projects collectively underscore RNP's commitment to fostering innovation and collaboration within the research and education communities.

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 The Research and Education Network of São Paulo (rednesp), (Joao Eduardo Ferreira, Coordinator of Rednesp)

The Research and Education Network of São Paulo (rednesp), has undertaken significant efforts in both financial investment and technical collaboration. In terms of financial investment, it has secured USD 5 million annually for the past 16 years. This funding has been crucial for establishing Atlantic and Pacific links, in collaboration with AmLight. The financial support for these endeavors comes from FAPESP, the São Paulo Research Foundation.

The second effort involves technical collaboration and the establishment of resilient links, each with a capacity of 2 x 100 Gbps. These resilient links are funded by FAPESP-rednesp and provided by Lauren. Additionally, the Monet Link, also operating at 2 x 100 Gbps, is facilitated through collaboration with AmLight. Another significant link is the Ella link, a part of the Bella Programme, which is provided through a European effort and managed in Brazil by RNP. These technical collaborations underline rednesp's commitment to advancing network infrastructure and connectivity in the field of research and education.

The third effort focuses on the evolution of its infrastructure, transitioning from an older 100Gbps system to a state-of-the-art 400Gbps network. The previous infrastructure, using obsolete and discontinued equipment, faced limitations in both capacity and upgrade possibilities. The new infrastructure adopts cutting-edge Juniper equipment, offering a significantly enhanced capacity of up to 14.4Tbps per slot. Notably, the PTX10004, a part of this upgrade, features four slots, totaling an impressive 57.6Tbps. This evolution represents a substantial leap in network capabilities, ensuring that rednesp stays at the forefront of technological advancements in the field of research and education network infrastructure.

The fourth effort undertaken by rednesp, referred to as Backbone-SP, involves the integration of eight academic institutions in the state of São Paulo at a high-speed rate of 100Gbps. This initiative is aimed at establishing a robust and high-availability connectivity infrastructure to support both teaching and research endeavors across the state. The Backbone-SP project encompasses the creation of a backbone network for both state and international connections, utilizing high-speed protocol-transparent point-to-point links. This infrastructure serves as an alternative for interconnecting research centers within the state, fostering collaboration and knowledge exchange. Furthermore, it plays a pivotal role as a backbone for the integration of High-Performance Computing (HPC) servers, enhancing the computational capabilities for research and academic activities in São Paulo.

The fifth effort by rednesp involves the implementation of Kytos-ng, a Software-Defined Networking (SDN) platform. This platform includes an SDN controller responsible for orchestrating SDN switches along the Pacific/Atlantic ring, connecting São Paulo, Brazil, to Florida, United States. Kytos-ng adopts a multi-component architecture and serves as a framework for developing Network Applications (NApps). Notable functionalities of Kytos-ng include E-Line (Point-to-Point Ethernet virtual circuits), LLDP network topology discovery, Pathfinder for computing constrained best paths, Bidirectional Forwarding Detection (BFD), and In-band network telemetry (INT). The platform is designed to be controlled via REST APIs or a Web UI, providing flexibility and ease of management in enhancing network capabilities and efficiency. In the upcoming Kytos-ng version 2023.2, rednesp plans to contribute by upgrading the core component of the Kytos-ng User Interface (UI) and supporting the development/evolution of the UI. These efforts highlight a commitment to enhancing the user experience and functionality of Kytos-ng, ensuring its continued effectiveness in SDN network management.

Rednesp has expanded its projects. The first project, led by Prof. Luiz Vitor de Souza Filho, focuses on linking the Cherenkov Telescope Array (CTA) observatory from Chile to Europe. With the support of a cooperation grant from FAPESP, the project aims to study extreme environments of the universe, exploring phenomena such as dark matter, the potential breaking of Lorentz invariance, and understanding the operation of supermassive black holes. The second project involves the integration of High-Performance Computing (HPC) Centers in São Paulo, aligning with the Scientific and Technological Cooperation Agreement between FAPESP, MCTI, and MCom. With a budget of USD 20 million, this initiative seeks to enhance scientific and technological cooperation, fostering collaboration among computing centers and advancing research capabilities in the state.

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

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 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.
The Vera Rubin Observatory's US Data Facility (USDF) is well-equipped for multi-site processing, boasting resources such as 10,000 batch cores, 30 PB disk storage, 50 Kubernetes nodes, and various servers. Notably, it has achieved a milestone by successfully processing data from the Auxiliary Telescope (AuxTel) at the summit, with routine processing now accessible in the Rubin science platform. The implementation of a "Long Haul Network" between the Summit and SLAC, using a combination of leased lines and ESNet, further enhances data transfer capabilities. The USDF has initiated a Hybrid model, with a contract in place with Google and production Qserv running with DC2 catalog, demonstrating access from the Google Cloud. This infrastructure supports approximately 300 staff and commissioners, facilitating successful bootcamps on USDF and aiding Full Camera Testing in IR2 with automated data transfers to France using Rucio/FTS.

The multi-site status of the Vera Rubin Observatory's data processing is progressing successfully. Access to 3,000 cores each at FrDF and UKDF has been established, showcasing the ability to submit and run jobs to capacity. Rucio, with servers at SLAC and Rucio Storage Elements at each site, is installed and configured, enabling routine data exchange among sites. Notably, a thorough shakedown of PanDA at SLAC during the HSC PDR2 reprocessing has been conducted, providing insights into the effectiveness of Campaign Management tools. Automated transfers of Full Camera data from SLAC to FrDF have been demonstrated, with FTS3 performing transfers based on Rucio rules. The finalization of connectors between Rucio and Butler is underway to ensure synchronization of dataset information for full multi-site capability.

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

The SLAC National Accelerator Laboratory is a US Department of Energy (DOE) Office of Science laboratory operated by Stanford University[18]. 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

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

other sites with multiple ESnet 100Gbps links (ability to scale Nx400Gbps in later 2023 or early 2024). 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. setup encompasses 97 racks, distributed across six rows with 15 racks each and one row with seven racks.

The S3DF Networking plan, currently in progress for the SRCF-II, outlines a robust infrastructure to support the facility's operations. It includes 97 racks organized into six rows with 15 racks each and an additional row with seven racks. The networking setup aims for a 2 Tbps connection to ESnet (aggregate), with a configuration of 100 GbE for each compute node and 200 GbE for storage servers (utilizing 2x100G). The architecture features 45 32-port x 400 GbE TOR switches, employing a fat tree/distribution approach to layer 3 routers. An alternative design involves direct connections from switches to layer 3 routers. The overall network is designed to facilitate 5,040 100GbE connections through 1,260 4x100GbE breakouts, ensuring a scalable and high-performance networking infrastructure for the S3DF.

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

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.

5.12 Energy Science Network (ESnet) (Joe Metzger, Senior Network Engineer)

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.

In the ongoing trans-Atlantic and EU ring upgrades, several enhancements are already in production, including the implementation of 400G and 100G connections between New York and London, 100G links from Boston to Amsterdam, and a 100G link between Washington and Geneva. Currently underway are additional upgrades, such as the deployment of 400G connections between Boston and London, Boston and CERN, and a comprehensive 400G upgrade to the Europe Ring in collaboration with GEANT. The next phase of upgrades is planned to achieve 2x400G, with a targeted capacity of 3+ Tbps by the end of 2027. These upgrades, driven primarily by the High-Luminosity Large Hadron Collider (HL-LHC), aim to enhance both capacity and resiliency across the network infrastructure.

Appendix A. Program for the SA3CC Meeting

Tuesday, August 1, 2023
9:50 – 10:00 Welcome – Julio Ibarra

Session I: Science Requirements & Activities Updates
10:00 – 10:20 Vera C. Rubin Observatory Operations (Bob Blum, Christian Silva) | Download Presentation
10:20 – 10:40 NOIRLab – ITOPS (Mauricio Rojas, Eduardo Toro) | Download Presentation
11:00 – 11:30 *Refreshment Break*
11:30 – 11:50 ALMA NRAO (David Halstead, Adele Plunkett) | Download Presentation
11:50 – 12:10 ALMA Network Infrastructure (Jorge Ibsen) | Download Presentation
12:10 – 12:30 FYST (a.k.a. CCAT) (Mike Nolta) | Download Presentation
12:30 – 13:30 *Lunch*
13:30 – 13:50 Sloan Digital Sky Survey (Guillermo Blanc) | Download Presentation
13:50 – 14:10 CMB-S4 (James Aguirre) | Download Presentation
14:10 – 14:30 Simons (James Aguirre) | Download Presentation
14:30 – 14:50 EHT (Jason SooHoo) | Download Presentation
14:50 – 15:20 *Refreshment Break*
15:20 – 15:40 US-ELT, (Lucas Macri) | Download Presentation
15:40 – 16:00 GMTO (Sam Chan) | Download Presentation
16:00 – 16:20 ngVLA (David Halstead) | Download Presentation
16:20 – 16:40 Open discussion

Wednesday, August 2, 2023
9:50 – 10:00 Welcome – Julio Ibarra

Session II: Providers updates
10:00 – 10:20 AmLight1: International links (Jeronimo Bezerra) | Download Presentation
10:20 – 10:40 AmLight2: Monitoring and Measurement Improvements (Renata Frez) | Download Presentation
10:40 – 11:00 Vera Rubin Observatory Network (Cristian Silva) | Download Presentation
11:00 – 11:30 *Refreshment Break*
11:50 - 12:10 UK & France Data transfer (Richard Hughes-Jones) | Download Presentation
12:10 – 12:30 REUNA (Albert Astudillo) | Download Presentation
12:30 – 13:30 *Lunch*
13:30 – 13:50 RedCLARA (Marco Teixeira) | Download Presentation
13:50 – 14:10 RNP (Ari Frazão) | Download Presentation
14:10 – 14:30 rednesp (Joao Eduardo Ferreira)| Download Presentation
14:30 – 14:50 USDF data movement and multi-site processing (Richard Dubois) | Download Presentation
14:50 -15:20 *Refreshment Break*
15:20 – 15:40 USDF infrastructure (Mark Foster) | Download Presentation
15:40 – 16:00 Internet2 (Chris Wilkinson) | Download Presentation
16:00 – 16:20 ESnet (Joe Metzger) | Download Presentation
16:20 – 16:40 Open discussion

Appendix B. Program for the Vera Rubin Observatory NET Meeting

Thursday, August 3, 2023

10:00 - Welcome and Introductions

- Goals and Objectives – Phil, Cristian and Julio (10 minutes)
- Rubin Observatory Network Status Overview – Cristian or Bob Blum (10 minutes)
- Q&A (10 minutes)

10:30 - *Session 1*: LHN Documents Review - Cristian Silva moderator. (20 minutes)

Objective: Catalog for documents to transition from Construction to Operations.

Catalog document: https://ittn-044.lsst.io/ITTN-044.pdf

10:50 - *Session 2*: Updates on the current and planned enhancements of the LHN network infrastructure– Cristian Silva moderator

Report on the network infrastructure since the 2022 Rubin Observatory NET meeting. A representation of the portion of your network that supports the Rubin Observatory is requested; anything else is outside the scope.

The outcome of Session 2 is to document what the Rubin Observatory NET has deployed since the 2022 Rubin Observatory NET meeting. Each network representative will present 1 - 2 slides and take questions.

Europe: (30 minutes)
- GEANT – Richard Hughes Jones (10 min)
- RENATER/IN2P3 – Frederic Loui/ Jerome Bernier from IN2P3 (10 min) Phil to inquire.
- UK/JANET - (Peter Clarke/Duncan Rand) (10 min). Phil to inquire.

11:20 Break (10 minutes)

11:30 South America: (50 minutes)
- Rubin Observatory Network – Cristian Silva (10min)
- REUNA – Albert Astudillo (10min)
- RedCLARA – Marco Teixeira (10min)
- RNP – Aluizio Hazin (10min)
- AmLight and Huawei bypass – Jeronimo (10 min)

12:20 Break (10 minutes)

12:30 CONUS: (30 minutes)
- FIU-AmLight – Jeronimo Bezerra (10min)
- SLAC - Mark Foster (10min)
- ESnet - Paul Wefel, Kate Robinson (10 min)

Outcome: Diagrams and description to be made available for LSE-78, LSE-479 and other Rubin documents.

13:00 Lunch

14:30 - *Session 3*: Updates to LSE-479 Rubin Observatory Network Technical Document – and Network Management and Operations Julio Ibarra and Phil Demar moderators (40 minutes)

Purpose: To 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). (20 minutes)

Purpose: To review Network and Operations Management Plan (20 minutes)

Outcome:

- 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.
- Network Management and Operations Plan

15:10 Break (10 minutes)

15:20 - *Session 4*: Review and update the NET activities and milestones as Rubin Observatory approaches Operations. Julio Ibarra Moderator (20 minutes)

Objective: To identify activities and milestones to accomplish before the start of Operations. (Cristian Silva)

Outcome: Update the Baseline Milestones for LHN project plan

15:40 - Wrap up and Actions.

16:00 - Adjourn.

Friday, August 4, 2023

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

- Overview of Day 1 meeting and Roadmap for Day 2

10:10 - *Session 5*: LHN End-to-end Test Plan and Performance measurement: Julio Ibarra moderator. Introduction (20 minutes)

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

How are the operators responding to the Rubin LHN SLA:

- Primary paths are dedicated by end of FY24 (including Boca - Atlanta in Q2 FY24). By definition, no need for QoS on the dedicated primary (only Vera Rubin traffic)
- Secondary: SLA Expectation: By the start of FY24, there is a 40G minimum (during observing 10 hours per night) required on your secondary.
  - What is the methodology each operator is using to provide the 40G minimum?
    - Vera Rubin, REUNA, AmLight, ESnet to present (1-2 slides)
- Summit to Base – Vera Rubin (Cristian, Hernan) (5 minutes)
- Base to Santiago – REUNA (Albert) (5 minutes)
- Santiago to Atlanta – AmLight (Renata) (5 minutes)
- Atlanta to SLAC – Esnet (Paul, Kate??, or Gisela) (5 minutes)

Outcome: (1) To document what methods the LHN operators are using to respond to the Rubin SLA.

10:30 *Session 6a*: USDF data movement and multi-site processing. Richard Dubois (20 minutes, 10 minutes Q&A/Discussion)

Purpose: To inform the NET of Rubin data movement from the USDF and multi-site processing. Identify Tools/applications for data movement (e.g., Rucio). What are the data movement requirements?

11:00 Scheduled Break (10 minutes)

11:10 Session 6b: Network requirements from USDF (SLAC) to GEANT, IN2P3, UK (Europe) (Panel Discussion: Richard Hughes Jones, Jerome or Frederic, Peter or ???, Mark Foster, ESnet, Richard Dubois) (30 minutes) (Phil to moderate)

  - What are the service requirements from USDF to IN2P3? and UK facility?
    - What are network requirements from Rubin Data Management?
    - 10G service requirement from USDF to Europe
    - Networks need to be clear on the requirements.

Outcome: To document use cases of data movements and their requirements to analysis sites in Europe

11:40 *Session 7a*: Measurement Infrastructure: (20 minutes)
- Present the measurement infrastructure for the LHN. Tests for Primary and Backup paths.
- Report on the mechanism to export measurement data (SNMP, sampled data, streaming data)
  - Keynote: Measurement requirements from Data Management (K-T Lim TBD)
    - What DM is doing. What tools DM is using, etc. Share what DM has in mind.
    - Parallel flows vs. single flows? Compliant with RFC 6349.
    - What recommendations does DM have for how the LHN and networks to analysis sites should be measured?
    - Cristian to invite KT.

12:00 Scheduled Break (10 minutes)

12:10 Session 7b: Measurement Infrastructure (continue) (45 minutes) (Phil to moderate)

  - LHN End-to-End measurements / monitoring:
    - Summit to USDF Storage (Julio C., Mark) (5 minutes)
    - Base to SLAC Border (Julio C., Mark) (5 minutes)
  - LHN Domain-level monitoring (intra-domain & cross-domain)
    - Summit to Base – Vera Rubin (Julio C, Hernan) (5 minutes)
    - Base to Santiago – REUNA (Albert) (5 minutes)

        - Santiago to Atlanta – AmLight (Renata) (5 minutes)
        - Atlanta to SLAC – Esnet (Paul, Kate ???, Gisela???) (5 minutes)
    - US-European network monitoring (intra and inter-domain):
        - SLAC to GEANT (Richard Hughes-Jones) (5 minutes)
        - SLAC to IN2P3 (Frederic Loui, Jérôme BERNIER) (5 minutes)
        - SLAC to UK/JANET (Peter Clarke/Duncan Rand) (5 minutes)

The outcome of session 7 is to:
- Document the mechanism to export measurement data. Relevant for the VNOC.
- Update relevant documents (e.g. LSE-479) with Measurement Infrastructure information.
- Prepare the End-to-End Test plan document for submission to the Rubin Observatory CCB for baseline.

12:55 Lunch (1 hours, 5 minutes)

14:00 - *Session 8*: VNOC (30-minute presentation, 20 minutes Q&A and discussion)

GNOC Template (Questions)

What does GNOC want to present? What information does GNOC want from LHN network operators to develop the VNOC?

Outcome: To inform the LHN network operators what data to export for the VNOC. To prepare a project plan with a timeline and milestones.

14:50 Scheduled Break (10 minutes)

15:00 *Session 9*: Rubin Observatory Networks Verification – Cristian Silva moderator (30 minutes)

Purpose: To inform the LHN network operators what must be accomplished to demonstrate to funding agencies and to Rubin Observatory management that by end of FY2024 the Rubin Observatory Network has met its requirements.

Review the Vera Rubin Observatory Network Verification plans and schedule.

- Rubin Observatory Network Verification (planning for formal tests/demonstrations) – Cristian Silva
    - Responses to the 2022 Pre-Verification Review.
    - LDM-732 Rubin Observatory Networks Verification Baseline (Josh Hoblitt)
        - LDM-732 describes the methodology used (how) the Rubin Observatory NET demonstrated that requirements were met.

    - Requirements on Rubin. Missing requirements. Rates are missing.

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

Acceptance tests? What is the format and content of acceptance documentation?

15:30 - *Session 10*: Operations Contracts, SLOAs, MOAs, baselining the O&M. Phil Demar (40 minutes).

Procedures to discuss:

- Troubleshooting on the LHN.
- Trouble Ticket System for the LHN.
    - Ticket system will be managed by Rubin Observatory.
    - Demonstration of the Jira Ticket System (Cristian, 10 minutes)
- How are operators going to conduct maintenance?
- How will maintenance be performed from a common perspective?
- Phil to provide a framework for discussion.

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

16:10 - Discussion and Next Steps (20 minutes)

16:30 - Adjourn

Appendix C. List of Participants SA3CC Meeting August 1-2, 2023

First Name	Last Name	Email	Organization	Country
Adele	Plunkett	aplunket at nrao.edu	NRAO	US
Albert	Astudillo	aastudil at reuna.cl	REUNA	CL
Aluizio	Hazin Filho	aluizio.hazin at rnp.br	RNP	BR
Andro	Fuentes	andrfuen at fiu.edu	FIU CIARA	US
Ari	Frazão	ari.frazao at rnp.br	RNP	BR
Chip	Cox	chipcox at me.com	AMPATH & Vanderbilt Univ.	US
Chris	Wilkinson	cwilkinson at internet2.edu	Internet2	US
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