TransPAC5
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Year 2 Annual
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Summary
The TransPAC5 project supports circuits and services for the use of high-speed networks between the US and Asia, with a focus on measurement and end user support. Year 2 highlights include significant work with the APOnet collaboration to include partner measurement data, a new joint Guam-Singapore Connectivity Consortium (GSCC) 100G Circuit between Guam and Singapore, the startup of the Routing Working Group, and the end-to-end performance work between the Atacama Large Millimeter Array (ALMA) in Chile and the National Astronomical Observatory of Japan (NAOJ).

1. TransPAC5 Overview
The TransPAC5 project is part of a larger portfolio supported by the International Networks at Indiana University (IN@IU) team. TransPAC5 supports two circuits:

1. The TransPAC-PacWave 100G circuit, which is a 100 Gbps link between Seattle, Washington, and Tokyo, Japan. This circuit has been in production since February 2016 and is the primary project circuit for production traffic for TransPAC5. This link is fully funded by NSF and is managed in cooperation with Pacific Wave (PacWave) and Pacific Northwest GigaPop (PNWGP).
2. The Guam-Singapore Connectivity Consortium (GSCC) 100G Circuit, which is a 100 Gbps link between Guam and Singapore. Consortium members include Internet2, Australia's Academic and Research Network (AARNet), SingAREN, University Hawaii, PacWave, and TransPAC. This circuit was accepted as production on January 20, 2022.

In Year 2, we also explored opportunities with our partners to move traffic more efficiently between the NEA^{3}R site in New York and the TransPAC/PacWave site in Seattle to provide a “Fast Track” connection. We plan to continue this work in Year 3, and more information can be found in Section 6.C. The TransPAC5 award also supports science engagement, experimental network research, measurement deployments, and security activities.

2. Staffing

In Year 2, TransPAC5 staffing levels increased to fully support all circuits and activities. New staff were added, and some existing staff had additional time allocations available. At the end of Year 3, funded staff included:

- Jennifer Schopf, PI, IN@IU Director
- Hans Addleman, Co-PI, TransPAC network architect
- Heather Hubbard, Project Support
- Brenna Meade, Engineering and routing
- Ed Moynihan, Science Engagement
- Doug Southworth, Measurement and monitoring.

Francis Lee, SingAREN, is a co-PI but does not receive funding for compensation.

TranPAC5 has a contract with the IU GlobalNOC to provide Tier 1 and Tier 2/3 networking support. This contract was put in place in January 2021, but TransPAC5 only began to cover the full costs in July 2021.

3. Conference and Workshops

TransPAC staff participated in various meetings to support their role in collaborations in Asia. During this time frame, most meetings were still being held virtually due to Covid-19 related travel restrictions. Meetings for Year 2 included:

- Ed Moynihan attended the NSF Antarctic Cable Workshop, June 29-July 1, 2021, https://www.pgc.umn.edu/workshops/antarctic-cable/. Moynihan participated in sessions with other REN operators and with researchers on the challenges of getting a cable to Antarctica and the value REN connectivity could bring to science on the continent.
- Southworth attended the perfSONAR Developer All Hands Meeting, July 13-15, 2021. Southworth participated in discussions that covered a variety of topics related to current release status, future releases, and training efforts.
- Moynihan attended and presented at the PRAGMA "reconnect" webinar, July 22, 2021. Moynihan presented on TransPAC5 and on the end-to-end performance work our team is doing with the Engagement and Performance Operations Center (EPOC).
- Schopf attended the APAN52 Conference, August 2-6, 2021, https://apan52.apan.net/wp/agenda/. Schopf gave an Invited Keynote about the APOnet collaboration, ran a BoF session for the Routing Working Group, and gave an update on TransPAC4 and TransPAC5 as part of the Network Engineering Workshop.
- Addleman attended the Internet2 Community Voices Series: Cost-Effective, Scalable Solution for Network Security at the Border, August 12, 2021, https://internet2.edu/internet2-community-voices-series-cost-effective-scalable-solution-for-network-security-at-the-border/. Addleman participated

in a discussion of the University of Michigan's new border security system, which uses a combination of network taps, zeek sensors, security load balancers, and homegrown software to automatically manage the border network security filters.

- Addleman and Meade attended the GNA-G Community VCs #6, September 14, 2021, https://www.gna-g.net/attend-a-meeting/community-vcs-q3-2021/. Addleman presented on the Routing Working Groups progress and meetings to date. Other GNA-G working groups gave updates and a Ciena engineer gave a presentation on subsea networking.
- Addleman attended the FAB All Hands Meeting, September 16, 2021. Addleman participated in discussions about the status of connecting the University of Bristol to the FABRIC network in the US. FABRIC staff also gave an update on the current FABRIC network and hardware deployment.
- Moynihan attended the 2nd Global Research Platform (2GRP) Workshop, September 20-21, 2021, https://www.theglobalresearchplatform.net/meetings/2nd-global-research-platform-workshop-2021/. Moynihan attended partner update sessions and sessions on NSF-funded projects FAB and BRIDGES.
- Addleman attended the Quilt Fall Members Meeting, September 29-30, 2021, https://www.thequilt.net/public-event/the-quilt-2021-virtual-fall-member-meeting/. Addleman participated in talks focused on the Mutually Agreed Norms for Routing Security (MANRS) project, a review of the NSF CC* PI Workshop, and the future of fiber purchases and inter-exchange point links.
- Meade and Moynihan attended the CI Lunch and Learn, October 8, 2021. Meade and Moynihan presented and answered questions about how NetSage can help identify performance and routing issues.
- Addleman, Moynihan, and Southworth attended the LHCOPN-LHCONE Meeting #47, October 11-12, 2021, https://indico.cern.ch/event/1022426/. Southworth presented a proposal for using NetSage to monitor LHC traffic in upcoming data challenges, and Addleman presented on updates to TransPAC infrastructure.
- Addleman attended the 2021 NSF Cybersecurity Summit, October 12-13, 2021, https://www.trustedci.org/2021-cybersecurity-summit. He participated in presentations and discussions on the required security levels of NSF projects, best practices for securing a ScienceDMZ, and securities impact on network architecture.
- Southworth attended the GlobalNOC Connects Annual Members Meeting, October 19-20, 2021, https://usergroup.globalnoc.iu.edu/events/globalnoc-connects-2021/. Southworth participated in discussions regarding

infrastructure updates, staffing changes, and plans for future product development.

- Schopf, Addleman, Moynihan, Southworth, and Meade attended the Internet2 Tech Extra conference, December 1-3, 2021, https://internet2.edu/techextra21-infrastructure-advanced-networking/ . Meade presented a lightning talk on the Routing Working Group highlighting the topics of the meetings and cases over the past six months and an overview of how to get involved in the Routing Working Group.
- Addleman attended the Cybersecurity Engagement in a Research Environment Workshop December 7-9, 2021, https://blogs.iu.edu/researchsoc/2021/11/11/workshop-cybersecurity-engagement-in-a-research-environment, to continue his network security training. Addleman participated in discussions on the security needs of researchers versus enterprise systems and about presenting security policy to researchers and working to meet their needs without overburdening the researchers.
- Schopf attended the virtual FABRIC KNIT Workshop Meeting, December 8-9, 2021, https://whatisfabric.net/events/knit-winter-2021-fabric-community-workshop. Schopf participated in discussions about the structure of FABRIC and how TransPAC might be able to support the project.
- Schopf attended the AGU21 Meeting, New Orleans, LA, December 13-15, 2021, https://www.agu.org/Fall-Meeting. Schopf participated in discussions with geoscience colleagues on how TransPAC could support Earth and space scientists.
- Meade and Moynihan attended the GNA-G Community VCs #7 Meeting, December 15-16, 2021, https://www.gna-g.net/attend-a-meeting/gna-g-community-vcs-q4-2021/. Meade gave a presentation about the SC21 SCinet Wide Area Network (WAN) and reported on the ongoing work of the Routing Working Group.
- Schopf attended the virtual TPRE meeting, January 14-19, 2022. She gave two talks, one an overview of the APOnet collaboration, including the new partnership with JUCC/HARNET, the other an overview of all IN@IU programs, with details from NetSage, for both the TransPAC4/5 and NEAAR/NEA^{3}R circuits.
- Schopf and Addleman attended the FABRIC Across Borders (FAB) all hands meeting, January 26, 2022. They participated in discussions centered around the installation of FABRIC sites at Bristol University and at CERN.
- Schopf attended virtually, 2022 NSF Cyberinfrastructure for Major Facilities Workshop: Getting Together, Working Together, March 2-3, 2022,

https://whova.com/web/hecmw_202202/. She participated in discussion about solutions to challenges facing the CI community.

- Addleman attended the 2022 Quilt Virtual Winter Member Meeting, March 7-10, 2022, https://www.thequilt.net/public-event/2022-quilt-virtual-winter-member-meeting/. He participated in talks on new and upcoming network technologies such as Hybrid WAN, low earth orbit satellite internet service, quantum networking, and an update on the Pacific Research Platform (PRP).
- Schopf, Addleman, and Meade virtually attended APAN53, March 7-11, 2022, https://apan53.apan.net/. Schopf presented to the engineering working group. Meade presented a Routing Working Group Birds of Feather in collaboration with APNIC ISIF Project's.
- Southworth attended the GÉANT 2nd Performance Management Workshop, March 8, 2022, https://events.geant.org/event/1084/. He presented ongoing NetSage development for campuses, HPC centers, and High Luminosity LHC data trials.
- Moynihan attended the opening session of the Building Collaborations: U.S. – India Workshop, March 15, 2022, https://usiai.iusstf.org/building-collaborations. He participated in the introduction of NSF's program to foster new IT collaborations between the US and India.
- Moynihan and Southworth attended the virtual LHCOPN-LHCONE meeting #48, March 29-30, 2022, https://indico.cern.ch/event/1110783/. Southworth gave a talk on NetSage and the potential for using it to monitor LHCONE traffic. Moynihan gave a talk on setting up deliberate back-ups across the ana trans-atlantic links for LHCONE traffic.
- Meade and Moynihan attended the GNA-G Community VCs Q1 meeting, March 30-31, 2022, https://www.gna-g.net/attend-a-meeting/gna-g-community-vcs-q1-2022/. Meade gave a brief update of the GNA-G Routing Working Group and participated in other GNA-G working groups updates and made plans for hybrid TNC22.
- Southworth attended the GÉANT 2nd Telemetry and Data Workshop, April 6, 2022, https://events.geant.org/event/1104/. This workshop focused on how monitoring data is collected and how to share that data in useful ways, and was attended by approximately 50 members of the network monitoring community.
- Southworth, Addleman, and Meade attended the Routing Working Group meeting, April 19, 2022. Southworth presented on routing using perfSONAR.
- Southworth attended the GlobalNOC Connects workshop, May 10-12, 2022, https://usergroup.globalnoc.iu.edu/events/virtual-globalnoc-connects-spring-2022/. This conference gave customers and stakeholders an opportunity to better understand GlobalNOC service, activities, and plans for the future.

- Schopf, Moynihan, and Meade attended TNC22, Trieste, Italy, June 11-17, 2022, https://tnc22.geant.org/. The team met face-to-face with several partners for both NEA^{3}R and TransPAC5 and attended several sessions on network updates and new international networking projects. Meade also led a Birds of a Feather (BoF) session for the Routing Working Group. During this BoF, she discussed the current open cases being addressed, tools for identifying, troubleshooting, and resolving routing problems, and provided an overview of efforts to create best practices for the global REN community.

Presentations and publications for Year 2 included:

1. Schopf, J., "NetSage and Finding Unexpected Routes", Invited Talk, Routing Working Group Meeting, July 20, 2021. Slides available online at: https://drive.google.com/file/d/1f8qFpwV3VkimemwVNV5IfoXwvtIdVvDi/view?usp=sharing
2. Moynihan, E., "IU@IN and TransPAC Update", Invited Talk, PRAGMA, July 22, 2021. Moynihan attended and presented at the PRAGMA "reconnect" webinar, July 22, 2021. Moynihan presented on TransPAC5 and on the end-to-end performance work our team is doing with the Engagement and Performance Operations Center (EPOC). Slides available online at: https://drive.google.com/file/d/1PBLRdMvZYvjYvNK3H39Ws0SqUZt0Mb6c/view?usp=sharing
3. Schopf, J., "Asia Pacific Oceania Network (APOnet)", Invited Keynote, APAN52, August 4, 2021. Slides available online at: https://drive.google.com/file/d/1Wb3yaq3j3DZv4I43sTABfnUGFHoOlfTI/view?usp=sharing
4. Schopf, J., "TransPAC4 and TransPAC5", Invited Talk, APAN52, August 3, 2021. Slides available online at: https://drive.google.com/file/d/1hRmraYEtW8WkxqEUIAff3WxNhDeY4J6b/view?usp=sharing
5. Schopf, J., "Routing WG Overview", BoF Talk, APAN52, August 5, 2021. Slides available online at: https://drive.google.com/file/d/1jEvF_Kb04zZPz1ciaGifsLRc6eUqvfgR/view?usp=sharing
6. Addleman, H., "Routing Working Group Update", Invited Talk, GNA-G Community VCs #6 Meeting, September 14, 2021. Slides available online at: https://drive.google.com/file/d/1j1X8aQROqLPdBhvX6BPni5gN1zkTBxqC/view?usp=sharing
7. Meade, B., Moynihan, E., "Investigating, troubleshooting, and improving performance with NetSage and the GNA-G Routing WG", Invited Talk, CI Lunch and Learn, October 8, 2021. Slides available online at:

https://drive.google.com/file/d/1ZIoCBDqlCdbopMVTHegXL4H3gsk6vXMW/view?usp=sharing

8. Addleman, H., “TransPAC/NEA^{3}R Updates International Networks Indiana University”, Invited Talk, LHCOPN-LHCONE Meeting #47, October 11, 2021. Slides available online at: https://drive.google.com/file/d/1vToz-Q8LYLcZBV7qsFWH0LybRhW_HKfC/view?usp=sharing
9. Southworth, D., “Understanding LHC Data Movement with NetSage”, Invited Talk, LHCOPN-LHCONE Meeting #47, October 12, 2021. Slides available online at: https://drive.google.com/file/d/1Fc9H8B5mP9GSkXgr5tLQ7UpeDye7urP1/view?usp=sharing
10. Meade, B., “International Routing Working Group”, Invited Lightning Talk, Internet2 TechExtra, December 2, 2021. Slides available online at: https://drive.google.com/file/d/1O8_ts6TyyaFoyO2nmteHVnETYDAynKG8/view?usp=sharing
11. Meade, B., “SC21 WAN Update”, Invited Talk, GNA-G Community VCs #7 Meeting, December 16, 2021. Slides available online at: https://drive.google.com/file/d/1ONu5v8YAEhI524Nlf2YqEcvh6jhayKwd/view?usp=sharing
12. Schopf, J. “Asia Pacific Oceania Network (APOnet)”, Invited Talk, TPRE meeting, January 15, 2022. Slides available online at: https://docs.google.com/presentation/d/12PLv51qF-nKNTYCzlWOMf8UTpEjZWcCaZdt6yrbb5Vo/edit?usp=sharing
13. Schopf, J. “International Networks at Indiana University (IN@IU) Update”, Invited Talk, TPRE meeting, January 15, 2022. Slides available online at: https://drive.google.com/file/d/1jnxE2jM2BhOj6SnXKpfCbc7Yyiw9L24a/view?usp=sharing
14. Southworth, D., “NetSage: Flexible Monitoring Framework for Multiple Applications”, Invited Talk, GÉANT 2nd Performance Management Workshop, March 8, 2022. Slides available online at: https://drive.google.com/file/d/1ZaswMI9KruBC7VyLXvIfI_MDcMK3yD6b/view?usp=sharing
15. Meade, B., "Developing a collaborative BGP routing, analyzing and diagnosing platform", Invited BOF, APAN53, March, 10, 2022. Slides available online at: https://drive.google.com/file/d/1s0X0YJZchWrCSrwaQQQUIZ_s4cB5qrdO/view?usp=sharing
16. Schopf, J. “APOnet and TransPAC5 Updates”, Invited Talk, APAN53 Network Engineering Working group, March 8, 2022. Slides available online at: https://docs.google.com/presentation/d/1BuDV6AnhHLLmW278bVKt6Nx7Sn8Bkztba1MBtv8L0AM/edit?usp=sharing

17. Southworth, D., "NetSage Demonstration", Invited Talk, LHCOPN-LHCONE meeting #48, March 29-30, 2022.
18. Meade, B., Moynihan, E., "Routing Working Group (RWG) GNA-G Update", Invited Talk, GNA-G Community VCs Q1 meeting, March 30-31, 2022. Slides available online at: https://drive.google.com/file/d/1sMoyMdIUE_IR2fOZ_PQlMDye4uoRzqeP/view?usp=sharing
19. Southworth, D., "CLI Testing and Troubleshooting", Invited Talk, Routing Working Group meeting, April 19, 2022. Slides available online at: https://drive.google.com/file/d/199dS9skiVOLATJwiTGcPA5zThOy70_PB/view?usp=sharing
20. Meade, B., "Addressing Global Routing Practices with the Routing Working Group", Invited BoF, TNC2022, June 16, 2022. Slides available online at: https://drive.google.com/file/d/1DbN8bLAylK1qf3caSO3edYoCTDS10FCL/view?usp=sharing

4. Collaborative Activities

4.A Asia Pacific Ring / Asia Pacific Oceanic Network (APOnet)

The most significant collaboration for TransPAC5 is the **Asia Pacific Oceania Network (APOnet) Consortium**, (https://www.aponet.global/), of which Schopf is the Consortium Lead. APOnet consists of:

- Australia's Academic and Research Network (AARNet),
- Arterial Research and Educational Network in Asia-Pacific (ARENA-PAC),
- Internet2,
- Korea Institute of Science and Technology Information (KISTI)/Korea Research Environment Open Network (KREONET),
- National Institute of Information and Communications Technology (NICT),
- National Institute of Informatics (NII)/ Science Information Network (SINET),
- Pacific Wave,
- Research and Education Advanced Network New Zealand (REANNZ),
- Singapore Advanced Research and Education Network (SingAREN),
- University of Hawaii, and
- TransPAC5.

During Year 2, Hong Kong Academic and Research Network (HARNET)/Joint Universities Computer Centre Ltd (JUCC) was added as a member to APOnet, bringing the number of members up to twelve. The full set of circuits and exchange points supported by the consortium is shown in Figure 1.

The Engineering Team is meeting monthly and has focused on defining deliberate backups and getting every member to contribute SNMP data to the APOnet NetSage portal, https://aponet.netsage.global. A perfSONAR MadDash is also being set up and is available at: https://aponet.ps.uhnet.net/maddash-webui.

Year 3 plans include expanding the NetSage data to include Flow data, increased cooperation to support SC22 experiments, and a replacement LHCONE VRF to support the data challenges.

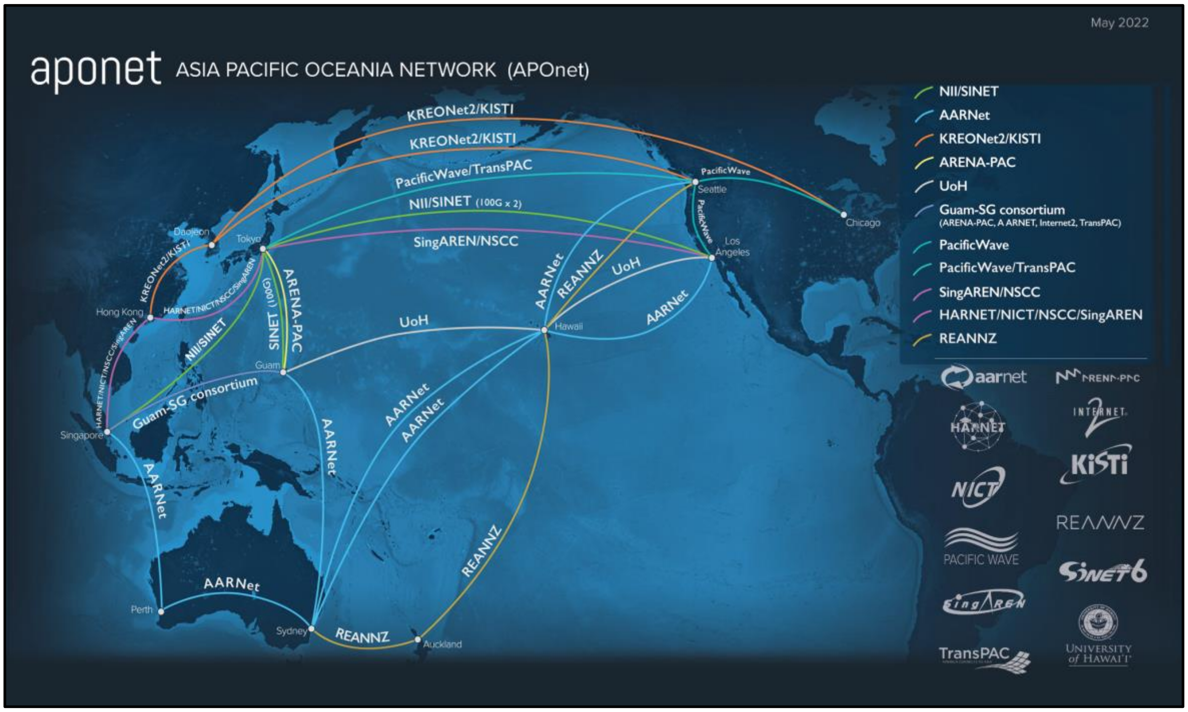

Figure 1: A map of the circuits and exchange points associated with the Asia Pacific Oceania Network (APOnet) collaboration.

4.B Collaborations with Partners

We continue our collaborations with international partner organizations around the world. In Year 2, interactions included:

- **Asia Pacific Network Information Centre Information Society Information Fund Asia (APNIC ISIF) BGP Routing Platform Project**- The APNIC ISIF BGP Routing Platform Project is building a collaborative BGP routing analyzing and diagnosing platform. This project is funded by the APNIC ISIF project and led by PI's Jilong Wang (Tsinghua University), Chalermpol Charnsripinyo (ThaiREN), and Simon Peter Green (SingAREN) (https://www.bgper.net/). Before the March 2021 APAN53 meeting, the program committee requested the RWG session be combined with an introduction session for the BGP Routing Platform Project. That began a series of conversations between the TransPAC team and the BGP Routing Platform Project team. TransPAC is now an official partner in their project, with Addleman a member of the coordination committee and Meade part of the technical committee. The BGP Routing Platform Project team has also joined the RWG and are providing updates on their work to the RWG.
  In Year 3, TransPAC will peer with the project's route collector and provide snapshots of our routing table. These routes will be used to enhance their BGP

tools' view of the global R&E network. We will also continue as part of their committees and collaborate with them in the Routing Working Group.

- **Asia Pacific Advanced Network (APAN)** - Schopf attended both virtual APAN meetings that took place in Year 2, attending multiple sessions for each and giving multiple presentations. During Year 2, we also held the second required introductory BOF for the Routing Working Group, joint with Warrick Mitchell, AARNet, thereby meeting the requirements for a new working group, which was officially announced as part of APAN in August 2021. Discussions to sign a new MOU between APAN and TransPAC5 have been delayed until we can schedule a face-to-face meeting.
- **Arterial Research and Educational Network in Asia-Pacific (ARENA-PAC)** - Several discussions took place with Jun Murai, who was the driver behind the Guam-Singapore Connectivity Consortium (GSCC), in addition to APOnet meetings.
- **Australia's Academic and Research Network (AARNet)** - We met multiple times with AARNet as part of the GSCC and APOnet discussions. We also worked with Warrick Mitchell of AARNet to establish the joint GNA-G/APAN Routing Working Group.
- **Collaboration Asia Europe (CAE)** - CAE is a consortium of six R&E networks: Australia's Academic and Research Network (AARNet) (Australia), GÉANT (Europe), NORDUnet (European Nordics), Singapore Advanced Research and Education Network (SingAREN) (Singapore), SURF (Netherlands), and TEIN*CC/Asi@Connect (Asia-Pacific). They have collaborated to fund and support a 100G circuit from Singapore to London. Work continues with CAE partners to ensure effective peerings are set up and to address routing anomalies within the Routing Working Group.
- **FABRIC/FAB:** The FABRIC testbed is an adaptive programmable research infrastructure for computer science and science applications. FABRIC Across Borders (FAB) is the international component that will connect FABRIC to international testbeds and institutions doing experiments. TransPAC has offered to support several of the international experiments, and TransPAC engineers are planning to work with FAB to ensure the end-to-end paths for the testbed are running smoothly once in place.
- **Global Network Architecture Group (GNA-G)** - The GNA-G was created as a result of the merger of the Global Network Architecture (GNA) Technical Working Group and the Global Lamba Integrated Facilities (GLIF) group. TransPAC staff continue to be engaged with this group through their participation in the Routing Working Group and attendance at the quarterly update meetings.
- **Internet2** - Internet2 has been part of the APOnet and the GSCC discussions. They also put in a bid for the Fast Track Circuit, although that RFP has been put on hold.

- **King Abdullah University of Science and Technology (KAUST) -** In Year 2, we worked with KAUST to collect SNMP data for their four new 100G international circuits (2 Singapore-Jeddah 100G circuits and 2 Amsterdam-Jeddah 100G circuits) and to add this data to the APOnet dashboard. We also worked with KAUST to look at routing issues on traffic to the US. In Year 3, we are planning to continue working with KAUST to add flow data to NetSage and to improve performance on their international traffic.
- **Korea Institute of Science and Technology Information (KISTI)** - KISTI is a member of APOnet, so we meet with them regularly. We also worked with KISTI staff to look at and fix routing anomalies on the TransPAC-PacWave 100G circuit. KISTI staff also participated in the RWG, attending monthly meetings and assisting the resolution of cases.
- **The National Institute of Information and Communications Technology (NICT)** - We met with NICT staff several times to discuss project goals and the APOnet. We are also working with NICT staff to update and sign a revised MOU.
- **National Institute of Informatics (NII)/ Science Information Network (SINET)** We had several meetings over the year with NII/SINET staff, primarily focused on the APOnet collaboration. We also worked with partners, including NII, on improving routing for traffic going from Japan to Korea and on performance issues on traffic to the US.
- **Pacific Wave/CENIC** - We maintained a close collaboration with Pacific Wave, not only through our joint support of the TransPAC-PacWave 100G circuit but also through bi-weekly calls to coordinate activities to ensure that our services and resources are complementary. Pacific Wave is part of both the GSCC and APOnet discussions as well.
- **Research and Education Advanced Network New Zealand (REANNZ) –** We met with REANNZ staff multiple times as part of our work with the APOnet collaboration. REANNZ staff also participated in the RWG assisting in the resolution of one case.
- **Singapore Advanced Research and Education Network (SingAREN)** - Francis Lee from SingAREN is a co-PI for the TransPAC5 project, and as such meets with the other PI's monthly. SingAREN is also a part of the GSCC, and the GSCC 100G Circuit lands on the Singapore Open Exchange (SOE) that is run by SingAREN. They are also part of APOnet. Lee and other staff members from SingAREN also attend RWG meetings and assist with resolving cases. We also worked with SingAREN on several end-to-end performance issues, as detailed in Sections 4 and 5.
- **University of Hawaii (UH)/Guam Open Exchange (GOREX)** - Work with University of Hawaii staff were focused around APOnet, the GSCC, and using GOREX as a landing point for the GSCC 100G Circuit. GOREX staff also participated in the RWG assisting in the resolution of one case. We worked with UH on several routing and end-to-end performance issues, as detailed in Section 4 and 5.

4.C Routing Working Group

Schopf, Addleman, and Mitchell were the co-chairs of the Routing Working Group (RWG) which was officially formed with GNA-G in June 2021 and approved by APAN in August 2021. Meade was brought on as a co-chair to replace Schopf in August 2021. BOFs were held at APAN in August 2021, as the second phase of the APAN setup process for a working group, at TNC in June 2022, and at APAN in March 2022. Updates were given to the GNA-G meetings in March and June 2022.

The working group meets monthly for case reviews or tool talks. In July, Schopf presented a NetSage overview using TransPAC and other examples to show how NetSage could be used to find data moving ineffectively. In September, Steve Wallace presented on Mutually Agreed Norms for Routing Security (MANRS). In October, Jonathan Stout gave a presentation on Router Proxy, and the December meeting was a presentation by Arnold Nipper on PeeringDB, both using TransPAC examples. Southworth presented at the April meeting about using perfSONAR to troubleshoot routing issues. From July 2021 through June 2022, the Routing Working Group worked on seventeen cases of routing anomalies, six related to traffic over the TransPAC-PacWave 100G circuit.

In Year 2, the RWG began working on best practice documents for BGP use in R&E networking, including scalability, load balancing, BGP peering agreements within the R&E community, and how to best use BGP communities. These documents will be published in Year 3.

The Routing Working Group is currently focusing on traffic from Europe to Asia traversing the US, Asia to Africa traversing the US, and internal to Asia traffic traversing the US via TransPAC-supported circuits. These cases include:

Bandung Institute of Technology (ITB), Bandung, Indonesia to ESnet Starlight DTN, Chicago, IL: Data transfers from the Bandung Institute of Technology (ITB) in Indonesia to the Starlight ESnet DTN in Chicago had an asymmetric routing that was causing both access and performance problems. The route from ITB to ESnet Chicago used the R&E network via TEIN circuits in Asia, the TransPAC-Pacific Wave 100G link between Tokyo and Seattle, and ESnet circuits from Seattle to Chicago, whereas the route from the Chicago DTN to ITB used commercial paths. This is a problem not only because the R&E routes will enable better performance, but the ESnet DTN cannot be accessed from commercial routes due to DOE usage restrictions. Meade worked with ESnet engineers to update route information to use the preferred R&E path. Trace routes are symmetrical now, and we received confirmation from ITB engineers that they are able to access the DTN.

Multiple institutions, Singapore to Multiple Institutions, New Zealand: Members of the RWG identified traffic between Singapore and New Zealand that was traversing the US using the TransPAC-PacWave 100G Circuit and also had asymmetric routing. The transfers were not specific to an institutional pairing but were taking place between several institutions in New Zealand and a set of institutions in Singapore. The path in one direction was:

1. Singapore to Tokyo, using the circuit supported by SingAREN jointly with NICT and HARNET,
2. Tokyo to Seattle, using the TransPAC-PacWave 100G Circuit, and
3. Seattle to Hawaii and on to New Zealand, on the REANNZ circuit.

The return path was not using the TransPAC-PacWave 100G Circuit, so its routing was not immediately clear.

Engineers from REANNZ, the New Zealand NREN, determined that a better routing would be from Singapore to Guam, using the GSCC 100G Circuit, and then Guam to New Zealand, over the AARNet circuit. The REANNZ engineers engaged with staff from GOREX to adjust path settings, and the traffic has shifted accordingly.

Chinese University of Hong Kong (CUHK) to Beijing Primezone Technologies: Engineers identified over 30,000 20G flows from the Chinese University of Hong Kong (CUHK) to Beijing Primezone Technologies that were traveling to the US, via the TransPAC-PacWave 100G circuit, and then being routed down the US west coast and back to Asia. Ideally, this traffic should stay within Asia. Meade worked with RWG member KW Pong, CUHK, to shift the traffic. They made changes so it preferred a circuit supported by the China Science and Technology Network (CSTNET), the local China NREN, that could then connect directly to capacity in Hong Kong supported by HARNET, the network that CUHK was connected to, therefore keeping traffic within Asia. As of May 2022, traffic is no longer using the TransPAC-PacWave 100G Circuit.

Better understanding of Connecting Asia to Europe (CAE) Network Routing: CAE consists of one 100G circuit between the EU and Asia. In 2021, the RWG began to investigate traffic over the CAE circuit in order to have a better understanding of how traffic was being routed, including backups, partnership agreements, and technical specifications for Layer 2 VLANs. Discussions were held at monthly RWG meetings led by members from SingAREN, King Abdullah University of Science and Technology (KAUST), and SURF.

Multiple Institutions, Holland to City University of Hong Kong (CityU), Hong Kong: Routing Working Group members noted an increase in flows from Holland, via the SURF network, to Hong Kong, specifically to the City University of Hong Kong, and decided to investigate the route since the volume of traffic was increasing. This case remains open, on hold, as engineers at SURF have not yet had sufficient time to begin investigating the cause of this traffic.

Nanyang Technological University (NTU), Singapore to Education Bureau, Kaohsiung City Government, Taiwan: Engineers identified traffic from the Nanyang Technological University (NTU), Singapore, to the Education Bureau, Kaohsiung City Government, Taiwan, by way of the US. The path it took in one direction was:

- Taiwan to Chicago, via the Academia Sinica Grid Computing (ASGC) circuit
- Chicago to Los Angeles, via Internet2

- Los Angeles to Singapore, via the SingAREN Los Angeles Circuit

In the other direction, the traffic path was:

- Singapore to LA, via the SingAREN Los Angeles Circuit
- LA to Seattle, via the Pacific Wave network
- Settle to Tokyo, via the TransPAC-PacWave 100G circuit
- Tokyo to Singapore, via the circuit supported by SingAREN jointly with NICT and HARNET
- Singapore to Taiwan, via a circuit supported by ASGC

Meade worked with engineers from Taiwan and SingAREN to change the preferred route to stay within Asia by shifting the traffic to prefer a path from Singapore to Taiwan by way of Tokyo in both directions. The asymmetrical routing that previously existed has been fixed based on the performance of perfSONAR tests. Round trip time has dropped from 290ms to ~49ms.

4.D Network Experimentation

TransPAC supports network research and experimentation by providing full or partial link capacity bandwidth on an ad hoc basis, including partial capacity support for the FABRIC Across Boards (FAB) project. Full link capacity support is currently provided to network researchers for experiments at conferences and workshops, including the SuperComputing conference series (SCXY), Super Computing Asia, and TNC. For full link capacity bandwidth support is made possible through collaborations with the APOnet partners so we can shift production traffic to a subset of the links and leave other circuits available for experiments.

As part of the project proposal, we had planned to put in place technology to support larger bandwidth blocks for experimentation. However, to date this has not been necessary. In Year 3, we will continue to evaluate and discuss possible approaches with our partners as needed.

We also planned to advertise the availability of TransPAC circuits for use by researchers for experiments to the broader community, but to date have only communicated this within the APOnet partnership and a limited set of conferences. In Year 3 we will make this resource more publicly known using conference mailing lists, including APAN and GNA-G, working with our APOnet partners, and reaching out to other groups such as the SCinet Network Research Exhibition (NRE) team and the Cyber Infrastructure Engineering mailing list.

Even without more formal support in place, we have been able to work with several experiments. In Year 2, we participated in discussions to be part of the Data Mover Challenge (https://www.nscc.sg/data-mover-challenge-2021/). We had planned to supply bandwidth on the TransPAC-PacWave 100G circuit to support an experiment that was transferring data between a NICT data transfer node in Tokyo and a node in Chicago at the Starlight facility. However, NICT dropped out of the challenge and this path was no longer needed. In Year 2, because SC21 was primarily virtual, SCinet did not need the support of the TransPAC circuits for their network experiments either.

In Year 3, we plan to work with the FAB project to connect a FABRIC node at the University of Tokyo via the TransPAC-PacWave 100G circuit to the FABRIC network in the US. We will also work with APOnet to allow for the use of six 100G links in support of experiments at SC22 led by NICT. Later in Year 3, we plan to support the Data Mover Exhibition (DME) hosted by SC Asia.

5 Science Engagement

TransPAC5 provides support for US researchers with projects and partnerships in the Asia Pacific region. Our science engagement approach includes not only reactive work with individual researchers or larger research teams, but also proactive end-to-end performance investigations.

In Year 2, the science engagement team focused its efforts on better understanding and supporting US scientists working in the Polar regions. We also continued to work to adapt our science engagement and outreach efforts to the challenges posed by the COVID-19 related travel restrictions. We worked closely with the Engagement and Performance Operations Center (EPOC) to proactively identify and fix end-to-end performance issues on international traffic. We also used NetSage to identify increases in data sources and to look at performance to ensure collaborations are getting expected end-to-end performance.

5.A Year of Polar

A major component of our science engagement efforts in Year 2 included working to better understand and support US scientists working in the Polar regions. The team reached out to US researchers and their collaborators, engaged with international research and science teams, and worked with US and international networking partners to improve the performance of international data flows.

Arctic Connect and other Arctic fiber projects - Throughout Year 2, we tracked the progress of the Arctic Connect fiber project, an initiative to build the first Arctic subsea cable system that would connect northern Norway and Finland to Alaska and Japan. Capacity on this system would allow for a diverse path connecting Europe to Asia, via the US. In Year 2, we learned that the project had stalled and eventually halted due to investment and geopolitical concerns. Other Arctic fiber projects are developing in its place, and we will continue to track in Year 3.

NREN Low Earth Orbit Satellite (LEOSat) Working Group - Moynihan participates in a working group that is exploring the feasibility of NRENs leveraging low Earth orbit satellites to help connect researchers in the Polar Regions and other remote areas of the world. The group includes representatives from IN@IU, NORDUnet, ESnet, Tertiary Education and Research Network of South Africa (TENET), Research and Education Advanced Network New Zealand (REANNZ), Internet2, AARNET, and CANARIE. We are working within this group to better understand and document the science use cases and future cyberinfrastructure needs and to learn how access to these new satellite deployments would support and increase US science in Polar regions. The group met with representatives from Starlink and Telesat, a Canadian LEOSat company, to learn more about their services and timelines for deployment. We are also engaged with Patrick Smith, from NSF's Office of Polar Programs, on NSF's interest in using LEOSat to support remote research. At the end of Year 2, this group had lost momentum due to some NRENs pursuing LEOSat possibilities on their own and the secretary of the group, Erik-Jan Bos, leaving his role at NORDUnet. However, we are hopeful these discussions will pick up again in Year 3.

Arctic Data Center (ADC) - The ADC (https://arcticdata.io/about/) is the primary data and software repository for the Arctic section of the National Science Foundation's Office of Polar Programs. We held a series of meetings in Year 2 with ADC staff to share information about our projects and to understand how researchers moved data to and from their archives. We showed them a Dashboard from NetSage that included their archives and discussed how it could potentially be used to provide ADC with a better understanding of how data was getting to their archives and who was accessing it. ADC introduced us via email to some of the researchers who utilized the archives. These meetings led to email discussions and potential meetings in Year 3. ADC also invited IN@IU staff to join their next workshop in Year 3 and to potentially present to Arctic researchers on utilizing R&E networks.

Our work in this space will continue in Year 3. We will also work with partners to look at climate data from the Polar regions on the TransPAC5 circuits.

5.B High Energy Physics

We participate in the Large Hadron Collider Open Network Environment (LHCONE) Large Hadron Collider Open Network Environment (LHCONE) overlay network in support of LHC-related computing centers in the US and Asia. TransPAC is an LHCONE Network Service Provider (NSP) and provides the connectivity between NICT and ESnet LHCONE VRFs across the TransPAC-PacWave 100G Circuit.

In Year 2, we began an engagement with the LHCONE community to provide additional support for LHC traffic using the GSCC 100G circuit between Guam (GOREX) and Singapore (the SingAREN Open Exchange (SOE)). In Year 3, we plan to continue working with ESnet and our APOnet partners to recreate the LHCONE VRF ring that previously used the Guam-Hong Kong circuits to provide redundancy between the LHCONE VRF in Tokyo and ESnet in Seattle.

We also engaged with the LHCONE community in preparation for the start of the LHC's third run, which started in April 2022. Within LHCONE, TransPAC5 staff are discussing the future capacity needs of LHC and potential new measurement and monitoring solutions for LHC traffic. We participated in meetings focused on the upcoming High-Luminosity Large Hadron Collider (HL-LHC) data challenges, where we helped lead discussions on the possibility of using NetSage to better understand LHC network usage during the data challenges. At the LHCOPN-LHCONE meeting #47 on October 12, 2021, we presented a demonstration of a NetSage instance, designed to showcase existing LHC, ATLAS, and CMS data, that explained how NetSage could be tailored to better serve the LHC community. This presentation resulted in interest from community members to form a working group around NetSage data collection and Dashboard development. This development work and our participation in LHCONE will continue in Year 3.

Other high energy physics end-to-end performance investigations in Year 2 included:

Tata Institute of Fundamental Research to Academia Sinica - Using NetSage, TransPAC5 staff noticed increases in LHC traffic from the Tata Institute of Fundamental Research, in India, to Academia Sinica, in Taiwan, that was routed across the TransPAC-PacWave 100G Circuit. As the National Knowledge Network in India has a more direct path via Singapore to Taiwan, TransPAC5 staff monitored this issue as a possible case for the RWG. However, further investigation showed that this routing was temporary and that the traffic had shifted back to the more efficient route without additional intervention. This finding was confirmed with the recent addition of flow data to NetSage from APOnet members, which gave better insight into the routing of this traffic.

Nanyang Technological University (NTU), Singapore to Stanford Linear Accelerator Center (SLAC) National Accelerator Laboratory - Engineers noticed poor performance (less than 10Mbps) on flows between NTU and SLAC. Further investigation revealed asymmetrical routing, with traffic from NTU to SLAC using the SingAREN-Los Angeles 100G circuit and then using ESnet circuits from Los Angeles to SLAC and flows from SLAC to NTU using ESnet from SLAC to Seattle, the TransPAC-PacWave 100G circuit from Seattle to Tokyo, and the SINET 100G Circuit from Tokyo to Singapore. Testing showed that using the SingAREN-Los Angeles path and ESnet was a more efficient route, so TransPAC staff reached out to ESnet engineers to begin making adaptations to the return route. Work to fix this issue will continue in Year 3.

5.C Geoscience/Climate

TransPAC is an active participant in the Earth Science Information Partners (ESIP) community, where we engage with researchers from NASA, NOAA, USGS, and other institutions about network performance enhancement and data transfer needs.

We also maintain a collaboration with Dr. Tho Nguyen from the University of Virginia (UVA), a Letter of Collaboration writer for TransPAC5, and his Mekong Water (MW) project. MW is a regional-scale cyberinfrastructure and water research community that provides data sharing and collaboration tools in support of a variety of international research teams studying groundwater and land subsidence issues in the Lower Mekong Basin. MW is developing an online water data collaboration platform for researchers in Vietnam to share data with other researchers around the world. We are working with Nguyen to ensure that stakeholders in-region are aware of and utilizing local R&E networking resources. In Year 2, travel restrictions continued to delay Nguyen's work, however, we met to discuss project updates and to look at data transfer performance using NetSage between stakeholders in the region.

Other Geoscience/Climate end-to-end performance investigations in Year 2 included:

National Institute of Informatics (NII), Tokyo, Japan to NASA data archives, Marshall Space Flight Center, Alabama - TransPAC5 staff used NetSage to identify NASA Earth Observation data transfers on the TransPAC-PacWave 100G Circuit from NII to NASA data archives at the Marshall Space Flight Center, Alabama. The performance of this traffic was variable, from 2Mbps to 100Mbps over time, but even the high end of this range was poorer performance than expected. Investigation revealed that this was unidirectional UDP traffic. Tests using perfSONAR from XX to the perfSONAR nodes at NII showed clean paths. At the end of Year 2, TransPAC staff were working with NII to confirm these findings and to determine if performance could be improved.

University of Hawaii (UH), Manoa, to NASA data archives, Marshall Space Flight Center, Alabama - TransPAC5 staff used NetSage to identify NASA Earth Observation data transfers between the UH and NASA data archives at the Marshall Space Flight Center in Alabama. The transfer rate for data from UH to NASA was noticeably higher than from NASA to UH, with overall performance from NASA to UH averaging less than 30Mbps. TransPAC5 staff reached out to engineers at UH to begin further investigation. These investigations revealed the traffic was earth rotation measurements from instruments on Mauna Kea to NASA data archives at Marshall Space Flight Center in Alabama. Based on this finding, UH engineers informed TransPAC staff that this asymmetric throughput behavior was expected, as the data being transferred from NASA to UH was simple telemetry data, as opposed to the larger earth rotation datasets being transferred in the other direction. In Year 3, we will continue to monitor these and other flows to NASA archives with our partners at UH.

University Corporation for Atmospheric Research (UCAR) to Multiple Sites in Asia - TransPAC5 staff used NetSage to identify traffic from UCAR to multiple sites in Asia. Data transfer rates were poor in both directions, but performed worse from Asia to the UCAR, most notably from National Taiwan University, Taiwan, to UCAR. TransPAC5 engineers have begun perfSONAR testing to help identify the cause of the degraded performance and will work in Year 3 to identify partners who can assist with resolving the issue.

We will continue to be involved in both ESIP and MW in Year 3 and are also planning to expand our efforts to look at and support climate and weather-related collaborations using TransPAC and APOnet resources.

5.D Astronomy

Event Horizon Telescope (EHT) - TransPAC staff are part of an ongoing project to collect baseline network performance information for the Event Horizon Telescope (EHT) collaboration with the goal of helping this collaboration use R&E networks. The data transfers take place between eleven different telescopes located around the world and the MIT Haystack observatory, which stores and processes the astronomical data. During Year 2, we continued work with four of the EHT telescopes, two in Hawaii, one in France, and one in Spain.

Working with staff from the telescopes, international networks including the Pacific Islands Research and Education Network (PIREN) and GÉANT and campus staff at the University of Hawaii, we were able to test, pinpoint, and make recommendations to increase the data transfer performance. In Hawaii, testing revealed packet loss between the two EHT sites and an on-campus aggregation point. The testing data was shared with the local network staff, and they are pursuing the issue. In Year 3, we will follow up with all four sites and help them retest to Haystack and continue troubleshooting efforts.

Atacama Large Millimeter/submillimeter Array (ALMA) - WIDE Project - In Year 1, we began discussions with engineers from the WIDE Project in Japan on improving performance for astronomy flows between the WIDE site in Tokyo and the ALMA project, in northern Chile. We observed over 5TB per month being transferred between the two sites with extreme variance in transfer rates and an overall average performance rate below 10Mbps. Initial discussions with engineers from both WIDE and ALMA led to a clearer understanding of the network topology, compute, and storage resources involved. Further investigation revealed a significant amount of packet loss between WIDE and the National Astronomical Observatory of Japan (NAOJ), the network through which WIDE gains access to APAN.

In Year 2, bi-weekly engineering meetings were held with WIDE staff to try and understand where the packet loss was occurring. Initially we suspected an aging 10G switch between the WIDE and NAOJ switches, however upgrading this to a direct 100G crossover between WIDE and NAOJ, along with the elimination of the 10G old switch, did not resolve the packet loss. Further equipment changes and fiber cleaning procedures also failed to alleviate the problem.

In Year 2 Quarter 4, WIDE staff informed us of plans to install new DTN hardware in place of the existing DTN currently used for transfers to ALMA. While they hope this will solve the packet loss issue, global hardware shortages have delayed this work until Year 3. Work on this problem will continue once the new hardware is in place and configured.

5.E Bioscience

National Library of Medicine (NLM) - SingAREN - TransPAC staff identified IPv6 traffic from National Library of Medicine (NLM) to sites behind SingAREN in Singapore with data transfers performing below expected and asymmetrical routing. Using NetSage, TransPAC staff were unable to determine the specific endpoint in Singapore for these flows. Engineers from SingAREN were engaged after perfSONAR tests confirmed the poor data transfer performance. At the end of the Year 3, we continue to work with SingAREN engineers to identify the endpoints in Singapore, to look at the asymmetrical routing, and to determine if anything can be done to improve performance.

In Year 3, we are planning to expand our work with the bioscience/bioinformatics community as this is a significant area of interest for our Asian partners and a significant source of traffic on the TransPAC5 circuits.

5.F Other Science Engagement

TransPAC5 also participates in several international science engagement and coordination projects including GEANT's Task Force on Researcher Engagement, the Pacific Research Platform, PRAGMA, and the Joint Engineering Team (JET). In Year 2, Moynihan gave a presentation on TransPAC to the PRAGMA community.

In Year 2, we also finished an effort to reach out to our Letter of Collaboration writers and other science partners to update them on the status of the project and to inform them of changes made to the original proposal.

End-to-end performance investigations that were not part of an overall science area included:

University of Washington (UW) to Multiple Sites in Asia - Using NetSage, TransPAC engineers noticed traffic from UW to sites in Asia performing worse than expected. TransPAC staff reached out to contacts at UW and began working to look into the issues. Initial testing was delayed because UW's perfSONAR node was no longer active. UW engineers worked to restore the node but determined new hardware was required. At the end of Year 2, UW engineers report that a new perfSONAR node had been installed, but that the performance issue could not be replicated. This finding was confirmed by TransPAC staff, and performance to well-connected sites in the APAN region is adequate. Staff will continue to monitor this issue in Year 3.

In Year 3, we plan to continue these efforts and to focus on bioinformatics, climate, and weather-related research.

6. Circuit Deployments and Technical Updates

The current TransPAC5 circuit diagram is shown in Figure 2.

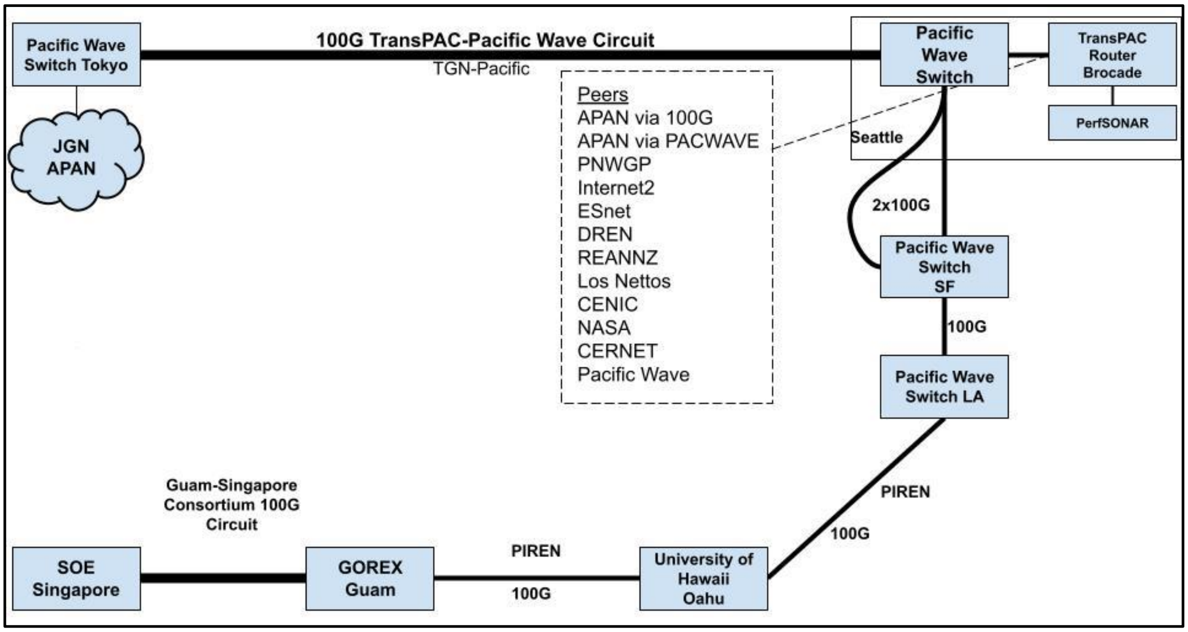

Figure 2: TransPAC5 circuit and peering diagram. Red links are supported by NSF TransPAC5 funding.

6.A Technical Updates for the TransPAC-PacWave 100G Circuit

The TransPAC-PacWave 100G Circuit is a 100Gbps network connection between the Pacific Wave Exchange switches in Seattle and Tokyo. The connection is across the Tata TGN-N subsea fiber cable. During Year 2, there were no major technical updates or changes made to the 100G TransPAC-PacWave circuit and associated equipment.

At the start of the project, PacWave had stated that they were renegotiating the contract with Tata for this circuit and that they would inform us when they had new terms and conditions. This did not impact the operation of the link, as we were on a month-to-month contract at that point. In early 2021, PacWave staff informed us that due to significant staff changes at Tata, they had changed plans and were going to leave the current agreement in place. This should have no operational impact on TransPAC5.

In Year 2, we continued evaluating the need for TransPAC-owned equipment located in the Pacific Wave PoP in Seattle. Pacific Wave is in the process of upgrading their exchange point to support Layer 3/ Border Gateway Protocol (BGP) peering sessions in addition to the VLAN service they have provided in the past. This upgrade could allow the removal of the TransPAC router as the peering services offered by TransPAC and Pacific Wave will overlap. This upgrade was delayed significantly due to software bugs in the Pacific Wave Exchange Point switch's operating system. In Year 3, after the upgrade, we plan to help Pacific Wave staff test a new peering service. Once this testing is complete, we will work with Pacific Wave and our TransPAC peers to move them off of the TransPAC switch and onto the Pacific Wave exchange.

As part of the defined TransPAC5 deliverables, we had planned to deploy and support BGP resource public key infrastructure (RPKI) in Year 2. However, as it is likely that the TransPAC router will be decommissioned, instead we plan to work with Pacific Wave to deploy RPKI on their Layer 3 exchange in Year 3. We will also continue to discuss and advertise RPKI as a best practice as part of our work with the Routing Working Group and MANRS.

6.B Guam-Singapore Connectivity Consortium (GSCC) 100G Circuit

In Year 2, we joined the Guam–Singapore Connectivity Consortium (GSCC) 100G Circuit, with partners ARENA-PAC, AARNet, CENIC/Pacific Wave, Internet2, SingAREN, and University of Hawaii. This 100G circuit runs between GOREX and the SingAREN Open Exchange on the SEA-US West and IGG cables. Internet2 holds the contract for a 15-year IRU with the circuit provider, RTI, and each of Internet2, TransPAC, ARENA-PAC, and AARNet have split the costs evenly, starting with a 5-year contract.

Initial testing of the link was completed, and the link became operational on December 7, 2021. Shortly after, an undersea fiber cable cut brought the link down. The cable was repaired, retested, and brought back into production on January 20, 2022. Unfortunately, since that time, the cable that the circuit is on has had numerous outages, and Internet2 staff are exploring the possibility of alternative paths between Guam and Singapore with the provider.

Shortly after the link went live, peerings between the Singapore Open Exchange (SOE) and the Guam Open Research & Education eXchange (GOREX) were established and traffic began to flow over the link between the US and many Asia Pacific based networks. During Year 2, peerings were established to GOREX or SOE for AARNet, ARENA-PAC, SINET, Route Views, University of Hawaii, and Internet2. These peerings allowed many of the networks that we served from the TransPAC Hong Kong Open Exchange to continue. In Year 3, we plan to engage ESnet, CERNET, and LHCONE to add peerings that will add redundant paths and help balance traffic loads across the Pacific. This will include replacing the VRF that had supported the LHC project over the previous TransPAC4 Guam-Hong Kong links.

6.C New Capacity - Fast Track

In Quarter 1, with our partners, we began exploring opportunities to more efficiently move traffic between the NEA^{3}R POP, in New York city, and the TransPAC/PacWave POP, in Seattle. This led to discussions with PacWave on creating a “fast track” that would leverage their 100G connection from Seattle to Chicago by adding a NEA^{3}R-supported 100G connection from New York to Chicago. This partnership would enable better data transfer support for European collaborations to west coast and midwest US researchers, as well as for Asians working with midwest and east coast researchers. It would also allow us to expand our peering partners, for example, KISTI lands in Chicago, and we would be able to work with KISTI and other networks present at Starlight to have VLANS directly to Europe.

Although a slight change of scope from the original project plan, we received approval from our NSF project officer to proceed. We prepared and released a RFP in Quarter 2. The estimated costs for this effort were around $12,000-$15,000 per month, however due to shifting priorities and the emergence of potential similar projects in the community, we decided at the end of Quarter 2 to postpone this effort. In Year 3 we will re-examine the process of the community projects and may re-issue an RFP if there is still community need.

7. Circuit Status and Performance

7.A. Measurement and Monitoring

We currently collect sampled flow data and SNMP data for the TransPAC-PacWave 100G circuit and SNMP data for the GSCC 100G Circuit. This data is shared with a NetSage deployment for TransPAC, which is online at https://transpac.netsage.global, in addition to the international data available at http://portal.netsage.global. Flow data for the GSCC 100G Circuit is included as a part of the flow data we have for the broader SingAREN Open Exchange in Singapore, but we expect th8is data to be broken out in Year 3.

As part of our work with APOnet, and as part of the APOnet NetSage deployment, we also collect flow and SNMP data for AARNET, PacWave, PIREN, and SingAREN. We also collect SNMP data for KAUST and KISTI. In Year 3, we expect to add flow data from ARENA-PAC, KAUST, and KISTI, as well as flow and SNMP data for NICT and REANNZ. In Year 3, with the additional Flow data being collected with the APOnet partners, we will focus on adding additional Top Talkers to the NetSage Science Registry.

In Year 2 Quarter 4, SingAREN resumed service of their public database mirror, available at ftp://dbmirror.singaren.net.sg/. This database mirror houses large R&E datasets across multiple science disciplines and allows for faster transfers than downloading these datasets from the original source. We worked with SingAREN to publish a list of the mirror sites, which were then added to the NetSage Science Registry, so that these transfers could be recognized as a coordinated project in NetSage.

7.B. SNMP Traffic Graphs

Figure 3 shows traffic on the TransPAC-PacWave 100G circuit for Year 2. The noticeable spike in the maximum rate just before September reflects a brief increase in network testing from several locations in APAN. The larger spike in throughput around the beginning of November is due to a large number of biomedical transfers from the National Library of Medicine and the University of Chicago to various endpoints in China. The other large peak rate spike, seen mid-March, was due to a series of high-rate, low-volume transfers from ESnet and the High Energy Accelerator Research Organization in Japan.

Figure 4 shows the traffic for the GSCC 100G Circuit for Year 2. Initial testing of the link was completed, and the link became operational on December 7, 2021, but within a few days suffered a cable cut. Connectivity was restored just after January 1, 2022, but was not re-accepted as production ready until January 20, 2022. it has experienced several other cable cuts, as noted in the figure.

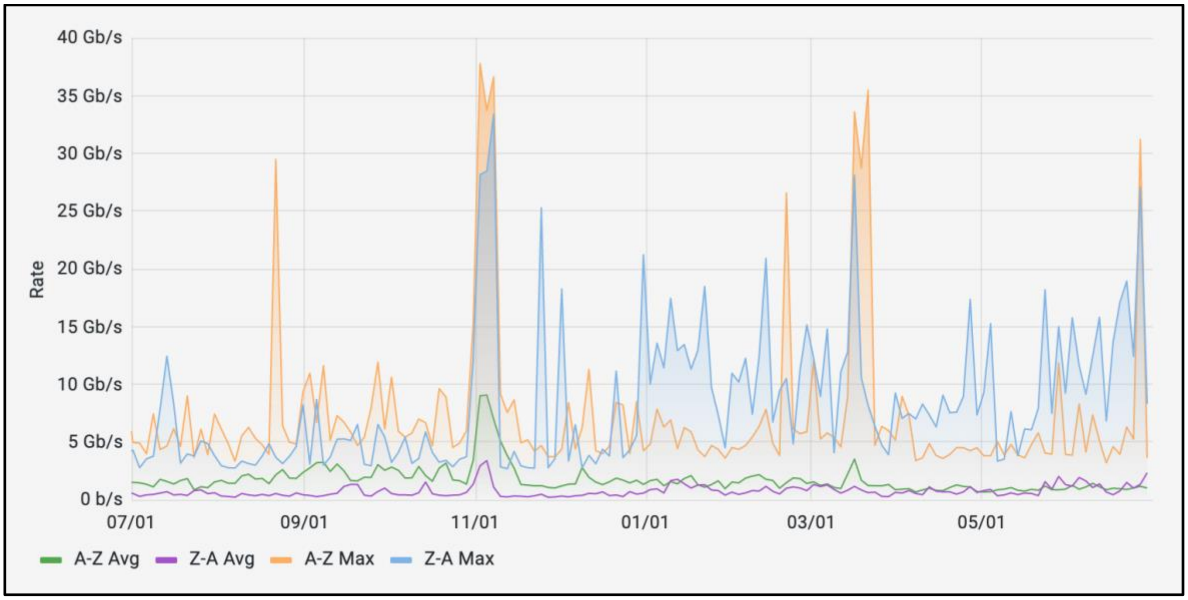

Figure 3: TransPAC-PacWave 100G circuit bidirectional traffic using smoothed and maximum daily averages, July 1, 2021 - June 30, 2022. Graph can be found online at:
https://aponet.netsage.global/grafana/d/000000003/bandwidth-dashboard?orgId=1&from=1625112000000&to=1656647999000

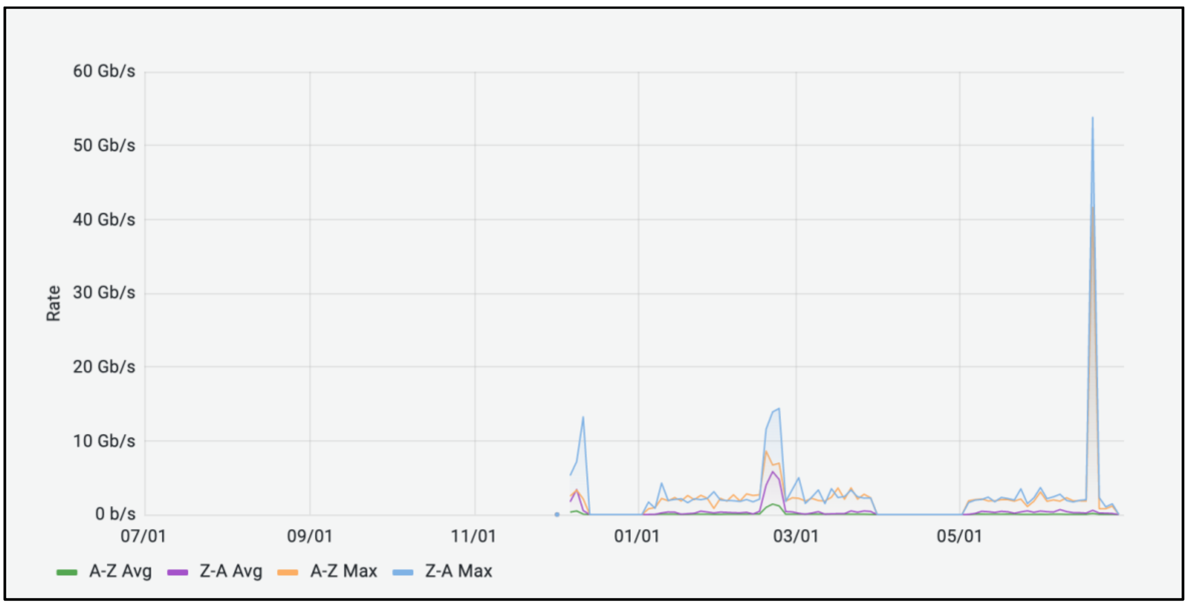

Figure 4: GSCC 100G Circuit bidirectional traffic using smoothed and maximum daily averages, July 1, 2021 - June 30, 2022. Graph can be found online at:
https://aponet.netsage.global/grafana/d/000000003/bandwidth-dashboard?orgId=1&from=1625112000000&to=1656647999000

7.C SNMP Traffic Volume

Table 1 shows that over 10 petabytes of data were transferred over the TransPAC-PacWave 100G Circuit and the GSCC 100G Circuit during Year 2.

Table 1: Traffic in petabytes transferred over TransPAC links, July 1, 2021 - June 30, 2022.

Source-Destination	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Total
Seattle-Tokyo	1.9	2.5	1.5	0.933	**6.833**
Tokyo-Seattle	0.527	0.644	0.869	0.905	**2.945**
Guam-Singapore	n/a	0.146	0.581	0.191	**0.918**
Singapore-Guam	n/a	0.023	0.132	0.027	**0.182**
Total	**2.427**	**3.313**	**3.082**	**2.056**	**10.878**

7.D Flows over the TransPAC-PacWave 100G Circuit

Figure 5 shows the Top Ten Talkers by source and Figure 6 shows this data by destination for the TransPAC-PacWave 100G circuit in Year 2. Table 2 shows the Top Talker pairs. We are in the process of setting up flow data collection for the GSCC 100G link.

During Year 2, the top sources, destinations, and pairs all indicate the diverse set of science disciplines that make use of this circuit. Atmospheric science transfers from the University Corporation for Atmospheric Research represented the greatest volume of flows by source, while high energy physics flows originated at sources including ESnet, the High Energy Accelerator Research Organization in Tsukuba, Japan, and Fermilab. The National Library of Medicine and University of Chicago were the biomedical sources transferring the most data. Astronomy sources NASA and ALMA indicate the strong collaborations between US and Asian astronomers.

In the top pairs, Beijing Primezone Technologies (BPT) and the Chinese University of Hong Kong (CUHK) were the fourth largest pair overall. This was due to a routing error, as discussed in Section 4.C. This routing error was corrected by the Routing Working Group in March 2022, after which this traffic was no longer present on the Seattle NetSage sensor.

By Volume			
Source	Total Vol. ↓	Largest Flow	# Flows
University Corporation for Atmospheric Research	854.5 TB	436.7 GB	1.0 Mil
High Energy Accelerator Research Organization, KEK	752.7 TB	839.4 GB	1.2 Mil
University of Chicago	525.9 TB	188.5 GB	940.5 K
ESnet	500.2 TB	552.3 GB	1.3 Mil
National Library of Medicine	499.8 TB	710.6 GB	1.6 Mil
Tata Institute of Fundamental Research	483.4 TB	35.3 GB	464.2 K
National Aeronautics and Space Administration	483.2 TB	794.0 GB	4.1 Mil
Beijing Primezone Technologies Inc.	464.4 TB	54.1 GB	169.7 K
Fermi National Accelerator Laboratory (Fermilab)	431.7 TB	115.1 GB	497.8 K
University of Southern California	411.0 TB	2.3 TB	54.0 K
ALMA - Atacama Large Millimeter Array	358.6 TB	3.7 TB	8.1 K
National Oceanic and Atmospheric Administration	334.5 TB	109.9 GB	3.9 Mil
Stanford University	201.9 TB	965.7 GB	461.2 K
Chinese University of Hong Kong (The)	181.6 TB	396.1 GB	96.2 K
University of Washington	180.5 TB	376.8 GB	928.9 K
University of Hawaii	152.7 TB	170.7 GB	152.6 K
National Energy Research Scientific Computing Center	151.4 TB	419.2 GB	1.3 Mil
San Diego Supercomputer Center	147.6 TB	282.1 GB	729.8 K
Academia Sinica	137.0 TB	1.7 TB	279.9 K
Asia Pacific Advanced Network - Japan	132.0 TB	75.2 GB	40.2 K
University of Pennsylvania	104.5 TB	919.7 GB	24.1 K
National Climatic Data Center	97.0 TB	28.5 GB	2.3 Mil
Jisc Services Limited	84.9 TB	245.2 GB	195.2 K
Lawrence Berkeley National Laboratory	75.1 TB	74.8 GB	329.2 K
Brookhaven National Laboratory	68.2 TB	533.0 GB	128.4 K

Figure 5: Top 25 Sources on TransPAC-PacWave 100G circuits July 1, 2021 - June 30, 2022. Graph can be found at: https://aponet.netsage.global/grafana/d/xk26IFhmk/flow-data-for-circuits?orgId=1&from=1625112000000&to=1656647999000&var-Sensors=TransPAC%20Seattle%20sFlow&var-country_scope=All&var-is_net_test=no

By Volume

Destination	Total Vol. ↓	Largest Flow	# Flows
China Education and Research Network Center	1.5 PB	2.3 TB	5.3 Mil
Academia Sinica	1.2 PB	1.4 TB	2.8 Mil
Brookhaven National Laboratory	827.0 TB	62.6 GB	1.3 Mil
Chinese University of Hong Kong (The)	550.5 TB	281.6 GB	357.6 K
City University of Hong Kong	511.2 TB	890.1 GB	1.7 Mil
Fermi National Accelerator Laboratory (Fermilab)	482.0 TB	35.3 GB	474.8 K
WIDE Project	428.2 TB	3.7 TB	130.7 K
CERNET2 IX at Shanghai Jiaotong University	394.2 TB	868.3 GB	1.8 Mil
Tata Institute of Fundamental Research	375.4 TB	100.7 GB	359.0 K
Beijing Primezone Technologies Inc.	280.7 TB	1.0 TB	2.6 Mil
National Infomation Society Agency	159.5 TB	3.0 TB	509.2 K
Indiana University	156.5 TB	121.6 GB	54.8 K
Asia Pacific Advanced Network - Japan	154.4 TB	16.9 GB	33.9 K
National Center for Research on Earthquake Engineering	143.9 TB	95.2 GB	2.4 Mil
CERNET2 IX at Southeast University	132.1 TB	502.8 GB	431.8 K
National Knowledge Network	127.6 TB	270.0 GB	635.9 K
Chonnam National University	118.7 TB	436.7 GB	627.1 K
Office of Info.Tech. Admin. for Educational Development	88.8 TB	768.0 GB	364.4 K
Hong Kong University of Science and Technology	75.1 TB	332.4 GB	193.1 K
CERNET2 IX at Peking University	72.6 TB	671.9 GB	306.0 K
China Next Generation Internet CERNET2	65.7 TB	478.3 GB	544.7 K
The University of Hong Kong	65.6 TB	701.2 GB	367.2 K
ESnet	61.7 TB	480.3 GB	33.3 K
Information Technology Services	58.3 TB	1.4 TB	210.7 K
Trans-Eurasia Information Network (TEIN2) - SG	57.7 TB	13.6 GB	5.0 K

Figure 6: Top 25 Destinations on TransPAC-PacWave 100G circuits, 0:00:00 July 1, 2021 - 23:59:59 June 30, 2022. Graph can be found at: https://aponet.netsage.global/grafana/d/xk26IFhmk/flow-data-for-circuits?orgId=1&from=1625112000000&to=1656647999000&var-Sensors=TransPAC%20Seattle%20sFlow&var-country_scope=All&var-is_net_test=no

Table 2: Top 25 Flow Pairs on TransPAC-PacWave 100G circuits, 0:00:00 July 1, 2021 - 23:59:59 June 30, 2022. Graph can be found at: https://aponet.netsage.global/grafana/d/xk26IFhmk/flow-data-for-circuits?orgId=1&from=1625112000000&to=1656647999000&var-Sensors=TransPAC%20Seattle%20sFlow&var-country_scope=All&var-is_net_test=no

Top Pairs

Source	Destination	Total Vol. ↓	Largest Flow	# Flows
High Energy Accelerator Research Organization, KEK	Brookhaven National Laboratory	728.2 TB	62.6 GB	1.2 Mil
University Corporation for Atmospheric Research	Academia Sinica	642.9 TB	47.5 GB	341.5 K
Tata Institute of Fundamental Research	Fermi National Accelerator Laboratory (Fermilab)	465.4 TB	35.3 GB	446.5 K
Beijing Primezone Technologies Inc.	Chinese University of Hong Kong (The)	460.5 TB	54.1 GB	157.5 K
University of Southern California	China Education and Research Network Center	397.6 TB	2.3 TB	36.1 K
Fermi National Accelerator Laboratory (Fermilab)	Tata Institute of Fundamental Research	373.1 TB	100.7 GB	347.1 K
ALMA - Atacama Large Millimeter Array	WIDE Project	358.6 TB	3.7 TB	8.1 K
University of Chicago	City University of Hong Kong	351.9 TB	76.0 GB	419.3 K
National Library of Medicine	Academia Sinica	242.1 TB	261.3 GB	573.5 K
National Aeronautics and Space Administration	CERNET2 IX at Shanghai Jiaotong University	210.7 TB	205.6 GB	1.3 Mil
ESnet	China Education and Research Network Center	133.4 TB	552.3 GB	391.0 K
San Diego Supercomputer Center	China Education and Research Network Center	132.7 TB	152.1 GB	685.2 K
Stanford University	China Education and Research Network Center	122.9 TB	756.3 GB	119.3 K
Chinese University of Hong Kong (The)	Brookhaven National Laboratory	95.1 TB	14.8 GB	43.1 K
University of Washington	China Education and Research Network Center	94.6 TB	355.5 GB	397.8 K
National Energy Research Scientific Computing Center	China Education and Research Network Center	92.2 TB	419.2 GB	1.3 Mil
University of Hawaii	Asia Pacific Advanced Network - Japan	90.1 TB	7.3 GB	17.6 K
National Aeronautics and Space Administration	China Education and Research Network Center	89.8 TB	33.1 GB	362.3 K
National Oceanic and Atmospheric Administration	National Center for Research on Earthquake Engineering	89.6 TB	15.5 GB	1.8 Mil
ESnet	CERNET2 IX at Southeast University	87.4 TB	105.1 GB	249.0 K
National Oceanic and Atmospheric Administration	Academia Sinica	72.9 TB	59.6 GB	410.0 K
Jisc Services Limited	Beijing Primezone Technologies Inc.	67.9 TB	209.8 GB	127.6 K
Lawrence Berkeley National Laboratory	National Knowledge Network	64.2 TB	23.9 GB	315.8 K
ESnet	CERNET2 IX at Shanghai Jiaotong University	60.4 TB	74.4 GB	182.7 K
University Corporation for Atmospheric Research	Chonnam National University	59.2 TB	436.7 GB	131.4 K

7.E Trouble Tickets

During Year 2, there were seven scheduled maintenance events, shown in Table 3, and ten unscheduled maintenance events, shown in Table 4. The latter included several cable cuts on the GSCC 100G Circuit cable.

Table 3: Scheduled Maintenance for TransPAC equipment and circuits, July 1, 2021 - June 30, 2022.

Ticket Number	Cust Impact	Ntwk Impact	Title	Maint Type	Source Impact	Current State	Start Time (UTC)	End Time (UTC)	Duration
CHG0054147	3 - Mod	3 - Mod	SEAT-TOKY	Circuit	Vendor	Closed	2021-09-14 10:51:55	2021-09-14 11:21:34	0 days 0 hr 29 min
CHG0055088	3 - Mod	3 - Mod	SEAT-TOKY	Circuit	Vendor	Closed	2021-10-19 10:04:25	2021-10-19 11:41:33	0 days 1 hr 37 min
CHG0056546	3 - Mod	3 - Mod	SEAT-TOKY	Circuit	Vendor	Closed	2022-01-05 19:13:20	2022-01-05 20:05:53	0 days 0 hr 52 min
CHG0057674	3 - Mod	3 - Mod	SEAT-TOKY	Circuit	Vendor	Closed	2022-02-19 23:21:23	2022-02-19 23:57:06	0 days 0 hr 35 min
CHG0058357	3 - Mod	3 - Mod	SEAT-TOKY	Circuit	Vendor	Closed	2022-04-03 03:05:51	2022-04-03 03:42:01	0 days 0 hr 36 min
CHG0059901	3 - Mod	3 - Mod	SEAT-TOKY	Circuit	Vendor	Closed	2022-05-23 15:04:20	2022-05-23 16:05:29	0 days 1 hr 1 min
CHG0059340	3 - Mod	3 - Mod	SEAT-TOKY	Circuit	Vendor	Closed	2022-05-23 15:04:20	2022-05-23 16:05:29	0 days 1 hr 1 min

Table 4: Unscheduled Outages for TransPAC equipment and circuits, July 1, 2021 - June 30, 2022.

Incident Number	Cust Impact	Ntwk Impact	Title	Outage Type	Source Impact	Current State	Start Time (UTC)	End Time (UTC)	Duration
INC0090620	2 - High	2 - High	SEAT-TOKY	Fiber	Vendor	Closed	2021-08-27 01:43:23	2021-08-27 08:25:20	0 days 6 hr 41 min
INC0091963	2 - High	2 - High	SEAT-TOKY	Fiber	Vendor	Closed	2021-09-14 14:01:51	2021-09-14 20:02:57	0 days 6 hr 1 min
INC0093164	4 - Low	2 - High	SEAT-TOKY	Undet	Vendor	Closed	2021-09-29 05:41:07	2021-09-29 05:53:32	0 days 0 hr 12 min
INC0104156	4 - Low	2 - High	SEAT-TOKY	Undet	Vendor	Closed	2022-02-19 13:18:27	2022-02-19 13:18:31	0 days 0 hr 0 min

INC0104540	2 - High	2 - High	SEAT-TOKY	Unann. Maint.	Vendor	Closed	2022-02-25 08:13:56	2022-02-25 14:22:21	0 days 6 hr 8 min
INC0105483	4 - Low	2 - High	SEAT-TOKY	Undeter	Vendor	Closed	2022-03-10 02:46:51	2022-03-10 02:47:51	0 days 0 hr 1 min
INC0105909	4 - Low	2 - High	SEAT-TOKY	Undeter	Vendor	Closed	2022-03-16 17:40:40	2022-03-16 17:40:51	0 days 0 hr 0 min
INC0107056	1 - Crit	1 - Crit	GUAM-SING	Circuit Fiber	Vendor	Closed	2022-03-30 13:48	2022-05-06 15:04	37 days 1 hr 15 min
INC0110435	4 - Low	2 - High	SEAT-TOKY	Undeter	Vendor	Closed	2022-05-16 04:40:58	2022-05-16 04:41:01	0 days 0 hr 0 min
INC0114341	3 - Mod	3 - Mod	GUAM-SING	Circuit Fiber	Vendor	Closed	2022-06-29 20:28	2022-08-05 9:42	36 days 13 hr 13 min

7.F Downtime and Availability

Tables 5 and 6 list the downtime for the project core nodes and circuits, respectively for Year 2. In Year 2, downtime was mostly vendor related due to repairing damaged or cut subsea fibers.

Table 5: Downtime and availability for TransPAC core nodes, July 1, 2021 - June 30, 2022.

TransPAC Nodes	Down Time Year 2	Year 2 Availability
test.seat.transpac.org	00 hr 00 min	100%
rtr.seat.transpac.org	00 hr 00 min	100%

Table 6: Downtime and availability for TransPAC circuits, July 1, 2021 - June 30, 2022.

TransPAC Backbone Circuits	Down Time Year 2	Year 2 Availability
TransPAC-PacWave Seattle-Tokyo 100G	1 day 1 hr 18 min	99.71%
GSSC Guam-Singapore 100G	38 days 4 hr 46 min	89.54%

8. Security Events and Activities

IN@IU maintains a set of publicly available documents that detail the policies and procedures for security incidents that may occur during the life of the TransPAC project. These documents were developed during the TransPAC4 project collaboratively with Trusted CI and are updated and reviewed at least quarterly. The full set of documents can be found online at https://internationalnetworks.iu.edu/about/policies.html. There were no security incidents to report in Year 2.

IN@IU also contracts with the GlobalNOC to manage and secure all network and server hardware owned by the TransPAC project. This mitigates the risk of missing a critical patch and allows the GlobalNOC's security hardened policies to be fully enforced. IN@IU as part of the Indiana University (IU) system has access to and implements recommendations and requirements outlined by IU's security policies.

In Year 2, Addleman attended the Internet2 Community Voices Series: Cost-Effective, Scalable Solution for Network Security at the Border in August, the Trusted CI CyberSecurity Summit in October, and the Cybersecurity Engagement in a Research Environment Workshop in December as part of his continuing security training. The security policies and documents will also continue to be reviewed and updated on an at least quarterly basis.

9. Milestones and Progress

Table 7 shows the Work Breakdown Structure for the full project timespan of five years. Table 8 details the Year 1 deliverables that continued into Year 2. Both of these were submitted as part of the Project Execution Plan.

Table 7: TransPAC5 Work Breakdown Structure Dictionary with status updates for Year 1.

	Summary	**Related to Y1 goal**	**Status**
1	**Planning / Coordination**		
1.1	Establish and support APR/APOnet coordination	G3	Project established and fully running- see Section 4.A
1.2	Revise APOnet MOU	G3	Completed - see Section 4.A
1.3	Invite additional partners to APOnet	G3	HARNET/JUCC added in Year 2 - see Section 4.A
1.4	Coordination with APOnet	G3	Ongoing - see Section 4.A
1.5	Work with partners for Arctic Connect circuit	G4	Planned Year 3
1.6	Additional MOUs	G4	Ongoing- Renewing NICT MOU - see Section 4.B
1.7	Coordinate with FABRIC for experiment support	G5	Ongoing - see Section 4.D
1.8	General project management		Ongoing
1.9	Project Reporting		Ongoing
1.10.	Documentation and dissemination of best practices as appropriate		Best practice documents for the RWG are planned for Year 3, see Section 4.C
1.11	Attend domestic and international conferences as feasible		Ongoing - TransPAC staff virtually attended conferences, meetings, and workshops - see Section 3
2	**Operations**		
2.1	Evaluate circuit capacity and community needs	G1, G2	Ongoing
2.2	Renew current Seattle-Tokyo 100G circuit	G1	Circuit stable, waiting on PacWave for new contract
2.3	Continued operation of Seattle-Tokyo 100G Circuit	G1	Ongoing - see Section 6.A
2.4	RFP and evaluation for Guam-	G2	Completed - see Section 6.B

	Asia circuit		
2.5	Continued operation of Guam-Asia circuit(s)	G2	Ongoing - Guam-Singapore Connectivity Consortium 100G Circuit operational starting 1/20/2022 - see Section 6.B
2.6	Evaluate and update existing POPs and equipment	G1, G2	Ongoing - see Section 6 and 6.C for Fast Track circuit
2.7	Work with APOnet partners to ensure redundancy/ availability of links	G3	Ongoing - focus of Engineering Team - see Section 4.A
2.8	Update NetSage data collection from TransPAC4	G1, G2	Data in TransPAC-specific Portal, http://transpac.netsage.global, see Section 7
2.9	Add additional data to TP5 dashboards for APOnet partners	G3	Ongoing - see Sections 4.A and 7
2.10.	Continued evaluation and updates to NetSage as appropriate for project	G3	Ongoing- see Section 7
2.11	Evaluate and set-up peerings with partner networks	G1, G2	Ongoing - see Section 6
2.12	Support for partial bandwidth experiments	G5	Planned for Year 3 - See Section 4.D
2.13	Support for full bandwidth experiments	G5	Ongoing - See Section 4.D
2.14	Support for route anomaly detection and resolution		Ongoing -- see Section 4.C
2.15	Deploy and Support BGP resource public key infrastructure (RPKI)		Plan to work with Pacific Wave to support RPKI as well as support RPKI in the RWG, both for Year 3. See Section 6.A
3	**Outreach**		
3.1	Ensure connectivity in support of the Large Hadron Collider	G6	Ongoing - see Section 5.B
3.2	Analyze genomics traffic and support as effort permits	G6	Ongoing - see Section 5.E

3.3	Analyze geoscience traffic and support as effort permits	G6	Ongoing - see Section 5.C
3.4	Analyze astronomy traffic and support as effort permits	G6	Ongoing - see Section 5.D
3.5	Evaluate top talkers for inclusion in NetSage science registry		Planned Year 3
3.6	As time permits, work with large data transfer end users to improve performance	G6	Ongoing, see Section 5

Table 8: TransPAC5 Submitted Goals for Year 1, with status updates for Quarter 3.

Y1 GOALS	**Objective**	**WBS #**	**Status**
Goal 1	**100G Seattle-Tokyo transitioned to TransPAC 5 support by 31 October 2020**		
MS 1.1	Extend current 100G circuit contract for 100G between Seattle and Tokyo with PNWGP for 5 years (life of project)	2.2	OBE - Current month to month contract with PNWGP will continue.
MS 1.2	Extend contracts for Seattle colocation and port fees	2.2,2.3	Currently month to month contract with PNWGP while they negotiate with Tata. New contract expected in Year 3.
MS 1.3	Ensure continuation of Tokyo port support with WIDE	2.2,2.3	Currently month to month contract with PNWGP while they negotiate with Tata. New contract expected in Year 2.
MS 1.4	Put in place GNOC contract to start with deployment	2.2	Completed - January 1, 2021, transferred from TransPAC4 in June 2021.
MS 1.5	Update full NetSage infrastructure for 100G circuit from TP4 set up from previous IRNC deployment to GlobalNOC NetSage	2.1	Completed - Data now in TransPAC-specific Portal, http://transpac.netsage.global

	Managed Service		
Goal 2	**Capacity between Guam and Asia**		
NOTES	Plans for connectivity from Guam is now to work jointly with an Asian consortium led by Jun Murai for 100G capacity (IRU) for Guam-Singapore. Meanwhile, maintaining some of the current Guam-HK capacity in place until that is stable. If the 100G IRU capacity is not in place by mid year 2, we will run an RFP for a 10G&100G capacity between Guam and Asia for a 2+2 year contract	2.4, 2.5	
MS 2A.1	Evaluate options with Asian partners for a 100G IRU	2.4	Completed - see Section 6.B
MS 2A.2	Issue RFP for 10 and 100g connections between Guam and Singapore, Hong Kong, and Daejong for comparison purposes		Completed - see Section 6.C
MS 2A.3	Put in place contract to support 5 years of consortium capacity (Note: NOC and CoLo support will no longer be the responsibility of TP5 for this link)	2.4	Completed - see Section 6.C
MS 2A.4	Put in place peering agreements for new capacity		Initial agreements completed Year 2, see Section 6
MS 2A.5	Shift current Guam-HK traffic to new circuit as		Planned for Year 3

	appropriate		
MS 2A.6	Update full NetSage infrastructure from TP4 set up from previous IRNC deployment to GlobalNOC NetSage Managed Service		Completed - see Section 7
MAS 2B.7	If IRU is not functional by June 2021, renew HK colocation and port agreements to continue Guam-HK connectivity (Note: CoLo in HK only available in 12 month increments)		Completed - Decision to decommission TransPAC4 Guam-HK circuits was made in Year 1.
MS 2B.8	If IRU is not functional by December 2021, issue request for quotes for one 10G or 100G leased circuit between Guam and endpoint TBD	2.4	Completed
MS 2B.9	Put in place contracts for capacity		Completed - see Section 6
MS 2B.10	Ensure GNOC support for supported contracts and timing		OBE - Internet2 will support this, no separate NOC contract needed for TransPAC5
MS 2B.11	Deploy, test and accept circuit		OBE - Internet2 will support this, no separate NOC contract needed for TransPAC
MS 2B.12	Update measurement and monitoring support for capacity		Ongoing - Data being added to the APOnet NetSage deployment, see Section 7
MS 2B.13	Update peerings and traffic mapping		In progress - Discussing with the partner technical contacts
Goal 3	**Asia Pacific Ring (APR), now Asia Pacific Oceania Network (APOnet) partner set-up by 31 April 2020**		

MS 3.1	Contact partners to begin set up of structure	1.1	Completed - see Section 4.A
MS 3.2	Write new APOnet MOU draft for partner signing	1.2	Completed - see Section 4.A
MS 3.3	Sign new APOnetPR MOU-in person	1.2	OBE
MS 3.4	Sign new APOnet MOU-virtual	1.2	Completed - see Section 4.A
MS 3.5	Set up regular policy meeting	1.1	Completed - see Section 4.A
MS 3.6	Set up regular engineering meetings	1.1	Completed - see Section 4.A
MS 3.7	Set up collaborative space	1.1	Completed - Google drive space and slack channel have been set up
MS 3.8	Initial conversations with APOnet partners to share data via NetSage	1.1, 1.4, 2.10	Ongoing - See Sections 4.A, 7
MS 3.9	SNMP additions to APOnet NetSage	1.1, 1.4, 2.10	Ongoing - See Sections 4.A, 7
MS 3.10	Flow additions to APOnet NetSage	1.1, 1.4, 2.10	Ongoing - See Sections 4.A, 7
Goal 4:	**Additional partner support by August 2021**		
MS 4.1	Define new MOU with APAN with specific deliverables	1.6	Planned for Year 3 - COVID delay
MS 4.2	Sign new APAN MOU in person	1.6	Planned for Year 3 - COVID delay
MS 4.3	Sign new APAN MOU virtually	1.6	Planned for Year 3 - COVID delay
MS 4.4	Define new MOU with TEIN with specific deliverables	1.6	Planned for Year 3 - COVID delay
MS 4.5	Sign new TEIN MOU in person	1.6	Planned for Year 3 - COVID delay
MS 4.6	Sign new TEIN MOU virtually	1.6	Planned for Year 3 - COVID delay

Goal 5	**Establish infrastructure for external experimental support by February 2021**		
MS 5.1	Discussions with FABRIC to understand detailed requirements	1.7	In progress - see Section 4.D
MS 5.2	Support for FABRIC	1.7	In progress - see Section 4.D
MS 5.3	Put in place tech for larger bandwidth blocks for experiments	2.13	On hold - specialized technology may not be needed.
MS 5.4	Advertise small BW support	2.12	In progress - Advertised to APOnet; Plans for larger advertisement to take place in Year 3
MS 5.5	Advertise larger BW blocks	2.13	In progress - Advertised to APOnet; Plans for larger advertisement to take place in Year 3
Goal 6	**Establish limited science support by December 2020**		
MS 6.1	Let LHCONE know of reduced support, plan for 3rd party involvement	3.1	Completed Year 1
MS 6.2	Contact Astronomy collaborators (ALMA, e-VLBI, MAST) and plan support, including check-in frequency	3.4	Completed Year 1
MS 6.3	Contact Bioinformatics (A-STAR, SDMS, HGB) and plan support, including check-in frequency	3.2	Ongoing, See Section 5.E
MS 6.4	Contact Science Support listed in proposal and let them know the effort was cut	3.6	Completed Year 2
MS 6.5	LHCONE support	3.1	In progress - see Section 5.B

MS 6.6	Astronomy support	3.4	In progress - see Section 5.D
MS 6.7	Bioinformatics support	3.2	In progress - see Section 5.E