# Enhancing HPC Education and Workflows with Novel Computing Architectures

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# Adapting to a Changing Compute Landscape

We present a case study of applying traditional HPC techniques to novel architectures, including but not limited to FPGAs, neuromorphic devices, quantum compilers, and SmartNICs.

Specifically, we looked at the following questions:

- How can we support larger numbers of students for a ***novel FPGA cluster*** that ties in with an existing HPC system, GT's Instructional Cluster Environment (ICE)?
- How do we support key requirements like ***data separation and privacy for student data*** while allowing for free flow of data between isolated clusters and local access points?
- What types of training would students require to migrate from "hands-on" infrastructure to a remotely scheduled cluster that uses a scheduler like Torque/Moab or Slurm?

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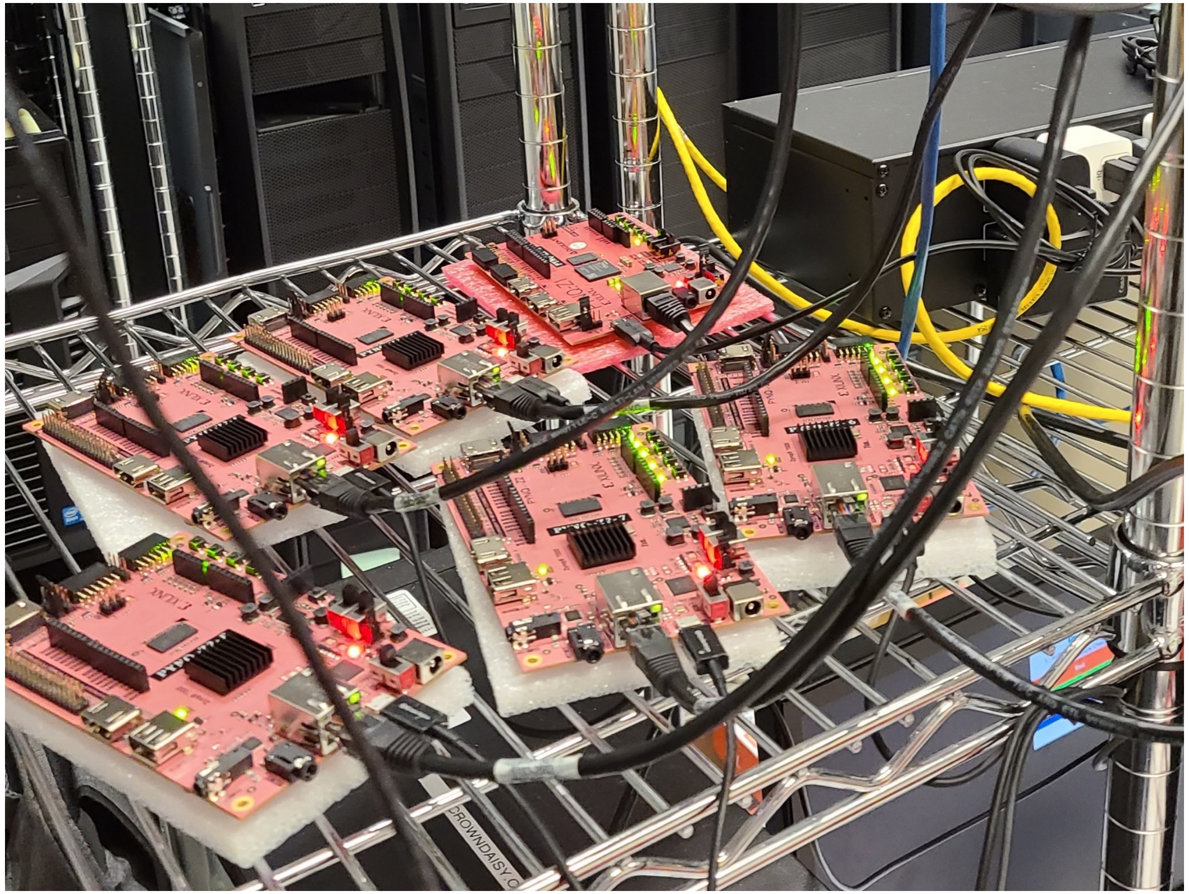
# Challenges with Existing Solutions

- Two courses with 90+ (CS 3220 and 40+ (ECE 8803) students
- Typical PYNQ FPGA workflows require:
  - The usage of Vivado and Vitis tools with large memory requirements
  - Hands-on interaction with a board to set up Jupyter webserver interfaces
- Supply chain issues limit the number of boards we can deploy



***How can we best support remote FPGA development and usage at scale?***

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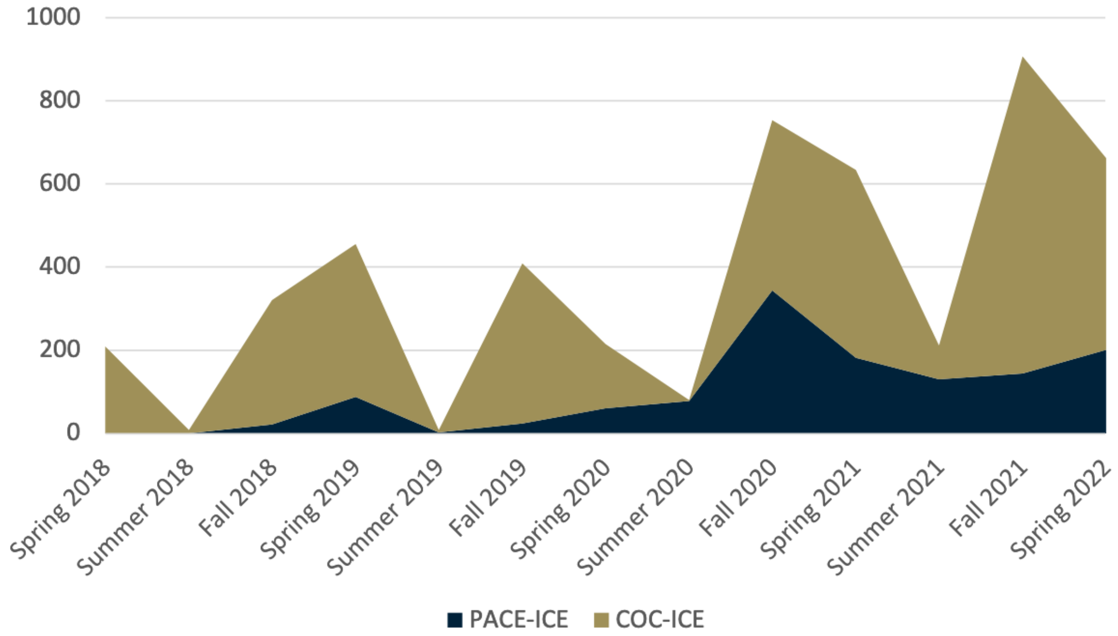
# Enterprise HPC Expertise to Facilitate Access

- PACE's Instructional Computing Environment (ICE) and the College of Computing Instructional Computing Environment (CoC-ICE) support over 1600 students and 20 classes in a given year (as of 2021)
  - CoC-ICE has 45 CPU/GPU nodes and is connected via InfiniBand
  - Traditional Torque/Moab scheduler that mirrors larger Phoenix and Hive Systems

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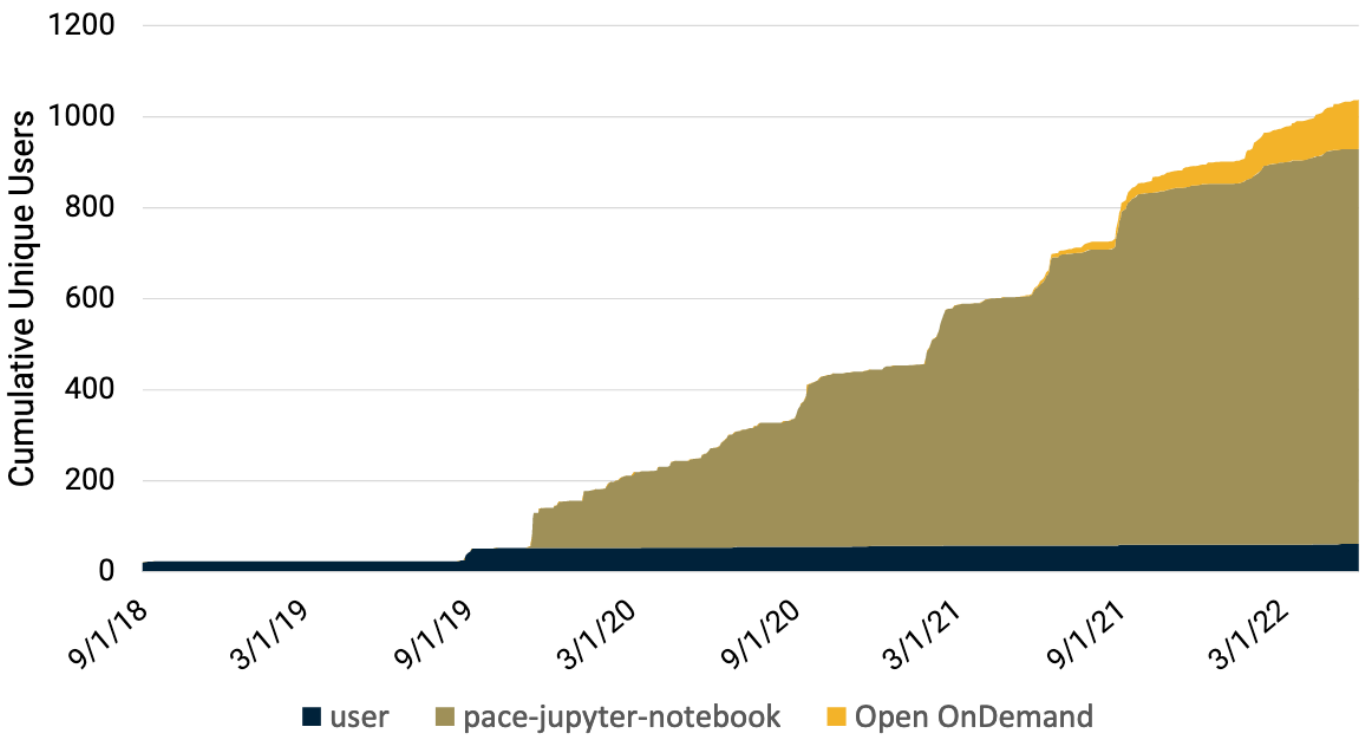
# Jupyter Wrapper to Lower Learning Barrier

PACE has deployed custom Torque/Moab Jupyter and VNC scripts that support notebook and GUI-based app usage

- Since its introduction in 2019, these efforts have dramatically increased utilization and the overall userbase
- Open OnDemand is likely to provide another "bump" in engagement with users.

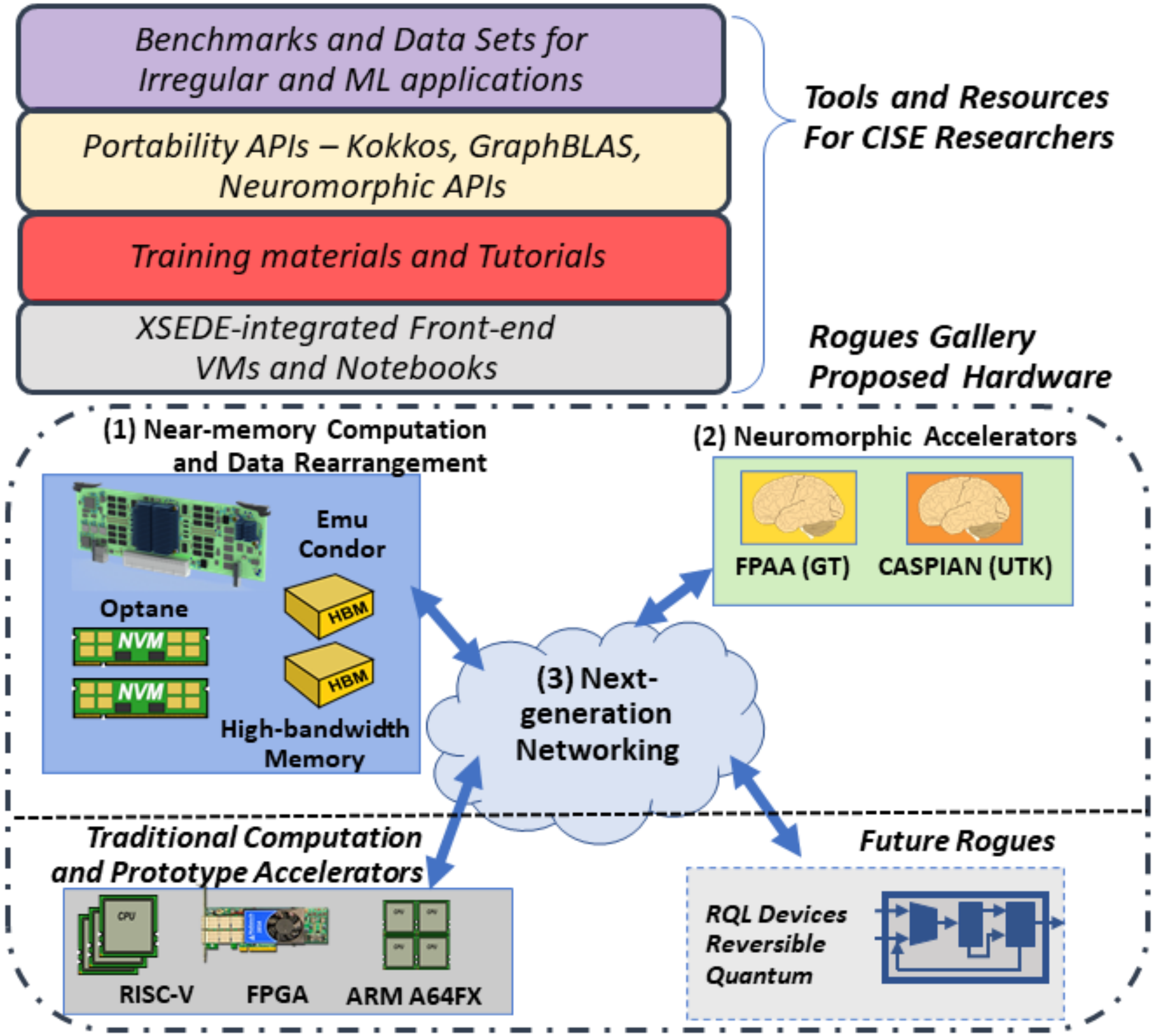


# CRNCH Rogues Gallery

The Rogues Gallery is an NSF funded testbed that is focused on increasing access to novel architectures for CISE researchers.

Critically, these systems must be ***accessible*** with ***appropriate training materials***.

- Georgia Tech courses provide good motivation to enhance these features of the testbed!

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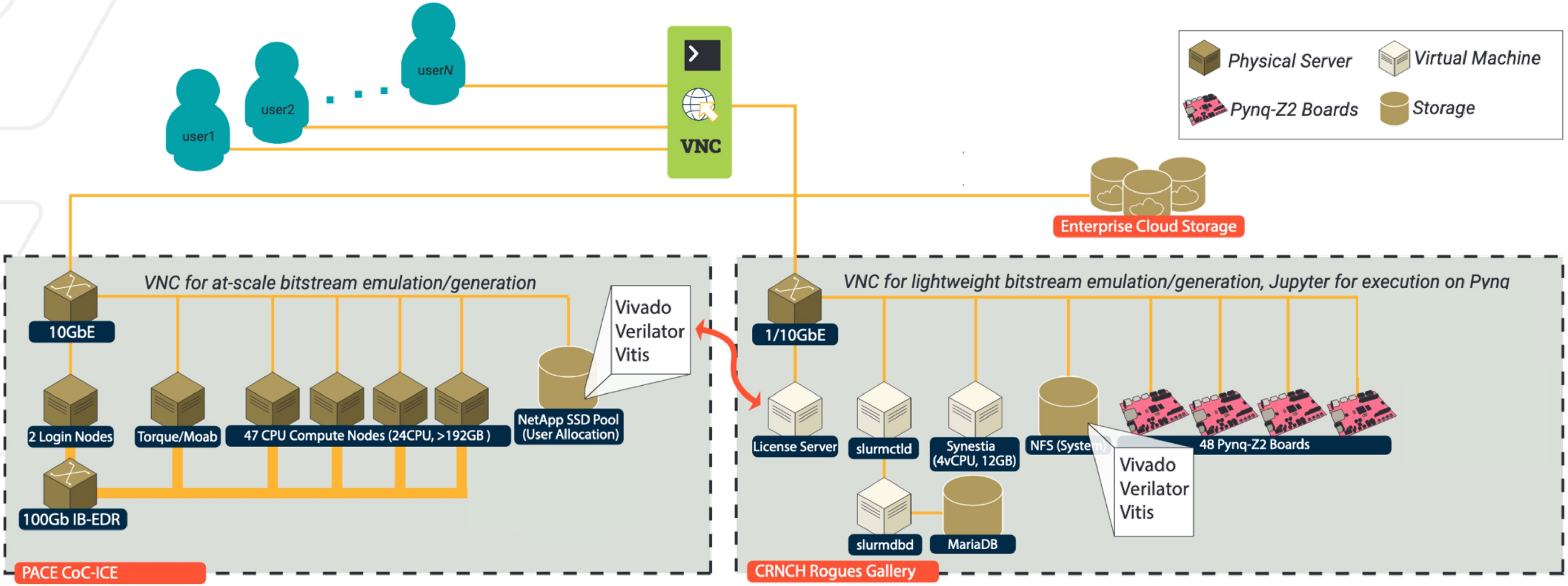
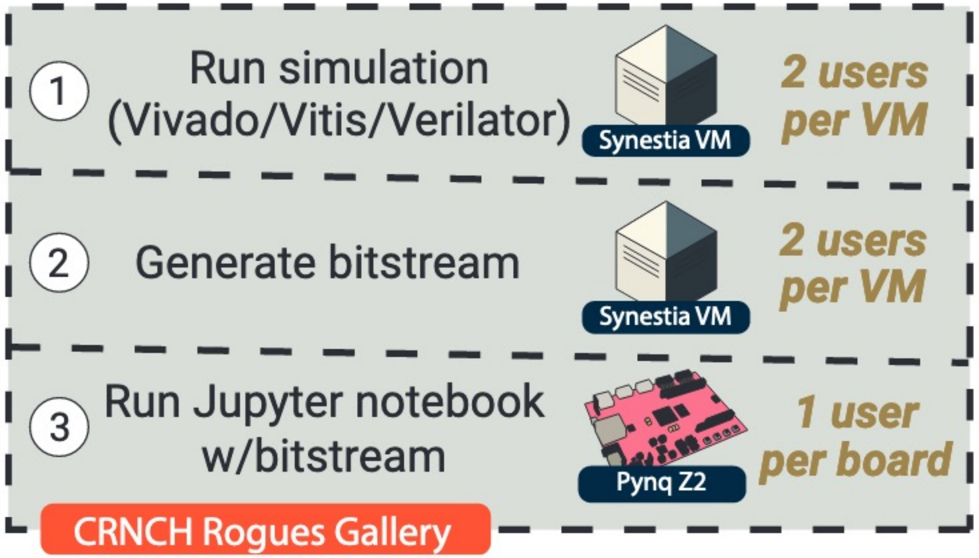
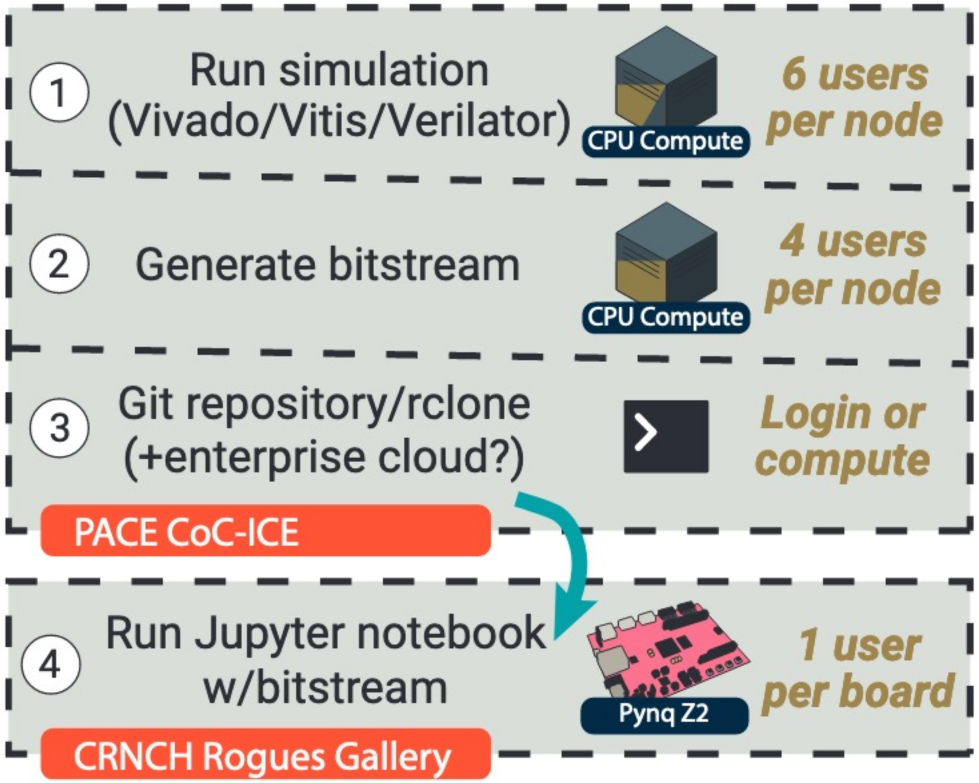
# CRNCH + PACE PYNQ Infrastructure



# Two User Workflows




A combined workflow allows for a dramatic reduction in the bottleneck of design and initial testing

- However, there are some issues to consider related to data security
- ICE is set up to manage student data unlike research testbeds like CRNCH RG

# Spring 2022 PYNQ Cluster Adoption

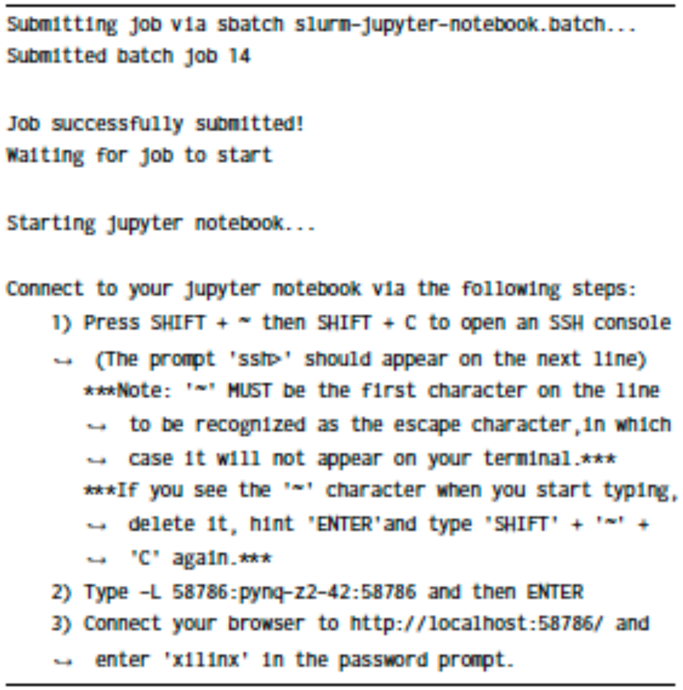
42 PYNQ Z2 FPGAs were deployed along with Vitis/Vivado 2021.1 tools on CoC-ICE and CRNCH-hosted VMs.

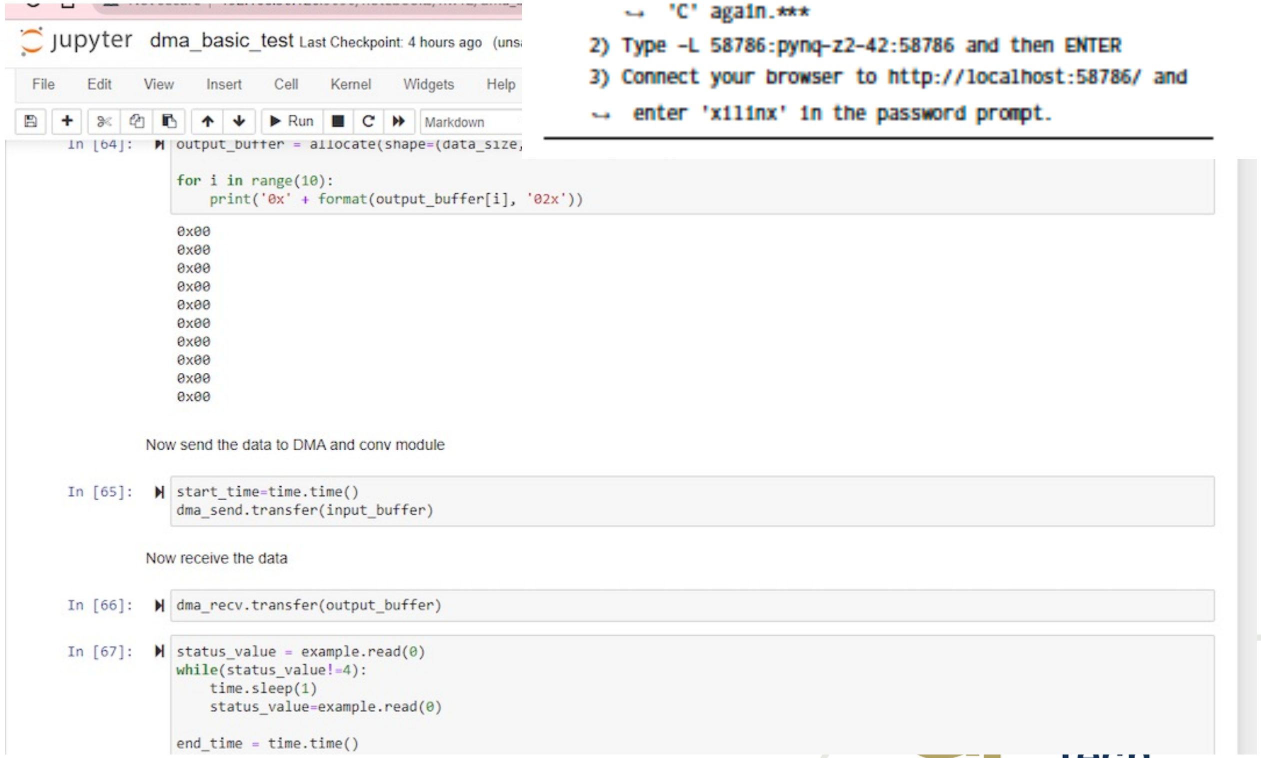
CoC-ICE was used to simulate code and generate bitstreams, and students used GT GitHub or rclone to migrate files between ICE and CRNCH RG testbed

- CRNCH nethome was set up with a class-specific folder login that could be wiped at the end of the semester.

Students used SSH port forwarding and Slurm to request an interactive PYNQ Jupyter session.

- Wrapper scripts were deployed to improve student experience and reduce training burden

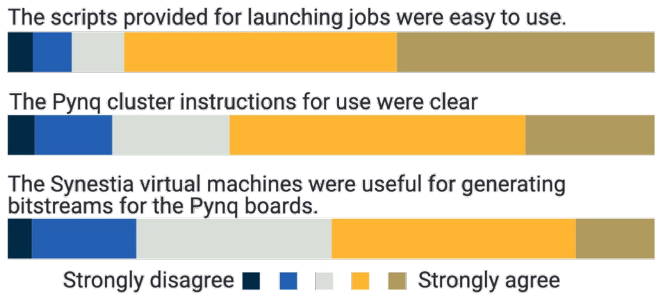


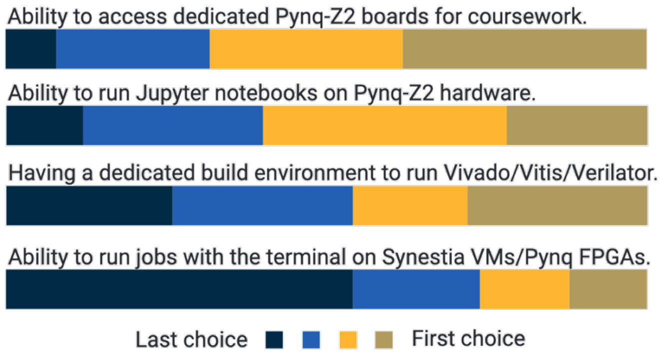



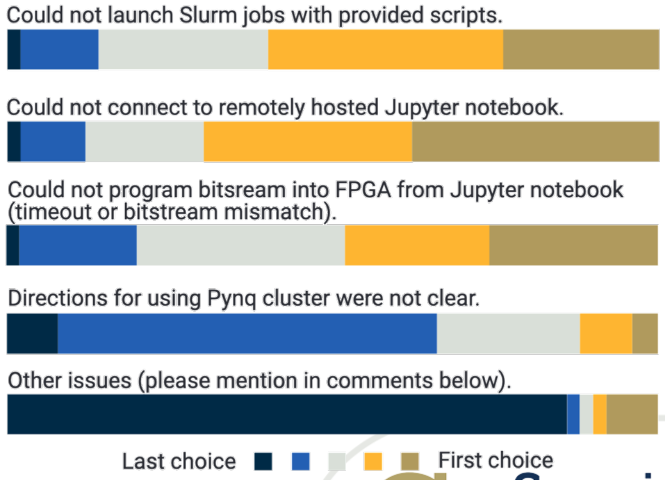
# End of Semester Student Feedback

Students were surveyed post-semester to garner user insights into the infrastructure/workflow efficacy

- Non-anonymous results were given extra credit
- ***Pros:*** Students appreciated the workflow including using HPC servers for large-memory jobs and the Jupyter interface and scripts to use PYNQ boards. Cost savings from not needing to buy a PYNQ board also exceeds $8,000 per semester.
- ***Cons:*** Students encountered errors related to launching Slurm jobs, user contention, and a few issues with PYNQ commands. Lack of Slurm accounting created high-utilization scenarios.

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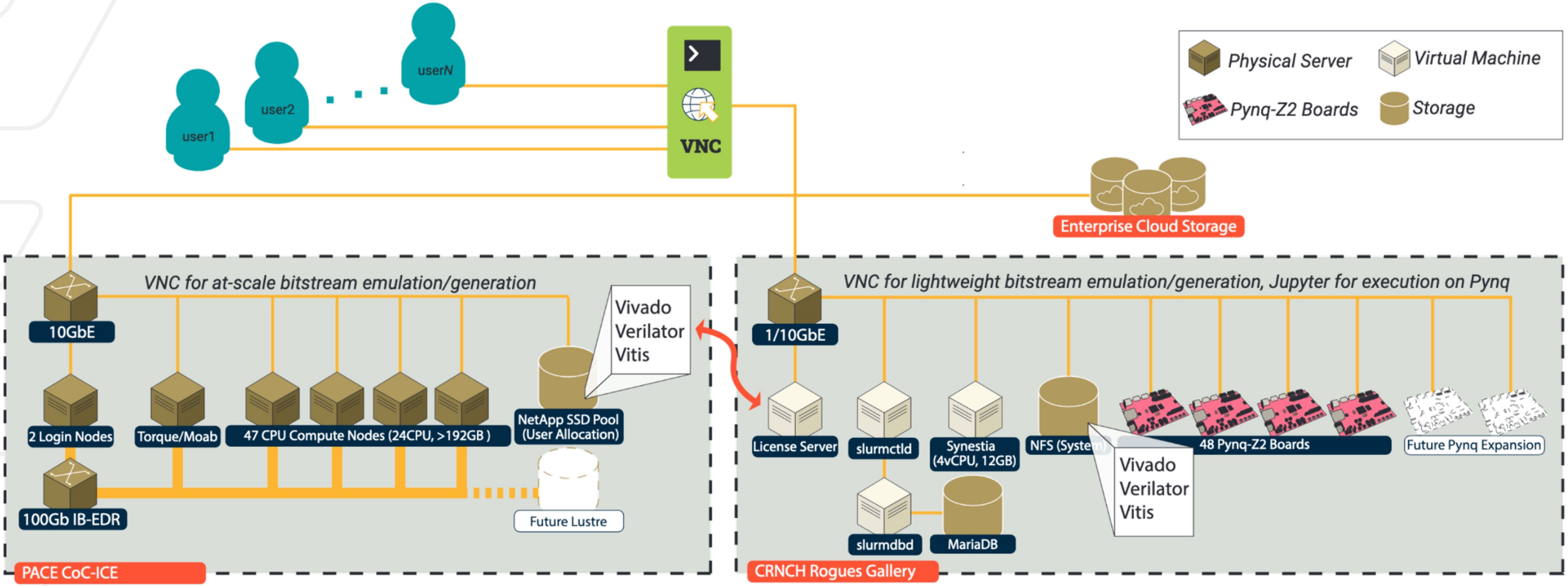
# Cluster Expansions in Response to Feedback

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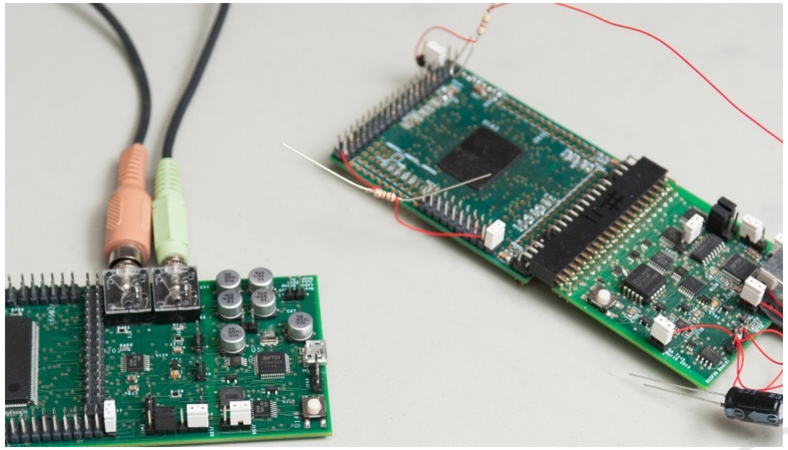
# Future Improvements

We are currently working on fully supporting Open OnDemand, Slurm accounting, and XDMod reporting

- This would minimize the need for custom scripts to launch jobs
- Accounting would be useful to set better job limits for users for exams, etc.

Other novel devices can follow this same model

- If it can be connected to a Raspberry Pi that can run slurmd, we can schedule it and create a notebook interface!
- Ex: The locally developed Field Programmable Analog Array for neuromorphic applications can act as a USB client to a scheduled Raspberry Pi node

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# Conclusion

## As post-Moore technologies continue to become mainstream, our courses and HPC resources will need to adapt:

- Novel architectures typically follow a defined simulation/hardware execution workflow that maps well to traditional HPC resources.
- Coursework requires special care for management of student data but existing techniques and tools can be used to bridge novel testbeds and traditional clusters.
- Students may need extra help to learn new concepts like schedulers and SSH port forwarding, but documentation and engagement can help to bridge their transition to remote novel architecture testbeds.

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***Learn more about CRNCH RG and request an account at [https://crnch-rg.cc.gatech.edu/](https://crnch-rg.cc.gatech.edu/) and PACE at [https://pace.gatech.edu](https://pace.gatech.edu)***

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