www. chameleoncloud.org

THE MANY COLORS OF CHAMELEON

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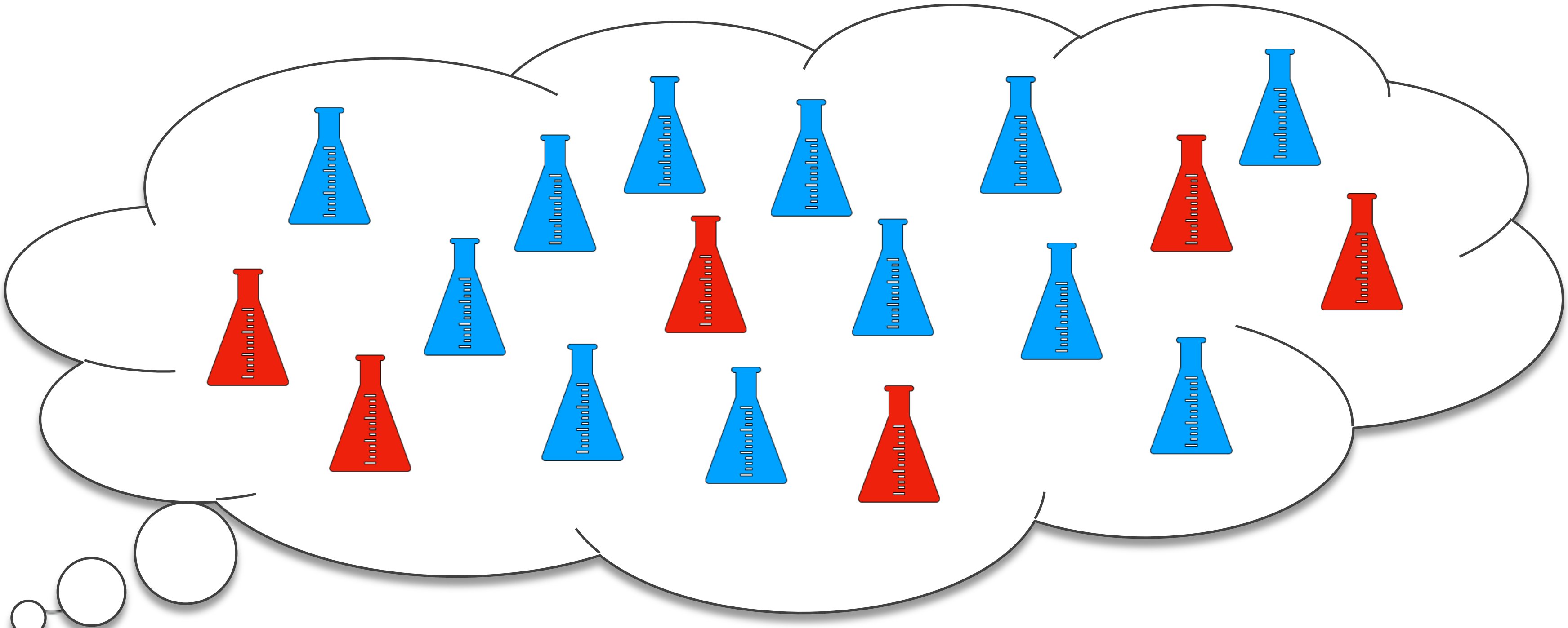
March 25, 2019
Accelerated Data and Computing Workshop 7, Oak Ridge, Tennessee

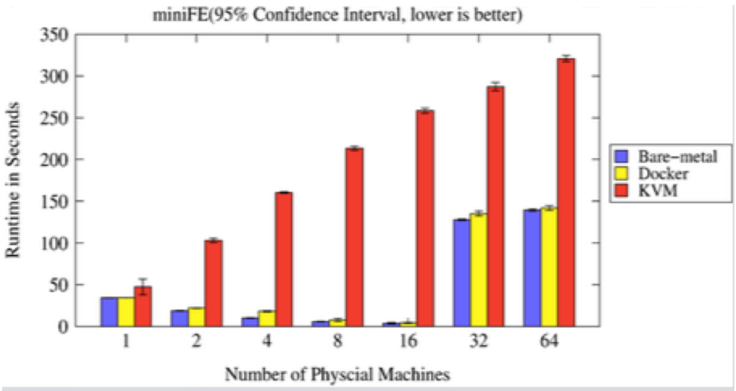
WHY DO WE NEED A TESTBED?

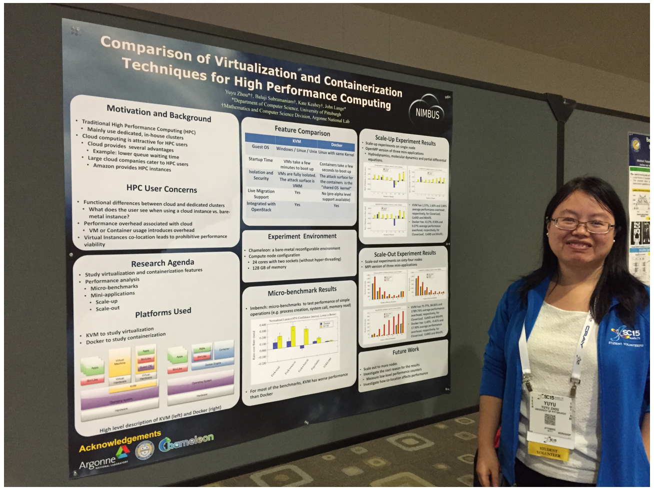


While the types of experiments we can design are only limited by our creativity, in practice we can carry out only those that are supported by an instrument that allows us to deploy, capture (observe and measure), and record relevant scientific phenomena

VIRTUALIZATION OR CONTAINERIZATION?

- Yuyu Zhou, University of Pittsburgh
- Research: lightweight virtualization
- Testbed requirements:
  - Bare metal reconfiguration, isolation, and serial console access
  - The ability to "save your work"
  - Support for large scale experiments
  - Up-to-date hardware

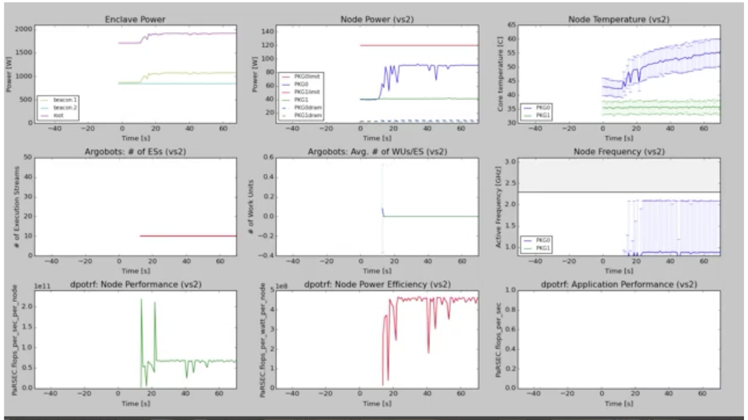




SC15 Poster: "Comparison of Virtualization and Containerization Techniques for HPC"

EXASCALE OPERATING SYSTEMS

- Swann Perarnau, ANL
- Research: exascale operating systems
- Testbed requirements:
  - Bare metal reconfiguration
  - Boot from custom kernel with different kernel parameters
  - Fast reconfiguration, many different images, kernels, params
  - Hardware: accurate information and control over changes, performance counters, many cores
  - Access to same infrastructure for multiple collaborators



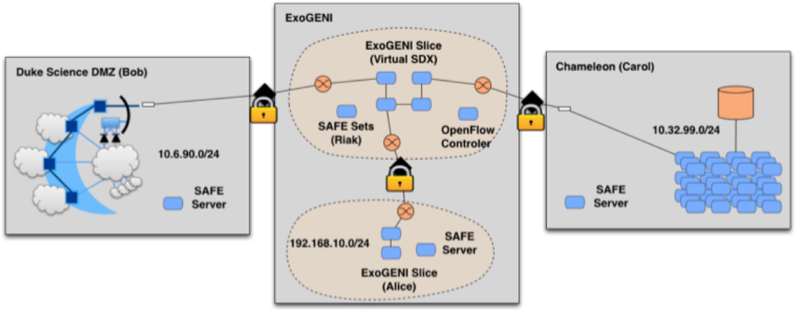
HPPAC'16 paper: "Systemwide Power Management with Argo"

CLASSIFYING CYBERSECURITY ATTACKS

- Jessie Walker & team, University of Arkansas at Pine Bluff (UAPB)
- Research: modeling and visualizing multi-stage intrusion attacks (MAS)
- Testbed requirements:
  - Easy to use OpenStack installation
  - A selection of pre-configured images
  - Access to the same infrastructure for multiple collaborators

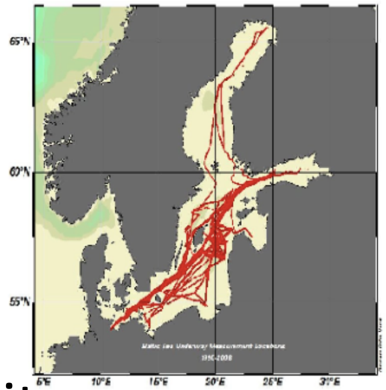
CREATING DYNAMIC SUPERFACILITIES

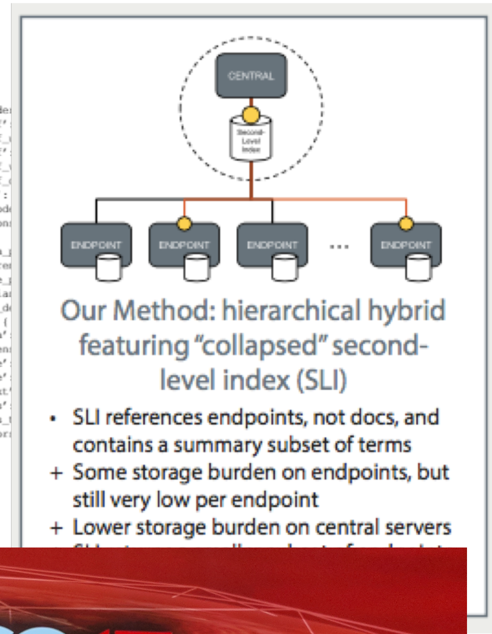
- NSF CICI SAFE, Paul Ruth, RENCI-UNC Chapel Hill
- Creating trusted facilities
  - Automating trusted facility creation
  - Virtual Software Defined Exchange (SDX)
  - Secure Authorization for Federated Environments (SAFE)
- Testbed requirements
  - Creation of dynamic VLANs and wide-area circuits
  - Support for slices and network stitching
  - Managing complex deployments



DATA SCIENCE RESEARCH

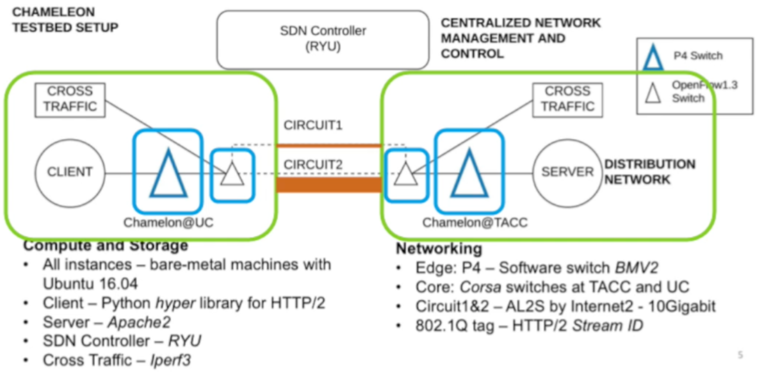
- ACM Student Research Competition semi-finalists:
  - Blue Keleher, University of Maryland
  - Emily Herron, Mercer University
- Searching and image extraction in research repositories
- Testbed requirements:
  - Access to distributed storage in various configurations
  - State of the art GPUs
  - Easy to use appliances and complex deployments





ADAPTIVE BITRATE VIDEO STREAMING

- Divyashri Bhat, UMass Amherst
- Research: application header based traffic engineering using P4
- Testbed requirements:
  - Distributed testbed facility
  - BYOC – the ability to write an SDN controller specific to the experiment
  - Multiple connections between distributed sites
- https://vimeo.com/297210055

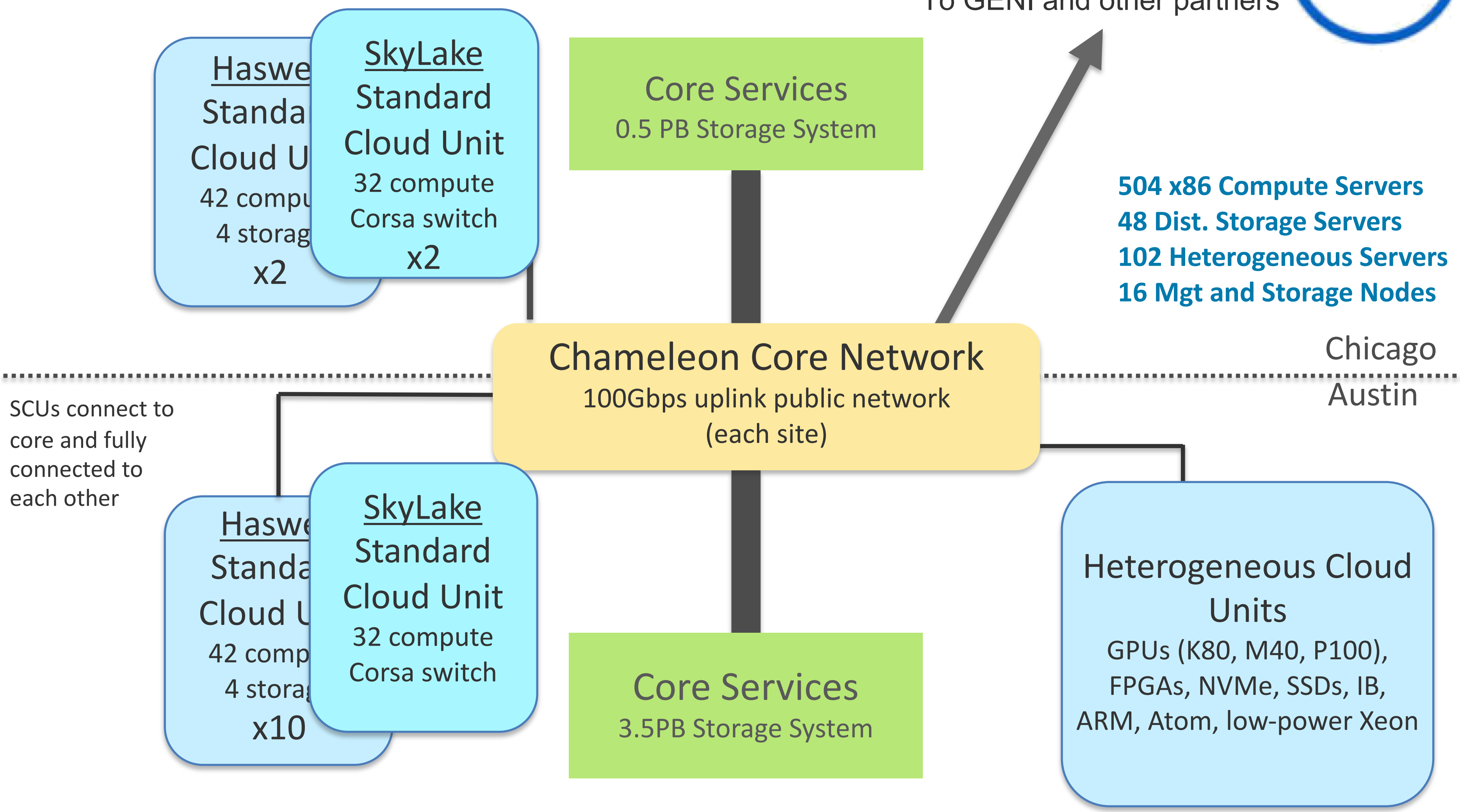


LCN'18: "Application-based QoS support with P4 and OpenFlow"

CHAMELEON IN A NUTSHELL

- **Deeply reconfigurable:** "As close as possible to having it in your lab"
  - Deep reconfigurability (bare metal) and isolation
  - Power on/off, reboot from custom kernel, serial console access, etc.
  - But also – modest KVM cloud for ease of use
- **Combining large-scale and diversity:** "Big Data, Big Compute research"
  - **Large-scale**: ~large homogenous partition (~15,000 cores), 5 PB of storage distributed over 2 sites connected with 100G network…
  - …and **diverse:** ARMs, Atoms, FPGAs, GPUs, Corsa switches, etc.
  - **Coming soon**: more storage, more accelerators
- Blueprint for a **sustainable** production testbed: "cost-effective to deploy, operate, and enhance"
  - Powered by OpenStack with bare metal reconfiguration (Ironic)
  - Chameleon team contribution recognized as official OpenStack component
- **Open, collaborative, production** testbed for **Computer Science Research**
  - Started in 10/2014, testbed available since 07/2015, renewed in 10/2017
  - Currently 3,000+ users, 500+ projects, 100+ institutions

CHAMELEON HARDWARE



CHAMELEON HARDWARE (DETAILS)

- “Start with large-scale homogenous partition”
  - 12 Haswell Standard Cloud Units (48 node racks), each with 42 Dell R630 compute servers with dual-socket Intel Haswell processors (24 cores) and 128GB RAM and 4 Dell FX2 storage servers with 16 2TB drives each; Force10 s6000 OpenFlow-enabled switches 10Gb to hosts, 40Gb uplinks to Chameleon core network
  - 2 SkyLake Standard Cloud Units (32 node racks); Corsa (DP2400 & DP2200) switches, 100Gb ulpinks to Chameleon core network
  - Allocations can be an entire rack, multiple racks, nodes within a single rack or across racks (e.g., storage servers across racks forming a Hadoop cluster)
- Shared infrastructure
  - 3.6 + 0.5 PB global storage, 100Gb Internet connection between sites
- “Graft on heterogeneous features”
  - Infiniband with SR-IOV support, High-mem, NVMe, SSDs, GPUs (22 nodes), FPGAs (4 nodes)
  - ARM microservers (24) and Atom microservers (8), low-power Xeons (8)
- Coming soon: more nodes (CascadeLake), and more accelerators

REQUIREMENTS FOR EXPERIMENTAL WORKFLOW

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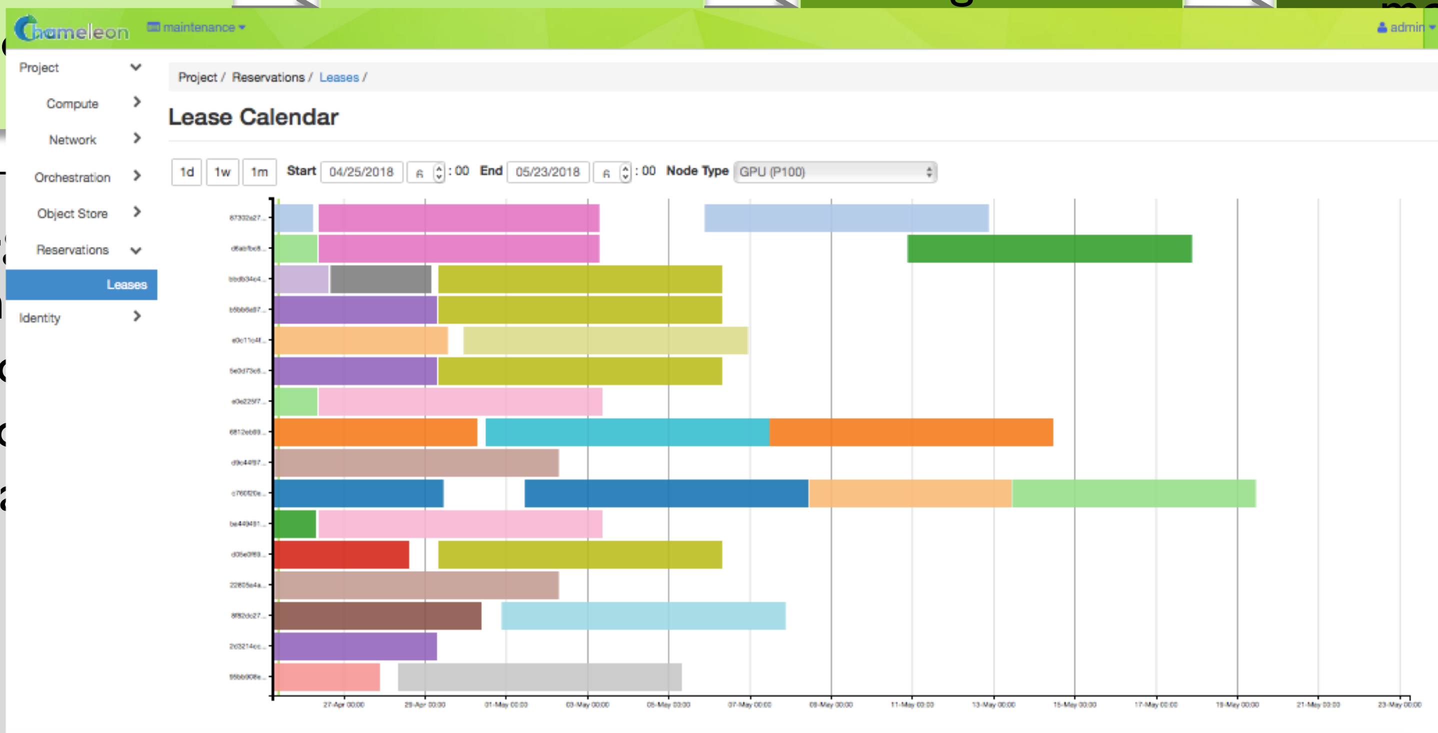


CHI = 65%*OpenStack + 10%*G5K + 25%*"special sauce"

BUILDING CHI (CHAMELEON INFRASTRUCTURE)

- Requirements for core functionality (proposal stage)
  - Interviews with ~20 research groups
- Architecture: **discover**, **provision**, **configure**, and **monitor**
- Technology Evaluation and Risk Analysis
  - Many options: Grid’5000, Nimbus, LosF, OpenStack
  - Final round: Grid’5000 and OpenStack
- Criteria: sustainability as design criterion
  - ***Does it fit our purpose?*** Feature coverage, incl. ease of use
  - ***Can we customize it?*** Open-source, configurable, extendable
  - ***Can we rely on it?*** Stable, scalable, supported
  - Can a CS testbed be built from commodity components?
- A mix of technologies with lots of tweaks (aka “special sauce”)
  - Grid’5000 for resource discovery and hardware verification
  - OpenStack for the rest (using Blazar, Ironic, and core OpenStack services)
- Core functionality built in just 3 months after evaluation

SUPPORT FOR EXPERIMENTAL WORKFLOW

discover resources → allocate resources → configure and interact → monitor

Grid'5000 Resource Discovery

OpenStack:
- Nova
- *Blazar*
- Swift

OpenStack
- Ironic
- Neutron
- Glance
- Heat

Other
- Appliances++
- Snapshotting

Network Isolation

OpenStack
- Gnocchi

Agents, custom integration, etc.

CHI = 65%*OpenStack + 10%*G5K + 25%*"special sauce"

WHAT IS OPENSTACK?

- Leading open-source IaaS implementation… and more

Traditional software

OpenStack

- Community: ~ 1,500-2,000 developers contributing to each release including many big companies contributing, e.g. Huawei, Red Hat
- Deployment base:
  - 2017 user surveys logged 1,000 unique deployments (~millions of end users)
  - 60 public cloud data centers, from e.g. Rackspace, OVH
  - Large-scale deployments, e.g. 300K cores at CERN

THE MISSING COMPONENT: OPENSTACK BLAZAR

- **Advanced reservation service** for OpenStack
- Originally developed 2013-2014 in the context of power management research
- From early 2015: adaptation for Chameleon
  - Improve stability, integration with Ironic
  - Dashboard improvements (Gantt chart)
  - Incremental operational improvements
- Fall 2016: revival
  - Joined forces with NTT and others working on capacity reservation for NFV
- **Official OpenStack project** in Sep 2017

BLAZAR
an OpenStack Community Project

OPENSTACK: LESSONS LEARNED

- The good
  - Large community rapidly developing new features
  - Common requirements → shared effort
  - Commodity for sustained use
  - Many users already familiar with OpenStack
- The bad
  - Large community rapidly developing new features
  - Complexity: it solves a complex problem
  - Some users assume Chameleon is like any OpenStack

BUILDING AN ECOSYSTEM

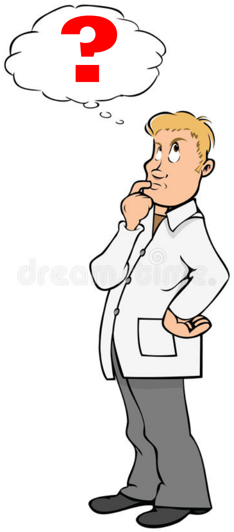
- Helping hardware providers interact
  - Bring Your Own Hardware (BYOH)
  - CHI-in-a-Box: deploy your own Chameleon site
- Helping scientists interact
  - Leveraging the common denominator
  - Integrating tools for experiment management
  - Making reproducibility easier
  - Facilitating sharing

CHI-IN-A-BOX

- CHI-in-a-box: packaging a commodity-based testbed
- CHI-in-a-box scenarios
  - **Testbed extension:** join the Chameleon testbed: generalize and package + define operations models
  - **Part-time extension:** define and implement contribution models
  - **New testbed:** generalize policies
- Understanding the support cost model
- Available since Summer 2018
- **New Associate Site at Northwestern!**
  - Nodes with 100G network cards

REPRODUCIBILITY DILEMMA

Should I invest in making my experiments repeatable?



Should I invest in more new research instead?

- **Reproducibility as side-effect**: lowering the cost of repeatable research
  - Example: Linux “history” command
  - From a meandering scientific process to a recipe
- **Reproducibility by default:** documenting the process via interactive papers

REPEATABILITY MECHANISMS IN CHAMELEON

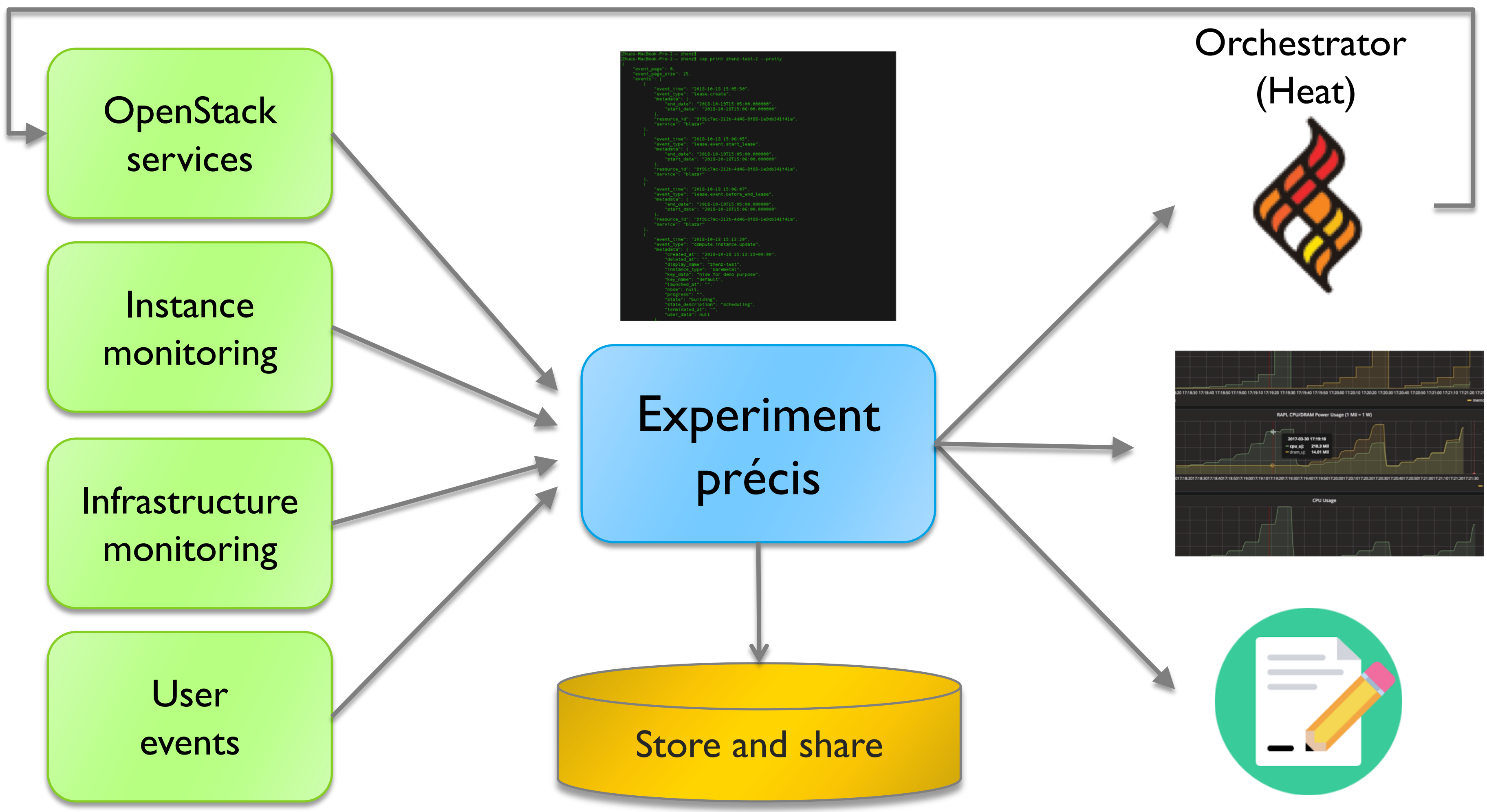
- Testbed versioning (collaboration with Grid'5000)
  - Based on representations and tools developed by G5K
  - >50 versions since public availability – and counting
  - Still working on: better firmware version management
- Appliance management
  - Configuration, versioning, publication
  - Appliance meta-data via the appliance catalog
  - Orchestration via OpenStack Heat
- Monitoring and logging
- **However... the user still has to keep track of this information**

KEEPING TRACK OF EXPERIMENTS

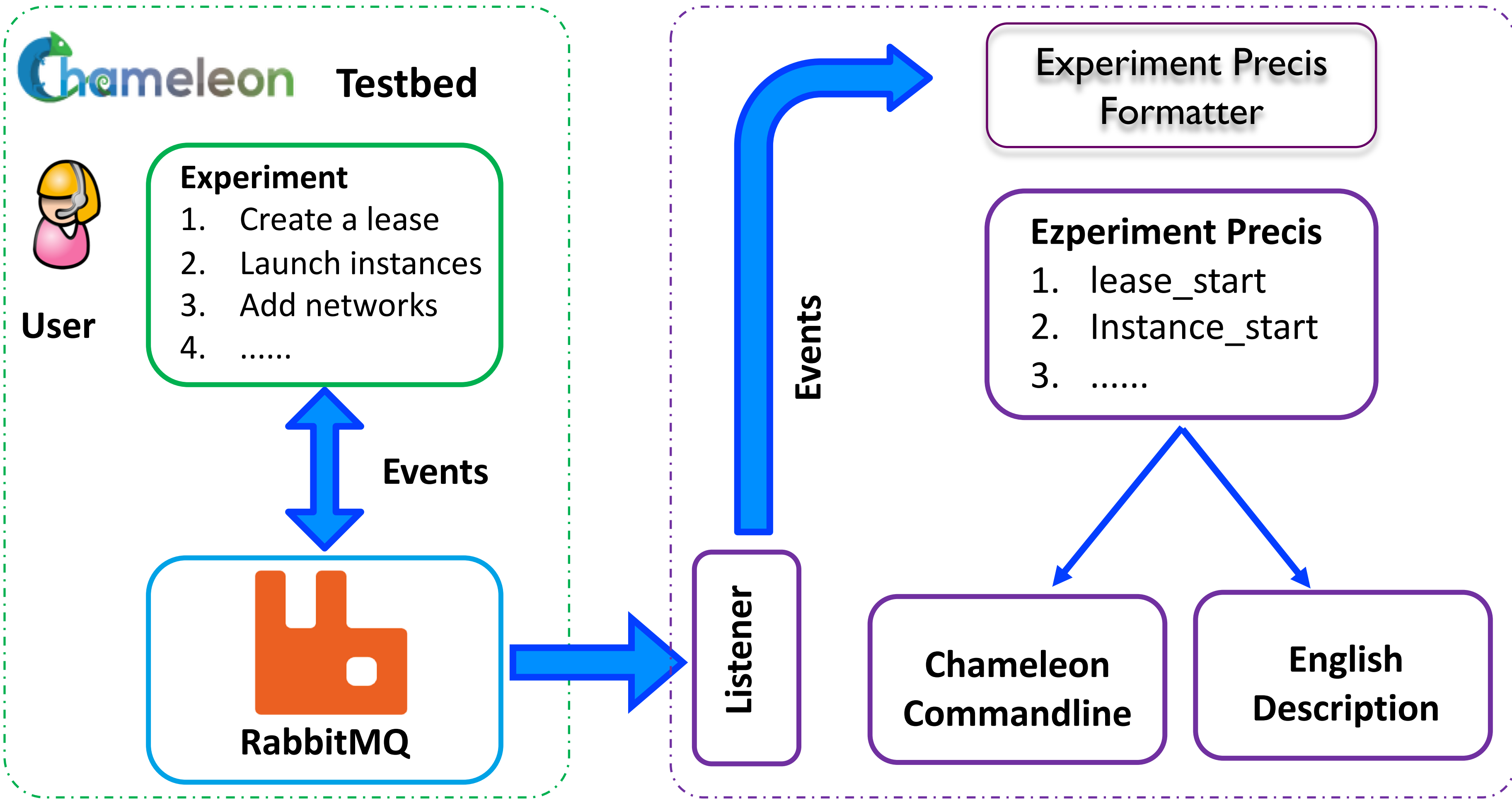
- Everything in a testbed is a recorded event
  - The resources you used
  - The appliance/image you deployed
  - The monitoring information your experiment generated
  - Plus any information you choose to share with us: e.g., “start power_exp_23” and “stop power_exp_23”

- **Experiment précis:** information about your experiment made available in a “consumable” form

REPEATABILITY: EXPERIMENT PRÉCIS

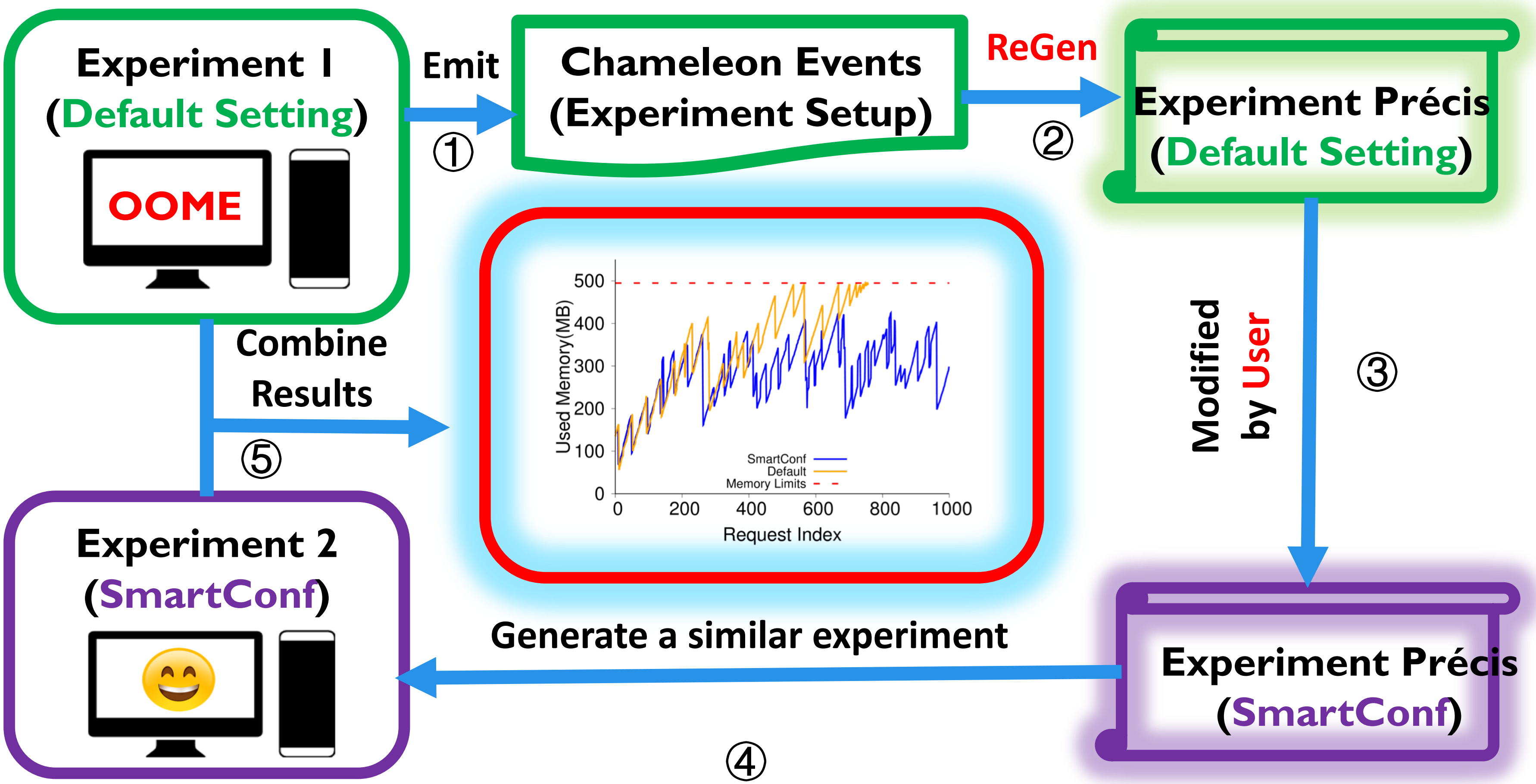


EXPERIMENT PRÉCIS IMPLEMENTATION



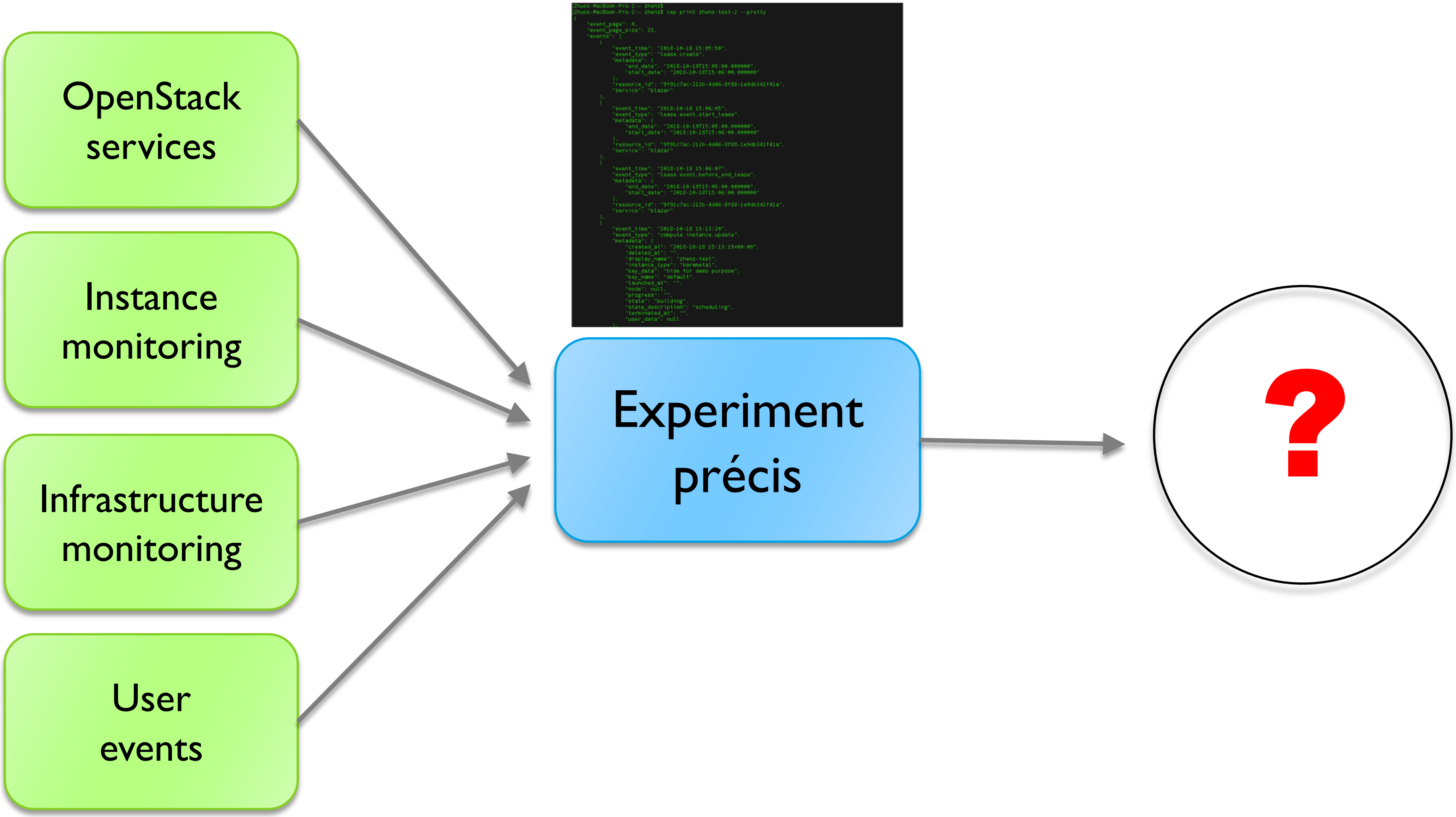
Wang et al., "Reproducibility as Side-Effect", SC18 poster

EXPERIMENT PRÉCIS: A CASE STUDY



Based on *Wang et al.*, Understanding and Auto-Adjusting Performance-Sensitive Configurations. ASPLOS, 2018

REPEATABILITY: EXPERIMENT PRÉCIS

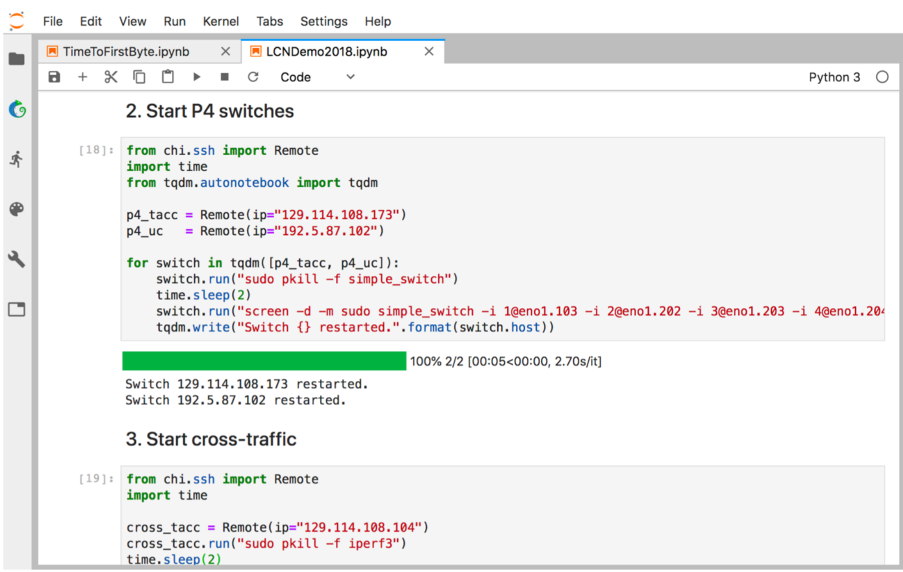


ACTIVE PAPERS: WHAT DOES IT MEAN TO DOCUMENT A PROCESS?

- Requirements
  - Easy to work with: human readable/modifiable format
  - Integrates well with ALL aspects of experiment management
  - Bit by bit replay – allows for bit by bit modification (and introspection) as well – element of interactivity
  - Support story telling: allows you to explain your experiment design and methodology choices
  - Has a direct relationship to the actual paper that gets written
  - Can be version controlled
  - Sustainable, a popular open source choice
- Implementation options
  - Orchestrators: Heat, the dashboard, and OpenStack Flame
  - Notebooks: Jupyter, Nextjournal

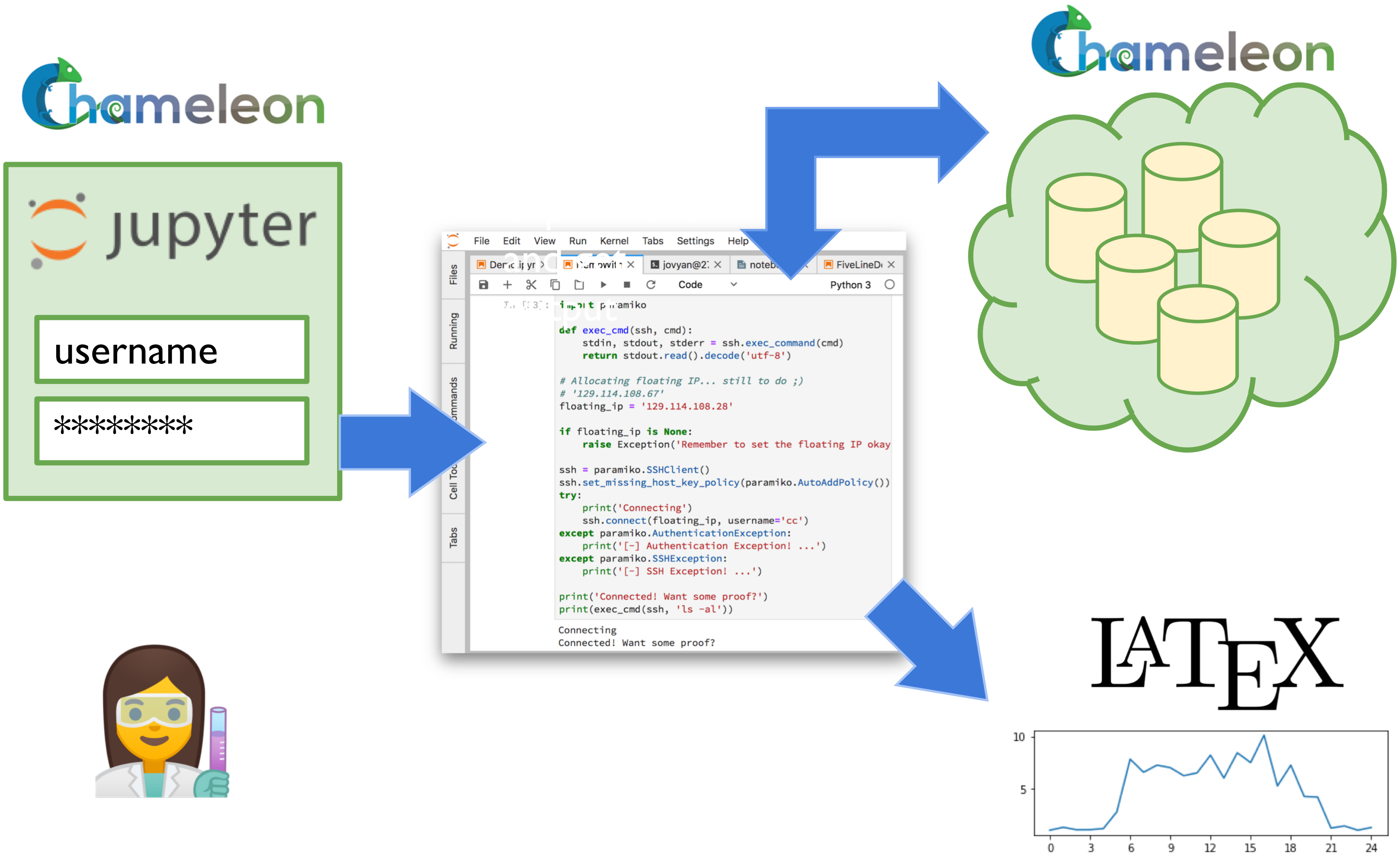
COMBINING THE EASE OF NOTEBOOKS AND THE POWER OF A SHARED PLATFORM

- Combining Jupyter with Chameleon
  - Storytelling with Jupyter: ideas/text, process/code, results
  - Chameleon shared experimental platform
- Chameleon/Jupyter integration
  - Alternative interface
  - All the main testbed functions
  - “Hello World” template
  - Save&share via object store
  - Versioning via integration with github

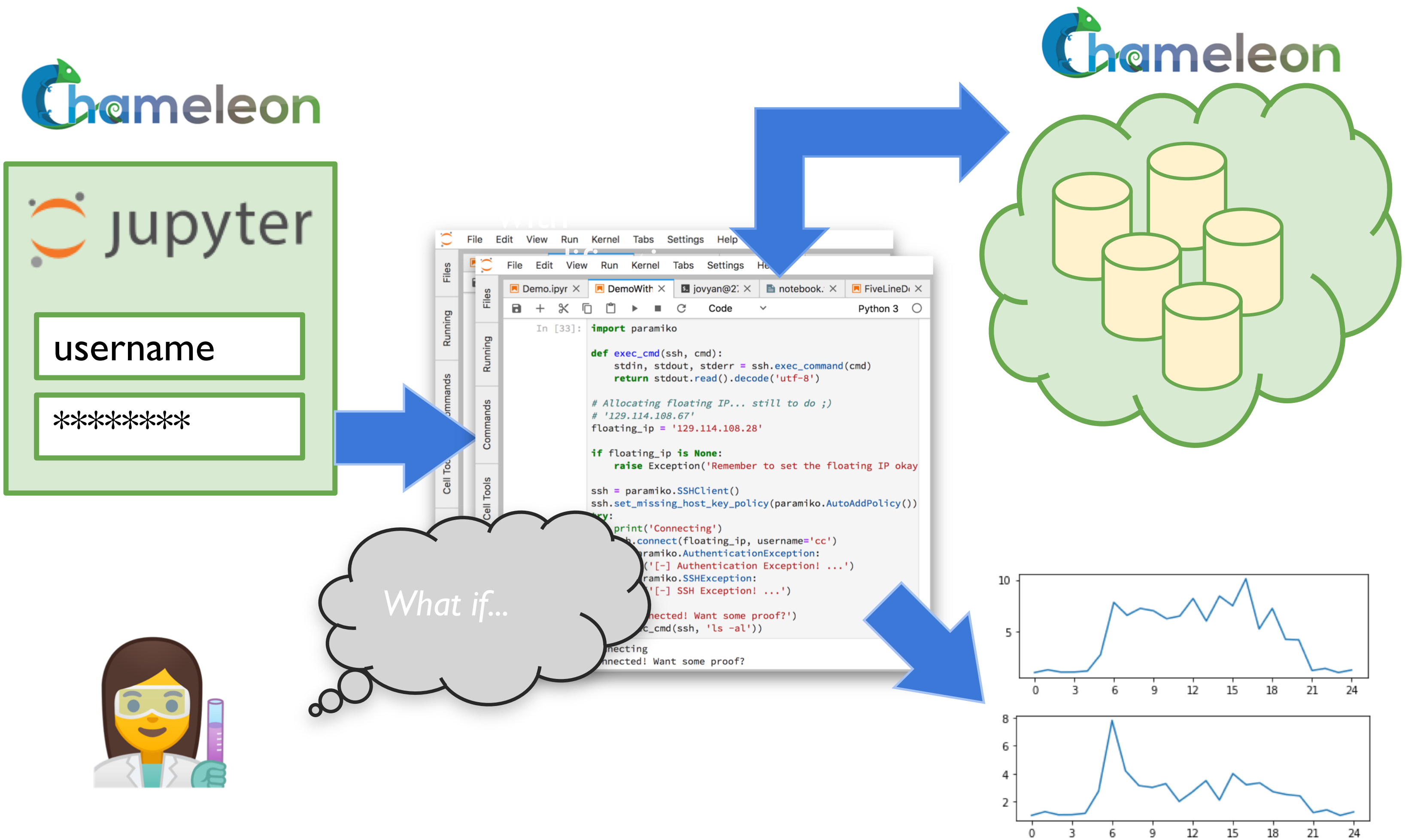


- Screencast of example experiment: https://vimeo.com/297210055

JUPYTER ON CHAMELEON



JUPYTER ON CHAMELEON



PARTING THOUGHTS

- Physical environment: adaptation is our thing!
  - Originally: “Adapts to the needs of your experiment”
  - But also: “Adapts to the changing research frontier”
- Ecosystem: a meeting place of users sharing resources and research
  - Testbeds are more than just experimental platforms
  - Common/shared platform is a “common denominator” that can eliminate much complexity that goes into systematic experimentation, sharing, and reproducibility
- Bring your color to the testbed
  - www.chameleoncloud.org

Questions?

www.chameleoncloud.org

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