www. chameleoncloud.org

THE MANY COLORS OF CHAMELEON: BUILDING A RECONFIGURABLE TESTBED FOR SYSTEMS RESEARCH

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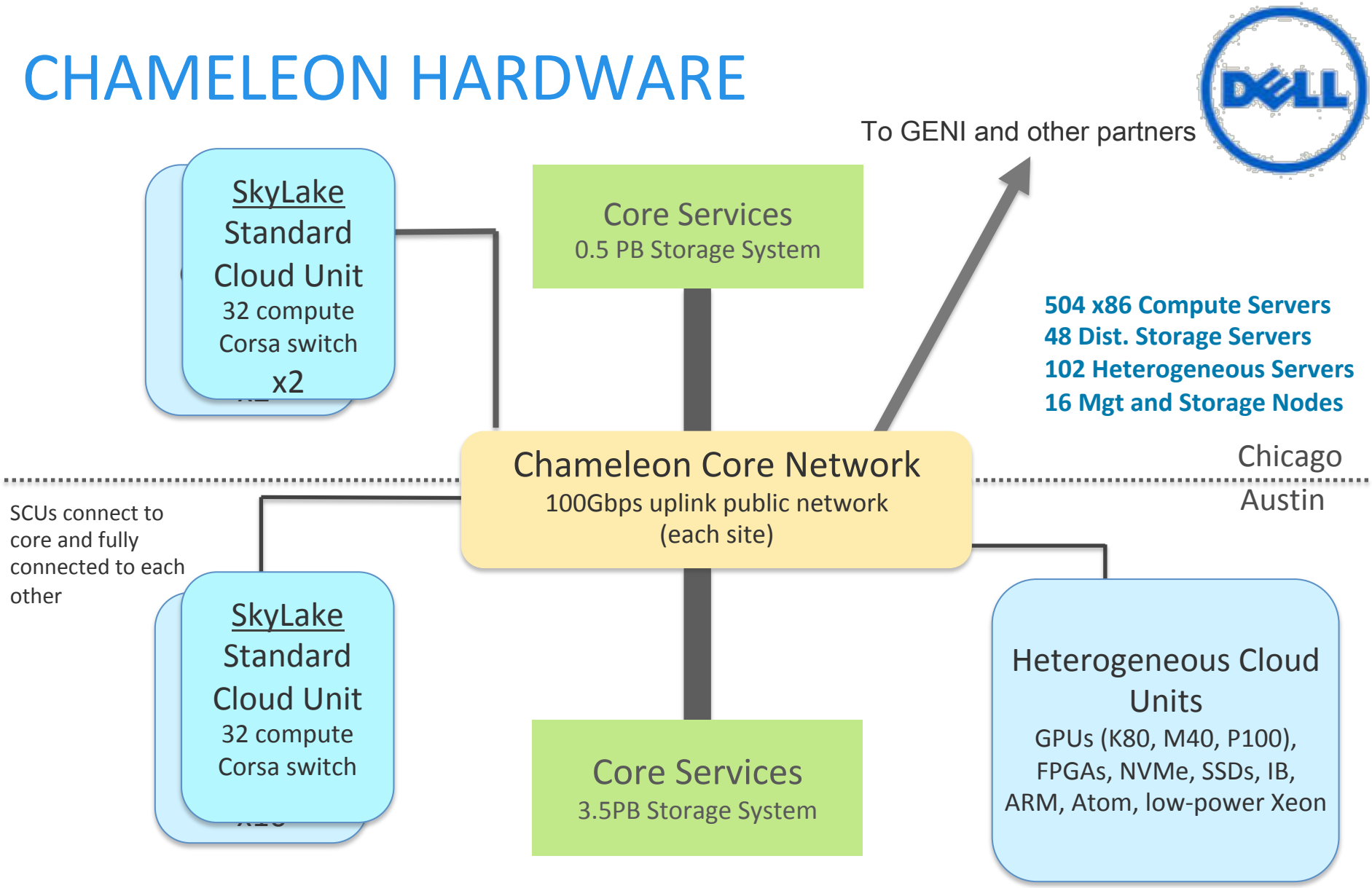
CHAMELEON IN A NUTSHELL

- **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, 450+ 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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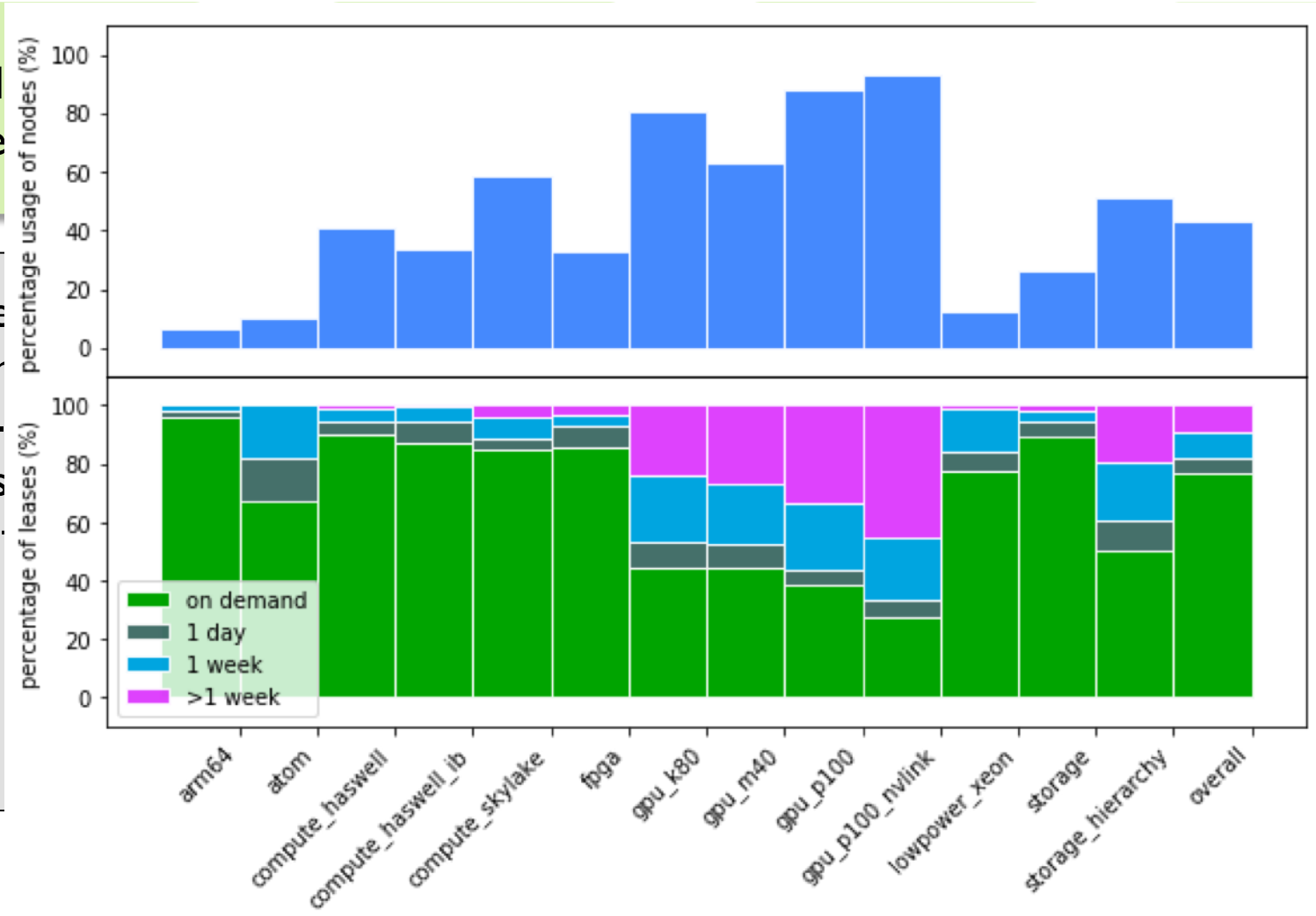

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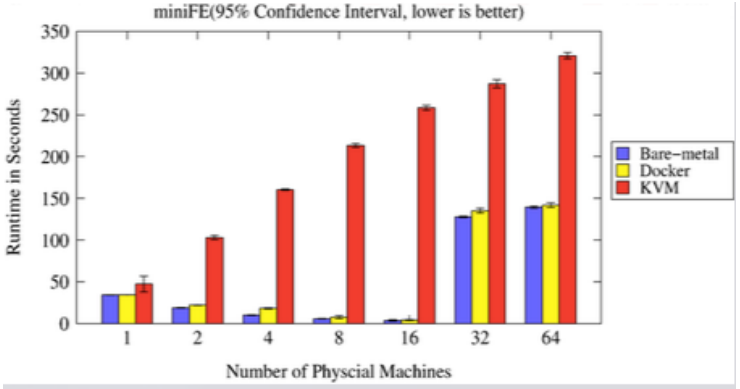
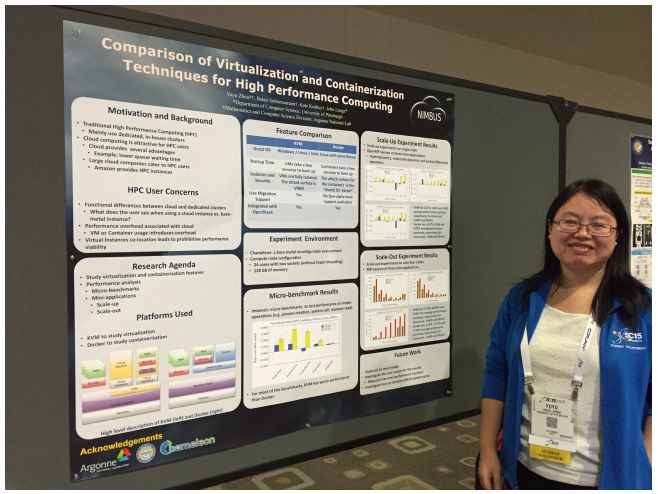
NEWEST CAPABILITIES

- Networking:
  - **Multi-tenant networking** allows users to provision isolated L2 VLANs and manage their own IP address space (since Fall 2017)
  - **Stitching** dynamic VLANs from Chameleon to external partners (ExoGENI, ScienceDMZs) (since Fall 2017)
  - VLANs + AL2S connection between UC and TACC for **100G experiments** (since Spring 2018)
  - **BYOC– Bring Your Own Controller: isolated user controlled** virtual OpenFlow switches (since Summer 2018)
- And many others: new lease management features, multi-region configuration, power consumption metrics, whole disk image boot for ARM nodes, serial console access, appliances, upgrades, usability improvements, etc.

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

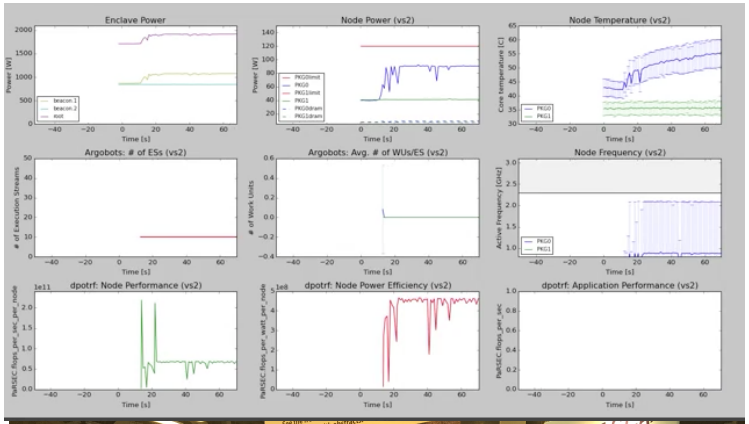




SC15 Poster:“Comparison of Virtualization and Containerization Techniques for HPC”

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



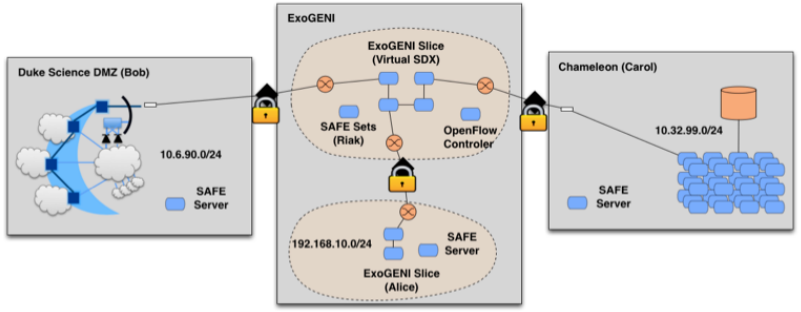
HPPAC'16 paper: "Systemwide Power Management with Argo"

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

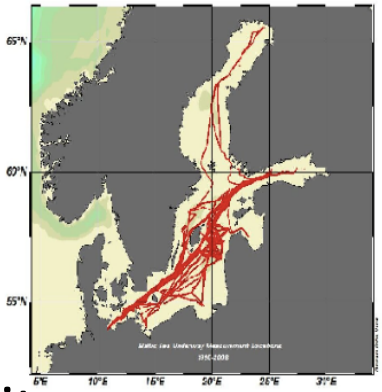
CREATING DYNAMIC SUPERFACILITIES

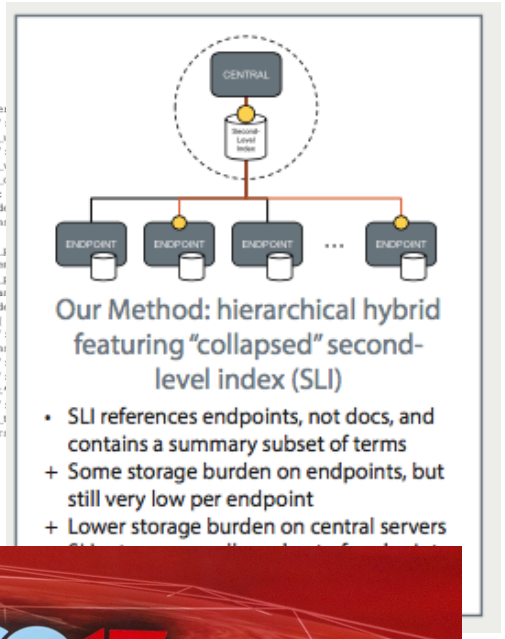
- NSF CICI SAFE, Paul Ruth, RENCI-UNC Chapel Hill
- Creating trusted facilities
  - Automating trusted facility creation
  - Virtual Software Defined Exchange (SDX)
  - Secure Authorization for Federated Environments (SAFE)
- Testbed requirements
  - Creation of dynamic VLANs and wide-area circuits
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



DATA SCIENCE RESEARCH

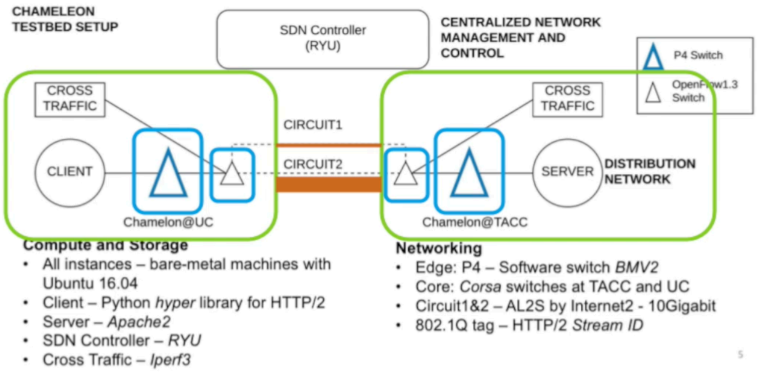
- ACM Student Research Competition semi-finalists:
  - Blue Keleher, University of Maryland
  - Emily Herron, Mercer University
- Searching and image extraction in research repositories
- Testbed requirements:
  - Access to distributed storage in various configurations
  - State of the art GPUs
  - Easy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

BUILDING AN ECOSYSTEM

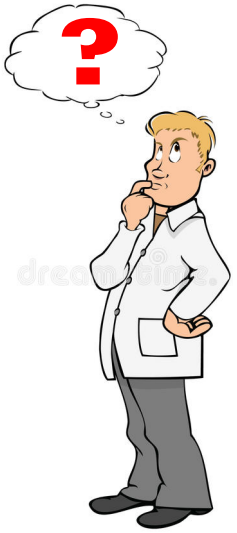
- Helping hardware providers interact
  - Bring Your Own Hardware (BYOH)
  - CHI-in-a-Box: deploy your own Chameleon site
- Helping scientists interact
  - Leveraging the common denominator
  - Integrating tools for experiment management
  - Making reproducibility easier
  - Facilitating sharing

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

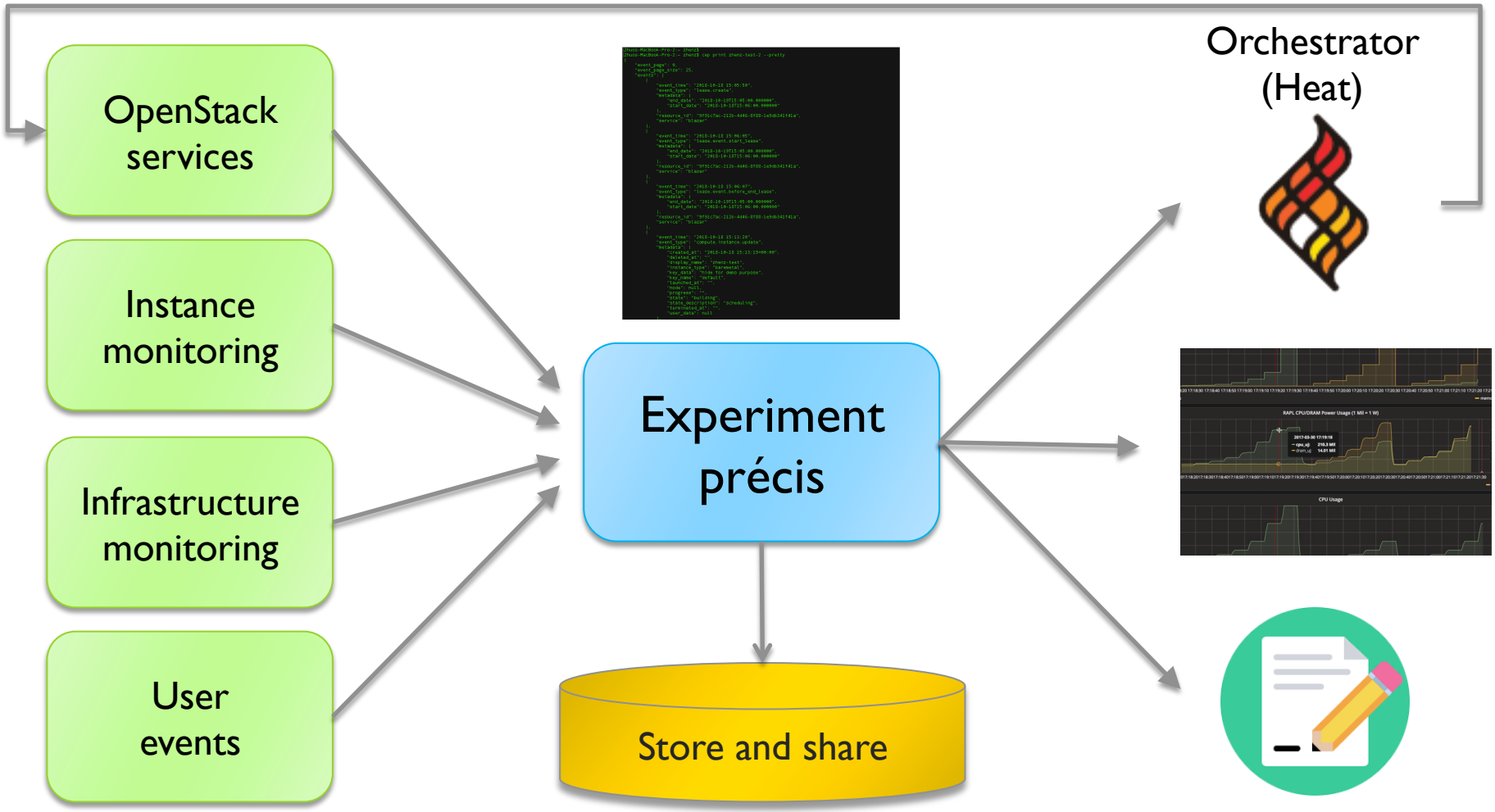
- Testbed versioning (collaboration with Grid'5000)
  - Based on representations and tools developed by G5K
  - >50 versions since public availability – and counting
  - Still working on: better firmware version management
- Appliance management
  - Configuration, versioning, publication
  - Appliance 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

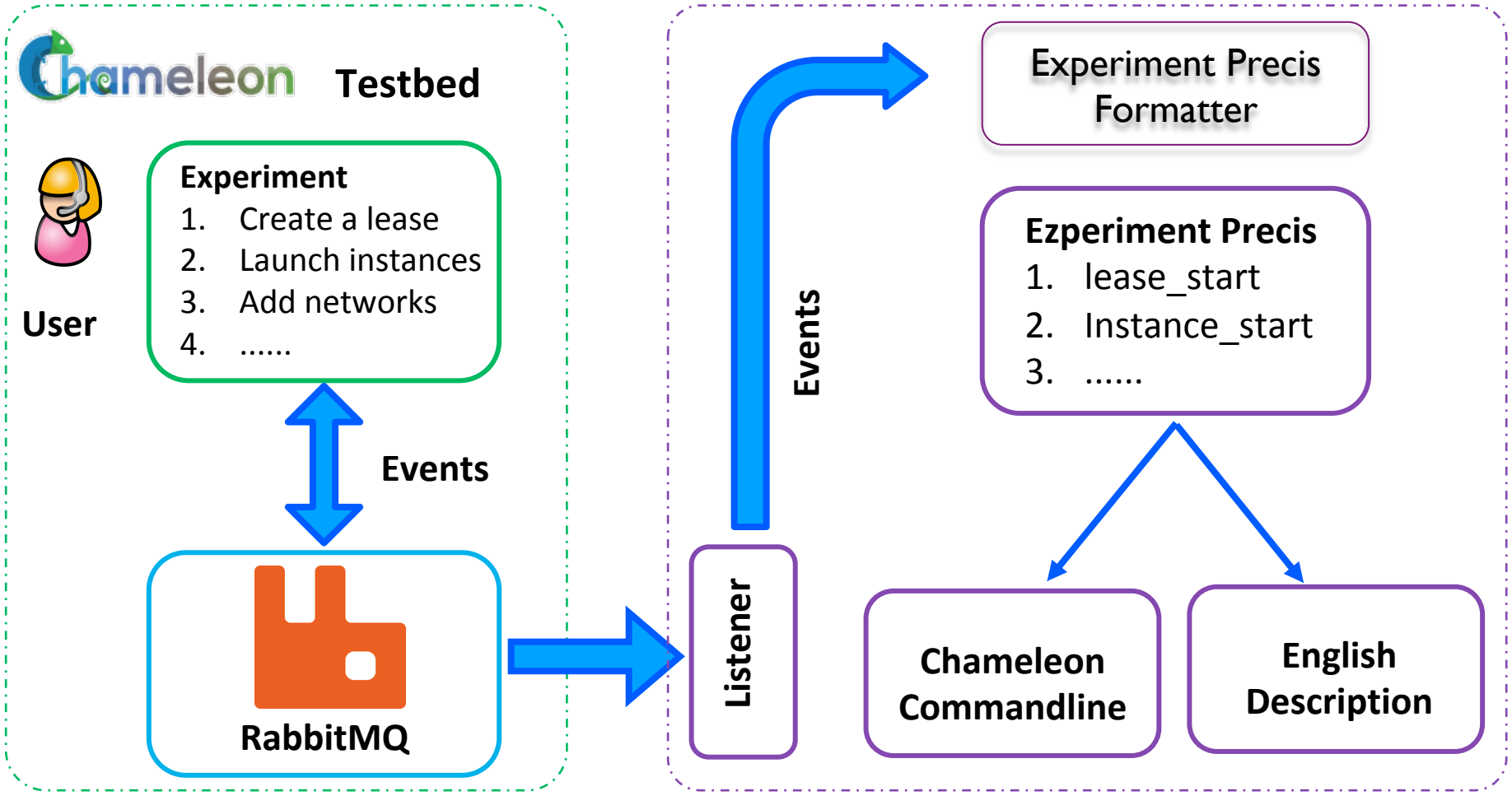
- Everything in a testbed is a recorded event
  - The resources you used
  - The appliance/image you deployed
  - The monitoring information your experiment generated
  - Plus any information you choose to share with us: e.g., “start power_exp_23” and “stop power_exp_23”

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

REPEATABILITY: EXPERIMENT PRÉCIS

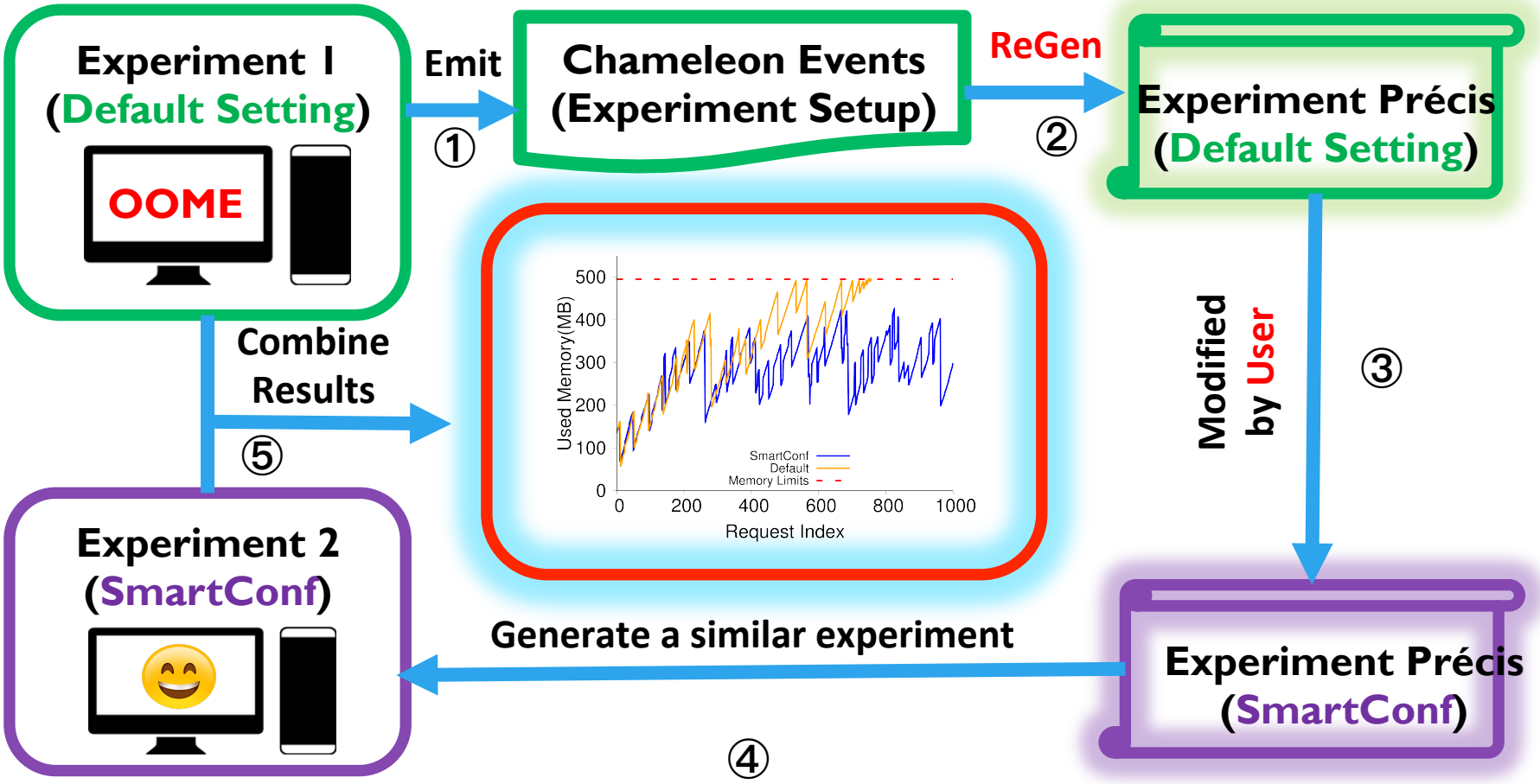


EXPERIMENT PRÉCIS IMPLEMENTATION



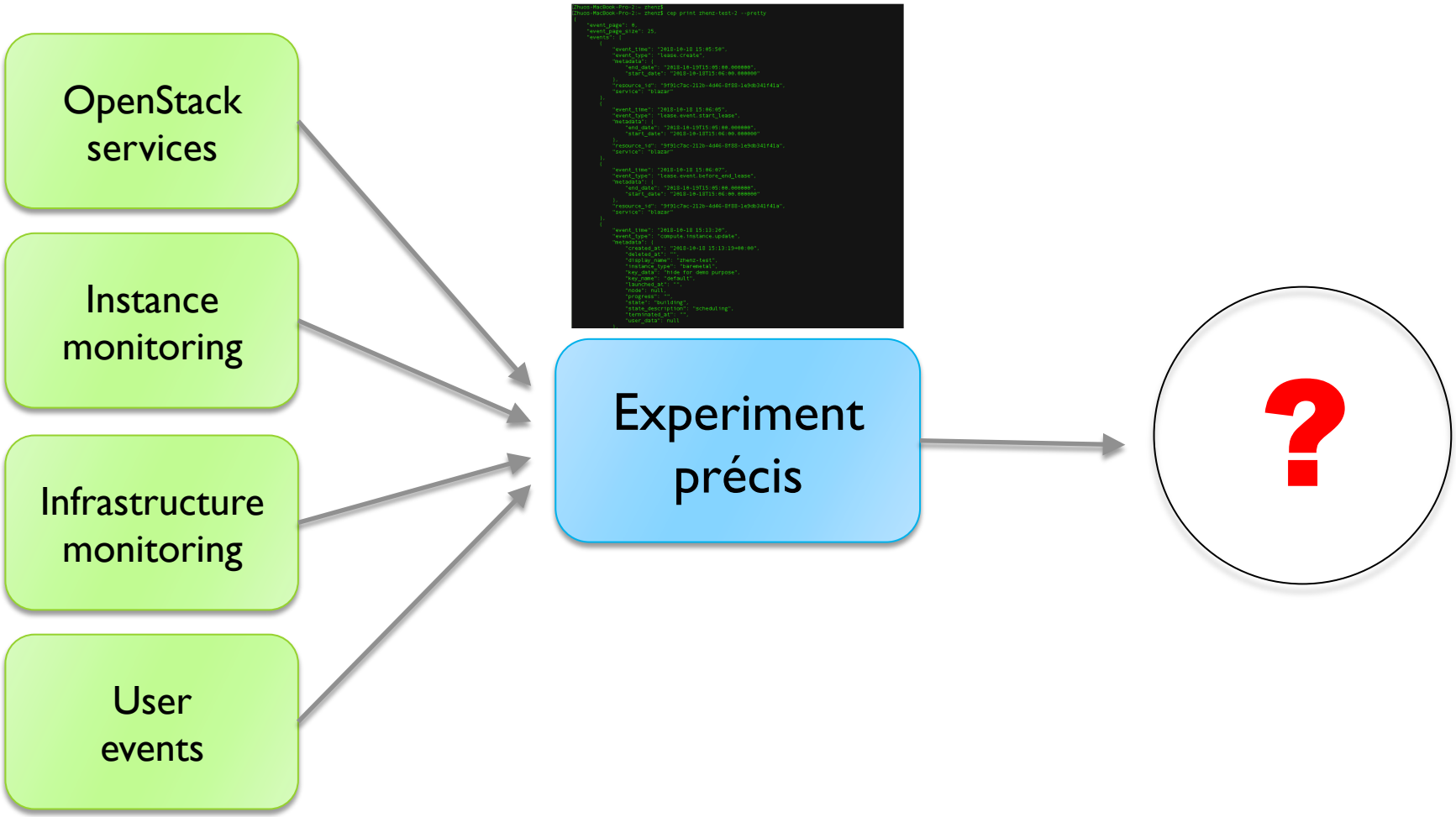
Come see our SC18 poster: "Reproducibility as Side-Effect"

EXPERIMENT PRÉCIS: A CASE STUDY



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

REPEATABILITY: EXPERIMENT PRÉCIS

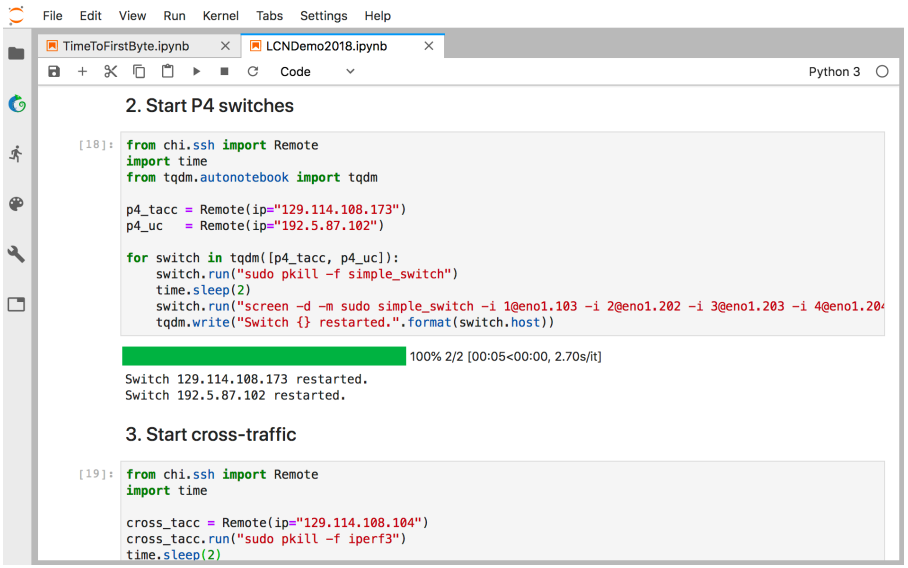


ACTIVE PAPERS: WHAT DOES IT MEAN TO DOCUMENT A PROCESS?

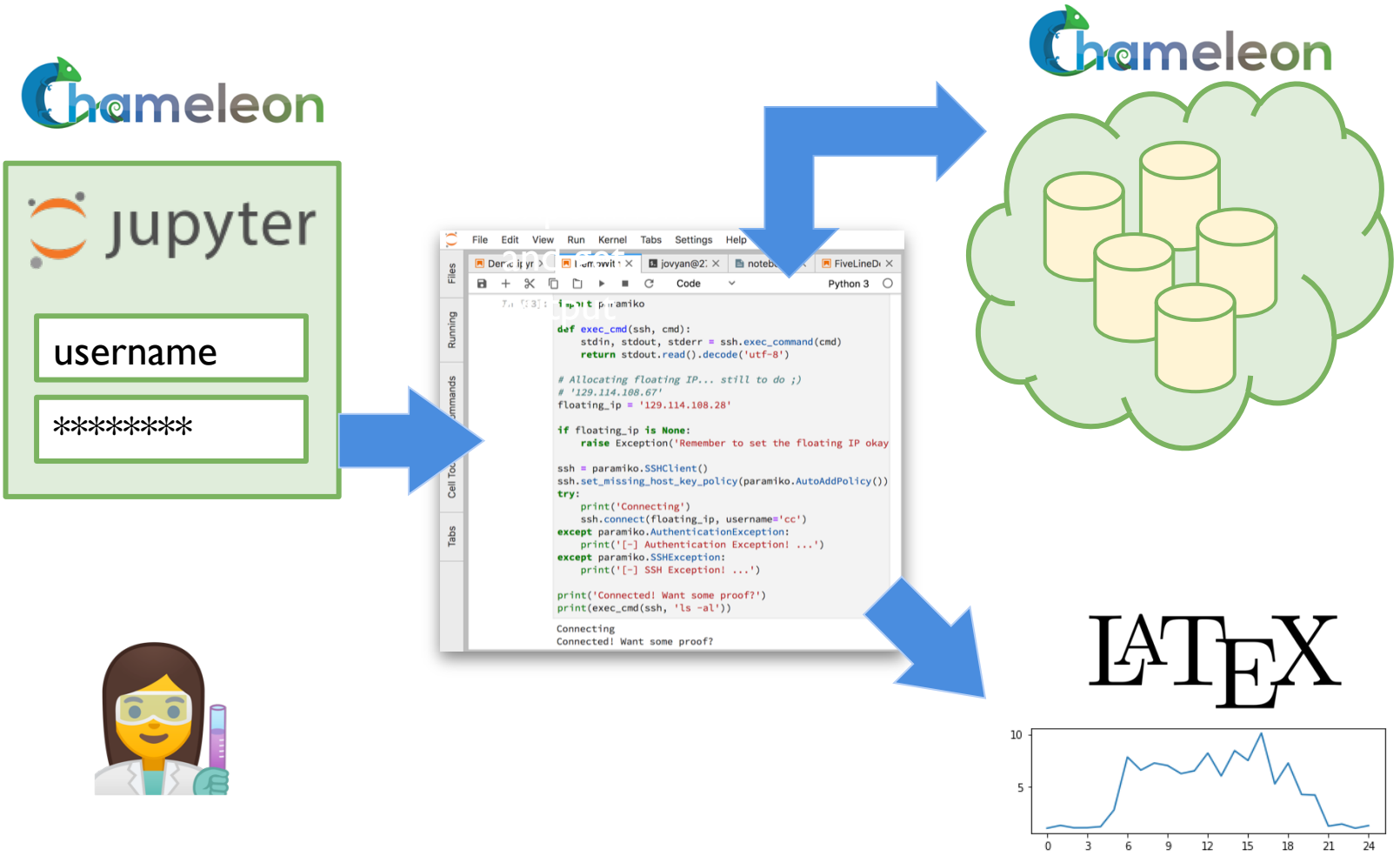
- Requirements
  - Easy to work with: human readable/modifiable format
  - Integrates well with ALL aspects of experiment management
  - Bit by bit replay – allows for bit by bit modification (and introspection) as well – element of interactivity
  - Support story telling: allows you to explain your 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

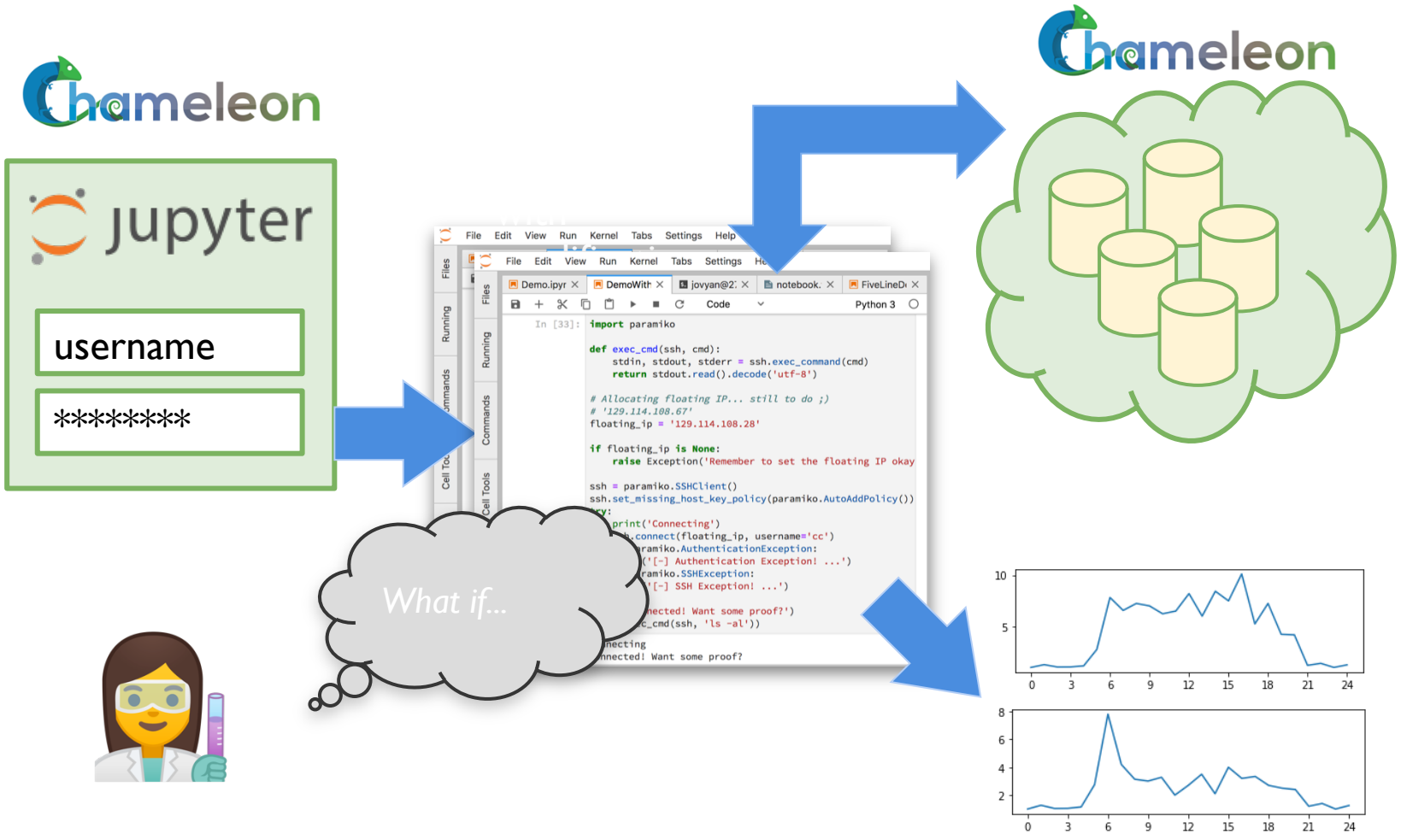
- Combining Jupyter with Chameleon
  - Storytelling with Jupyter: ideas/text, process/code, results
  - Chameleon shared experimental platform
- Chameleon/Jupyter integration
  - Alternative interface
  - All the main testbed functions
  - “Hello World” template
  - Save&share via object store and github integration
- Screencast of a complex experiment
  - https://vimeo.com/297210055



JUPYTER ON CHAMELEON



JUPYTER ON CHAMELEON



PARTING THOUGHTS

- Physical environment: Chameleon is a rapidly evolving experimental platform
  - 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
- Get engaged: www.chameleoncloud.org

Questions?

www.chameleoncloud.org

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