# OCCAM: Is there a future for open-access simulation and experimentation?

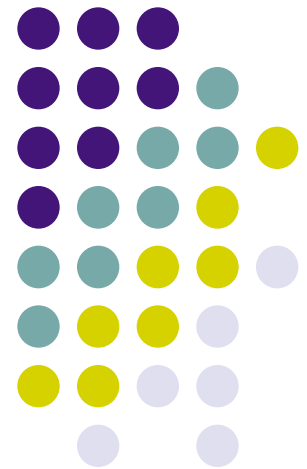Bruce Childers†, Alex Jones‡, **Daniel Mossé**†

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University of Pittsburgh, Pittsburgh, PA 15260
{childers,mosse}@cs.pitt.edu
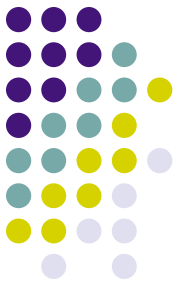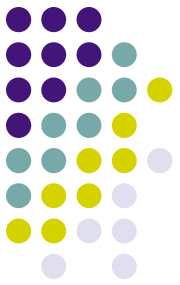akjones@ece.pitt.edu

# Computer Architecture Innovation

- $111B processor market[†]
- Relies almost exclusively on artifacts
  - Software simulation
  - Hardware emulation
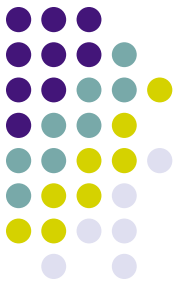  - Benchmarks
  - And a cast of a thousand other tools…

*[†] IMS Research, 2011*

# Prolific Artifact Production

**Simulators**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Single-core** | X | X | X | . | . | X | X | X | X | X | X | X | X | X | X | X | X | . | X | X | X | . | X | X | X | X | X | X | X | X | X |
| **Multi-core** | X | X | X | . | . | X | X | X | X | X | X | . | . | X | X | . | . | . | X | X | X | X | . | X | X | . | . | X | . | . | . |
| **Homogen. multi-core** | . | X | X | . | . | X | X | X | X | X | X | . | . | X | X | . | . | . | X | . | X | X | X | X | . | . | . | X | . | . | . |
| **Heterogen. multi-core** | . | . | . | . | . | . | X | . | . | . | . | . | . | . | X | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| **SMT** | . | . | . | . | . | . | . | X | . | X | . | . | . | X | X | X | . | . | X | . | . | . | . | . | . | . | . | . | . | . | . |
| **Shared memory** | . | X | X | . | . | X | X | X | X | X | . | . | X | X | X | X | . | X | X | X | X | X | X | . | . | . | . | . | . | . | . |
| **Private memory** | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| **Timing** | X | . | X | X | . | X | X | X | X | X | X | X | X | X | X | X | X | . | X | X | . | X | X | X | X | . | X | X | . | X | X |
| **Cycle-accurate** | . | . | X | X | . | X | X | X | X | . | X | X | X | X | X | X | X | . | X | . | X | X | X | . | . | X | X | . | X | X | X |
| **Functional** | . | X | . | . | . | X | X | X | X | X | X | X | X | . | . | . | X | . | X | . | . | X | X | . | X | . | X | . | X | . | . |
| **Full system** | X | X | . | . | X | . | X | X | X | X | . | . | X | X | . | . | . | . | X | . | . | . | . | X | . | . | . | . | . | . | . |
| **Caching** | . | . | X | X | . | X | X | X | X | X | X | X | X | X | X | X | X | . | X | . | X | X | X | X | . | X | X | X | . | . | X |
| **Cache coherence** | . | . | . | . | . | X | X | X | X | X | . | . | X | X | . | X | . | X | . | X | . | X | X | . | . | X | . | . | . | . | . |
| **In-order** | . | . | . | . | . | X | . | X | X | X | X | X | X | X | . | X | . | X | . | X | X | . | . | X | X | . | X | X | . | X | X |
| **Out-of-order** | . | . | . | . | . | X | X | X | X | . | X | . | . | . | X | . | X | . | . | X | X | . | . | X | . | X | . | . | . | . | . |
| **Superscalar** | . | . | . | . | . | X | X | X | X | X | X | . | X | X | X | . | X | . | . | X | X | X | . | . | X | . | X | . | . | . | . |
| **Virtualization** | . | . | . | . | . | . | X | . | . | . | . | . | X | . | . | . | . | . | X | . | . | . | . | . | . | . | . | . | . | . | . |
| **Virtual memory** | . | X | . | . | X | . | X | . | X | . | . | X | X | X | . | . | X | X | X | . | . | X | . | . | X | . | . | . | . | . | . |
| **VLIW** | . | . | . | . | . | . | . | . | . | . | X | . | . | . | . | . | . | . | . | . | . | X | . | . | . | . | . | . | . | . | . |
| **DRAM controller** | X | . | . | . | . | X | X | X | X | . | X | X | . | X | . | . | X | X | X | . | . | X | . | X | . | . | . | . | . | . | . |
| **Scheduling** | . | . | . | . | . | X | X | X | X | . | X | X | . | . | . | . | X | X | X | . | . | X | . | X | . | . | . | . | . | . | . |
| **Concurrency** | . | . | . | . | . | X | X | X | . | . | X | X | . | . | . | . | X | X | X | . | . | . | . | . | . | . | . | . | . | . | . |
| **DRAM error sim** | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| **On-chip network** | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | X | . | . | . | . | . | X | . | . | . | . | . | . | . | . |
| **System on chip** | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | X | . | . | . | . | . | . | . | . |
| **Power consumption** | . | . | X | X | . | . | X | . | X | . | . | . | X | X | . | . | . | . | X | . | . | X | . | . | . | . | . | . | X | . | . |
| **Gate-level** | . | . | . | . | . | . | . | . | . | . | X | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | X | . | . | . |
| **Validated** | . | . | . | . | . | . | . | . | X | . | . | X | . | X | . | X | . | . | X | . | . | X | . | . | . | . | . | X | X | | |

# Prolific Artifact Production

**Simulators**

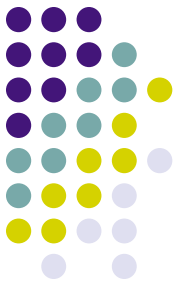| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Single-core** | X | X | X | . | . | X | X | X | X | X | X | X | X | X | X | X | X | . | X | X | X | . | X | X | X | X | X | X | X | X | X |
| **Multi-core** | X | X | X | . | . | X | X | X | X | X | X | . | . | X | X | X | . | . | X | X | X | X | . | X | X | . | . | X | . | . | . |
| **Homogen. multi-core** | . | X | X | . | . | X | X | X | X | X | X | . | . | X | X | . | . | . | X | . | X | X | X | X | . | . | . | X | . | . | . |
| **Heterogen. multi-core** | . | . | . | . | . | . | X | . | . | . | . | . | . | . | X | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| **SMT** | . | . | . | . | . | . | . | X | . | X | . | . | . | X | X | X | . | . | X | . | . | . | . | . | . | . | . | . | . | . | . |
| **Shared memory** | . | X | X | . | . | X | X | X | X | X | . | . | . | X | X | X | X | . | X | X | X | X | X | X | . | . | . | . | . | . | . |
| **Private memory** | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| **Timing** | . | X | . | X | X | . | X | X | X | X | X | X | X | X | X | X | X | . | X | X | . | X | X | X | X | . | X | X | . | X | X |
| **Cycle-accurate** | . | . | . | X | X | . | X | X | X | X | . | X | X | X | X | X | X | . | X | . | X | . | X | X | . | . | X | X | . | X | X |
| **Functional** | . | X | . | . | . | . | X | X | X | X | X | X | X | X | X | . | . | . | X | . | X | . | . | X | X | . | X | . | X | . | . |
| **Full system** | X | X | . | . | X | . | X | X | X | X | X | . | . | X | X | . | . | . | . | X | . | . | . | X | . | . | . | . | . | . | . |
| **Caching** | . | . | X | X | X | . | X | X | . | X | X | X | X | X | X | . | X | . | X | . | X | X | X | X | X | . | X | X | X | . | X |
| **Cache coherence** | . | . | . | . | . | . | X | X | X | X | X | . | . | X | X | . | X | . | X | . | X | . | X | X | . | . | . | X | . | . | . |
| **In-order** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Out-of-order** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Superscalar** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Virtualization** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Virtual memory** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **VLIW** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **DRAM controller** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Scheduling** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Concurrency** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **DRAM error sim** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **On-chip network** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **System on chip** | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | X | . | . | . | . | . | . | . |
| **Power consumption** | . | . | X | X | . | . | . | X | . | . | X | . | . | X | X | . | . | . | . | . | . | . | . | X | . | . | X | . | . | X | . |
| **Gate-level** | . | . | . | . | . | . | . | . | . | . | X | . | . | . | . | . | . | . | . | . | . | . | . | X | . | . | . | . | . | . | . |
| **Validated** | . | . | . | . | . | . | . | X | . | . | X | . | X | X | . | X | . | X | . | . | . | . | . | X | . | . | . | . | X | X | . |

Just a *small* selection of 31 artifacts!

Tremendously diverse, different, overlapping…
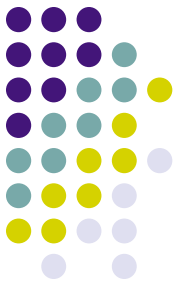Compounded by many experiments…

# A brewing (brewed?) crisis…
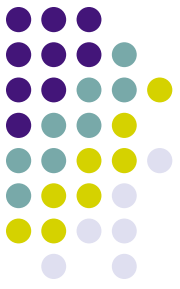
- Symptomatic of fragmented, ad hoc, internal existing effort and investment

- Research expediency and results
  - Small incentive to build, release, maintain
  - Duplicating effort to re-implement for comparison
  - May not understand artifact and its use
  - Creating your own artifacts instead
- Missing (often?) accountability, repeatability

# **Community, open source effort**

- Community ***is asking for openness***
  - Activities by NSF, DOE, DARPA/DoD, CRA over last ten years to inspire, engage the community
  - More recent activities events at SC11—SC13, MICRO45, HiPEAC CSE13, ISCA13, and today!

- Quality artifacts ***are*** available, emerging
- Quality experiments ***are*** being done

- How can we build and leverage this?

# Vision for OCCAM

- Inspired by Occam's Razor, which suggests minimum assumptions and most succinctness

- Create a shared instrument that everyone can and should use to save time, be fair, advance science: *OCCAM: Open Curation for Computer Architecture Modeling*

- Community-supported digital curator for simulation, emulation benchmarking and experimental results
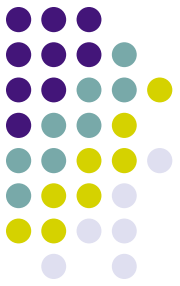
# Vision for OCCAM

- Efforts in different areas successful
  - nanoHUB (Nanotechnology)
  - arXiv (Physics and other sciences)
  - EarthCube (Geosciences)
  - C-tuning
  - Data-mill
  - Others

# OCCAM pillars
## Building a bridge to open access



Infrastructure

Community

Education

# OCCAM pillars
## Building a bridge to open access



**Constituents**

Developers
Experimentalists
Consumers
Managers

Education

Community

Infrastructure

Photo attributed to Sergey Prokudin-Gorsky, http://www.flickr.com/photos/prokudin-gorsky/

# Infrastructure Pillar
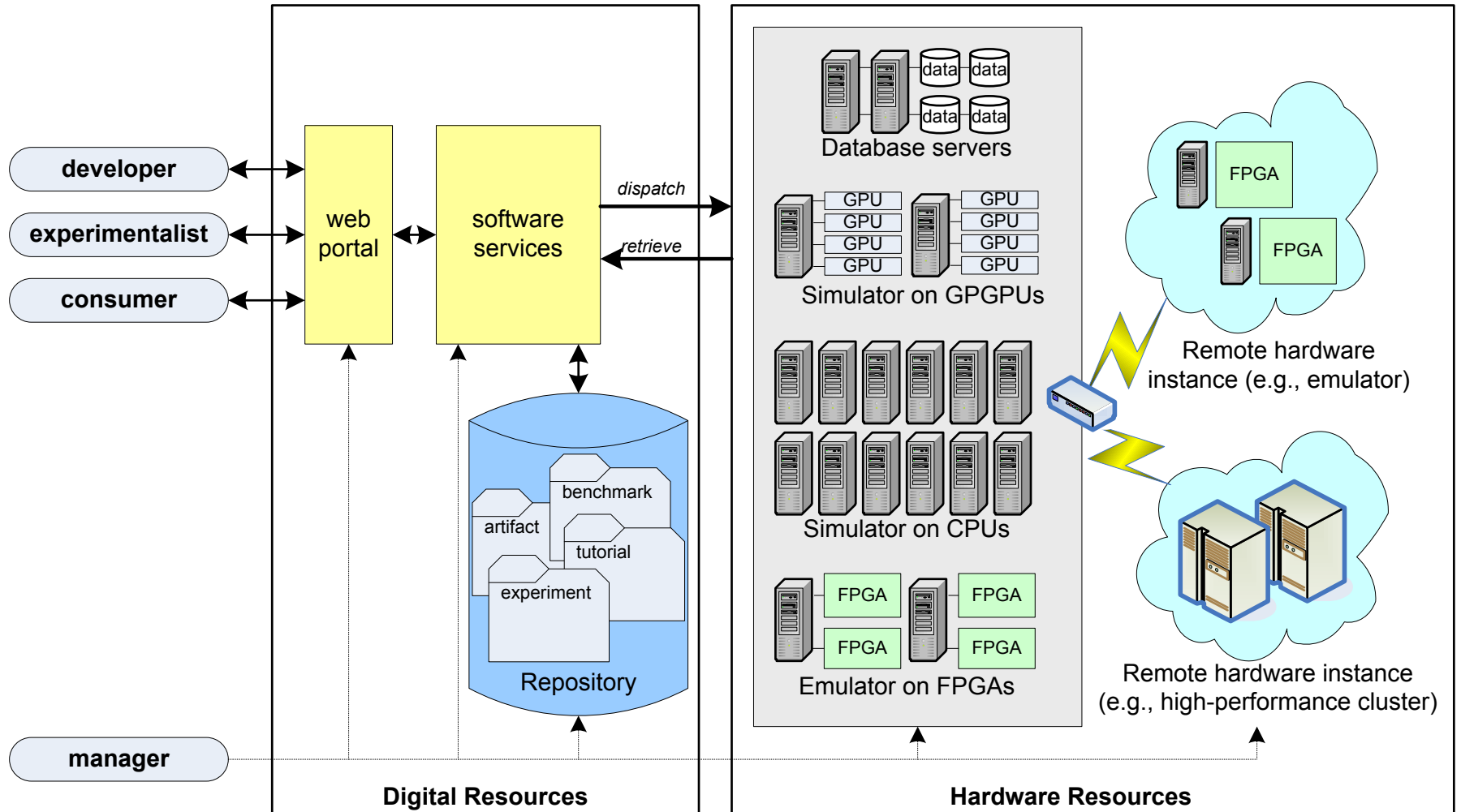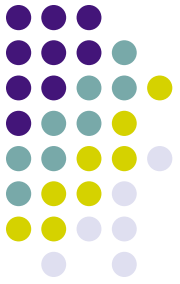
# Infrastructure Pilot ("v0")
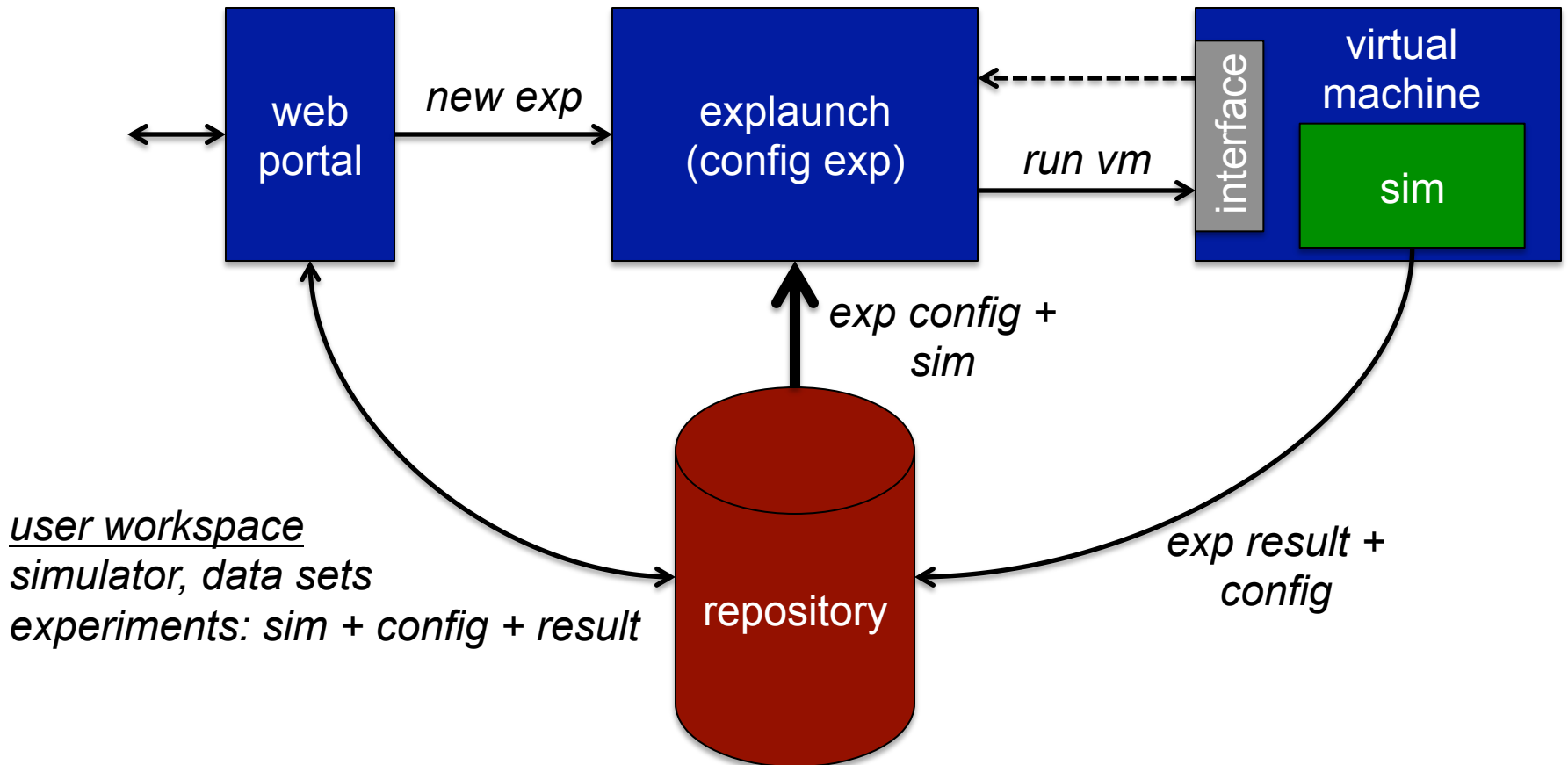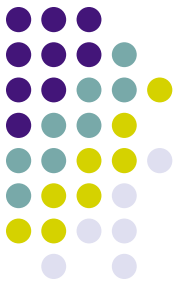
# Community Pillar

- Create, foster community
    - Establish procedures and policies
    - Contribute artifacts and experiments
    - Ingrain and use repository, e.g., conference submission and publication of experiments
    - Advocate and convince people of value and values behind open-access repository

# Community Pilot ("v0")

- Determining governance structures
- Initial procedures and policies

  ① **Incentive and reward**
  ② **Privacy and security (privacy, data/code safety, access rights, time limits)**
  ③ **Resource contribution (credit/pricing, fairness)**
  ④ Methodology (guidelines, checks, rewards)
  ⑤ Assessment (usage, quality of service to users)
  ⑥ Ontology (classification for query & search)

# Education Pillar

- "Build it and they'll come" is not a paradigm that has worked

- Rather, address *barrier to adoption*
  - Best practices of building artifacts, using them and running experiments
  - Scientific process (accountable, repeatable)

- Training
  - Developer's, Experimentalist's Bootcamp
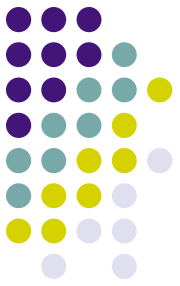  - Summer School for Simulation and Emulation Short (10 min), Medium (30-60 min), Long (hrs)

# Starting the Effort

- Pilot repository http://www.occamportal.org

> **News! Content!**
> 1. **Survey of needs**
> 2. Best practices
> 4. Catalog of artifacts

# http://www.occamportal.org

# It Takes a Community...

Many++ have contributed... CSA workshop and other activities

| | | |
|---|---|---|
| Tor Aamodt | Engin Ipek | Eric Rotenberg |
| Ahmed Amer | Alex Jones | Sonia Sachs |
| Jason Bakos | Hyesoon Kim | Ali Saidi |
| Christopher Batten | Martha Kim | Kevin Skadron |
| Nathan Binkert | Michael Kistler | Evan Speight |
| Bruce Childers | Jack Lange | Richard Uhling |
| Derek Chiou | Benjamin Lee | James Tringali |
| Sangyeun Cho | Ahmed Louri | Noel Wheeler |
| Almadena Chtchelkanova | Nicolas Maillard | David Wood |
| John Davis | Jason Mars | Sudhakar Yalamanchili |
| Sandhya Dwarkadas | Chris Mineo | Li Zhao |
| Lieven Eeckhout | Daniel Mossé | SC11 BoF |
| Kriszitian Flautner | Frank Mueller | SC12 BoF |
| Jean-Luc Gaudiot | Steve Poole | MICRO45 |
| James Hoe | Steven Reinhardt | HiPEAC CSE13 |
| | Arun Rodrigues | ISCA13 |
| | | MSE |

**Thank you**