The Future of Computing Research

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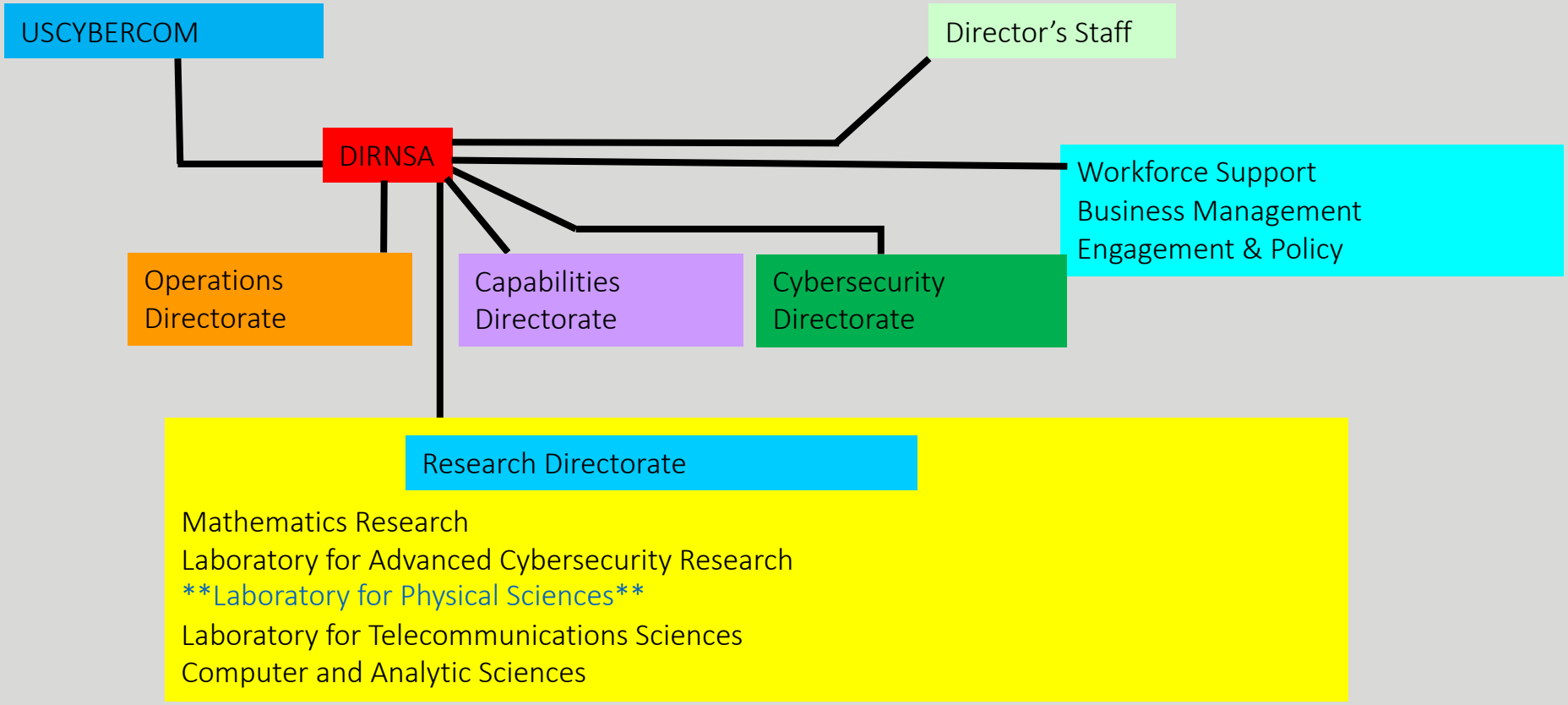
A little background

A little context

A little dream

Who is ACS?

LABORATORY FOR PHYSICAL SCIENCES



Who is ACS?

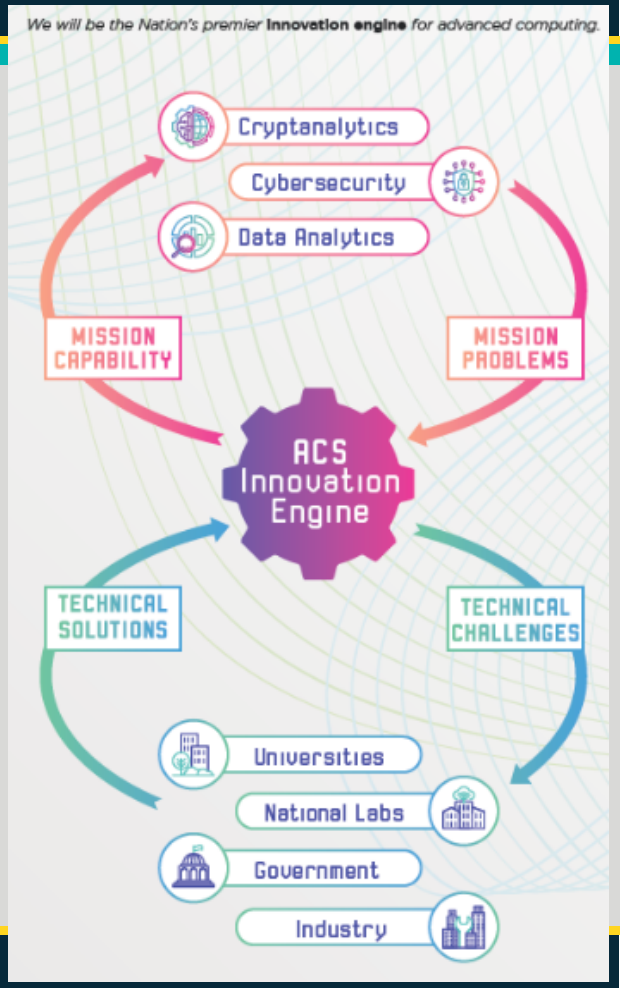
LABORATORY FOR PHYSICAL SCIENCES

Advanced Computing Systems (ACS) Research Program

We will be recognized, both internally and externally, as the **nation's premier innovation engine for advanced computing**.

We conduct **exploratory research** that combines *algorithms, architectures and technologies* to demonstrate and/or develop **advanced computing systems that provide asymmetric advantage for agency mission**.

Our innovation engine is built upon **mission oriented participatory research.**



Resilience | Productivity | Modeling and Simulation | Computer Arch & Eng | Neuromorphic Computing | Energy Efficiency

Major areas of exploration

- Advanced memories
  - Technologies
  - Architectures that are data and memory centric
- Probabilistic Computing
  - Fault Models
  - Algorithmic advances
  - Technology matching
  - Chip micro-architecture
- High Performance Data Analytics
  - System explorations and demonstrations
  - Tensor analysis
- Modeling-Simulation-Emulation
  - System Simulation Toolkit
- Neuromorphic Computing (NMC)

My view of things

- Easy system wins through scaling have been diminishing for the last 15 years
- Future improvements will require advancements across a much wider base of technologies
- Innovations in computer architecture will be a key part of the future
- This changes the type of researchers needed for advanced computing research

Project 38

Project 38 is a set of vendor-agnostic architectural explorations involving NSA, the DOE Office of Science, and NNSA (these latter 2 organizations are referred to below as “DOE”). These explorations are expected to accomplish the following:

Near-term goal: Quantify the performance value and identify the potential costs of specific architectural concepts against a limited set of applications of interest to both the DOE and NSA.

Long-term goal: Develop an enduring capability for DOE and NSA to jointly explore architectural innovations and quantify their value.

Project 38 team

LABORATORY FOR PHYSICAL SCIENCES

Argonne NATIONAL LABORATORY

National Nuclear Security Administration

IARPA

Sandia National Laboratories

BROOKHAVEN NATIONAL LABORATORY

BERKELEY LAB

Los Alamos NATIONAL LABORATORY EST.1943

Pacific Northwest NATIONAL LABORATORY

OAK RIDGE National Laboratory

U.S. DEPARTMENT OF ENERGY | Office of Science

Lawrence Livermore National Laboratory

Solicitations

- Changes to the type of research projects we focus on:
  - Previous BAA (2012) -- Computing runtimes that can effectively and efficiently trade off energy efficiency, performance, and resilience
  - Current BAA (2019) -- Innovative proposals addressing the following:
    - Novel methods of Computing
    - HW and SW system components
    - Exploration of System Concepts
    - Algorithms and Architectures

Project scope and scale

Previous

- Photonics for system interconnect (ACS, UC-Davis, Ben Yoo)
  - Small team, 10-12 total collaborators
  - Optics, material science, electrical engineering
  - 2-3 years with a tight focus

Now

- Probabilistic Computing (ACS, LANL, Mayo, Portland State, GWU, MIT-LL)
  - ~50 total collaborators
  - Algorithms, statistics, iterative techniques, multi-precision arithmetic, FPGA design, simulation, ECC, machine learning, material science, cryo-CMOS, nanomagnetics, analog devices, optics/nanophotonics, machine learning, memristors, etc.
  - 3-4 years with a very broad purview requiring a disciplined experimental process

- Significantly changes the type of research skills required for mission oriented participatory research

Skills Development

- Math, Computer Science, Computer Architecture/Engineering, Electrical Engineering, Physics
- Undergraduate – fundamental and general
- Master's -- filling in the gaps
- Doctorate – specific in idea, broad in exploration
- Post-doc – key contributor to a larger team that demonstrates an advanced prototype

Unknowns

- What is missing?
- How does this compare to what is possible today?
- How does this compare to what is typically done today?
- How can advanced prototypes be created/leveraged in support of this?
- What are key steps to make this happen?
- How can I help?


Laboratory for Physical Sciences
LPS