National Strategic Computing Initiative

<u>Carl J. Williams</u>, PML
Ronald Boisvert, ITL
Christina Hacker, PML
Robert Hanisch, MML
Alex Liddle, CNST
Eric Lin, MML
Nikolai Zhitenev, CNST

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

National Strategic Computing Initiative

July 29, 2015

EXECUTIVE ORDER

\- - - - - - -

CREATING A NATIONAL STRATEGIC COMPUTING INITIATIVE

By the authority vested in me as President by the Constitution and the laws of the United States of America, and to maximize benefits of high-performance computing (HPC) research, development, and deployment, it is hereby ordered as follows:

The NSCI is a whole-of-government effort designed to create a cohesive, multi-agency strategic vision and Federal investment strategy, executed in collaboration with industry and academia, to maximize the benefits of HPC for the United States….

https://www.whitehouse.gov/the-press-office/2015/07/29/executive-order-creating-national-strategic-computing-initiative

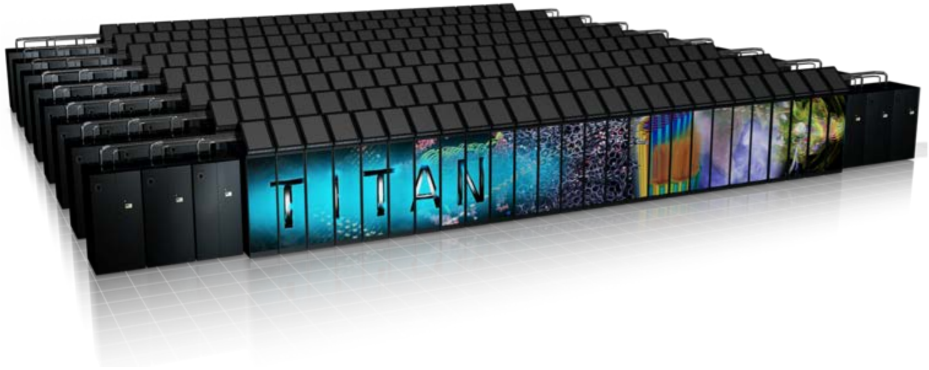
NSCI Principles

To sustain and enhance its scientific, technological, and economic leadership position in HPC research, development, and deployment, the U.S. must …

- deploy and apply new HPC technologies broadly for economic competitiveness and scientific discovery.
- foster public-private collaboration, relying on the respective strengths of government, industry, and academia to maximize the benefits of HPC.
- adopt a whole-of-government approach that draws upon the strengths of and seeks cooperation among all executive departments and agencies with significant expertise or equities in HPC while also collaborating with industry and academia.
- develop a comprehensive technical and scientific approach to transition HPC research on hardware, system software, development tools, and applications efficiently into development and, ultimately, operations.

Comparing Two Large-Scale Systems

Modern supercomputer

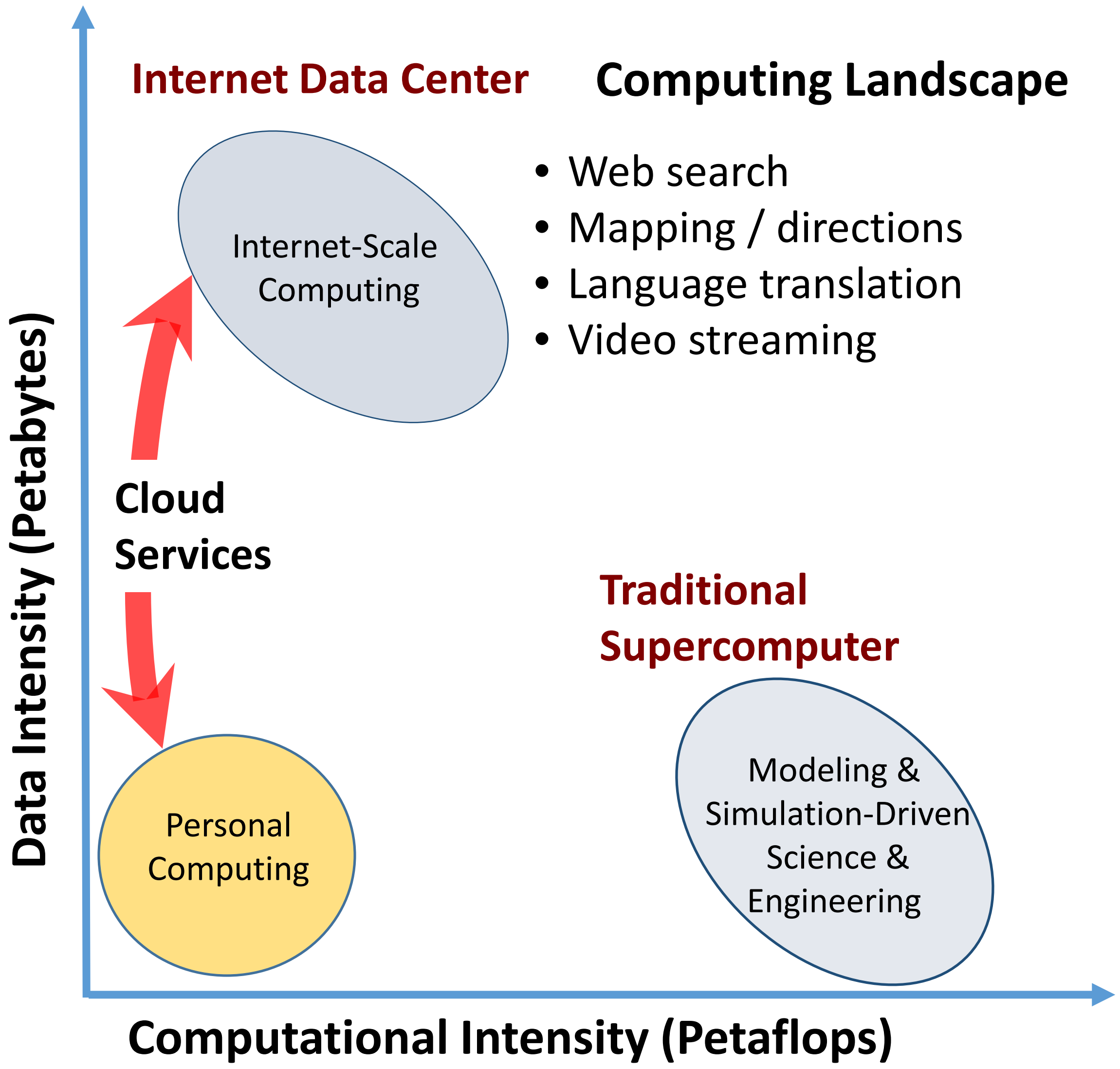


- Run programs in hours or days that would require decades or centuries on normal machine
- Designed for numerically-intensive applications

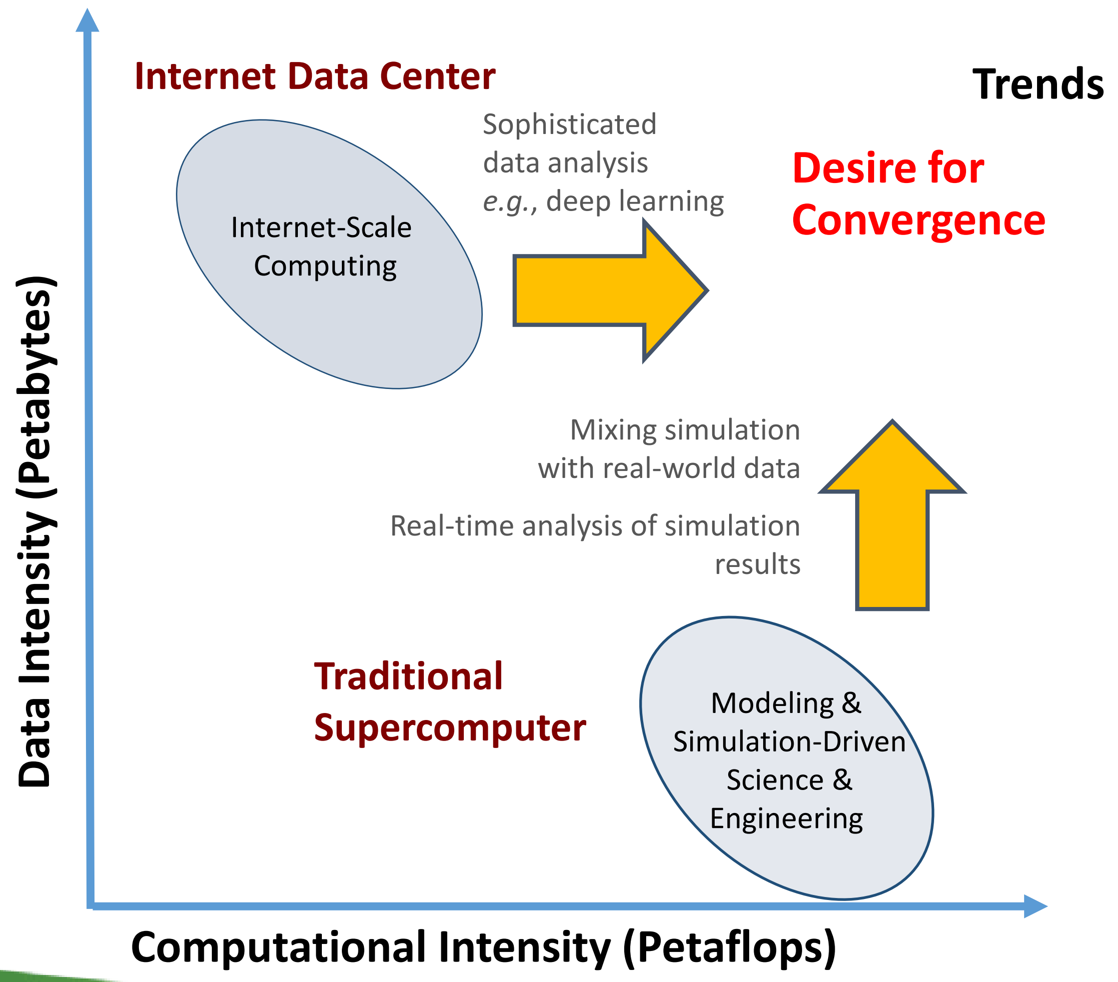
Internet Data Center

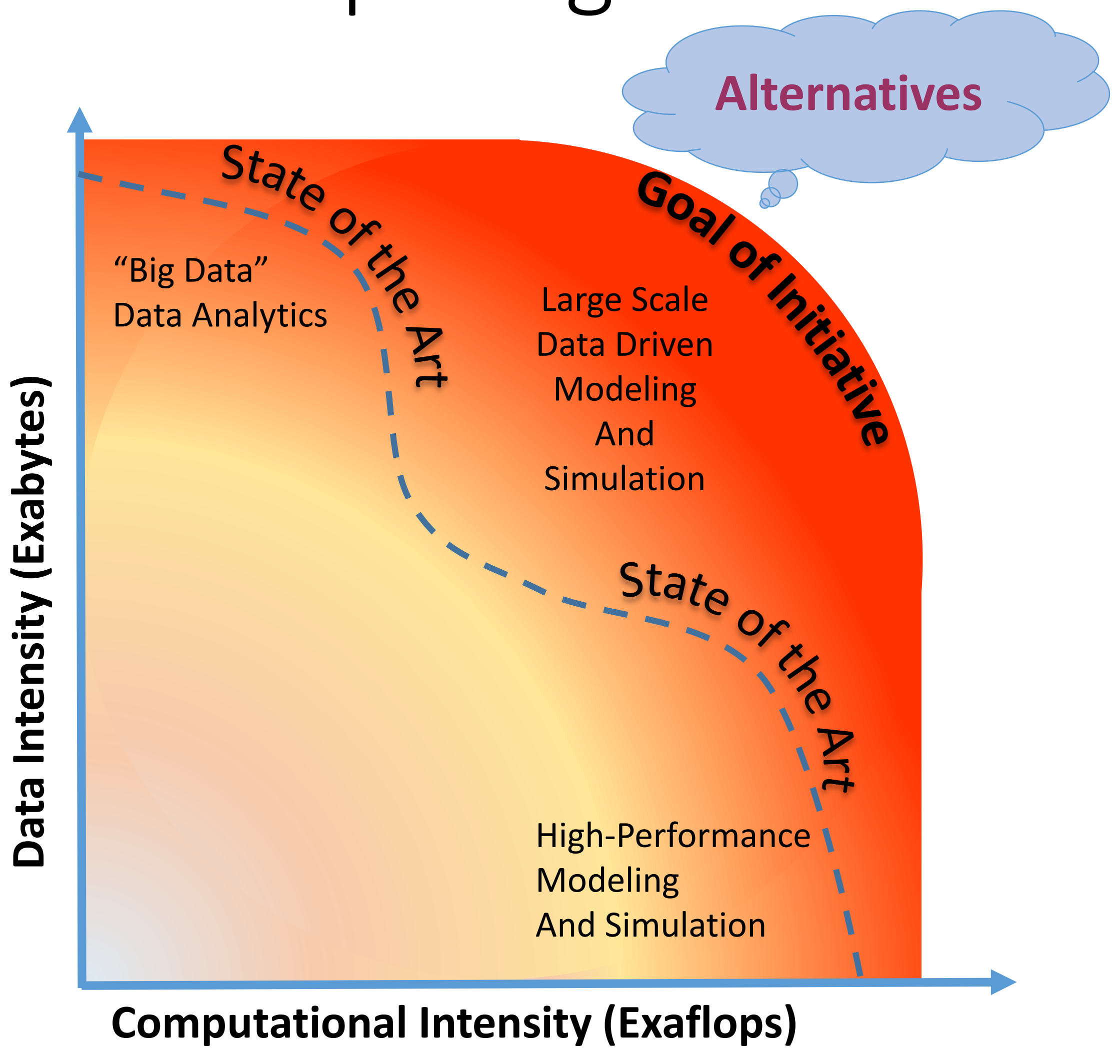
- Support millions of customers
  - Mostly small transactions
  - + large-scale analytics
- Designed for data collection, storage, and analysis

Today's Computing Landscape



Convergence and Future Computing





Future High Performance Computing

- Expect HPC of the future to be more specialized with classical von Neumann type machines complementing specialized alternative machines such as neuromorphic and quantum
- Need real-time data analytics
  - Why rerun a calculation taking 10,000's of CPU hours at higher resolution (time, spatial, or both) if you can determine you need more resolution part way through a computation?
  - Is video surveillance only good in forensics or can we have real-time video alert to anomalous behavior?
- Why do a classical computation if an alternative computational model may be quicker to the end goal?

NSCI Strategic Objectives

1. Accelerating delivery of a capable exascale computing system that integrates hardware and software capability to deliver approximately 100 times the performance of current 10 petaflop systems across a range of applications representing government needs.
2. Increasing coherence between the technology base used for modeling and simulation and that used for data analytic computing.
3. Establishing, over the next 15 years, a viable path forward for future HPC systems even after the limits of current semiconductor technology are reached.
4. Increasing the capacity and capability of an enduring national HPC ecosystem that addresses factors such as networking technology, workflow, downward scaling, foundational algorithms and software, accessibility, and workforce development.
5. Developing an enduring public-private collaboration to ensure that the benefits of R&D are, to the greatest extent, shared between the USG and industry and academia.

https://www.whitehouse.gov/the-press-office/2015/07/29/executive-order-creating-national-strategic-computing-initiative

NIST Role

Foundational Research and Development Agencies. There are two foundational research and development agencies for the NSCI: …

IARPA and the **National Institute of Standards and Technology (NIST)**… **NIST will focus on measurement science to support future computing technologies.**

The foundational research and development agencies will coordinate with deployment agencies to enable effective transition of research and development efforts that support the wide variety of requirements across the Federal Government.

Getting Started

Before the Executive Order (EO) was signed NIST was engaged

- Senior leadership working with OSTP ensured NIST was described in an appropriate manner in the EO
- Senior leadership was made aware of the *likely* EO so NIST could prepare a FY17 budget proposal that would support the EO. Budget proposal included input from ITL, MML, and PML – CNST was added later

After the Executive Order (EO) was signed

- The ADLP requested a $3.0M plan that would use SERI money to *jump-start* a NIST effort – $2.0M for *hardware* and $1.0M for *software*
- NIST is represented on the Executive Council of the NSCI
- NIST contributed to the interagency implementation plan

What is hard about the NSCI

- Scope of the NSCI is very large – hardware, software, architecture, data analytics, software validation, data verification, cybersecurity, alternative computational paradigms, …
- For NIST this is a *substantial commitment and an unusually large program that must be integrated across NIST, across the USG, and with outside partners*
- NIST decided to create an internal coordinating council to:
  - —scope out our program
  - —identify our strengths and current investments
  - —assess our gaps
  - —evaluate where we should be in a decade
  - —create a path forward

Developing a NIST Program

- Develop collective understanding of NIST's role within NSCI to "focus on measurement science to support future computing technologies"
  - Created a multi-laboratory (PML, ITL, MML, and CNST) coordination group
  - Solicited ideas from NIST staff (2 page whitepapers) as basis for a workshop
  - Held *an internal workshop* (other agencies invited to attend) to brainstorm NIST's role
- Use this to identify gaps and create a multi-laboratory, integrated program
- Identified 2 Strategic Thrusts for *building* the NIST portfolio – Proposal:
  - Beyond Moore's Law: Enhanced General Purpose High Performance Computing
  - Special Purpose Computing and Transduction
- Recognized that the NSCI complements other NIST strategic thrusts (QIS, Photonics, Big Data, MGI, Bio, CPS)

Agenda of Internal Workshop

FEBRUARY 25, 2016

1:00 - 1:10	Welcome (Charles Romine)
1:10 - 1:30	Setting the Stage and Logistics (Carl Williams)
1:30 –2:30	**Tom Theis** - Beyond CMOS
2:30 – 3:00	Break and move to Sessions
3:00 – 4:30	**Breakout Session 1#**: Beyond CMOS including Superconductivity
4:45 - 5:30	ReCap of Day 1: Summary of Breakouts

Agenda of Internal Workshop

FEBRUARY 26, 2016

8:30 - 9:15	**Chris Krieger** - Neuromorphic Computing
9:15- 10:00	**David Moehring** - Quantum Computing
10:00-10:30	Break and move to Breakout sessions
10:30 - 12:00	**Breakout Session 2#**: Alternative Computational Paradigms
12:00 - 12:45	Lunch
12:45 – 1:45	**Alex Szalay** - Algorithms, Architectures, Big Data
1:45 – 2:00	Break and move to Breakout sessions
2:00 – 3:30	**Breakout Session 3#**: Algorithms, Architectures, Big Data
3:45 - 4:30	ReCap of Day 2, Summary of Workshop, and Next Steps

Beyond Moore's Law

- Characterization of Materials, Devices and Circuits:
  - 2D Heterostructure Devices
  - Non-Volatile Memory
  - Interconnects and Transduction
  - Device and Materials Validation
  - Advanced Measurement Capabilities
- Algorithms, Architectures, and Applications
  - Access to Leadership Class Computing Facilities
  - Ensuring Reliability of HPC Applications
  - Enabling Multi-Scale High Performance Networks for Exascale Computing
  - Cybersecurity for Next Generation Computing Systems
  - Developing a Robust Big Data Ecosystem

Special Purpose Computing and Transduction

- Cryogenic Computing – for this to succeed one need high-speed, cryogenic compatible memory and ability to move signals in and out of a low temperature cryostat
- Neuromorphic Computing – this is both a hardware and software problem where NIST clearly lags others
- Quantum Computing – final path remains undetermined but NIST has developed a world class effort in this area
- Transduction – crucial to high-speed, efficient process whether in a von Neumann architecture or an alternative paradigm

Complicating Factors

- Program is very large by traditional NIST standards
  - NIST will have to prioritize in moving ahead since there are many gaps to fill
  - NIST must manage to coordinate a national program that crosses multiple OUs
- NIST must continue to identify key technical gaps, critical capabilities, and salient questions
- NIST must both influence and adapt to the interagency coordination

Main PROBLEM with current NIST approach: Co-design

NIST has decided that we will set this aside for now since we lack expertise. NIST will engage with DOE who have experience to discuss approaches to key measurement science challenges in this area

Current Plans

- Build on existing strengths:
  - Materials and device characterization – in the limit where every atom counts
  - Push the limits of measurement science – lower energy, higher speed
  - Quantum computing – how do we control and manipulate hundreds of individual quantum systems
- Begin filling out identified major gaps:
  - Create *holistic program* in neuromorphic computing – what makes such a computer powerful, how do I quantify accuracy of an inherently non-reproducible system
  - Build security from the ground floor into future HPCs
  - Create a robust ecosystem for big data