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How Much Computing Power Will We Need

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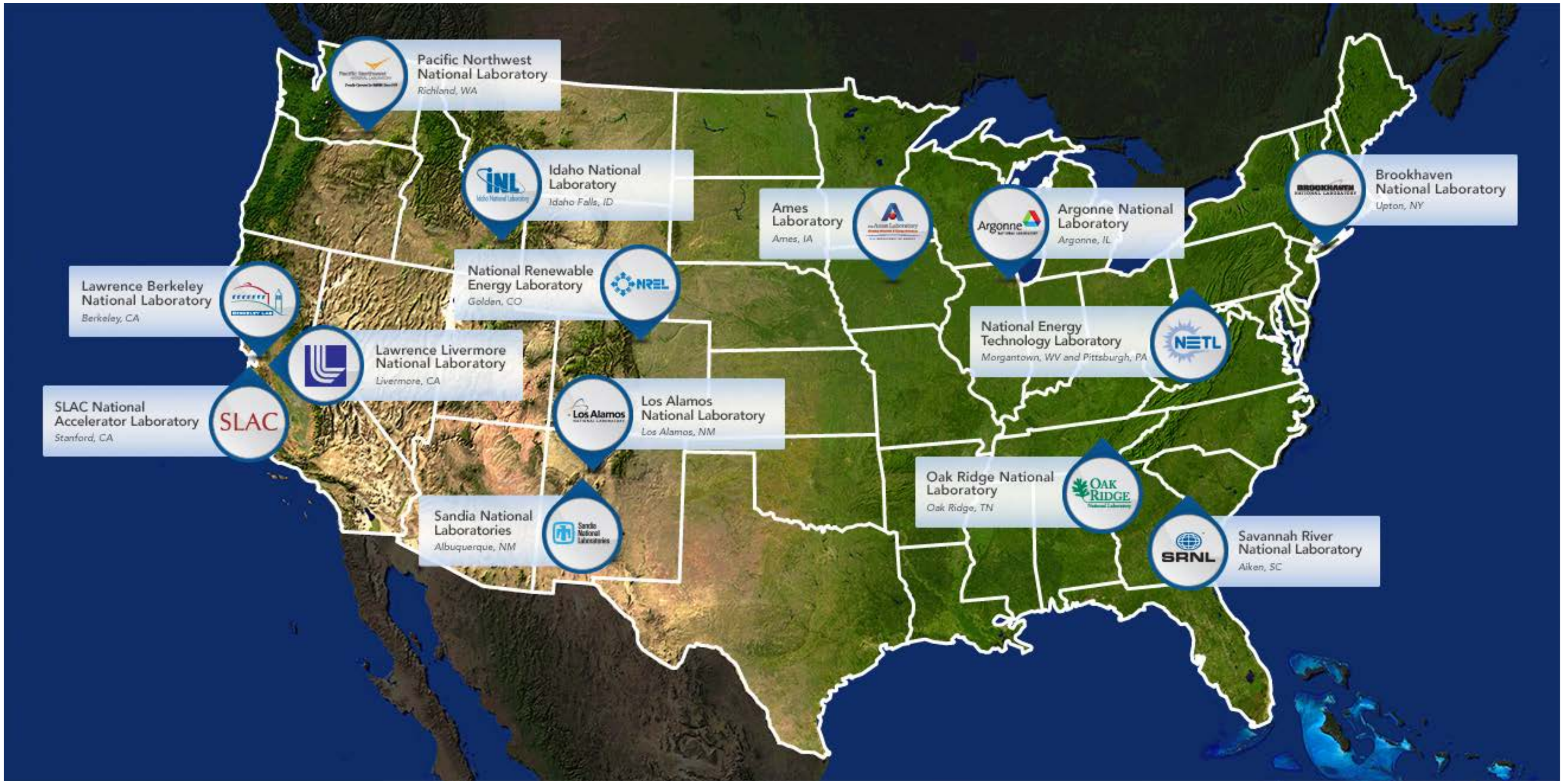
DOE Identified Need for Grid Modernization

Five key trends are driving Grid Modernization and challenge the current grid, but they provide the opportunity to transform our grid into a platform for greater prosperity, growth, and innovation.

- Changing mix of types and characteristics of electric generation (in particular, distributed and clean energy)
- Growing demands for a more resilient and reliable grid (especially due to weather impacts and cyber- and physical-attacks)
- Growing supply- and demand-side opportunities for customers to participate in electricity markets
- Emergence of interconnected electricity information and control systems
- Aging electricity infrastructure.

DOE's Solution: Grid Modernization Laboratory Consortium

- 14 National Labs are teaming together across the country to align DOE funded research into tackling these problems
- The GMLC is reducing the redundancy across the DOE portfolio and blending the strengths of each lab to produce the best quality research



DOE's Solution: Grid Modernization Laboratory Consortium

- National Labs developed six technical areas for next generation research
  - Design and Planning Tools
    - Create grid planning tools that integrate of transmission and distribution system dynamics
  - Devices and Integrated Systems Testing
    - Develop new devices and integrated systems that are cost effective and interoperable
  - Institutional Support
    - Provide tools and data for informed decision and reduce risk on future power grid operations

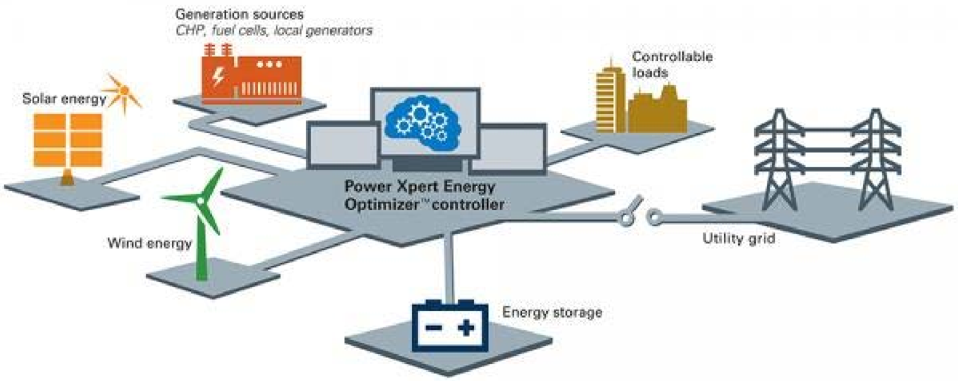
DOE's Solution: Grid Modernization Laboratory Consortium

- National Labs developed six technical areas for next generation research
  - Security and Resilience
    - Develop advanced solutions and real-time incident response capabilities
  - Sensing and Measurement
    - Develop tools and strategies to gain full visibility of the grid and advanced low-cost sensors, analytics and visualization
  - System Operations, Power Flow, and Control
    - Design new grid architecture that coordinates millions of devices and integrates with EMS

DOE focused Research Categories that Increase Computing Power Need

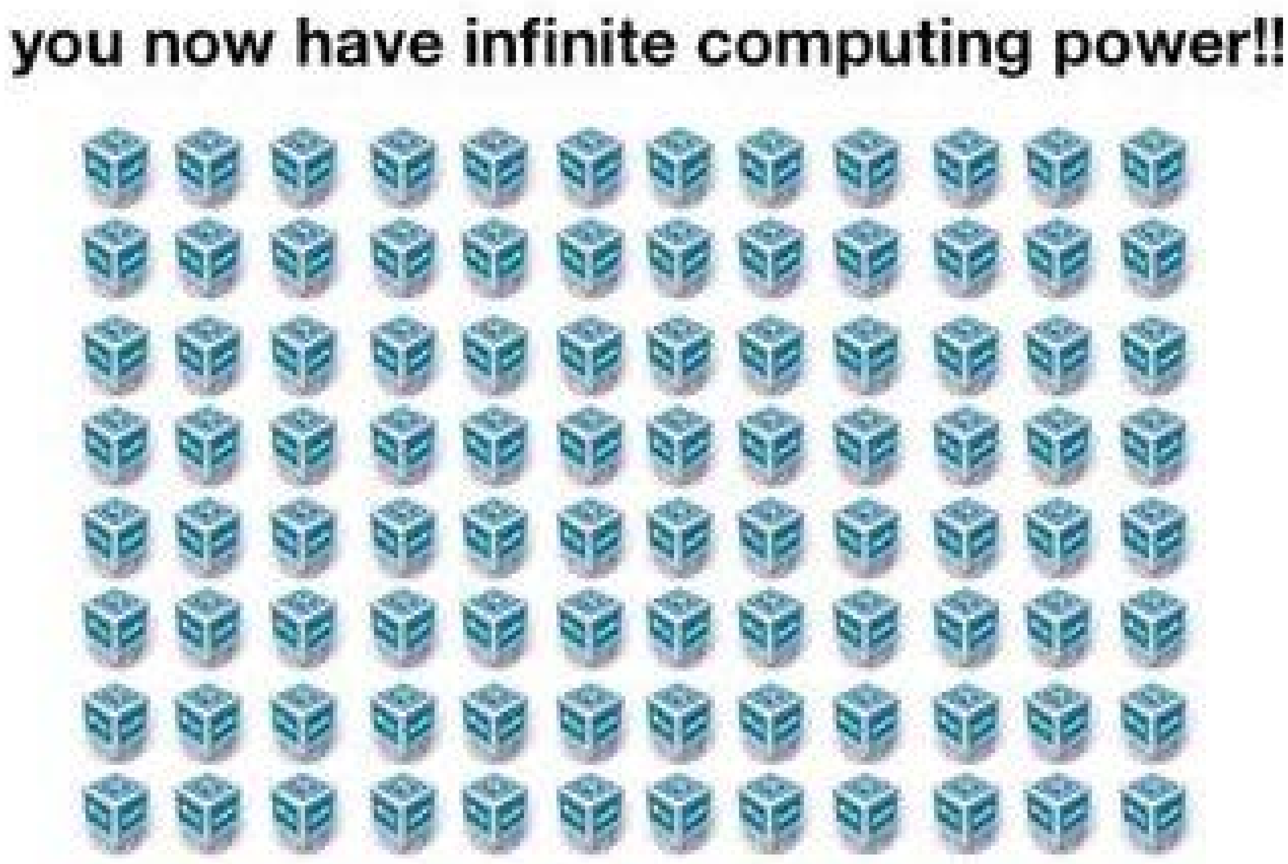
- Operational Tools
- Dig Data and Data Analytics
- Visualization platforms
- Power System Modeling
- Cybersecurity and Risk Tools
- Microgrid Controls & Energy Storage
- Advanced Grid Components
- Power Electronics

Reasons for Needing More Computing Power



How does this relate to computing power?

- All six of these focus on integration on new computing methods or aggregation on more and more and more sensors or controllers.
  - coordinates millions of devices and integrates with EMS
  - gain full visibility of the grid
  - integrate of transmission and distribution system dynamics
- If you look at these three the only solution is as much computing power as possible



Yay now we can do everything

Sorry You Can't have Infinite Computing Power

Well what's the next best thing?

- National Labs and DOE think it starts with supercomputers and high performance computing
- Supercomputers are an aggregate of processors that have advanced architecture, resources, and components to achieve massive computing power.
- Capable of performing trillions of calculations per second
- High performance computing is the use of parallel processing to run advanced applications efficiently, reliably and quickly
- HPC is requires supercomputers to operate above a tera floating-point operations per second

Super Computers in the DOE National Lab Complex

Rank	National Lab	Name	Cores	TFLops/s
#1	ORNL	Summit	2,282,544	122,300
#3	LLNL	Sierra	1,572,480	71,610
#7	ORNL	Titan	560,640	17,590
#9	LANL	Trinity	979,968	14,014
#17	ANL	Mira	786,432	8,586
#21	ANL	Theta	280,320	6,920
#33	LLNL	Vulcan	393,210	4,293
#69	PNNL	Cascade	194,616	2,539

- National Labs have been building and using super computers for years
- They are leading the world in capabilities by holding four of the top ten spots
- Supercomputers are floors full of racks and racks of processors

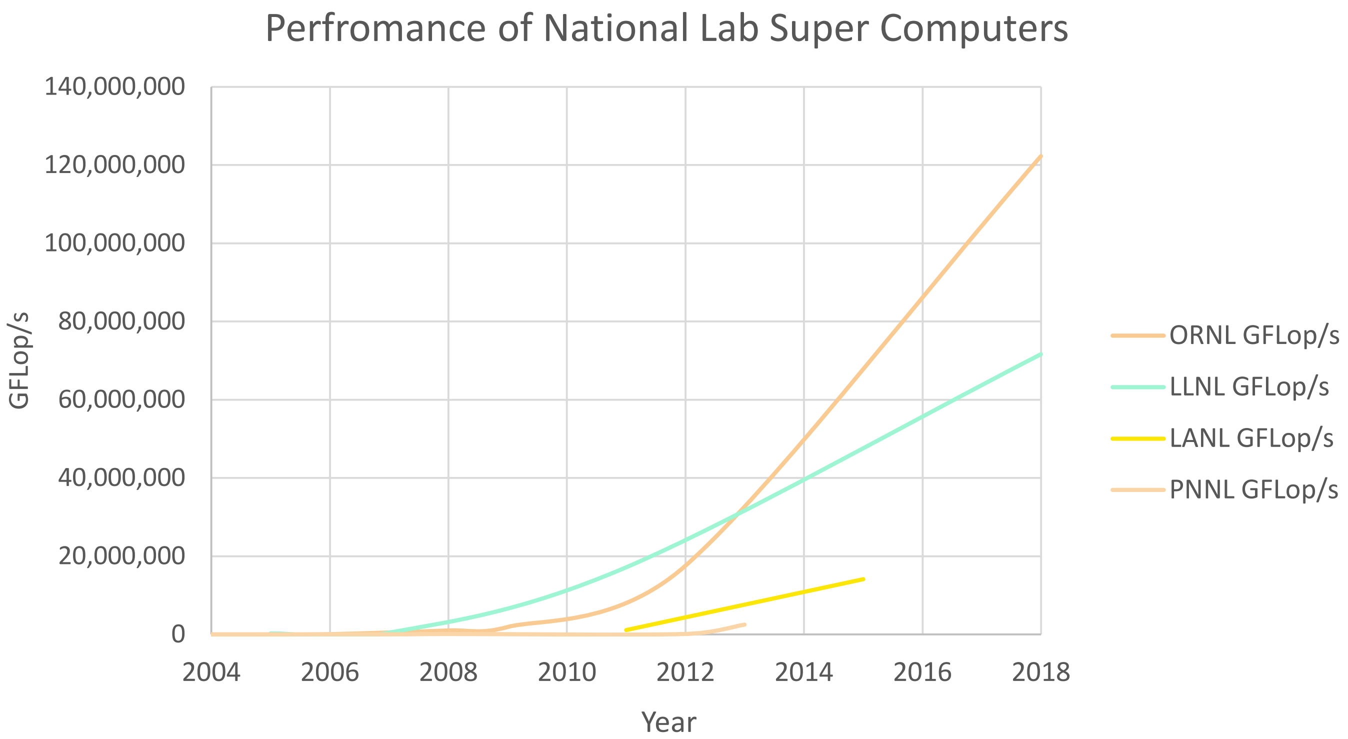
Of that previous research list these really benefit for supercomputers and HPC, but not at the scale that National labs are doing.

- Operational Tools
- Dig Data and Data Analytics
- Visualization platforms
- Power System Modeling

This is because National labs are trying to model the nations grid which is exponentially bigger than a utilities

How Supercomputers have Changed in a short period

- Supercomputer's performance is related to semiconductor performance and follows Moore's Law
- In 10 years the performance has grown exponentially and the capabilities with that



Operational Tools

- Scaling Tools for Comprehensive Economic Assessments
  - Economic assessment at all time scales with reduced run times
- Developing and Adapting Tool for Improved Reliability and Resilience
- All of this requires advanced computing technologies to reduce solving time

Big Data and Data Analytics

- Installation of PMUs, Smart Meters, IIOT tech is pushing for computations with big data sets
- If operational tools want to reduce run times and increase visibility they require data analytics to achieve
- These data sets will never be able to be handled by regular computing methods

Visualization Platforms

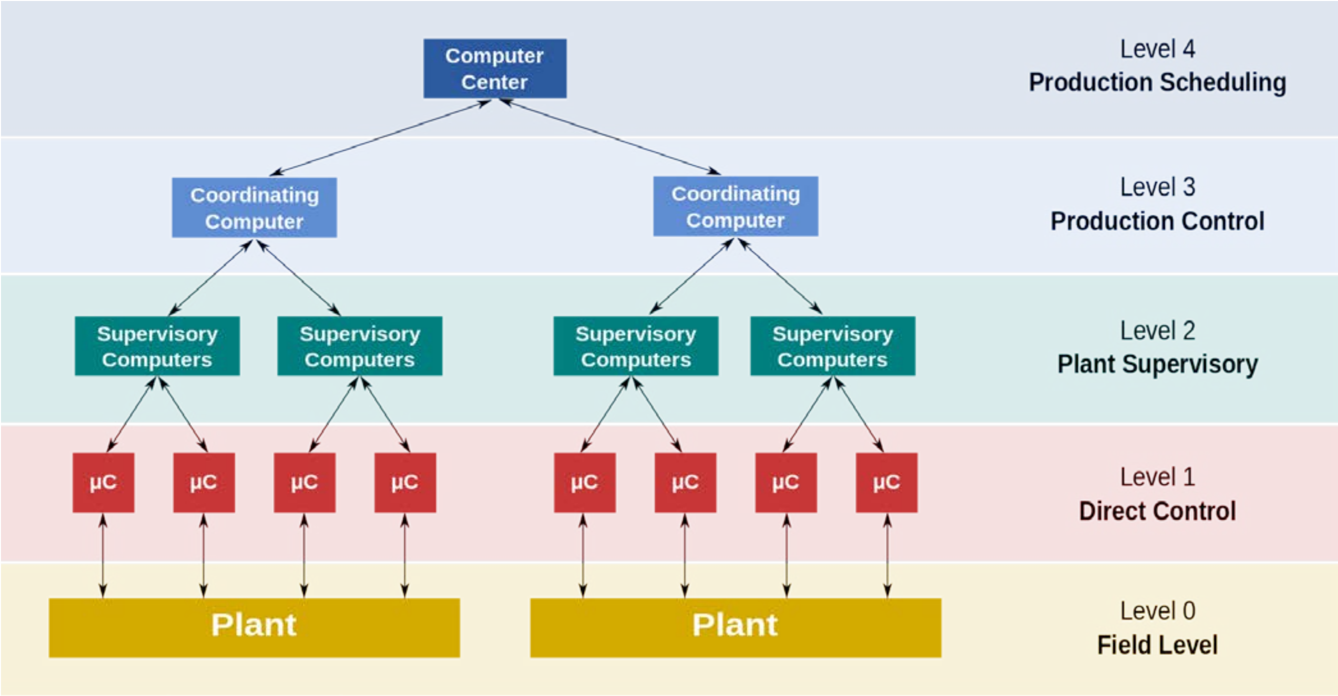
- Visualizations mapping storm systems, grid vulnerabilities and power failures can help direct emergency response teams
- Advanced Restoration and first responders, tools that make emergency response similar and more structured
- EAGLE-I (Environment for Analysis of Geo-Located Energy Information) DOE funded and supported and tracks power outages across the nation

Power System Modeling

- Many different methods for modeling the power system and multiple platforms
- Power System Analysis Modeling
  - Power World, PSS/E, PSCAD, RTDS, Opal-RT, Gridlab-D, MATLAB
- Distribution Modeling vs Transmission Modeling vs Blended vs power electronic
- Each modeling platform provides different data
- Depending on need for operational tools more realistic modeling is needed

Use of distributed control systems/autonomous end controllers

- Industrial Internet of Technology is advancing DCS
- Adding more intelligence at end devices can over well data to high control levels
- Adding autonomous control at Level 1 and 2 reduces the amount of super computers and data centers at level 3 and 4
- Advanced manufacturing office in DOE is funding research in improving autonomous control and cybersecurity of low level connected devices.

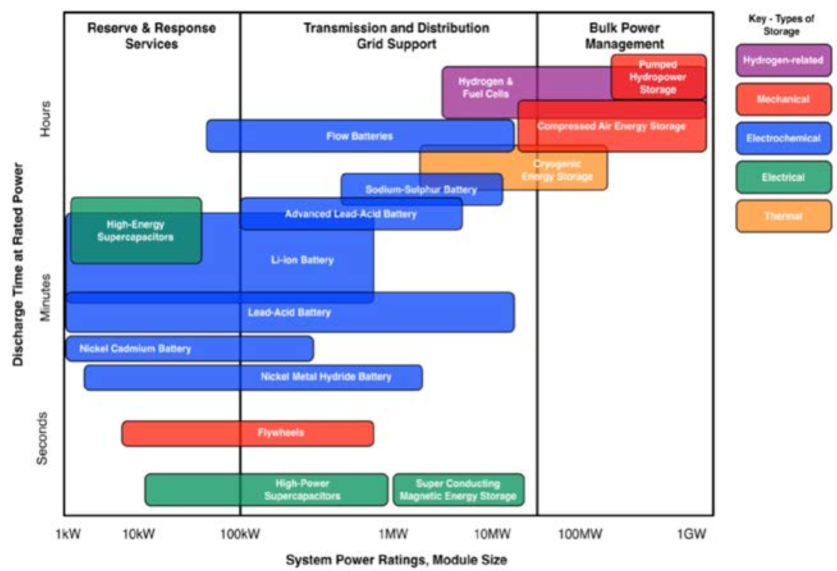


Cybersecurity and Risk Tools

- IIOT devices add exponential access points to the operation technology network
- Can handle cybersecurity by utilizing supercomputers, but can be done locally through distributed control
- Reduces need for large single location computation power, but still is aggregated together is equal
- Level 1 to level 2 planed cybersecurity implements smart secure networks without monitoring from above

Microgrid Controls & Energy Storage

- Inherently microgrid control can be distributed.
- Local control is normal with monitoring at the point of common coupling.
- Similar energy storage depends on application



Advanced Grid Components

- Advanced meters, load control devices, voltage regulators, capacitor banks, and etc. All add added smarts to the grid.
- These can be communicated and controlled through cellular to a control center
- Or mesh communication can be used to have system communicate within themselves and aggregator
- Aggregator would be level 2 device and making decisions

Power Electronics

- Power electronics build in four quadrant capability anywhere in the system
- These components can provide VARs/Voltage support.
- Locally controlled, but must not fight each other
- Require FPGA/microcontroller for control
- CAPER new project is a power electronic tap changer for voltage regulators

Best of Both Worlds for DOE Grid Modernization

Blending the use of supercomputers/high performance computing and distributed control system/autonomous controllers to accomplish advancing

- High Performance Computing
  - Operational Tools and Synchrophasors
  - Dig Data and Data Analytics
  - Visualization platforms
  - Power System Modeling

- Distributed Control Systems
  - Cybersecurity and Risk Tools
  - Microgrid Controls
  - Advanced Grid Components
  - Power Electronics
  - Energy Storage

In Conclusion the amount of computing power will be a lot, but it doesn’t need to be centrally located for every added capability/functionality.

Questions??