OAK RIDGE National Laboratory

Oak Ridge National Laboratory

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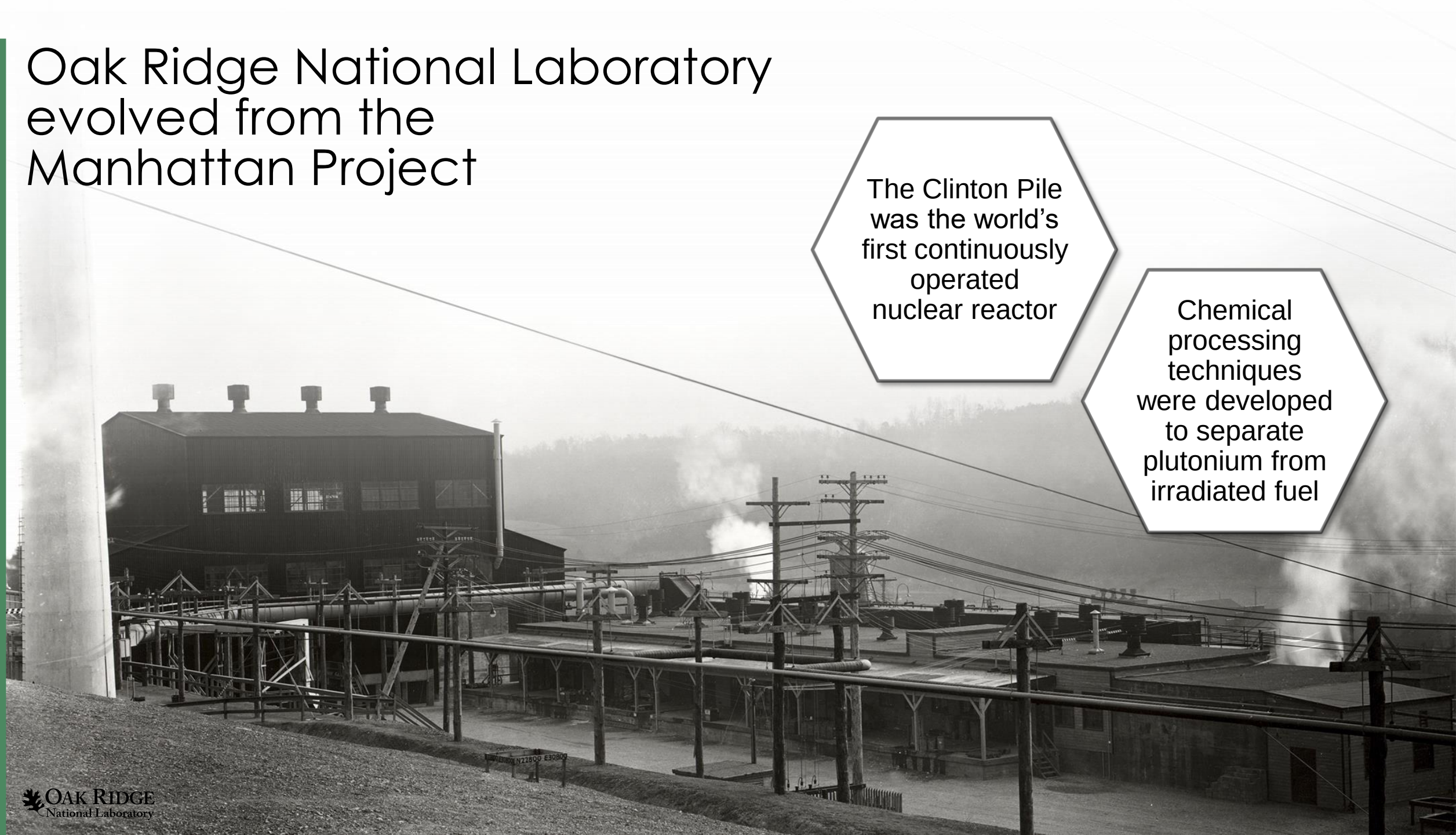
ORNL is managed by UT-Battelle, LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

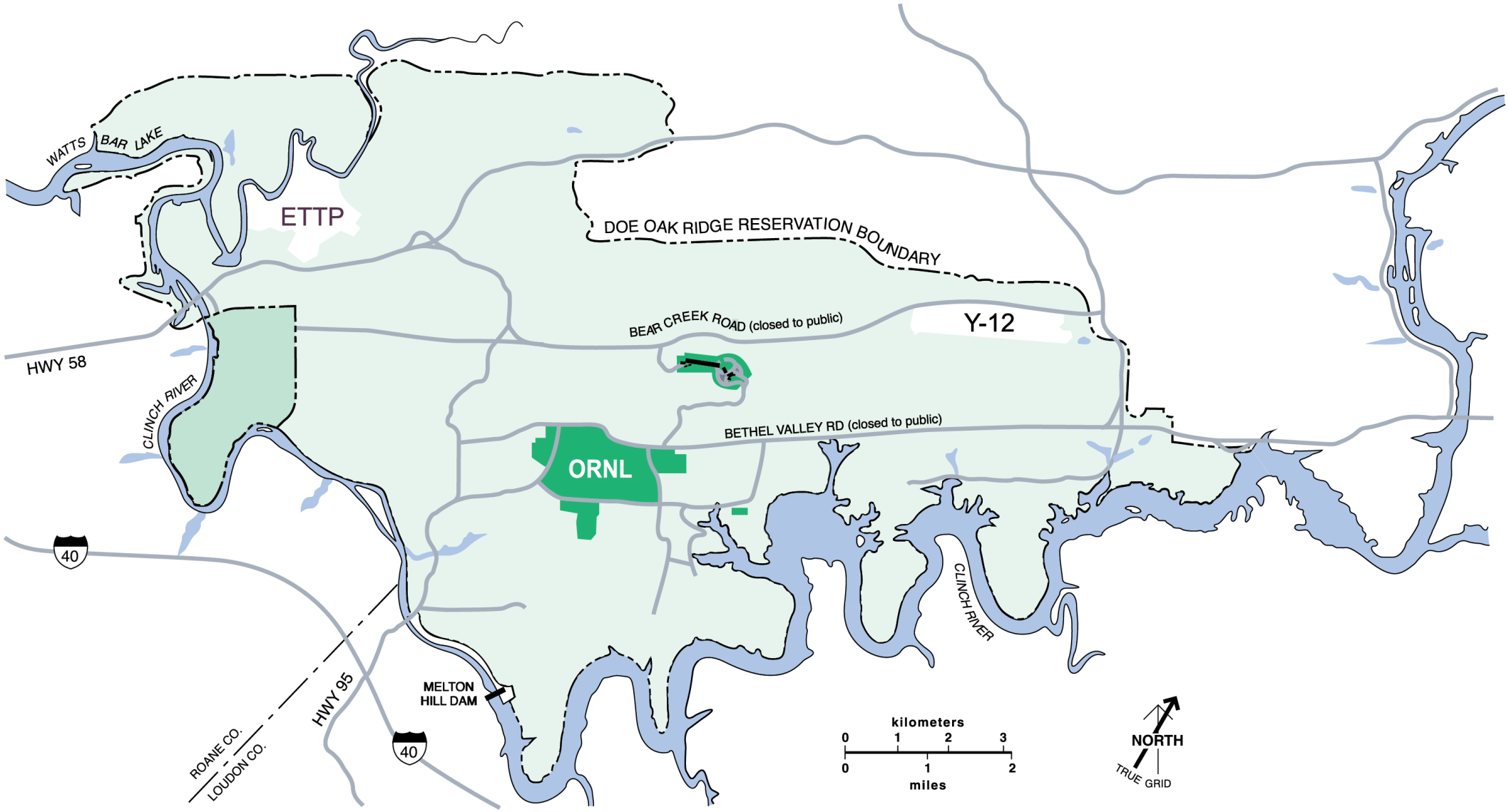
Oak Ridge National Laboratory evolved from the Manhattan Project



The Clinton Pile was the world's first continuously operated nuclear reactor

Chemical processing techniques were developed to separate plutonium from irradiated fuel

DOE has 3 large sites in Oak Ridge



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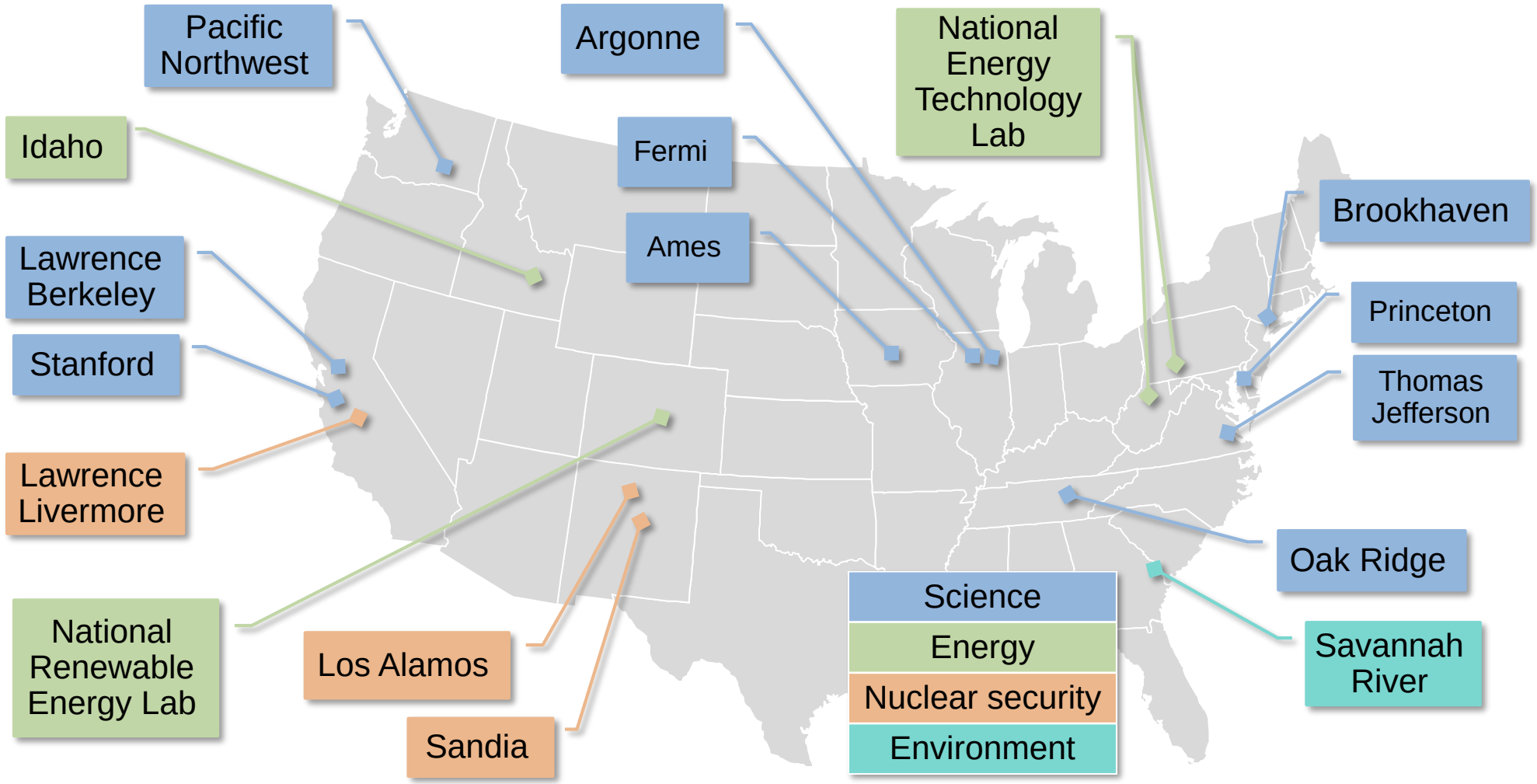
The national laboratories of the U.S. Department of Energy constitute a network for discovery and innovation



ORNL has a distinguished history of making groundbreaking discoveries and meeting national needs

Development, production, and distribution of radioisotopes and stable isotopes

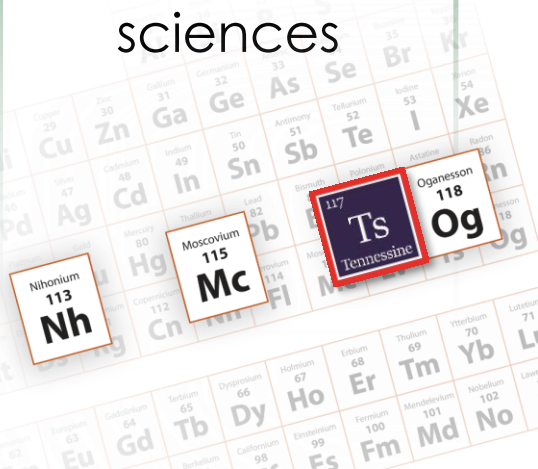
Science and engineering of the nuclear fuel cycle

- Reactor technology
- Materials and fuels
- Separations chemistry

Development of neutron scattering, neutron activation analysis, and other innovative research tools

Development and application of high-performance computing resources

Delivering advances in physical and life sciences



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Reliable energy is required to elevate standards of living

Environmental impacts of energy production, distribution, and use

Global security implications of energy scarcity

Economic consequences of energy prices

Energy access in developing nations

ORNL's mission

Deliver scientific discoveries and technical breakthroughs needed to realize solutions in energy and national security and provide economic benefit to the nation

Integrating and applying 23 core capabilities, spanning the range from basic to applied, to deliver mission outcomes

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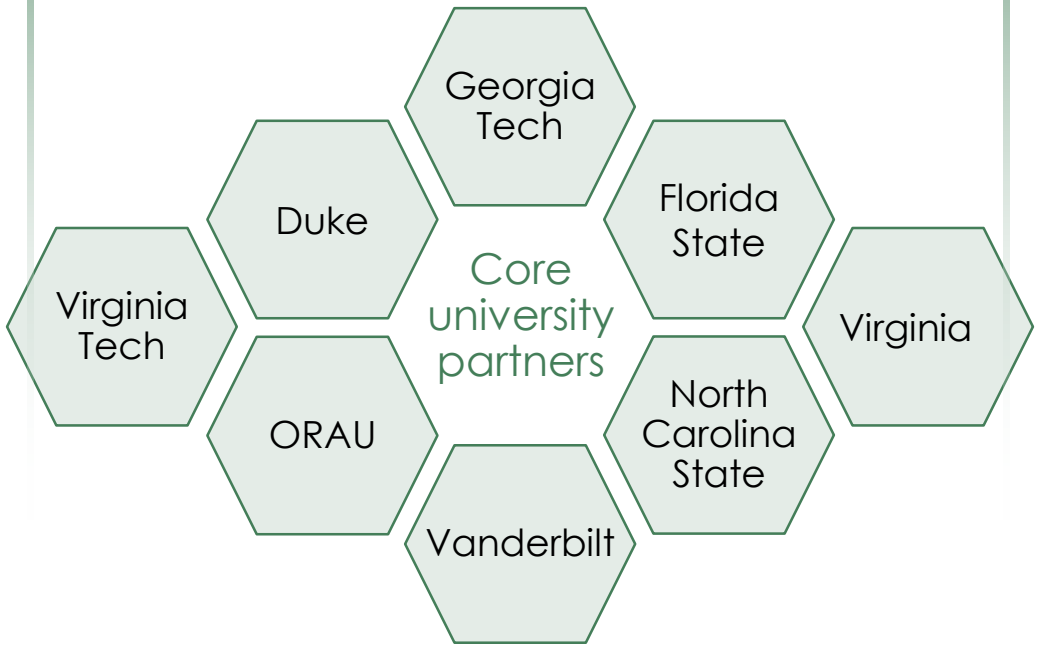
THE UNIVERSITY of TENNESSEE

- ORNL partner since 1946
- State-funded Science Alliance started in 1982, to build programs with ORNL
- Shared research, education, and joint appointments
- Joint institutes:
  - Advanced materials
  - Biological sciences
  - Computational sciences
  - Neutron sciences
  - Nuclear physics

UT-BATTELLE

Management contractor for DOE's Oak Ridge National Laboratory



BATTELLE
It can be done

- 75-year relationship with DOE
- Develops and deploys technology worldwide
- Manages or co-manages 7 DOE national labs:
  - ORNL (with UT)
  - Brookhaven (with SUNY-Stony Brook)
  - Idaho
  - Lawrence Livermore (with UC and Bechtel)
  - Los Alamos (with UC and Texas A&M)
  - NREL (with MRI)
  - Pacific Northwest

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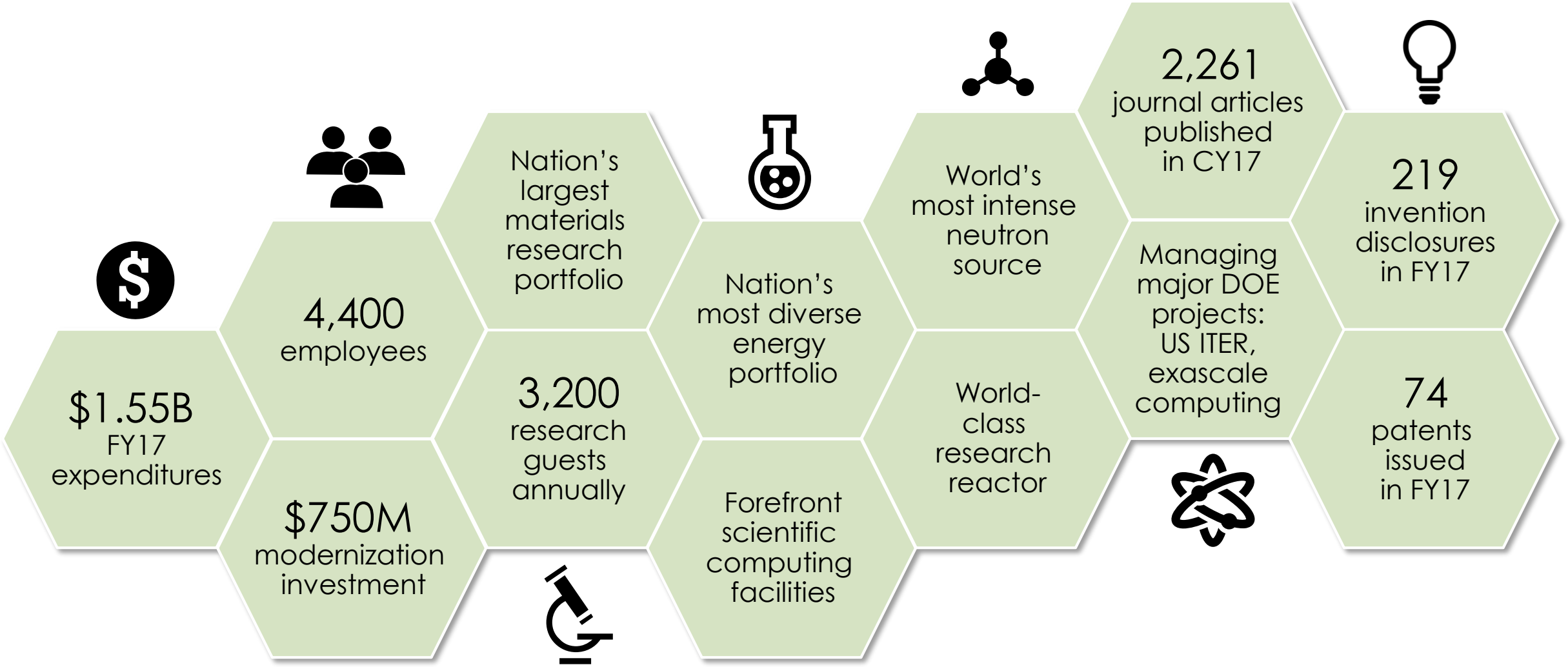
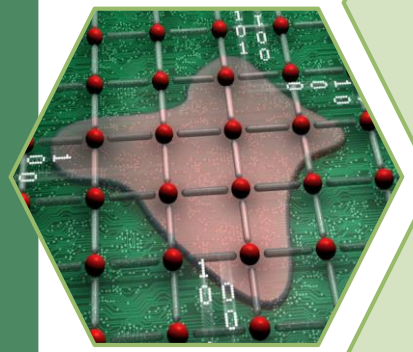
Today, ORNL is a leading science and energy laboratory



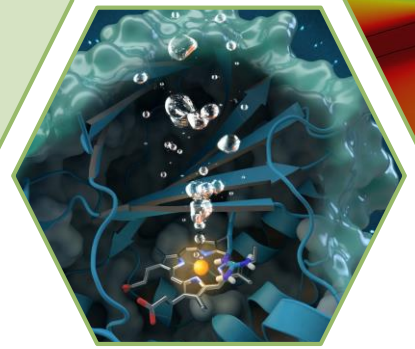
ORNL's major science and technology initiatives

Advance ORNL's science and Innovation culture



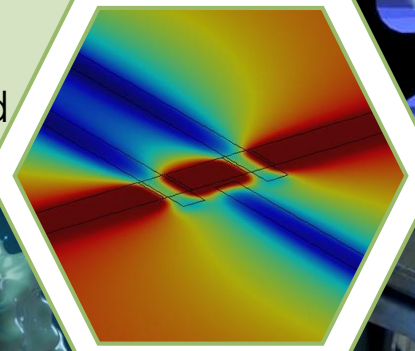
Accelerate the discovery and design of new materials for energy

Advance the science and impact of neutrons

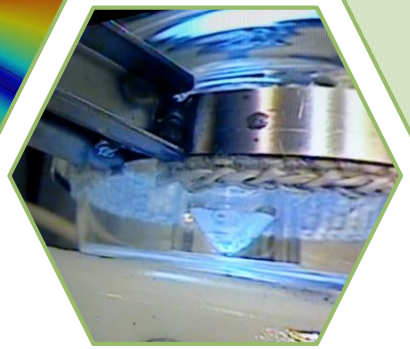


Scale computing and data analytics to exascale and beyond

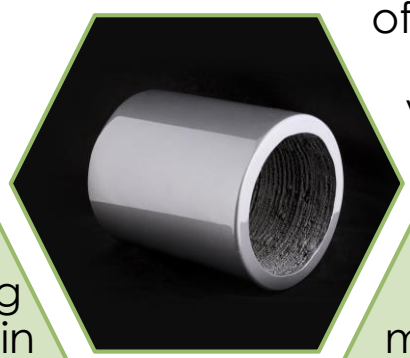
Advance scientific basis for break-through nuclear technologies and systems

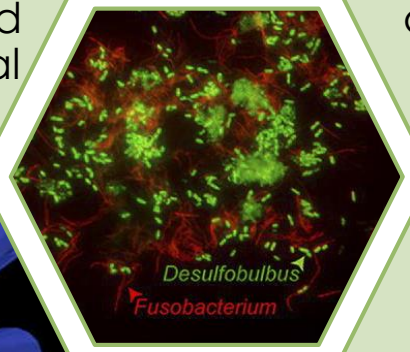


Advance understanding of complexity in biological and environmental systems



Enhance strategic capabilities in isotopes



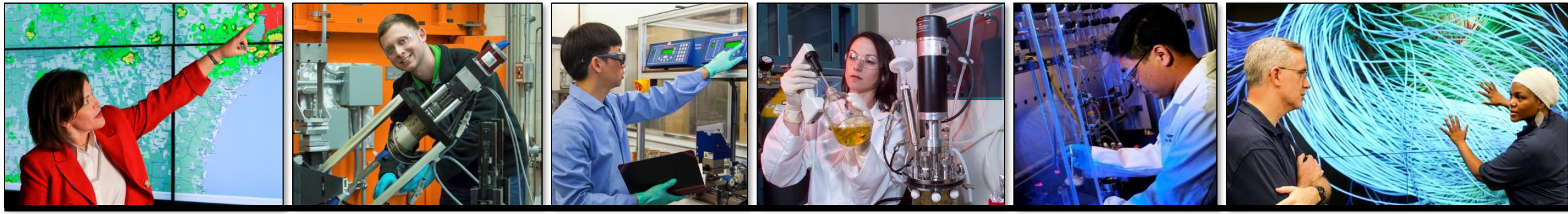


Accelerate R&D and manufacturing of integrated energy systems

Deliver S&T to address complex security challenges

Accelerate deployment of DOE IP and engagement with universities and industry

ORNL's distinctive facilities bring thousands of R&D partners to Tennessee each year



- Building Technologies Research and Integration Center
- Carbon Fiber Technology Facility
- Center for Nanophase Materials Sciences
- High Flux Isotope Reactor
- Manufacturing Demonstration Facility
- National Transportation Research Center
- Oak Ridge Leadership Computing Facility
- Spallation Neutron Source

Partnerships are vital to accelerating technology transition and engaging with industry and universities

Technology transfer

- Cooperative R&D Agreements (CRADAs)
- Strategic Partnership Projects
- Technology licensing

Industry and economic development partnerships

- Regional industry recruiting and cluster development
- State and local economic development partnerships
- Institute for Advanced Composite Materials Innovation (IACMI)

Graduate/postgraduate education and university partnerships

- Graduate education
  - UT-ORNL Bredesen Center: Entrepreneurial and policy options
  - Graduate Opportunities (GO!) program
  - DOE Office of Science Graduate Student Research program

- ~280 joint faculty appointments

ORNL innovations have billion-dollar impacts

Big-area additive manufacturing: US investment >$1B

Fueleconomy.gov: $1B in cost savings $1B

Ceramic matrix composites for gas turbines $150B

Lab-on-a-chip: Caliper acquired by PerkinElmer $0.6B

Cesium extraction: Basis for waste processing plant $1.3B

Reactor life extension: $20B cost avoidance $20B

Advanced alloys: Chrome-moly steel in widespread use

Ion implantation: Integrated circuits and medical implants

Cryopreservation (mouse embryos): Livestock reproduction

Centrifuge technology: Basis for vaccine purification and US enrichment industry

Instrumentation: Products and spinoffs from ORTEC and TENNELEC >$1B

Reactor technology: Concepts for light water, high temperature, and molten salt reactors

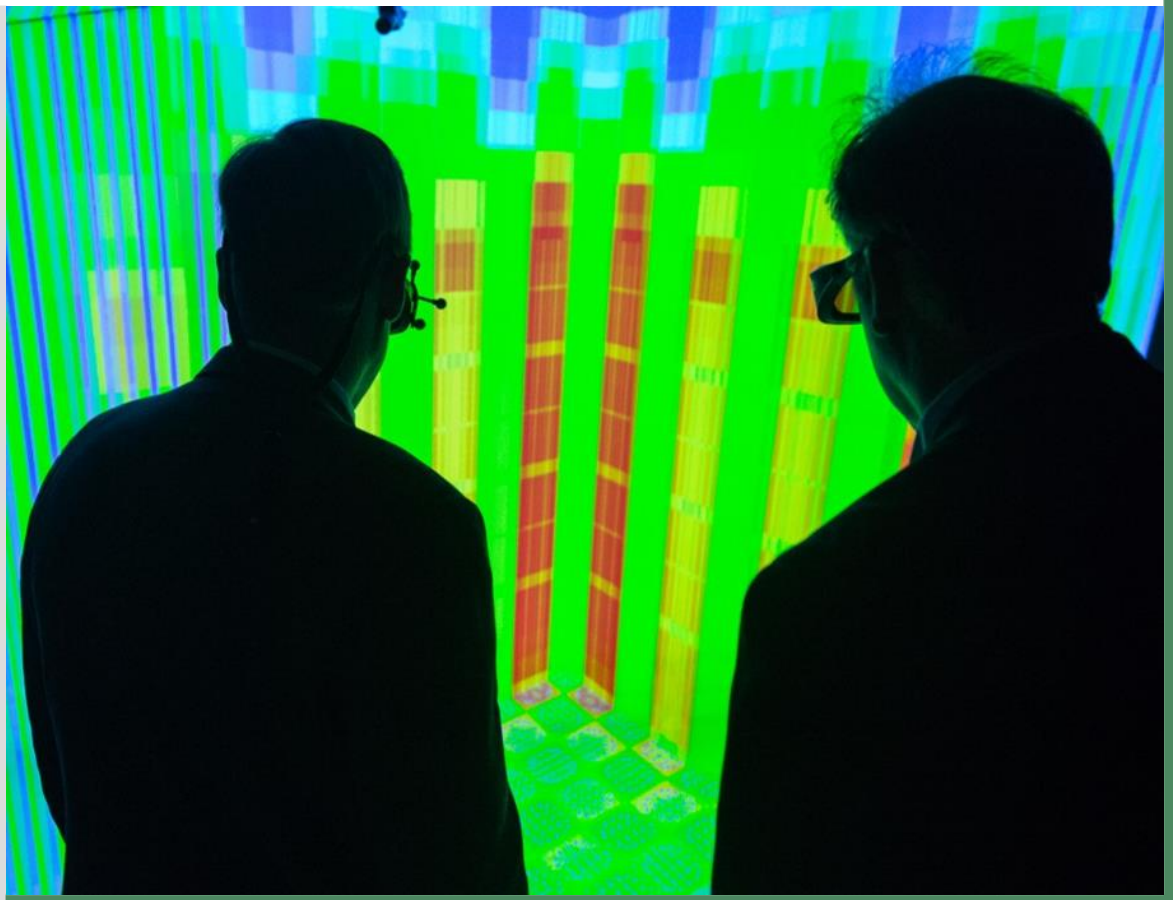
PUREX: Basis for nuclear fuel reprocessing techniques used worldwide

Radioisotopes: Multibillion dollar industry (>100 million procedures per year) >$5B/ year

1940s **Today**

We are entering a second machine age

- The steam engine enabled the first machine age
- Advances in computing and digital technology over the past 50 years are enabling the second machine age

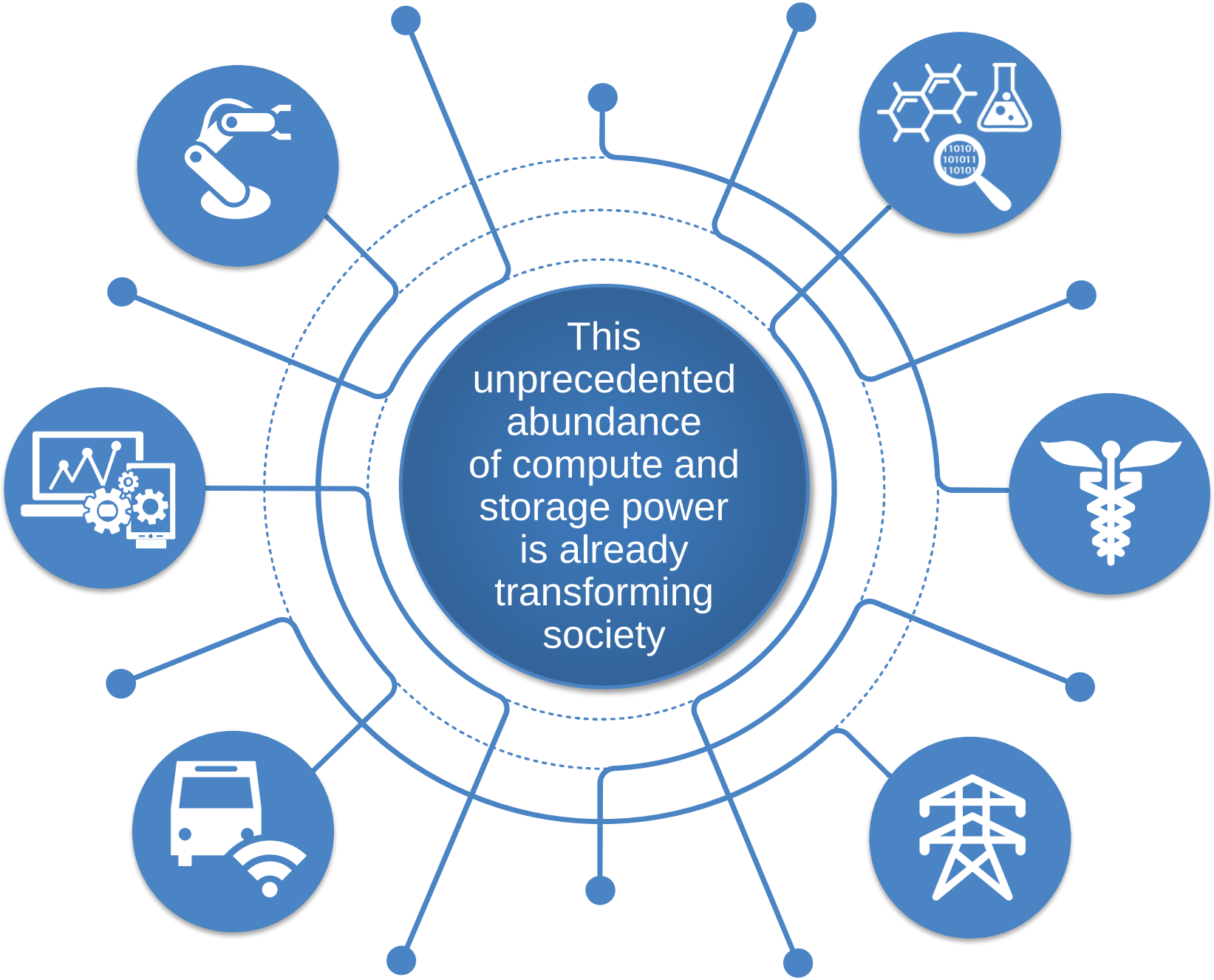


Operating the world's most powerful supercomputer

- ORNL's new Summit system is delivering scientific results at the exascale
  - Materials
  - Genomics
  - Medicine
- Summit will be available to the scientific user community in 2019

Digital information is shaping the second machine age

- Today: Our ability to collect and store data exceeds our ability to use it in traditional ways
  - Scientific data sets
  - Internet of Things (IoT)
  - Health information
- Our ability to process data has increased exponentially


This unprecedented abundance of compute and storage power is already transforming society

Electric grid management

- New data monitoring tools provide real-time feedback from the electric grid
  - Pinpointing outages
  - Enabling incorporation of renewable energy sources and "smart home" technology
  - Identifying electricity theft
- Data volume and data security pose challenges for electricity providers

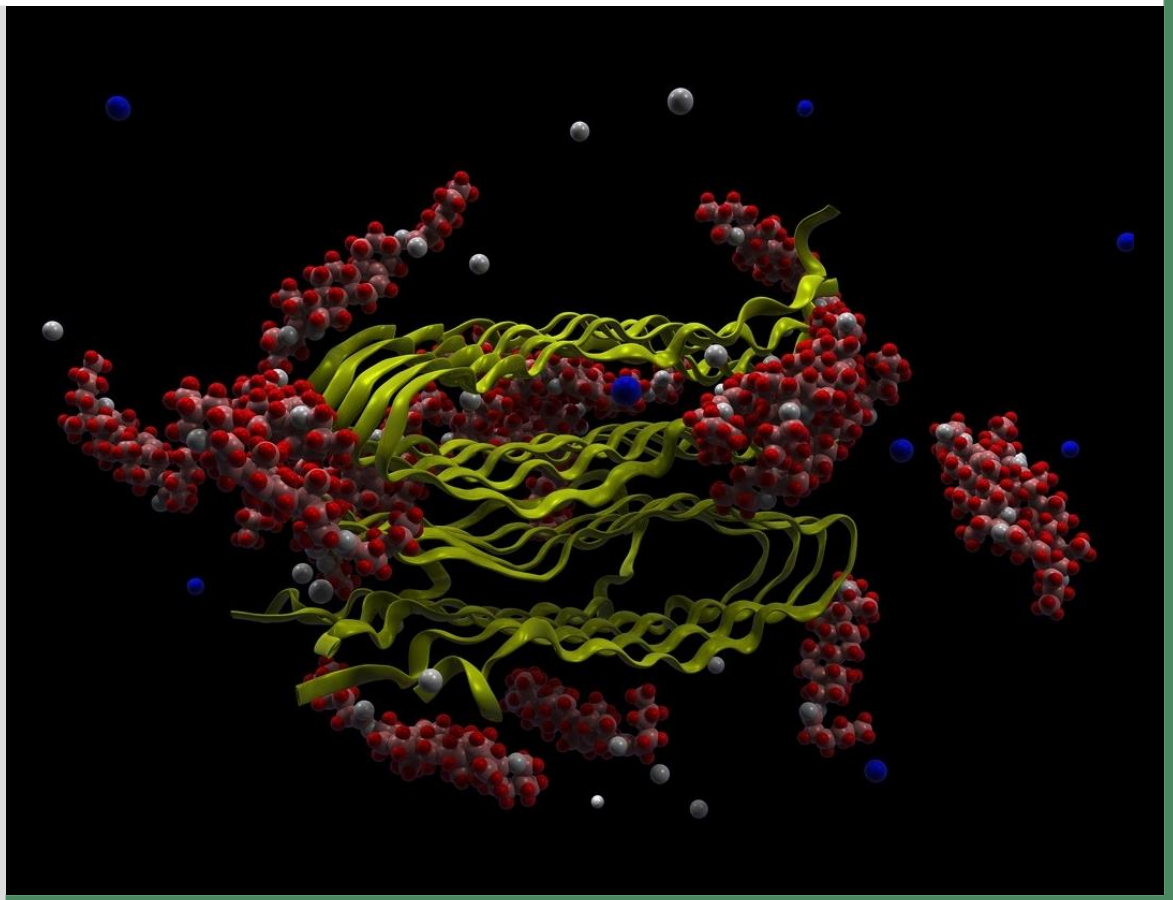
Courtesy of Chattanooga EPB

Enabling advanced manufacturing

- Computationally assisted development of new materials and processes
- Application of big data, artificial intelligence, and automation to transform production, distribution, and delivery

Healthcare

- Accelerating data-driven biomedical discoveries and healthcare delivery
  - MVP-CHAMPION
  - Cancer Moonshot
- Enabling personalized medicine
- Providing information for healthcare management and policy



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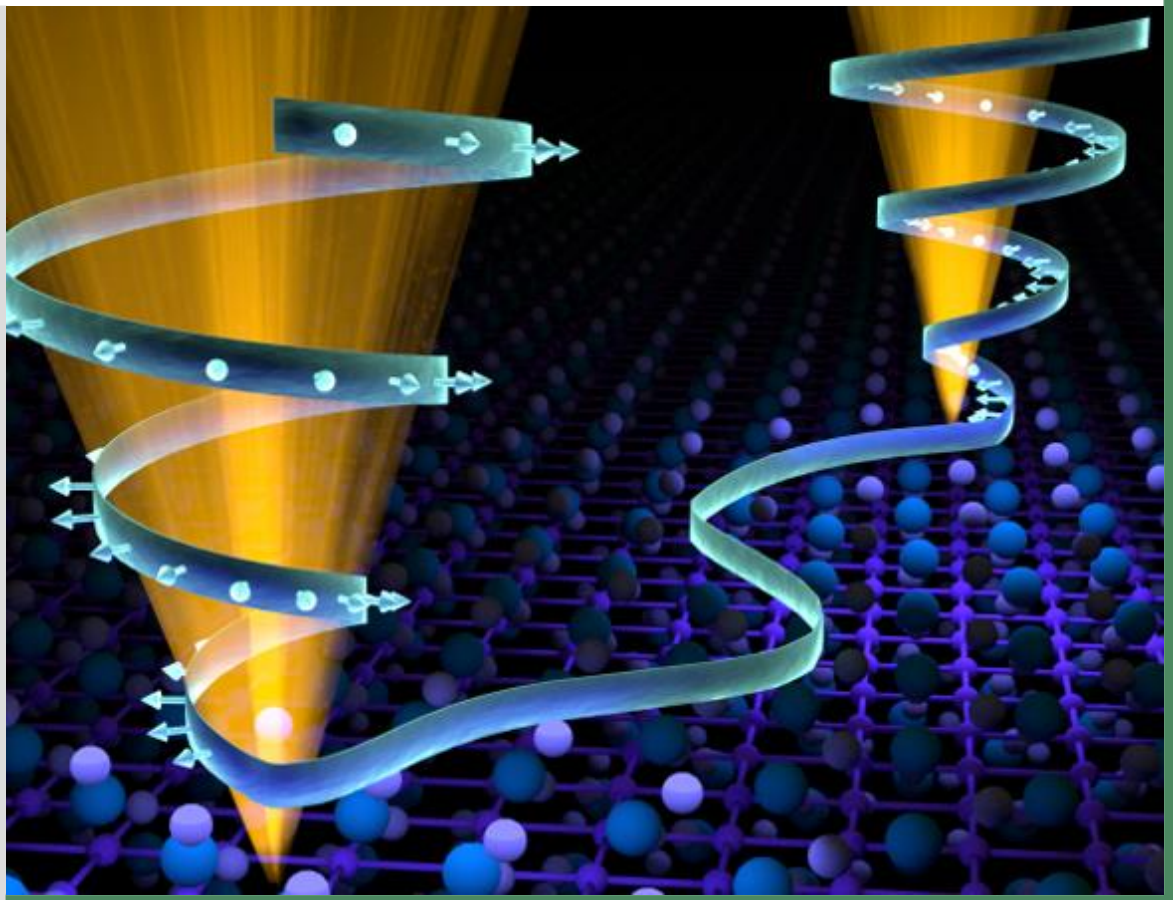
Transportation

- Autonomous vehicles
- Traffic analysis and management
- Transportation policy and planning
- Logistics and supply chain management

Racing with (not against) the machine

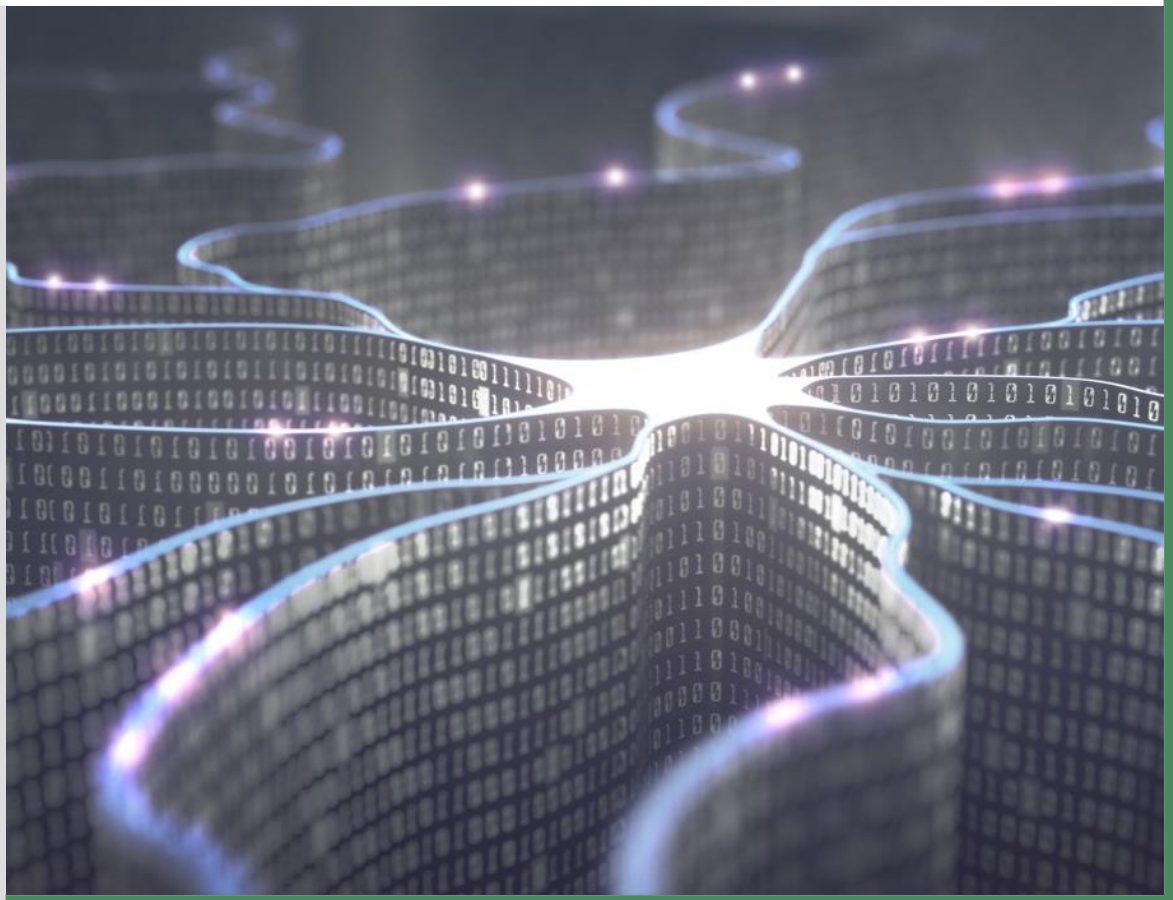
Exploiting today's resources

- Automating routine processes
- Advanced algorithms that extend human abilities
- New devices and applications



Developing and using the next generation of digital technologies

- Advanced computing architectures
  - Processors and memory
  - Quantum computing
  - Neuromorphic systems
- New materials and methods
- Software and standards for managing and processing massive data sets



We are committed to strengthening the regional innovation ecosystem

Focusing on high-technology clusters

- Leverage unique capabilities, research strengths, graduate education, and workforce development to create regional competitive advantage
  - Carbon fiber
  - Additive manufacturing
  - Automotive industry
  - Computing and data

Supporting startups

- Entrepreneurial leave, Innovation Crossroads, helping to attract venture capital

Engaging regional stakeholders

- Innov865, regional and state economic development organizations
- UT, TVA, area industry
- ORNL Chattanooga Office

Positioning our region as a mini-Route 128 or Research Triangle

Periodic Table of the Elements

117
Ts
Tennessine

1 IA 1A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 VIII 8	10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbo 12.01	7 N	8 O	9 F	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silico 28.08				18 Ar rgon 9.948
19 K Potassium 39.098	20 Ca Calcium 40.078						26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germar 72.63				36 Kr ypton 3.798
37 Rb Rubidium 85.468	38 Sr Strontium 87.62						44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.7				54 Xe enon 1.294
55 Cs Cesium 132.905	56 Ba Barium 137.328	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.085	79 Au Gold 196.967	80 Hg Mercury 200.592	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [278]	110 Ds Darmstadtium [281]	111 Rg Roentgenium [280]	112 Cn Copernicium [285]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [289]	116 Lv Livermorium [293]	117 Ts Tennessine [294]	118 Og Oganesson [294]

Lanthanide Series	57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.243	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.055	71 Lu Lutetium 174.967
Actinide Series	89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]

Discussion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