



ANNUAL REPORT

2016

## Message from the Acting Director:



Nearly twelve years after it was outlined as a concept in 2005, CAES has proved itself a model of collaboration between a national laboratory and regional independent research institutions. In 2016, CAES continued its emphasis on research that enhances industry competitiveness and helps regional stakeholders address emerging energy and environment challenges.

Increasingly, there is a growing awareness that advancing energy solutions includes addressing impacts on water resources. In July 2016, CAES hosted an energy-water nexus workshop with industry representatives that focused on building sustainable energy-water strategies, along with identifying associated research and development needs. Follow-up activities are planned for 2017.

In the field of data sciences, Dr. James Money is refreshing the CAES Applied Visualization Laboratory. Researchers now have at their disposal a suite of open source data science software tools giving them the ability to analyze massive amounts of data. Immersive environments such as the Computer-Assisted Virtual Environment (CAVE) and new augmented and virtual reality systems provide ideal verification and validation environments for data science and analytics.

With the addition of a second Temporal Analysis of Products (TAP) Reactor and “user portal” funding from the Department of Energy’s (DOE) Advanced Manufacturing Office, Dr. Rebecca Fushimi and her team of researchers are set to provide scientists from industry and academia vital insights into shale gas utilization and ammonia synthesis, two of the most energy-intensive processes in the manufacture of platform chemicals.

In May 2016, DOE held a summit with key stakeholders on improving the economics of the current U.S. operating nuclear power plants and the unintended

consequences that could arise from early closures. Through the CAES-led Energy Systems Strategic Assessment Institute (ESSAI), CAES personnel compiled the summit report and provided deeper insight into potential actions that could be taken to address the situation. In addition, a second analysis was carried out on economic and market challenges of the U.S. commercial nuclear fleet in Illinois and New York.

Moving forward, CAES remains committed to fostering world-class capabilities, empowering the region’s best researchers, educating and inspiring new cohorts of energy scientists, and giving industry the tools for competing successfully in an increasingly competitive world.

Sincerely,

A handwritten signature in black ink, appearing to read "Michael Hagood". The signature is fluid and cursive, written over a white background.

Michael Hagood  
Acting Director, Center for  
Advanced Energy Studies

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ON THE COVER: “SILVER WIRES WITH IODINE CONDENSATE” IS A DIGITALLY RECOLORED IMAGE OF SILVER IODIDE/SILVER WOOL CAPTURED BY A SCANNING ELECTRON MICROSCOPE (SEM). THE IMAGE WAS A THIRD PLACE WINNER IN THE CAES ALTERNATIVE ENERGY CONTEST. SEE PAGES 9 AND 24 FOR MORE DETAILS.

## FY 2016 | By the Numbers

### INVESTMENTS

**\$3M**

STATE OF IDAHO INVESTMENT IN CAES

**\$1.6M**

UNIVERSITY OF WYOMING INVESTMENT IN CAES OPERATIONS AND INFRASTRUCTURE

**\$33.4M**

RESEARCH PROGRAM AND OTHER FUNDING FOR CAES INCLUDING LABORATORY DIRECTED RESEARCH AND DEVELOPMENT FUNDING AND RESEARCH GRANT AWARDS FROM DOE, NSF, NRC, AND PRIVATE INDUSTRY, INCLUDING:

**\$2.4M**

NUCLEAR ENERGY UNIVERSITY PROGRAMS (NEUP) FUNDING

**\$7.2M**

IDAHO NATIONAL LABORATORY INVESTMENT IN CAES INFRASTRUCTURE, OPERATIONS AND RESEARCH, INCLUDING:

**\$458,789**

CAES JOINT APPOINTMENTS

**\$600,000**

LABORATORY DIRECTED RESEARCH AND DEVELOPMENT PROJECTS

### OUTREACH

**2,734**

VISITORS EXPERIENCED THE CAES COMPUTER-ASSISTED VIRTUAL ENVIRONMENT (CAVE) 3-D DATA IMMERSION RESEARCH ENVIRONMENT

**214**

CAES PRESENTATIONS, PUBLICATIONS AND PROCEEDINGS

**92**

EVENTS HOSTED IN THE CAES IDAHO FALLS FACILITY

### STUDENT IMPACT

**61**

STUDENTS FROM THE CAES PARTNER UNIVERSITIES INTERNEED AT INL IN AREAS INCLUDING NUCLEAR ENGINEERING, BIOLOGICAL SCIENCES, COMPUTER SCIENCE AND MECHANICAL ENGINEERING, PLUS:

**11**

STUDENTS WORKED AT CAES THROUGH THE CENTER FOR SPACE NUCLEAR RESEARCH SUMMER FELLOWS PROGRAM

**6**

STUDENTS HAD A CAES INTERNSHIP AT BOISE STATE UNIVERSITY

**4**

STUDENTS INTERNEED AT CAES THROUGH UI-IF'S KOREA WEST EXCHANGE PROGRAM

**1**

STUDENT HAD A CAES INTERNSHIP AT UNIVERSITY OF WYOMING (UW)

**7**

STUDENTS HAD CAES GRADUATE ASSISTANTSHIPS AT UW



## Regional Leadership

CAES is in a prime position to provide insight into the challenges and opportunities distinct to a region where the energy picture is in a state of constant change. The Intermountain West is rich in energy resources, with a unique transmission and transportation infrastructure. In 2016, CAES took a leading role in facilitating stakeholder engagement with energy-related summits and events, participation in regional projects, and interaction with industry and trade associations.

### Industry Water-Energy Workshop 2016

In July, CAES hosted its first Industry Water-Energy Workshop, welcoming speakers from INL, the University of Wyoming, the University of Idaho and trade groups like the Northwest Food Processors Association. Industry participants included representatives from 26 companies including Intel Corp., J.R. Simplot Co., Inland Empire Paper Co. and PacifiCorp. Following a 2013 directive from the U.S. Department of Energy (DOE) to address challenges related to the energy-water nexus, CAES was able to establish its brand with regionally relevant industries, offering information and education, and receiving detailed accounts from industry of the challenges they face. The workshop met a primary goal for CAES to provide regional leadership for DOE, working with industry to speed up clean energy innovation. Industry leaders made it clear that clean energy can increase competitiveness and that clean energy is not only about reducing greenhouse gas emissions but also reducing impacts on water resources.



### Energy Policy Research Conference (EPRC6)

The 2016 Energy Policy Research Conference (EPRC6), hosted by the Energy Policy Institute at Boise State University, was held Sept. 8 and 9 in Santa Fe, New Mexico. The keynote speaker was Curt Hébert Jr. former chairman of the Federal Energy Regulatory Commission and executive vice president of Entergy, who spoke about cybersecurity, utilities and the role of regulation. Participants in the conference came from national laboratories; federal, state and local governments; industry; nongovernmental organizations; and 25 universities. Overall, there were 100 attendees, 20 panels and 67 presentations. Select papers from the conference were published in a symposium issue of *The Electricity Journal* (October 2016).

EPRC6 BY THE NUMBERS:

100

ATTENDEES

20

PANELS

67

PRESENTATIONS

### PBS 'NOVA' films at CAES

CAES found itself “ready for prime time” in December 2015 when a team from PBS’s science program NOVA came to CAES to film an interview with Idaho National Laboratory scientist Shannon Bragg-Sittton. Bragg-Sittton discussed the potential of hybrid energy systems – light water reactors transitioning to advanced reactor technology – to address climate change, highlighting research into materials and advanced nuclear fuels. Filming took place in the CAES gallery and the Computer-Assisted Virtual Environment (CAVE) (at right). The program aired Jan. 11, 2017.



### TEDxIdahoFalls

CAES researcher Rob Podgorney presented a TEDx talk at the TEDxIdahoFalls event held in April. His presentation, “We’re Sitting on the Sun,” highlighted the tremendous energy potential enhanced geothermal systems can provide. Eleven other speakers presented on a wide array of topics. TEDxIdahoFalls is affiliated with the worldwide TED (Technology, Entertainment and Design) Talks, but organized on a local level. In addition to the main speaking event, participants took part in TEDucation Tours, including two tours of CAES.

RON PODGORNEY PRESENTING  
A TEDX TALK ON GEOTHERMAL  
ENERGY. (PHOTO CREDIT: PAUL  
ALLEN)



## Meetings and Workshops

In FY 2016 CAES hosted, sponsored or participated in more than 40 meetings that attracted researchers from the region and beyond:

- 2015 Landscape Discussion on Energy Law & Policy in the Rockies
- 2nd Snake River Geothermal Conference: Reservoir Creation in Igneous Rocks
- 4th Annual Collaboration for Advanced Research on Accident Tolerant Fuel (CARAT)
- 6th Annual Energy Policy Research Conference (EPRC6)
- Advances in Structural and Chemical Imaging Workshop
- Bay Area Maker Faire 2016
- Campbell Scientific Instrumentation & Measurement Tools presentation
- Carbon Conversion Working Meeting
- Chemical Separations: Functional Nanomaterials for the Selective Separation of Targeted Species Seminar
- Economic Viability of Small Modular Reactors Seminar
- Economics of Climate Change Response Policies Seminar
- Fuel Cells and Clean Energy Economy Seminar
- Fracture Networks Seminar
- Geothermal Resources Located at the Boundaries of Tectonic Provinces – The Paisley Geothermal System and Camas Prairie System(s) Seminar
- Energy Connected 2016
- Industry Water-Energy Workshop
- Institute of Electrical and Electronics Engineers CAES Expo
- Intermountain Energy Summit
- International Advanced Coal Technologies Conference
- International Conference on Future Technologies for Wind Energy – WindTech 2015
- Climate Change: Investment and Strategic Decisions Seminar
- Lab-Corps Lunch & Learn
- Modeling and Optimization of a Concentrated Solar Supercritical CO2 Power Plant
- NSF-Sponsored Resilience Workshop
- Performance of Biosensors Modified with Polymers, Nanoparticles, and Biomolecules Presentation
- Power Systems Working Group Meeting
- Potential and Challenges of Engineered Geothermal Systems Using Multi-stage Seminar
- The Nuclear Promise: 1954-2016 Seminar
- Consortium for Interface Reaction & Catalyst Engineering (CIRCE) meeting
- Some Like It Hot: Mass and Heat Transfer in the Yellowstone Caldera Seminar



REBECCA FUSHIMI PRESENTS AT THE CONSORTIUM FOR INTERFACE REACTION AND CATALYST ENGINEERING (CIRCE) MEETING HELD AT CAES IN MARCH.

- Symposium on Alloys and Compounds for Thermoelectric and Solar Cell Applications IV
- Symposium on Materials and Processes for CO2 Capture, Conversion and Sequestration
- TAP Reactor System for Materials Characterization Seminar
- The Preston Geothermal Prospect: Re-examining a Previously Studied Geothermal System Seminar
- The Role of Fracture Fluid in Hydraulic Fracture Manipulation in Complex Highly Heterogeneous Formation Seminar
- TopFuel 2016
- Topographic Stress Controls on Bedrock Weathering Revealed by Geophysical Imaging Seminar
- Two-dimensional Electrical Resistivity Structure of the Eastern Snake River Plain: New Insights from Old Data Seminar
- University of Idaho Engineering & Design EXPO 2016
- Produced Waters Collaborative Workshop
- Rural Water Association of Utah Water & Energy Nexus Forum
- Water Repellent Materials and Beyond Seminar
- Wyoming Unmanned Aerial Vehicles (UAV) Symposium

## 2016 CAES Steering Committee

Kelly J. Beierschmitt (chair)  
Idaho National Laboratory  
deputy laboratory director for  
Science & Technology and chief  
research officer



Steven Aumeier (through  
October 2016)  
Idaho National Laboratory  
Former CAES director



William A. Gern  
University of Wyoming  
vice president for Research and  
Economic Development



Janet Nelson  
University of Idaho  
vice president for Research and  
Economic Development



Mark Rudin  
Boise State University  
vice president for Research and  
Economic Development



Cornelis J. (Neels) Van der Schyf  
Idaho State University  
vice president for Research and  
dean of the Graduate School





## People: Appointments, Awards and Accomplishments



UNIVERSITY OF IDAHO ASSISTANT PROFESSOR DR. JULIET CARLISLE (CENTER), WINNER OF THE 2016 ENERGY POLICY INSTITUTE ASSOCIATE OF THE YEAR AWARD, PICTURED WITH BOB SMITH, BRIAN ELLISON AND ANDY KERSTEN (LEFT TO RIGHT).

**Timothy Behrends**, Idaho State University, won an NRC graduate fellowship, January 2016 to May 2017.

**Dr. Juliet Carlisle**, University of Idaho, was named 2016 CAES Energy Policy Institute Research Affiliate of the Year.

**Dr. Indrajit Charit**, University of Idaho, received the UI Presidential Mid-Career Award.

**Andres Correa**, an undergraduate student at Boise State University, received an Integrated NSF Support Promoting Interdisciplinary Research and Education (INSPIRE) Award and a National Institute of Standards and Technology Summer Undergraduate Research Fellowship.

**Aline Elquist**, an undergraduate student at Boise State University, received a National Institute

of Standards and Technology Summer Undergraduate Research Fellowship.

**Dr. Dario Grana**, University of Wyoming, received the J. Clarence Karcher Award, given in recognition of significant contributions to the science and technology of exploration geophysics by a young geophysicist.

**Jon Huff**, an undergraduate student at Boise State University, received a National Institute of Standards and Technology Summer Undergraduate Research Fellowship.

**Leslie M. Kerby**, Ph.D., M.B.A., Idaho State University, was elected director of the Idaho Section of the American Nuclear Society (IANS).

**Rajiv Khadka**, a Ph.D. student at the University of Wyoming studying computer science, was the INL Intern Poster Session winner for the "Enabling INL Business and Support Operations" category. The title of his poster was "Remote Heterogeneous Collaborative Virtual Environments."

**Jay F. Kunze**, Idaho State University, was named an associate editor of the *Journal of Nuclear Engineering and Radiation Science* (ASME Nuclear Engineering Division).

**Matthew Lawson**, a student at Boise State University, received BSU's Student Research Program Fellowship.



**Donald M. McEligot**, University of Idaho, was named a USA Designee to the IAEA Technical Meeting on Heat Transfer, Thermal Hydraulics and System Design for Supercritical Water Cooled Reactors, Sheffield, U.K., August 2016.

**Cody Muchmore**, Idaho State University, won an NRC graduate fellowship award for 2016-2018 master's graduate studies.

**Quin Miller**, a Ph.D. candidate at University of Wyoming and a CAES graduate assistant, was the recipient of three grants to support his dissertation research: the 2016 Robert C. Reynolds Jr. Research Award given by the Clay Minerals Society, a student research scholarship from the

Unconventional Reservoir Special Interest Group of The Society of Petrophysicists and Well Log Analysts, and the 2016 Spackman Award from the Society for Organic Petrology.

**Larinda Nichols**, Idaho State University, won an NRC graduate fellowship award for 2016-2018 master's graduate studies.

**Emerald D. Ryan**, Idaho State University, won the ISU College of Science and Engineering Outstanding Student Award.

**Jordan Vandegrift**, Boise State University, received the Materials Science Outstanding Junior Award from the Micron School of Materials Science & Engineering.

**Jennifer Watkins**, Boise State University, received the Materials Science Undergraduate Distinguished Achievement Award from the Micron School of Materials Science & Engineering.

**Kayla Yano**, Boise State University, won the Best Student Poster Award at the American Nuclear Society in New Orleans.

The following Idaho State University students received NRC undergraduate scholarships during Fiscal Year 2016: **Brian Anderson, Matthew Beatty, Gerrit Brughaug, Ben Johnson, Chase Juneau, Sterling Morrill, Cody Muchmore, Larinda Nichols, Paul Pierson.**

## CAES ARternative Energy Contest Winners

See page 24 for more details about the contest

### First Place

#### **Biomass in Blue** *(pictured at right)*

Lisa McDougall – ISU,  
Dr. Allison Ray – INL

### Tidal Wave

Dr. Joshua Kane,  
Tammy Trowbridge – INL

### A Virtual Peek Beneath Wyoming

Nick Jones, Emma-Jane  
Alexander – UW

### The World of Uranium

Dr. Darryl P. Butt, Dr. Brian Jaques,  
Kelci Lester – BSU

### Second Place

#### **Fiber Optic**

David Chichester,  
Chris Morgan – INL

#### **Microscopy of a Precursor**

Jacqueline Hodge – BSU

### Zygnema

Lisa McDougall – ISU

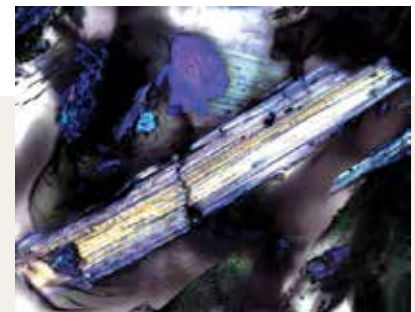
### Third Place

#### **Corn Stover Streaks**

Dr. Allison Ray – INL,  
Lisa McDougall – ISU

#### **Formation of Framboids**

Dr. Darryl P. Butt, Dr. Brian Jaques,  
Kelci Lester – BSU



### Silver Wires with Iodine Condensate

Mary Adamic, Dr. Matt Watrous,  
Tammy Trowbridge – INL

### Fourth Place

#### **End View of ATR Fuel Element**

Dr. Sean O'Kelly, Jeff Brower – INL

### Fireworks

Jatuporn Burns – BSU

#### **Laminar, Transition, and Turbulent Flow in a Nuclear Reactor Channel**

Dr. Brian Williams, Dr. Donald  
McEligot, Dr. Glenn McCreery – ISU

## People: New Research Staff

### Dr. Richard Christensen

Director of Nuclear Engineering,  
University of Idaho

In fall 2015, CAES welcomed Dr. Richard Christensen as the new director of Nuclear Engineering for University of Idaho. Prior to this position, he spent several years at the Ohio State University, first as a professor and for 13 years as a professor emeritus. Christensen has an extensive background in teaching, research, program management and mentoring. He is an internationally recognized scholar and leader in a wide range of nuclear and thermal sciences research areas. His research spans diverse areas such as nuclear thermal-hydraulics, nuclear waste isolation, advanced reactor concepts with a focus on inherently safe nuclear reactors, thermally activated heat pumps, waste heat recovery, and a variety of fundamental convective and radiative heat transfer investigations. He received his doctorate in nuclear engineering from Stanford University.



### Dr. Michael Haney

Assistant Professor,  
Department of Computer Science,  
University of Idaho

Dr. Michael Haney came to the University of Idaho-Idaho Falls campus and CAES in 2015 as an assistant professor in the Department of Computer Science. He holds a doctorate in computer science from the University of Tulsa. Before that, his career encompassed 15 years in the private sector, designing, implementing and managing information assurance programs for SMB and Fortune 500 consulting clients. Haney's research interests are in data visualization, specifically visualizing available network and log data to improve intrusion detection and response for large-scale networks. He studies cyber-security issues of energy assurance, supporting a more resilient "smart" infrastructure, with a focus on "honeypot" research. He also studies cryptography, specifically novel applications of advanced cryptographic techniques to support privacy on the internet.



### Dr. Leslie Kerby

Assistant Professor, Nuclear  
Engineering & Health Physics,  
Idaho State University

In December 2015, CAES welcomed Dr. Leslie Kerby, an assistant professor in nuclear engineering and health physics for Idaho State University and an INL joint appointee. Her research lies in the computational nuclear science field, and focuses on Monte Carlo methods and applications, particularly with respect to reactor physics and coupling with deterministic codes. Kerby has collaborations on funded projects with a variety of national laboratories and universities, including Idaho National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, and Massachusetts Institute of Technology. She earned her master's and doctorate degrees in nuclear engineering from University of Idaho. She holds a master's in Business Administration from University of Wisconsin-Whitewater and a bachelor's in physics from Brigham Young University.



### **Dr. James H. Money**

Applied Visualization Laboratory Lead, Idaho National Laboratory

Dr. James Money came to CAES in May 2016 to become the Applied Visualization Laboratory lead. He has more than 20 years of industrial and academic experience in numerical methods, differential equations, image processing, immersive visualization, and software engineering. Before joining INL, he led multiple efforts in the modeling and simulation community, to bridge 30-year-old solutions to leading edge products both in the areas of computations and visualization. He led the first U.S. Department of Defense initiative to provide in-situ or live data sets inside a Cave Automatic Virtual Environment (CAVE), which also incorporated touch displays, mobile devices and large format video. He has worked extensively in geospatial technologies, including seven years at the National Geospatial-Intelligence Agency (NGA), and several other intelligence agencies. Money earned his doctorate and master's degrees in mathematics

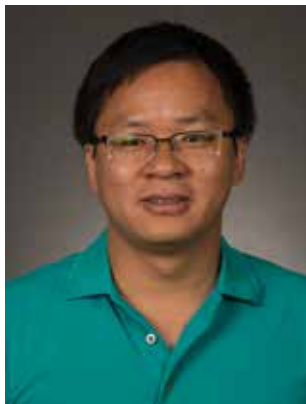


from the University of Kentucky, and his bachelor's degree in computer science from James Madison University.

### **Dr. Haiming Wen**

Research Assistant Professor, Nuclear Engineering and Health Physics, Idaho State University

Dr. Haiming Wen came to CAES in January 2016 as a research assistant professor at Idaho State University and on a joint appointment with INL as a staff scientist. Before joining CAES, he was a postdoctoral researcher at INL. Wen received his doctorate from University of California, Davis in Materials Science and Engineering. His research interests include nuclear fuels and structural materials designed for current and next-generation nuclear reactors. He has studied irradiation effects in materials, development, fabrication, microstructure characterization, mechanical behavior and deformation mechanisms of bulk nanostructured metals, alloys and composites with dramatically higher strength and irradiation



resistance than conventional coarse-grained counterparts, and application of these materials as nuclear structural materials and fuel cladding.

“This is a great time for CAES. In 2016, we brought in tremendous new talent and are delighted to see the innovative research that has resulted. During the coming year we’re continuing to fill vacant positions with motivated, talented faculty and staff who have the skills needed to build our existing and new programs and train students.”

–Dr. Tom Wood, University of Idaho  
CAES Associate Director

## Research with Impact

### LDRD Highlight: Transforming How the Nation Uses Coal

Researchers from INL and University of Wyoming are working on a CAES Laboratory Directed Research & Development (LDRD) project called “Development of Direct Carbon Fuel Cells.” The project aims to fundamentally change the coal industry paradigm from combustion to electrochemical oxidation so that carbon – derived from coal, biomass or biowastes – can be used as a clean energy source. Transformative Direct Carbon Fuel Cell (DCFC) technologies could accelerate this transformation while producing a number of high-value chemicals. The project focuses on developing fast ionic conductors and novel catalysts for carbon electrochemical oxidation. A steam pyrolysis process will also be developed to convert coal to fuel-cell-grade carbon.

### LDRD Highlight: Quantifying Fracture Behavior in Irradiated Alloys

Metallic alloys are widely used as structural and protective cladding materials in current and future nuclear reactors. Under irradiation, cohesion strength at grain boundaries (where individual crystals meet) decreases due to interaction with defects and impurities, leading to intergranular fracture and embrittlement of alloys. A CAES Laboratory Directed Research & Development (LDRD) project led by Chao Jiang of INL is developing a technique to quantify grain boundary cohesion and its impact on fracture behavior in irradiated alloys. Investigators are using multiscale modeling in concert with transmission electron microscopic (TEM) in situ cantilever testing, a novel approach for studying the real-time mechanical response of materials. This work involves four CAES institutions - INL, BSU, UI and UW - and is helping strengthen the science and technology development in Idaho and Wyoming.

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A VISITING RESEARCHER FROM UNIVERSITY OF ILLINOIS WORKS ON THE CAES TEM.





## DOE awards money for rare earth mineral assessment

The U.S. Department of Energy announced in June that University of Wyoming, Idaho National Laboratory and the U.S. Geological Survey had been chosen to receive up to \$4 million to assess rare earth minerals and other critical materials that may be dissolved in high-temperature fluids associated with energy extraction. The project aims to develop a database of rare earth elements and trace metals from oil- and gas-produced waters from some of the nation's most prolific

hydrocarbon basins; identify similar oil and gas reservoirs; and create a mathematical screening tool to test national geochemical databases.

Rare earth elements are a series of chemical elements found in Earth's crust and dissolved in water. Due to their unique chemical properties, they have become essential components of many technologies, including electronics, computer and communication systems, transportation, health care, and national defense. The demand and cost of rare earth elements have

grown significantly over recent years, stimulating an emphasis on economically feasible approaches for their recovery.

UW has been a member of the CAES consortium since October 2014. In addition to the federal grant, the Wyoming Legislature has appropriated funding for research into rare earth elements.

“This is a big award that really supports the importance of these regional associations – in particular, UW’s with INL. It wouldn’t be possible otherwise.”

- Dr. Don Roth, University of Wyoming CAES Associate Director

## CAES RECEIVES NEUP R&D AWARDS, INFRASTRUCTURE GRANTS

CAES received significant support from the U.S. Department of Energy in 2016 with the announcement of more than \$2.4 million in energy research and development awards and infrastructure grants, part of \$35.5 million awarded by Nuclear Energy University Programs (NEUP).

### FY 2016 R&D

A Science Based Approach for Selecting Dopants in FCCI-Resistant Metallic Fuel Systems (University of Idaho, \$800,000)

Advanced Electrochemical Separations of Actinide/Fission Products via the Control of Nucleation and Growth of Electrodeposits (University of Idaho, \$350,000)

### FY 2016 Nuclear Energy Enabling

Effects of High Dose on Laser Welded, Irradiated AISI 304SS (Boise State University, \$500,000)

Enhancing Irradiation Tolerance of Steels via Nanostructuring by Innovative Manufacturing Techniques (Idaho State University, \$500,000)

### FY 2016 Infrastructure

Boise State University received \$250,000 for an aerosol jet printer to establish additive manufacturing capability to make functional materials and sensor devices for nuclear energy applications.

Idaho State University received \$80,805 to replace the BF3 detectors in the AGN-1 Reactor with modern B-10 lined detectors.

## AVISTA, CAES study water-energy in food processing

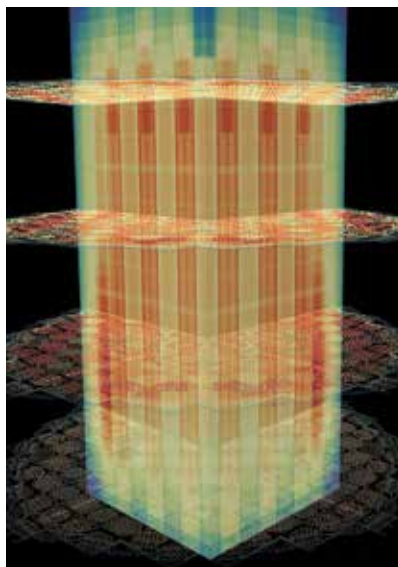
With support from Avista Corp., a Spokane-based utility, CAES researchers are studying how Idaho food processing companies can reduce their energy and water use. Avista awarded a grant to the research team for a one-year project to evaluate one or two North Idaho food processing companies' plants. The research has focused on one company's operations, Litehouse Foods in Sandpoint, doing data modeling

assessments of the refrigeration and air conditioning systems that have evolved at the company's three plants. With mentoring from INL researchers, the UI researchers are creating an in-depth model of the plant's energy and water use, focusing on elements such as heat transfer and fluid flow to identify how the company might introduce new technology or techniques to conserve water and energy. The resulting study will offer opportunities for rebates and energy-efficiency incentives from Avista. The project is expected to

lead to benefits for other Avista customers and Northwest food processing companies interested in analyzing and improving their own facilities. Project leader Richard Christensen of University of Idaho (UI) is an expert in heat transfer; co-leader Karen Humes is a Moscow-based UI geography professor in the College of Science, who studies hydrology and renewable energy; and project collaborator Dennis Keiser is a faculty member in the UI-Idaho Falls technology management program.

**“The Avista project is a CAES collaboration between INL, the University of Idaho and regional food industries to join forces to improve energy-water usage.”**

*– Michael McKellar, INL senior research*



A COMPUTER VISUALIZATION OF THE POWER IN A NUCLEAR REACTOR USING SHIFT.

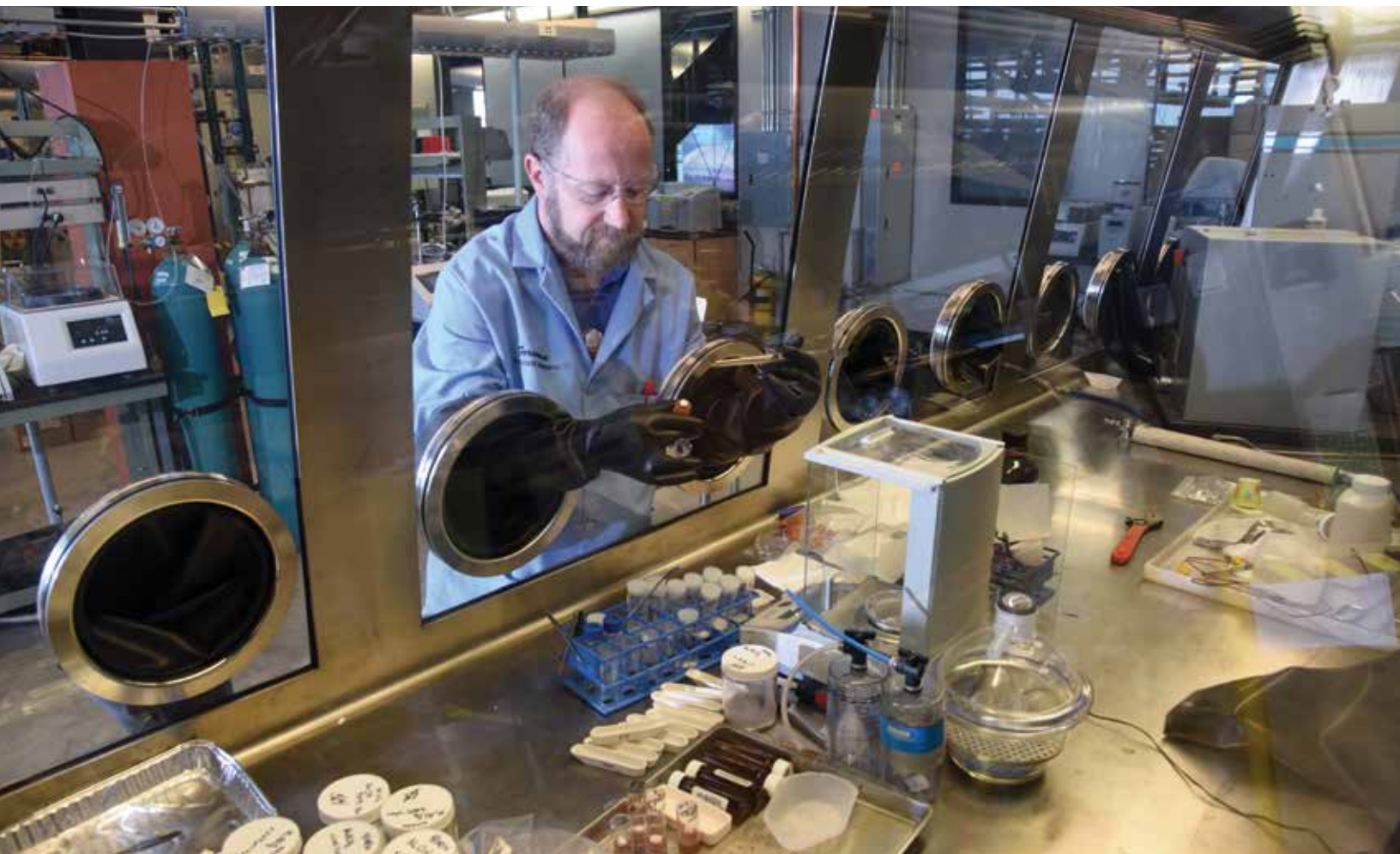
## ISU, INL take part in DOE Exascale Small Modular Reactor modeling, simulation

CAES members ISU and INL are collaborating with Oak Ridge National Laboratory, Argonne National Laboratory and Massachusetts Institute of Technology on one of 15 projects funded through the U.S. Department of Energy's Exascale Computing Project, which in September announced a \$39.8 million initiative directed toward advanced modeling and simulation solutions. Exascale refers to high-performance computing systems capable of at least one billion calculations per second, 50 to 100 times faster than the most powerful computers being used in the United States. These new systems will be the “next-generation” supercomputers and have yet to be built. The Exascale projects are in support of DOE missions in science, clean energy and national security. Dr. Leslie Kerby of Idaho State University is on the team studying Coupled Monte Carlo Neutronics and Fluid Flow Simulation of Small Modular Reactors. This project is aimed at providing multicycle operational design parameters and benchmarks for small modular reactors by 2025. Small modular reactors offer the prospect of affordable electricity production while avoiding some of the traditional limitations that encumber large reactor designs, such as high capital costs and long construction timelines. The majority of the team's effort will be toward optimization of algorithms for exascale performance, but the team will also look at numerics and model development to efficiently enable the fully coupled physics.

### **BSU and INL work with Fluor on testing and analysis**

CAES is assisting Fluor Idaho in establishing operating strategies and control boundaries for the Idaho Integrated Waste Treatment Unit (IWTU) at the Department of Energy's Idaho Site through small-scale testing and engineering analyses. These studies and tests are critical to understanding the chemical reactions and fluid-mechanic conditions occurring in the Denitration and Mineralization Reformer (DMR), IWTU's main reaction vessel. Bryan Forsmann of Boise State University was approached by INL's Nick Soelberg to set up processes that would answer questions about IWTU chemical processes, bed stability and wall deposits. Using equipment in the CAES Advanced Materials Laboratory, Forsmann fabricated apparatus that allowed for analysis of IWTU samples to identify reaction pathways and how pathways might influence the DMR process (equilibrium, kinetics) or how DMR conditions might influence the reactions (mass transfer, presence of key reactants). The work will continue and is likely to be expanded to a larger scale, possibly in CAES's Radiochemistry Laboratory.

BRYAN FORSMANN WORKS ON THE IWTU PROJECT IN THE CAES ADVANCED MATERIALS LABORATORY.





## Operating Safely and Effectively

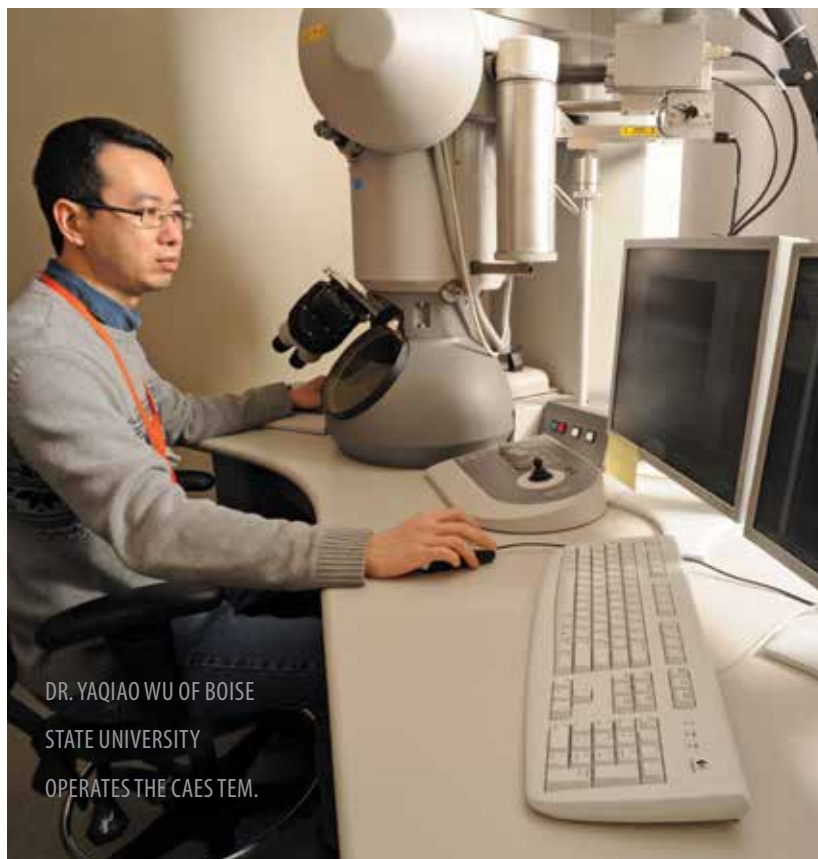
### Operations

In 2016 the CAES consortium took several steps to enhance the safety, quality and performance of laboratory operations. The CAES Safety Committee was reorganized to be comprised of laboratory operations leaders from multiple CAES member institutions and chaired by the CAES Safety Officer. The committee's first major task in 2016 was the development of a more automated review and tracking process for project approval, aimed at improving access to technical subject matter experts and mentors, and increasing process efficiency. In addition, the Safety Committee has initiated a voluntary CAES Safety Education Certificate program for students, the goal of which is to reward students who demonstrate laboratory safety and work control leadership. A CAES Facility Plan was developed for managing equipment and laboratory utilization. The plan is quickly showing results, as equipment and projects have begun to move within CAES to accommodate near- and long-term strategic priorities and program growth.

## New Capabilities & Equipment

### Transmission Electron Microscope Upgrades: ASTAR V2.0 and TopSpin Strain-Mapping

Two new upgrades were added to the transmission electron microscope (TEM) located in the CAES Microscopy and Characterization Suite. The new ASTAR system allows the TEM to provide grain orientation information of nano-sized grains. The TopSpin Strain-Mapping module is a software shell for the ASTAR system that provides a user-friendly interface and adds functions such as strain mapping of a sample. These tools are useful in analyzing defects and impacts of materials that result from mechanical testing or irradiation processes.



DR. YAQIAO WU OF BOISE  
STATE UNIVERSITY  
OPERATES THE CAES TEM.

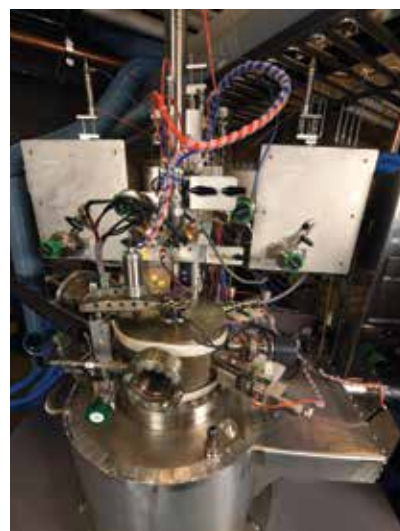
### Thermo Scientific iPCM 12A

A new Thermo Scientific iPCM 12A Personnel Contamination Monitor was installed in the CAES Radiochemistry Laboratory in August 2016. Using 21 detectors to monitor body, hands and feet, it provides excellent alpha and low-energy beta detection. Detectors are split into four zones to minimize background interference and achieve high detection limits to allow personnel to be monitored and cleared quickly.



## Temporal Analysis of Products (TAP) Reactor System for Materials Characterization

A refurbished Temporal Analysis of Products – or TAP – reactor system arrived at CAES in September. This is the second TAP in CAES. It was procured from a corporate donor and refurbished by Mithra Technologies, an industry partner. CAES now has two of the three TAP reactors in the United States (the other one is at Harvard University). CAES researcher Dr. Rebecca Fushimi traveled to St. Louis to work with Mithra on refurbishing the system and participate in the final phases of testing and training. The TAP reactor system puts CAES in a unique position to interact with both industry and academia. TAP is primarily being used for catalyst development that benefits industrial processes such as shale gas utilization and ammonia synthesis, the top energy-consuming chemical processes. TAP systems have the ability to extract detailed kinetics on complex industrial materials. The same level of detail is presently only achieved through surface science experiments on well-defined single crystals. Using the TAP, researchers can take materials directly from industrial reactors and understand how both synthesis and process conditions impact the kinetic properties of the catalyst and its ability to coordinate a multistep reaction sequence.



OVERHEAD VIEW OF THE TAP REACTOR SYSTEM (ABOVE). RESEARCHERS USING THE TEMPORAL ANALYSIS OF PRODUCTS REACTOR SYSTEM IN CAES (LEFT).



### DID YOU KNOW?

IN 2016, MACS SUPPORTED THE WORK OF 59 CUSTOMERS FROM SEVEN DIFFERENT INDUSTRIAL COMPANIES, 13 UNIVERSITIES AND THREE NATIONAL LABS.

### Rigaku X-ray diffractometer

Located in the Department of Physics & Astronomy's Physical Sciences Building at the University of Wyoming, the X-ray diffractometer is used to determine crystal structures of crystalline materials, metals and alloys, minerals, organic and inorganic compounds, thin films, and nanoparticles. It is an indispensable tool for physicists, chemists, materials scientists, biological and pharmaceutical scientists and engineers to quickly characterize unknown materials. It is also widely used in fields such as geology, mineralogy, forensic science and archaeology.



### ESPEC BTL 433 Benchtop Humidity Chamber

Located in the Advanced Materials Laboratory at Boise State University, the ESPEC BTL 433 is a benchtop humidity chamber used to test health monitoring sensors for spent nuclear fuel storage canisters. The 4-cubic-foot chamber can produce temperatures from -20 °C to 180 °C and relative humidity ranging between 10 and 95 percent.

### Shielded Autoclave

CAES researchers continue to refine and develop a shielded autoclave located in the CAES Advanced Materials Laboratory. The autoclave is used for researching irradiation stress corrosion cracking (SCC) in samples. It can simulate coolant environments in nuclear reactor vessels to determine how they can be improved for safety and longevity.

RIGAKU X-RAY DIFFRACTOMETER AT UW (ABOVE). SHIELDED AUTOCLAVE IN THE CAES ADVANCED MATERIALS LABORATORY (RIGHT).

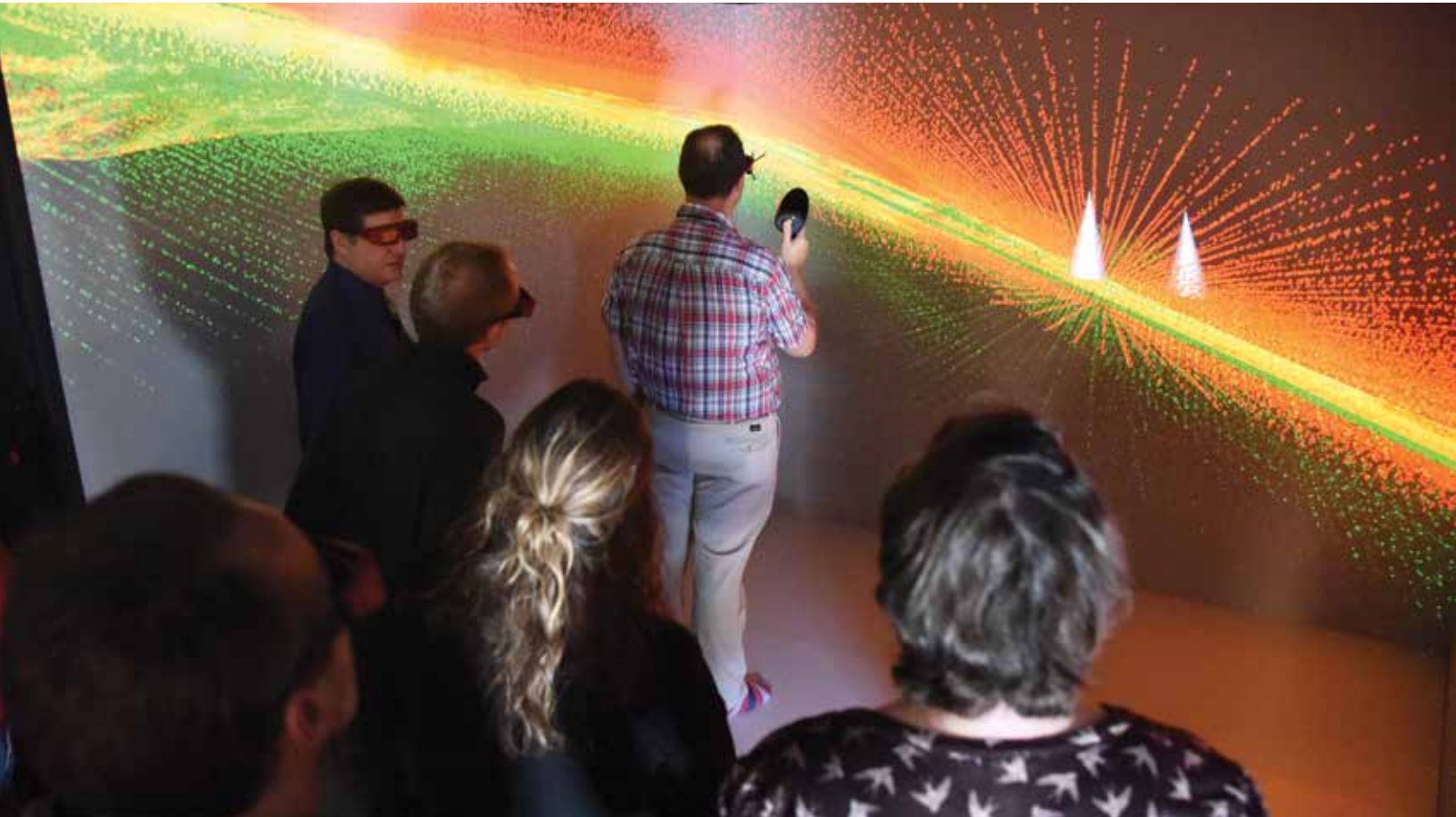


**6524**  
TOTAL NUMBER OF HOURS MACS  
WAS BOOKED IN 2016

**709**  
NUMBER OF HOURS MACS WAS  
BOOKED IN AUGUST 2016

## Applied Visualization Laboratory Upgrades

The Computer Assisted Virtual Environment (CAVE) at CAES was renamed the Applied Visualization Laboratory (AVL) in May 2016. Although the CAVE is still located inside the laboratory, the name change reflects an overall mission change, with more focus on applications, scientific exploration and data science.



### Computer-Assisted Virtual Environment (CAVE) Upgrades

A number of CAVE upgrades were completed including:

- Advanced Realtime Tracking (ART) TrackPack/E to replace the aging Intersense IS-900 tracking system. This new system provides better quality tracking and is more reliable.
- Video card upgrades to provide faster rendering and to enable larger data sets to be used in the CAVE.
- CAVE system upgrades to provide additional capacity on the system for analysis as well as provide a dedicated Windows-based system for researchers.

DR. JAMES MONEY RUNS A SIMULATION IN THE CAVE.



## New Virtual Reality Capabilities in the Applied Visualization Laboratory

### Stereo Wall/ IQ-Station System

A stereo wall, also known as a portable Inexpensive Interactive Immersive Interface Station (IQ-Station) was added and is used for testing and continued production-level work when the four-walled CAVE is unavailable.

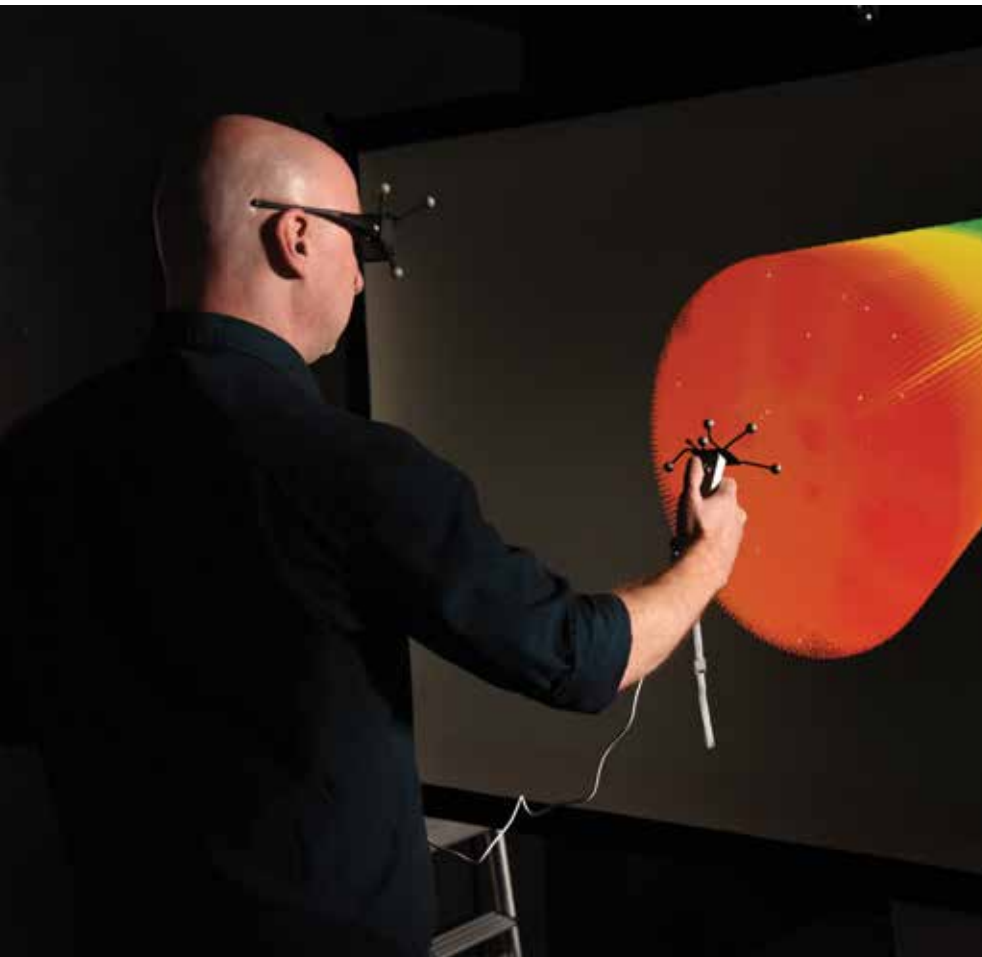
### HTC Vive Virtual Reality Headset

The HTC Vive virtual reality headset provides a much lower cost immersive experience for users who want to perform work in remote locations outside of the Applied Visualization Laboratory.

INL'S BEN BRETZ OPERATES THE STEREO WALL (LEFT). INL'S DR. JAMES MONEY USES THE HTC VIVE VR HEADSET AND WIRELESS CONTROLLERS (RIGHT).

### Content Development Workstation and Software

A new Windows-based content development workstation supports model manipulation, conversion and display. A suite of software supports these tasks.





### Smartphones and Samsung Gear Virtual Reality Headset

Smartphones coupled with Samsung Gear VR virtual reality headsets provide the functionality of the CAVE on a smaller scale and allow users to view and collect data from anywhere in the world.

### Furniture

New furniture was installed for use in day-to-day analytics by researchers and scientists. The new furniture allows for collaboration and meetings to take place in the AVL.

### Haptic and hand gesture systems

Several new haptic and hand control systems, in particular, the Leap Motion system and 5DT Data Gloves, were acquired to support the development of capabilities in the AVL in addition to hand input devices such as Wii-Motes and wand controls.

### Unity 3-D

Unity software is a professional 3-D engine for developing new content in AVL. This software also supports tablets, virtual reality headsets and many other platforms. This software enables cross-platform development and quicker deployment of solutions to various devices.



DR. JAMES MONEY DEMONSTRATES  
A TABLET VISUALIZATION.

## Education and Outreach

### Internships and Assistantships

Each year, internships and assistantships provide opportunities for the best and brightest students to further their education by working with world-class CAES scientists and engineers. Internships and assistantships are an opportunity for universities and Idaho National Laboratory to showcase capabilities and get new perspectives on research. Students learn how to solve real-world problems under the guidance of distinguished scientific and technical experts.

This year, 90 students had a CAES internship or assistantship or came from CAES partner universities and worked on Idaho National Laboratory projects.



## Student Impact:

**61** STUDENTS FROM THE CAES PARTNER UNIVERSITIES INTERNEED AT INL IN AREAS INCLUDING NUCLEAR ENGINEERING, BIOLOGICAL SCIENCES, COMPUTER SCIENCE AND MECHANICAL ENGINEERING.

**11** STUDENTS WORKED AT CAES THROUGH THE CENTER FOR SPACE NUCLEAR RESEARCH SUMMER FELLOWS PROGRAM

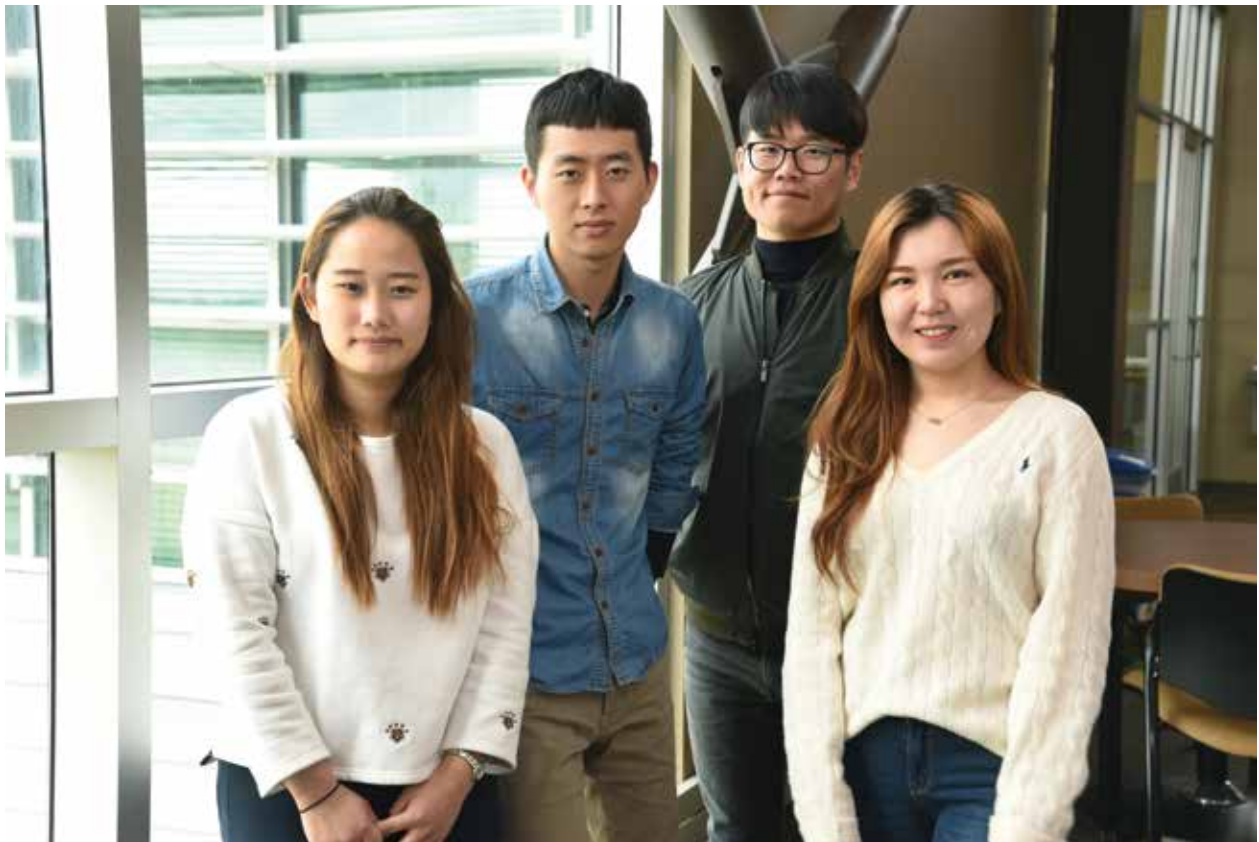
**4** STUDENTS INTERNEED AT CAES THROUGH UNIVERSITY OF IDAHO – IDAHO FALLS’ KOREA WEST EXCHANGE PROGRAM

**6** STUDENTS HAD A CAES INTERNSHIP AT BOISE STATE UNIVERSITY

**1** STUDENT HAD A CAES INTERNSHIP AT UNIVERSITY OF WYOMING (UW)

**7** STUDENTS HAD CAES GRADUATE ASSISTANTSHIPS AT UW

INTERNS IN THE UNIVERSITY OF IDAHO – IDAHO FALLS’ KOREA WEST EXCHANGE PROGRAM (FROM LEFT): KYOUNGHEE JEON, JAEMYUNJ LEE, SENNGJE OH AND YUMIN KWAK.



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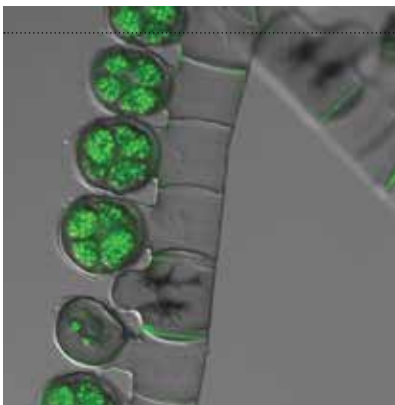
# \$7,500

TOTAL PRIZE MONEY AWARDED DURING  
THE CAES CO-SPONSORED GEOTHERMAL  
DESIGN CHALLENGE

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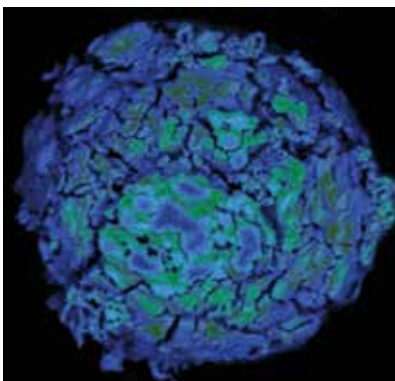
## CAES co-sponsors Geothermal Design Challenge 2016

CAES joined DOE's Geothermal Technologies Office and INL to sponsor the Geothermal Design Challenge 2016. More than 100 teams from across the United States, composed of two or three students each, participated, and winners were announced Aug. 10 at the Intermountain Energy Summit in Idaho Falls. The contest challenged high school and college students to design an infographic illustrating the value and potential of geothermal energy. A committee of engineers, energy experts and creative professionals judged entries, and three teams were chosen as official winners, receiving \$2,500 each.

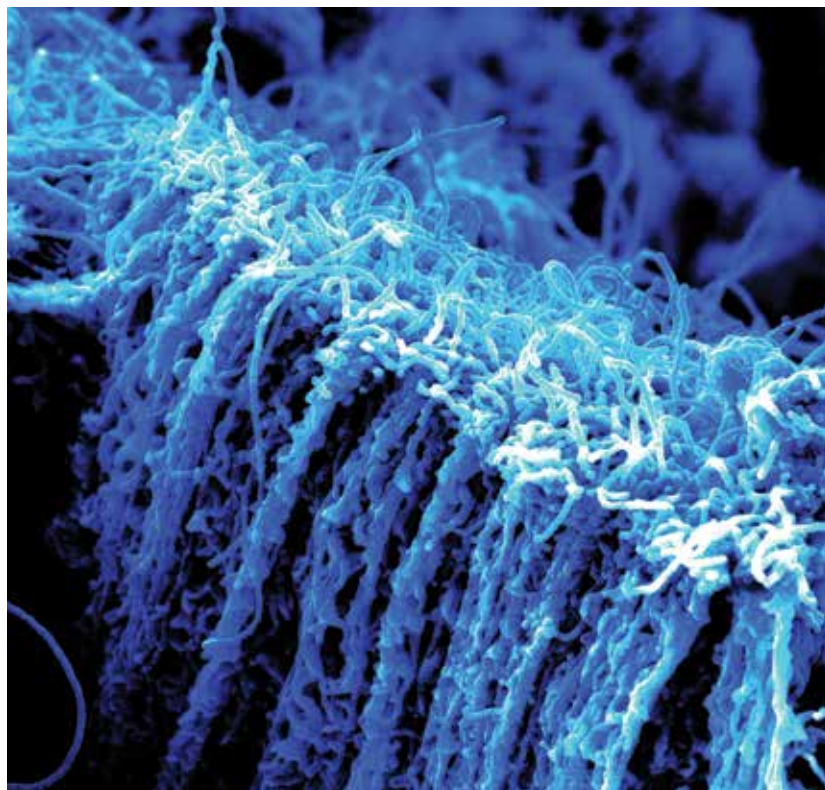


## ARTernative Energy Contest art on display

Student and faculty entries from all five CAES consortium members – INL, Boise State University, Idaho State University, University of Idaho and University of Wyoming – were announced in June as part of the CAES ARTernative Energy Contest. The images were produced in the course of energy-related scientific research and include everything from microscopic views of uranium nitride powder to auto-fluorescent laser-scanned corn stover to virtual reality immersion in Wyoming's geologic formations. More than 50 images were submitted, and the top entries from each CAES member institution were selected. Images are on display in the CAES building gallery and online at <https://artsci.inl.gov/SitePages/CAES%20ARTernative%20Energy%20Contest.aspx>.



ISU SECOND PLACE, ZYGNEMA (TOP); BSU  
FIRST PLACE, THE WORLD OF URANIUM  
(MIDDLE); AND INL FIRST PLACE, TIDAL WAVE  
(RIGHT).





## INL, UI develop course based on 'GridGame'

CAES members INL and University of Idaho jointly developed a new interdisciplinary course with INL research engineer Tim McJunkin's "GridGame" as its centerpiece. The GridGame is a desktop simulation that allows students to experience what it is like to manage a power grid in the face of adverse conditions as harsh as cyberterrorism. The multiplayer format allows participants to buy and sell power, add new generation sources, find new customers, and defend themselves from computer-based attacks. The course is to be added to UI's Fall 2017 catalogue as Resilient Control of Critical Infrastructure. Idaho State University and Boise State University are also considering adding the course, which is intended to provide insight on how industrial control systems work and how they can fail. Learn more or download the game at [gridgame.ironforidaho.net](http://gridgame.ironforidaho.net).

## CAES Graduate Assistantship Program

This year, University of Wyoming funded seven CAES graduate assistantships as part of its CAES Competitive Graduate Assistantship Program. The goal of the program is to catalyze interdisciplinary, cooperative energy research and academic programs, promote workforce development, and engage industry partners in transformational energy programs. A list of students and their research follows:

- Angela Benavides, a master's student in computer science, worked on a CAVE to CAVE project under Emma-Jane Alexander and Dr. Amy Banic.
- Rohini Ghosh, a second-year Ph.D. student in economics and finance, worked on developing a web-based, searchable Western Energy Corridor Resources Map under Dr. Rob Godby.
- Weibo Gong, a Ph.D. student in chemical engineering, researched syngas-to-diesel reactions under Dr. Maohon Fan.
- Chenggong Lu, a Ph.D. student in civil engineering, researched "Numerical Simulation of Desalination Process Using Lattice Boltzmann Method" under Dr. Gang Tan.
- Quin Miller, a Ph.D. student in geology and geophysics, researched chemistry and mineralogy of the Woodford Shale under Dr. John Kaszuba.
- Kaidi Sun, a Ph.D. student in chemical engineering, researched aromatization of methane under Dr. Maohon Fan.
- Kyle Walter, a master's student in civil engineering, researched "Thermal-Hydro-Mechanical Interaction for Geothermal Energy and Wellbore Stability Studies" under Dr. Kam Ng.

## Middle schoolers visit CAES, express appreciation

Middle schoolers from Bonneville School District 93 visited CAES on March 28 and learned about the Computer-Assisted Virtual Environment (CAVE), Heavy Vehicle Simulator, and how to engineer earthquake-resistant structures. Here are some excerpts from the thank you cards that came the next week (some spelling corrections have been made):

*"I am a girl who hates science, you surely made it sound fun!"*

—An Ammon 6th Grade Student

*"It was awesome, fun, and full of learning. I learned so much. But one thing that I loved is that learning can be fun."* —Porter

*"I learned that when you are building something that you never give up, you keep trying, and you always work together on engineering."* —Kilee

*"I learned to think outside the box, and how to make better structures. It was amazing!"* —Kate



## Advancing Industry Competitiveness

Today, Idaho's three universities – Boise State University, Idaho State University and the University of Idaho – and the University of Wyoming are allied with Idaho National Laboratory through the CAES consortium to offer a model of collaboration and engagement with the private sector on multiple fronts.



INL'S MATTHEW BALDEREE OPERATES AN UNMANNED AERIAL SYSTEM.

### **CAES unmanned aerial systems partnership between INL, UI, Empire Unmanned, zData**

With funding from the Idaho Commerce Department's Idaho Global Entrepreneurial Mission (IGEM), INL and University of Idaho are collaborating with Empire Unmanned, an unmanned aerial systems (UAS) company in Hayden, Idaho and zData, a Boise data-systems company. The project involves developing management systems for data collected by UAS so it can be integrated into industrial, agricultural and scientific applications. INL's data analytics and visualization capabilities and zData's ability to create big data services on demand will provide unique approaches to handling diverse data sets and providing information to customers, as well as generating economic solutions for the unmanned aerial vehicle industry.

### **Inergy Solar partners with CAES on off-grid technology**

In May, the Idaho Commerce Department's Idaho Global Entrepreneurial Mission (IGEM) funded a commercialization research project between the University of Idaho, Idaho National Laboratory and Inergy Solar, a company based in Chubbuck, Idaho. Researchers are working to develop a 6,000-watt split phased gallium nitride high-frequency inverter, which should allow Inergy to advance toward developing a complete home solar solution. The project also addresses network cybersecurity protection for this off-grid energy source. The IGEM funding is to miniaturize the power control systems for these solar-powered portable energy devices. Additional funding to integrate these units into scalable microgrids came from DOE's Small Business Voucher program.



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# 36

CAES AFFILIATES COLLABORATED  
WITH 36 COMPANIES IN  
FY 2016, 11 OF  
WHICH ARE BASED IN IDAHO.

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### **UI collaborates with NIATT, Evolutionary Markings**

The University of Idaho, the National Institute for Advanced Transportation Technology (NIATT) and Evolutionary Markings, a Boise company, received funding from the Idaho Commerce Department's Idaho Global Entrepreneurial Mission (IGEM) to validate solar-powered, battery-operated LED Raised Pavement Markers (LRPM) models and document their safety benefits in different applications. LRPMS may be used to supplement or replace line striping. Using light guide technology, an LRPM's LED signal can be focused without glare and visible for over 650 feet, twice the normal stopping distance of a vehicle traveling 70 miles per hour. With its energy management system, even in low light caused by inclement weather or other conditions, it will remain lighted for up to five days. With polymer casing, the technology is cost-effective, environmentally friendly and road tough, with expected duration of five years.

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AN LED RAISED PAVEMENT MARKER.

## CAES Industry Advisory Board

CAES utilizes an eight member Industry Advisory Board to bring in outside expertise from the private sector to help guide our expansion and engagement with industry.

*2016 Industry Advisory Board Members*

**Bill Bellamy**, CH2M HILL, Fellow & senior vice president

**Paul Kjellander**, Idaho Public Utilities Commission, president

**Jay Larsen**, Idaho Technology Council, president & founder

**Jeff Malmen**, IDACORP & Idaho Power, vice president for Public Affairs

**Jim Nottingham**, Hewlett-Packard, LJ Enterprise vice president and general manager

**Janine Rush-Byers**, Micron, University Relations manager

**David Spurling**, Simplot, senior vice president, secretary, and general counsel

**Raino Zoller**, Trailhead executive director

DR. JAYA TUMULURU EXPLAINS HIS LAB-CORPS PROJECT TO INL LABORATORY DIRECTOR DR. MARK PETERS.

## Economies of small report on NuScale SMR design

The Energy Policy Institute (EPI) submitted a proprietary draft report to NuScale Power on the economies of small for its innovative small modular reactor (SMR) power plant design. Among the contributors to the industry-funded project are EPI Director David Solan, Boise State University Economics Professor Geoff Black, and University of Idaho Nuclear Engineering and Economics faculty members Fatih Aydogan and Steve Peterson.

## Accelerating Lab Impact – Lab-Corps Year II

A CAES team led by Dr. Jaya Tumuluru, of Idaho National Laboratory, received the highest number of interviews at DOE's Spring 2016 Lab-Corps "boot camp" at the National Renewable Energy Laboratory in Golden, Colorado. Lab-Corps was established in 2014 to help link research scientists and engineers with entrepreneurs, to explore new paths for commercializing ideas and technologies to meet industrial users' needs. Teams participate in a six-week cohort involving in-person sessions and weekly webinars. In addition to evaluation by experts, the validity of a team's effort is measured by the number of interviews with potential partners or collaborators. Each three-person entrepreneurial team consists of a principal investigator, an entrepreneurial lead and an industry mentor. Tumuluru was assisted by Erica Belmont, of the University of Wyoming, serving as entrepreneurial lead, and INL Technology Deployment's Art Baker as industry mentor. The pelleting process they have developed decreases drying costs and manages the feedstock moisture more efficiently. Techno-economic analysis indicated the process reduces energy and production costs by about 40 to 50 percent compared to conventional pelleting methods. Scale-up of the high moisture pelleting process from lab to pilot and commercial scale is in progress.





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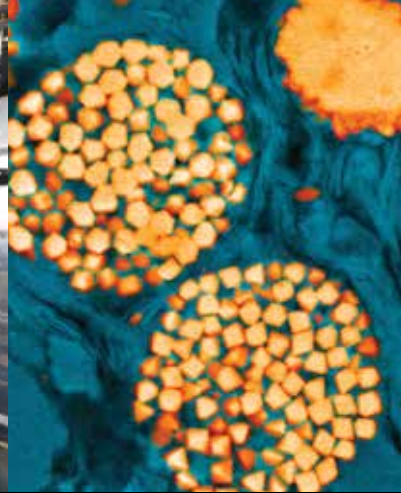
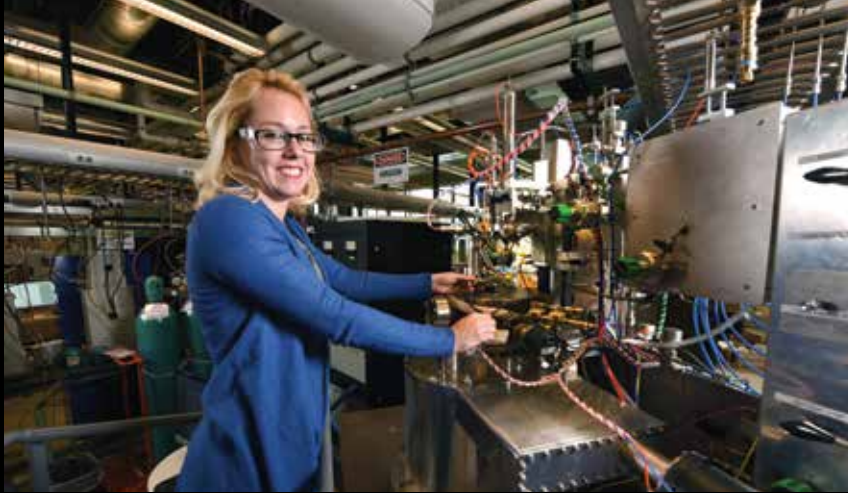
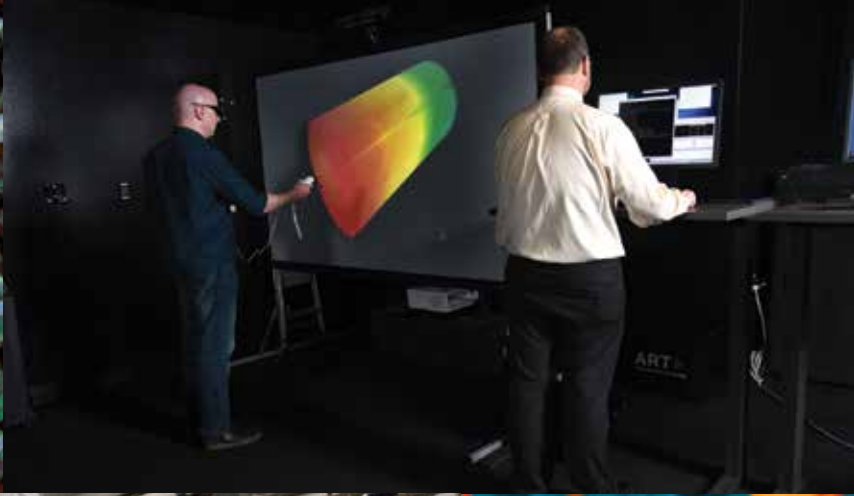
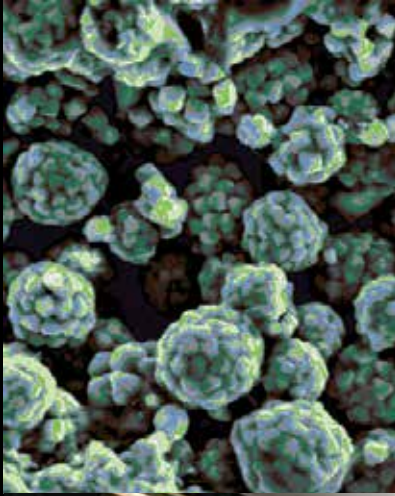


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