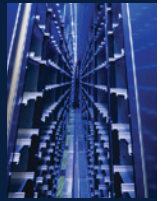




ILLINOIS APPLIED RESEARCH INSTITUTE



The Applied Research Institute's mission is to rapidly provide cost-effective solutions to problems of mutual interest across sectors and agencies of government, with a sharp focus on commercial development of technologies that are validated before they leave the laboratory. From the beginning, our vision has been to create a new model for a university-based laboratory, where industry and federal clients connect with researchers in an integrated environment to understand their needs and rapidly bring solutions to the market.



**AGILITY. ABILITY. ACTION.**



Since 1867, the University of Illinois has provided opportunities for education for our residents, ensuring the economic competitiveness of State of Illinois and our workers. As the State of Illinois' flagship Land Grant institution, the university has connected the people of Illinois to the world's most transformative innovators, and the world's most transformative innovators to the people of Illinois.

The University of Illinois will soon celebrate its 150th birthday, and as the sesquicentennial approaches we have been reflecting on how we could bring a renewed focus on translational technology impact. The Applied Research Institute, since our founding in 2013, has brought together the University of Illinois' faculty, researchers, and students to deliver impact in an environment of sustained engagement with our federal and private-sector clients. Throughout these three years, the Applied Research Institute has remained responsive to the needs of the State of Illinois and of the nation, focused on solving problems.

What has emerged over the past three years is an evolving model for university-based research, where researchers are proactive about solving problems and developing innovative approaches for funding their work. What has also become evident is the need to bring the full breadth of the university's resources to

Over the past three years, the Applied Research Institute has remained responsive to the needs of the State of Illinois and of the Nation, focused on solving problems.

bear in providing solutions for the client. Finally, as the needs of our clients change, our researchers must be able to quickly adapt and provide solutions that cut across sectors and agencies of government. These are the principles of an effective university-based laboratory that can support research and development during a time when corporations are no longer able to do so internally, and federal agencies are developing new approaches to supporting research.

As the possibilities of life sciences push the bounds of imagination, as the physical world ties together into the Internet of Things, and as governments struggle to keep our nation's infrastructure up to date, our economy is in critical need of a laboratory that can collaboratively design solutions that are ready for the marketplace. This has been the mission of the Applied Research Institute, and we look forward to continuing to advance that mission.



## DIRECTOR'S MESSAGE



**Dr. Jeffrey L. Binder**

Director,  
Applied Research Institute

**Welcome to the first progress report on the Illinois Applied Research Institute (ARI). The purpose of ARI was to execute applied R&D normally considered beyond the traditional boundaries of the university research enterprise. This report documents the growth and success of ARI in its first three years of existence, the future opportunities for applied R&D at the University of Illinois, and our potential to generate economic impact for the State of Illinois and the Nation.**

As the University of Illinois approaches its 150th anniversary in 2017, it is exciting to remember that our university in the early 20th century actually defined the future of applied R&D for public and land-grant universities. We did this through establishment of the Illinois Engineering Experiment Station. The Station's model was duplicated at public universities throughout the country and arguably led to the creation of the university research ecosystem that our country leaned heavily on to win two world wars and become an economic superpower. Specific to the Illinois Station, advances in areas such as transportation, and building construction and operation, significantly changed the manner and the quality of how Americans live, work, and play. It is this spirit of contributing to America's future and the economy of our state that has been in a sense reborn at the University of Illinois through the establishment of ARI. Delivering applied R&D that fundamentally improves our lives, enhances our security, and contributes to the economic growth of our nation and state is what drives us at ARI, just as it did for the researchers at the Illinois Engineering Experiment Station more than 100 years ago.

Over the first three years of ARI we have not only brought together expertise from a variety of engineering, science, and business disciplines, but more importantly we have looked across traditional business lines and government agencies to address some of the most important technology issues we face.

**With this perspective as a backdrop ARI has developed five key thrusts:**

- Big Data and Analytics
- Engineering Design and Simulation Technologies
- Materials and Manufacturing
- Homeland and Global Security
- Cyber-Physical Systems and Solutions

These thrusts we believe strongly leverage the core capabilities of the University of Illinois and the State of Illinois, and will make impacts on some of the most critical issues facing our country.

The future is bright for ARI and as you read through this report, I hope you will learn about and share my enthusiasm for our work and potential for impact.

A handwritten signature in dark ink that reads "Jeffrey L. Binder". The signature is written in a cursive, flowing style.





“ Our partnership with the Illinois Applied Research Institute has greatly expanded our capacities in targeting challenges of mutual interest. The opportunities to collaborate and share information with Dr. Binder and his team have been a real force multiplier for Sandia National Laboratories.”

---

Dr. Rob Leland, chief technology officer  
for Sandia National Laboratories

## THE ARI ENGAGEMENT MODEL

When the Applied Research Institute (ARI) launched in 2013, it provided a unique model for R&D. Instead of other university-based applied research laboratories that largely exist outside of their universities' academic mission, ARI is integrating the University of Illinois' faculty and students into our research. Our researchers collaborate with University of Illinois students and faculty, and our clients, on mission-driven research into finding solutions to national problems of mutual interest.

This model fits the needs of the market. Our clients have consistently stressed that they can no longer look at research with a focus on a specific sector. Accordingly, the Applied Research Institute has built thrusts of collaborative research, where we support partnerships with other universities and national laboratories. This collaborative research environment is one where researchers maintain focus on developing solutions to pressing problems.

With many American corporations struggling to fund internal R&D, the Applied Research Institute focuses on new product designs, and reducing risk. We place strong emphasis on ensuring that our researchers are capable of quickly adapting to the changing needs of the market. We have plans to make our resources available at cost-effective rates.

Intellectual property generated at ARI are strictly protected for the benefit of the researcher and those institutions funding the research, creating strong incentive alignment for all parties involved. When ARI does receive awards from state and federal agencies, national lab, foundations or industry partners, ARI works with University authorities to develop appropriate, individualized proprietary

agreements, and intellectual property licensing arrangements, as may be warranted. For proprietary, sensitive, or classified projects, ARI will be able to agree to significant restrictions on publication.

This model is a win-win for our clients, our faculty and students, and the State of Illinois. Our clients are provided a research partner that can service their R&D needs while, at the same time, reduce risk. Our faculty and students participate in research that targets real-world, national problems. And for the State of Illinois and the entire Midwest region, the Applied Research Institute provides an engine where technologies are being designed, developed, and eventually commercialized here at home.

## UNIVERSITY RESEARCH

Institutes

Faculty Research

Other Resources

Basic Research & Development

## MARKET APPLICATIONS

Federal Need  
National Labs  
Industry  
Foundations

Application Needs

Venture Capital

Research Park

Tech Management

Corporate Relations

A R I

Technology Readiness Level

Applications

### ARI BY THE NUMBERS (2013-16)

#### 36 STAFF

17,000 SQ. FT.  
OF OFFICE SPACE

6,100 SQ. FT.  
OF LAB SPACE

5 THRUST AREAS  
DEVELOPED

#### 61 PROJECTS AWARDED

111 FACULTY  
COLLABORATIONS  
(INCLUDING PROJECTS  
AND PROPOSALS)

34 COLLABORATIONS  
WITH EXTERNAL  
PARTNERS

#### 50 STUDENT INTERNS

\$556K IN FUNDS  
FOR 13 SEED  
PROJECTS TO  
UNIVERSITY FACULTY

\$36.4M IN AWARDS





# THRUST AREAS AND PROGRAMS



There are five primary thrust areas where ARI sees opportunities for applied research to develop innovative products and solutions.

**Big Data and Analytics**

**Engineering Design and Simulation Technologies**

**Materials and Manufacturing**

**Homeland and Global Security**

**Cyber-Physical Systems and Solutions**



An abstract graphic featuring a dark blue background filled with numerous small red and blue dots. These dots are connected by thin, flowing lines in red and blue, creating a complex, interconnected network that resembles a data visualization or a neural network. The lines and dots are more densely packed on the right side of the image, tapering off towards the left.

# BIG DATA AND ANALYTICS

**MISSION** To make use of data and machine-learning tools to generate physical and engineering insight.

The Applied Research Institute intends to play a key role in the secure capture, storage, and curation of large data sets for our clients, revealing market trends and providing insights. By employing big data, our researchers are advancing medical sciences to improve patient outcomes, and driving precision agriculture to better make use of our natural resources and feed the world's seven billion people.

ARI, in partnership with the University of Illinois' National Center for Supercomputing Applications (NCSA), is able to provide our clients data storage infrastructure and operational support. ARI is part of the Midwest Big Data Hub, a data science network of Midwest universities and industry partners, and provides support in materials data and related data-science initiatives on campus.

We are able to provide data analytics in a secure environment, where our clients can share proprietary and sensitive data with the strongest level of protection. For our partners in the healthcare industry, ARI analyzes de-identified patient data in compliance with the federal Health Insurance Portability and Accessibility Act (HIPAA). For our federal partners, all staff members supporting data analytics hold required security clearances.

Finally, ARI provides the insight that we are able to generate from our data analytics with simple, accessible presentations.



A great example of ARI's ability to illustrate findings in accessible presentations is found in our "Uncertainty in Tracking" project, a two-year collaboration between ARI and Sandia National Laboratories (described later) to integrate data from multiple remote imaging systems to better understand the human patterns of life. This analysis requires the integration of data from a multitude of sources, including trajectory and image data gathered by sensors monitoring the movement of vehicles, to produce a high quality, semantic labeling of the data,

including a quantification of the uncertainty. Successful combination of trajectory and image data would be of interest to many customers across the intelligence community, the Department of Defense, and the Department of Homeland Security.

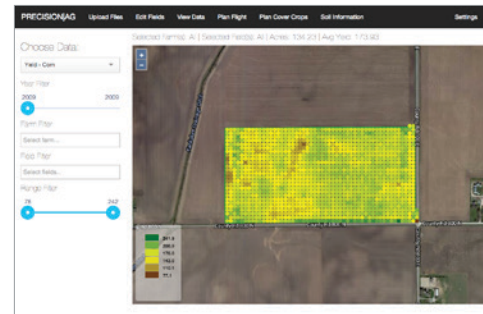
To date, the U.S. Department of Defense, the U.S. Department of Homeland Security, the Mayo Clinic, Boeing, General Electric Global Research Center, Exelon, and Oak Ridge National Laboratory, just to name a few, have all received support from the Applied Research Institute across a range of applications.

Colleen Bushell, senior research scientist at the Applied Research Institute, leads ARI's data and visual analytics group, which is researching how to apply data and machine-learning approaches to challenges of human disease diagnosis and treatment in research and clinical practice. "We focus our effort at ARI on the domain of precision health by applying state-of-the-art approaches to health care research and clinical care," Bushell said.

In 2014, Bushell and her team launched a collaboration with NCSA and Northwestern University, among others, to better understand human microbiome and metabolics data. The work of this ARI-led collaboration resulted in a critical insight for those suffering from Interstitial Cystitis, or bladder pain syndrome. From their collaborative research, a potential biomarker was identified in the human gut that the team believed modulates pelvic pain in those suffering from Interstitial Cystitis. Their findings were published in the Nature Scientific Reports in May 2016, and presented at multiple conferences. Recently, the National Institutes of Health agreed to fund four additional years of research to continue their work.

Bushell has helped an effort to build a user interface, the Knowledge Engine for Genomics (KnowEnG), for analyzing genomic data and presenting relationships on an intuitive platform. She and her team at ARI are responsible for the design, development, and implementation of the visualizations and user interface. Bushell is one of the

lead investigators in this NIH-funded, five-year project, along with multiple faculty members at the University of Illinois and the Mayo Clinic.



Precision Ag application that shows the ability of user to interact with ARI's Precision Ag software by uploading yield data collected from a farm implement. Precision Ag project started using ARI Seed funding and is now funded from McKnight Foundation. Professor Jonathan Coppess in Colleges of ACES participated in the project.

Finally, the Applied Research Institute is gaining a better understanding of hydrology of agricultural fields by using data, drones, and aerial imagery to find drainage lines, and understand how water moves in a field.

This has allowed ARI researchers to gain a better understanding of "cover crops," or crops that farmers plant during the winter to hold onto the soil's nutrients, to be released as they decompose before the next planting season. Our researchers have designed software for farmers to predict the behavior of cover crops on their fields under different weather conditions. The software uses several decades of data – daily, sometimes hourly observations of temperature, rainfall, humidity, soil radiation measurements – as well as soil data compiled by the U.S. Geological Survey, to keep farmers informed and minimize risk.



# ENGINEERING DESIGN AND SIMULATION TECHNOLOGIES

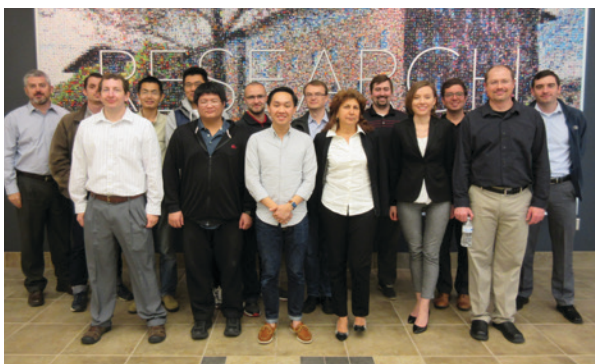
## MISSION

To develop a comprehensive modeling simulation program that customizes product design to market needs, shortens R&D time, and engineers new products with performance, cost, and manufacturability in mind.

**The Applied Research Institute's Engineering Design and Simulation Technologies (EDST) team's efforts are categorized in three domains:**

- Applied material and engineering systems, designed using high-performance computing;
- Accelerated material design by simulating material processing and manufacturing steps;
- Testing and validating large-scale engineering simulation codes before deployment.

**Using supercomputing to serve applied research needs:** ARI researchers use supercomputers on and off the University of Illinois campus for simulations needed to serve our clients' needs. We have helped provide solutions for the U.S. Department of Defense using their secure supercomputers. In other instances, ARI is working collaboratively with the National Center for Supercomputing Applications (NCSA), located a few blocks from ARI. NCSA



A workshop organized by ARI at NCSA in May, 2016 on Consortium for Advanced Simulation of Light Water Reactors, CASL's Virtual Environment for Reactor Applications with participants from ARI, Department of Nuclear Plasma and Radiological Engineering, Computational Science and Engineering at the University of Illinois, and Nuclear Fuels Department at Exelon Corporation.

overseas the most powerful supercomputer on a university campus in the United States, named "Blue Waters." NCSA also oversees "iForge," a high-performance computing cluster which can be configured from four distinct hardware platforms designed specifically for industry partners.

ARI staff adds our experience in designing experiments to the NCSA team's technical familiarity with large supercomputing systems. This ARI-NCSA partnership is aimed at providing industry partners a full range of services to tackle their most urgent challenges.

**Support accelerated material design with simulated experiments:** To date the ARI's Accelerated Materials Research team, led by Dr. Santanu Chaudhuri, has attracted funding from the U.S. Department of Defense, the U.S. Department of Homeland Security, and the National Science Foundation, among a host of other federal funding sources, to run simulated experiments on new materials. The team now works with a growing list of partners, including Honda R&D Americas, Boeing, Ford Motor Company, GE Global Research

Center, FMC Technologies, and IHI Technologies. The Accelerated Materials Research team works with more than 25 faculty members in the College of Engineering at the University of Illinois to build robust teams and strong proposals.

In a recent success, Dr.

Chaudhuri joined Professor David Ruzic at the University of Illinois to lead a team that won a \$1.7 million grant from the U.S. Department of Defense's Strategic Environmental Research and Development Program (SERDP) to replace harmful chemical waste from the military's manufacturing processes using atmospheric pressure plasma technology for surface treatment and protection. Dr. Chaudhuri's experience in applied coatings, corrosion and multiscale simulation research, combined with Professor Ruzic's pioneering contributions in developing atmospheric plasma spray technologies made this team successful in attracting this applied research project to campus.

ARI's customized simulated experiments allow researchers to test a design against a range of conditions. For example, ARI has employed supercomputing capabilities to test light-weight alloys for next-generation combat vehicles and body armors for the Army Research Laboratory. The Boeing Company has employed ARI to run simulated experiments to test automated paint-spray systems the company is designing to paint aircraft fuselages. "We can test


variations and we can see the difference in performance in simulations before someone ever lays a hand on these materials or manufacturing systems," said Dr. Chaudhuri.

This ability to simulate conditions maximizes our analysis, gains critical insight for our clients, and dramatically reduces costs and the time required to test a design for helping to transition manufacturable solutions at a competitive price.

**Testing and validating code before deployment into the market:** ARI provides clients with the ability to test coding and ensure quality control before a design is introduced into the market. With changing funding cycle constraints, many federal investments in such technologies face challenge to sustain the initial effort. ARI provides a path to keeping the codes fresh by developing testbeds for new applications of specialized codes.

An example of our work in testing code is seen in the field of nuclear power generation. The Consortium for Advanced Simulation of Light Water Reactors (CASL) was established by the Department of Energy in 2010 to help accelerate R&D of the nuclear energy industry, using simulation and modeling. Innovation is tough in an industry that is, by necessity, conservative and heavily regulated. Led by Oak Ridge National Laboratory, this consortium turned to the Applied Research Institute to predict the performance of new designs and test the coding of critical reactor functions of commercial nuclear power plants under simulated conditions. The project is expected to complete in early 2017.





# MATERIALS AND MANUFACTURING

## MISSION

To advance technology of manufacturing processes, equipment, and machines to manufacture and design materials using cloud computing, analytics, big data, and connected machines.

Manufacturing technologies have brought into convergence cloud computing, analytics and big data, and the Internet of Things (IoT), connecting machines to create a supply chain where data and products flow seamlessly. Future advances in artificial intelligence will enable autonomous machine action and collaborative machine-to-human interaction, paving the way toward increased productivity for companies and countries.

The Applied Research Institute seeks to drive and advance this new industrial revolution, and help our clients capitalize

on opportunities and address the challenges associated with introducing new technologies into the market. ARI is focusing research on designing a seamless digital thread in manufacturing processes, developing manufacturing processes that use sensors to understand performance. We are also designing manufacturing equipment that support variable day-to-day production.

As the market changes, our clients must rapidly change with it. The Applied Research Institute seeks to help our clients accelerate R&D and maximize agility, a requirement for manufacturers to compete in the current



ARI researcher, Mohamed Aboukhatwa at the Materials Research Laboratory (MRL) facility at the University for use of surface probing and nanomechanical characterization of multilayered thin films.

"The Applied Research Institute has been an invaluable partner for UI LABS in helping us execute DMDII's plan for translating technology to market in advanced manufacturing,"

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Caralynn Nowinski Collens,  
CEO of UI Labs  
(which oversees DMDII)

market, by rapidly producing and testing designs. ARI's Accelerated Materials Research team helps our clients refit their manufacturing facilities to change product lines as the market changes.

There are a number of facilities on the University of Illinois at Urbana-Champaign campus, and facilities supported by the university outside of our campus, that are developing materials at the nano and micro scale. ARI is focusing these facilities to do more applied research, using these facilities to design and test materials before they are introduced into the market.

The Applied Research Institute has supported the launch and growth of the Digital Manufacturing and Design Innovation Institute (DMDII) in Chicago, a manufacturing laboratory focused on designing digital processes for manufacturing products with the highest degree of precision and efficiency. As a part of our relationship with DMDII, ARI is leading projects to better understand manufacturing cybersecurity and supply chain visibility. Of the seven DMDII projects awarded to the University of Illinois and its partners (valued \$8.55 million in total), ARI is leading two projects. In addition, ARI is a team member on two additional projects related to development of an operating system for cyber-physical manufacturing and virtually guided certification.

ARI's research in advanced materials has focused on a broad range of material classes and industries. ARI designs "soft materials," or polymers, biomaterials, and nanocomposites that can develop new

solutions for automotive, aerospace, agriculture, and medical applications. ARI-designed metal alloys have supported critical military programs for lightweight combat vehicles, as well as the American railroad system for research on low-cost innovation to strengthen existing tracks for high-speed rails.

The University of Illinois at Urbana-Champaign campus features a number of facilities that are excellent for advanced materials at a very small scale. To complement these facilities, the ARI is focused on extending these capabilities towards more applied research – focused on scaling up designs of new materials, mapping manufacturing processes that are relevant for industry partners, testing life cycles of products, and conducting macroscale materials testing that meets ASTM International's standards. Initial processing equipment will include general materials processing, coatings and additive manufacturing.

ARI's research in advanced materials has focused on a broad range of material classes and industries. ARI designs "soft materials," or polymers, biomaterials, and nanocomposites that can develop new solutions for automotive, aerospace, agriculture, and medical applications. ARI-designed metal alloys have supported critical military programs for lightweight combat vehicles, as well as the American railroad system for research on low-cost innovation to strengthen existing tracks for high-speed rails. ARI researchers have also examined how to expand the utility of 3-D printers.





# HOMELAND AND GLOBAL SECURITY

## MISSION

To develop and translate technologies critical to our homeland and global security.



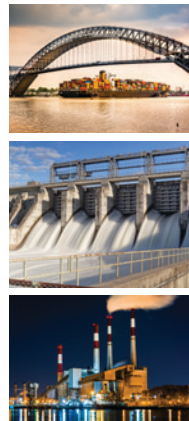
The Applied Research Institute is a leading partner in designing systems to equip and defend our warfighters, and in ensuring our critical infrastructures are safe and secure.

ARI's Accelerated Materials Research team led by Dr. Santanu Chaudhuri has been a critical partner for the U.S. DoD's Defense Threat Reduction Agency (DTRA), helping design measures to counter roadside Improvised Explosive Devices (IEDs) and counter weapons of mass destruction. Blast and shock wave propagations pose a complex set of problems; solving them is critical to protect ground troops and protect critical infrastructure.

We have also partnered with the U.S. Department of Homeland Security to design solutions to protect our energy grid, and our water and food supply. Our research for the U.S. Department of Homeland Security includes reviewing vulnerabilities, and designing commercially viable solutions to improve the resilience of the energy grid and transportation hubs. Dr. Santanu Chaudhuri recently joined Professor Paolo Gardoni in the Department of Civil Engineering at the University of Illinois in a National Science Foundation-funded team, joining faculty members from three other universities, to design computational tools for improving food security and resilience for communities deemed to be at risk.

Since 2015 the Applied Research Institute has supported the Critical Infrastructure Resilience Institute (CIRI), an interdisciplinary research center commissioned by the U.S. Department of Homeland Security to advance our understanding, and generate game-changing, blue-sky solutions, in ten critical infrastructures: the chemical industry, commercial facilities, communications, critical manufacturing, dams, emergency services, government facilities, information technology, nuclear reactors, and transportation.

Researchers at CIRI are supported by a five-year, \$20 million Department of Homeland Security grant to take a comprehensive approach toward securing our critical infrastructures. Our researchers analyze business decisions, assess vulnerabilities of our commercial supply chain, and design effective regulations that secure our homeland and allow for economic growth. CIRI evaluates the linkages between public utilities, industry, and consumers to design effective public-private partnerships.



Finally, CIRI is committed to providing job training for our homeland security workforce to maximize their skill sets. Both current and future homeland security workers must understand homeland security vulnerabilities, and administer the most effective remedial strategies. CIRI is a critical Department of Homeland Security partner to ensure the strength and competence of our homeland security workforce.

In August of 2016, ARI announced the hiring of Dr. Mark C. Petri as CIRI's first permanent director. Dr. Petri had served as the director of Iowa State University's Iowa Energy Center, a research center that designs alternative energy and energy efficiency technologies. Before his tenure at the Iowa Energy Center, he spent 23 years at Argonne National Laboratory. Upon assuming his new role at CIRI, Petri issued three requests for proposals (RFPs), centered on infrastructure resilience. The first RFP focuses on designing infrastructure resilience insurance, the second on industrial supply chains, and the final RFP looks at infrastructure dependencies and interdependencies. In a short time, CIRI received 50 letters of intent from 29 organizations, demonstrating CIRI's ability to attract a wide range of partners and capabilities to address the Department of Homeland Security's needs.

"Our military relies on the research community to design solutions to equip our warfighters and protect the homeland. The Applied Research Institute is providing those solutions."

Maj. Gen. Richard Hayes, adjutant general, Illinois National Guard



# CYBER-PHYSICAL SYSTEMS AND SOLUTIONS

## MISSION

To secure and advance the cyber systems that connect our physical world.

As our physical world becomes more connected through our cyber world, our economy and our day-to-day lives are confronted with exciting new horizons. In the very near future, our buildings, homes, and roads will operate in a parallel digital framework. We will be able to turn on our lights and air conditioning units remotely from our mobile devices. We will be able to use those same mobile devices to monitor the air quality of our homes and office spaces. And the medical community will be able to gain unprecedented insight employing system-of-systems technology.





Hands-on classroom training session at Indoor Climate Research & Training (ICRT). ARI is partnering with ICRT to model systems for sensing air quality in buildings and homes in order to bring practical solutions to high performance in buildings.

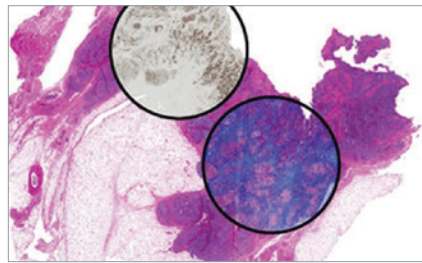
The Applied Research Institute is gaining the ability to analyze and understand this parallel digital framework to help ensure that our cyber security systems keep pace, asking the right questions to design effective solutions. How do we balance the need to capture the exciting possibilities cyber-physical systems present, while ensuring proper safeguards against cyber attacks, either from a foreign enemy or your neighbor? What is the appropriate role of government in regulating these systems? What are the unintended consequences of cyber-systems technologies?

Dr. Santanu Chaudhuri and Dr. Jeffrey Binder participated as panelists in a panel discussion with other experts from University of Illinois at Champaign-Urbana and Argonne National Laboratory during "Resilience Week," a three-day symposium on securing cyber-physical systems, held in August 2016 in Chicago.

The University of Illinois' Indoor Climate and Research Training (ICRT) program is a new addition to ARI's thrust on smarter homes and buildings, and the combined team will focus on using cyber systems and sensors to improve the lives of

occupants. The ICRT recently completed a study, with some help from the National Center for Healthy Homes, on the impact of ventilation on indoor air quality and health. The study found that recent federal ventilation standards have reduced a range of contaminants in households, a finding mentioned in a recent *Newsweek* article. The study also found that contaminant

levels vary widely from home to home; the ventilation standards were written in a prescriptive fashion, and individual home contaminant levels were not taken into account.



The 3 stains in breast tissue were generated using computerized analysis of data obtained by a new imaging system, and without actually staining the tissue. Researchers at ARI helped design and develop the software for Professor Rohit Bhargava in Bioengineering at the University of Illinois.

Our findings demonstrated the need for improved indoor air quality sensing that can be done at low cost, with reasonable accuracy, and can be integrated into ventilation controls. There are currently controls that are based on carbon dioxide, but none that comprehensively cover the broad range of pollutants found in homes. By focusing research on building performance against a full range of pollutants, ARI is now modeling sensing systems to advance the air quality in buildings and homes that could lead to practical solutions for occupants.

The ICRT team, led by engineer Paul Francisco, is integrating this effort with ARI's smart building effort and expanding their approach to other commercial and federal buildings. This program could implement smart and secure Internet of Things technologies to improve people's lives across different income levels.

Finally, through chemical imaging, ARI seeks to transform the way we diagnose cancers. Instead of using dyes and manual assessment, ARI is developing chemical imaging technology involving computer algorithms to automatically provide real-time diagnoses. In partnership with the Beckman Institute at the University of Illinois and the Chemical Imaging and Structures Laboratory, ARI has designed software that uses infrared images of cells and runs them through machine-learning schemes to do online cancer detection. These intense computations use massive data sets that had required several days to complete. By redesigning the code used to complete these computations, ARI software engineer Andrew Ayers has dramatically reduced the time required to identify cancer cells.

*"ARI is helping develop the software and its integration with hardware for rapid, real-time imaging and diagnosis. The software enables researchers to greatly speed up information extraction from the chemical imaging technology and provides them with high quality images much faster than previously possible."*

*Dr. Rohit Bhargava, professor of Bioengineering at the University of Illinois at Urbana-Champaign*



# OUTREACH AT ARI



The Applied Research Institute has demonstrated a unique capability to forge relationships with external partners that bring a wealth of insight and value for the University of Illinois students and faculty.



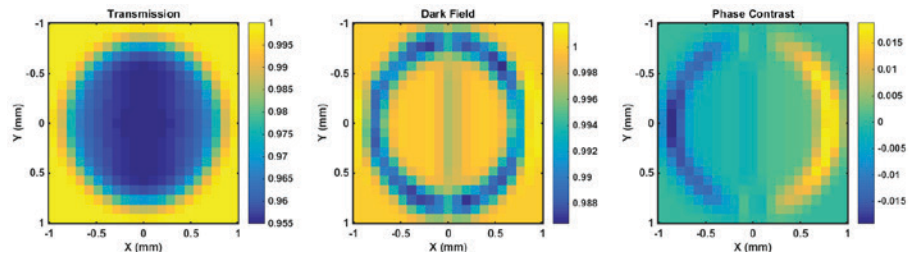
## SANDIA PARTNERSHIP

In November of 2014, the University of Illinois and the Sandia National Laboratory announced a five-year research partnership, focusing on data science, complex systems, digital manufacturing, and on-demand power. For both UI-ARI and the Sandia National Laboratory, the partnership built a two-way highway. The partnership is built on three pillars: transferring technology into private sector hands, recruit top PhD candidates and faculty members, and collaborate to solve big, national problems.

For the Applied Research Institute, the Sandia partnership cemented this new model of research emerging from ARI. Some examples are discussed below:

In 2015, the Sandia-ARI partnership collaborated on research to design advanced X-ray imaging for both industrial and biological structures. The X-ray Phase-Contrast Imaging, or XPCI, design allows for the detection of micro structures that cannot be imaged by existing X-Ray technology. ARI generated code to simulate experiments with the XPCI designs.

Sandia and ARI partnered this year to launch a two-year research project to generate an imaging system that is able to understand and quantify the uncertainty in our physical world. As our physical world becomes more connected in a massive cyber system of systems, it is critical for engineers, researchers, and municipal authorities to understand our patterns of life, such as how our vehicles move through the grid. The Sandia-ARI partnership will seek solutions by integrating data sources.



The 3 panels show standard transmission (normal X-Ray image), dark field, and phase contrast images reconstructed using X-Ray Phase-Contrast Imaging (XPCI) for silicon wafer (280 micron thick) with two embedded copper wires arranged in a cross. ARI helped coordinate the efforts of faculty at University with Sandia National Labs by developing code to simulate the system.

Another project that resulted from Sandia-ARI partnership is a collaboration between Dr. Santanu Chaudhuri and Dr. Wenbo Du at ARI to design a tool for estimating different investment scenarios in alternative energy technologies. The researchers showed that it is possible to recoup the cost in alternative energy solutions by improving the resilience of the power supply. Their work can potentially guide O'Hare International Airport on how to make their power supply more resilient by combining large-scale battery, wind, and solar-energy-generation strategies, and at the same time, recover the cost by investing in

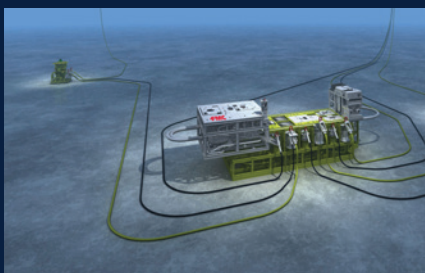
resilience. Students from Illinois Business Consulting developed the financial model for investment in alternative energy, and participated in the process of developing an engineering software with real-life impact.

"ARI continues to be an excellent trusted partner for Sandia National Laboratories," said Dr. Bill Seng, senior manager of integrated nanotechnologies at Sandia. "During my tenure as the Sandia-Illinois partnerships manager, I particularly enjoyed the quick response time from its staff, combined with the forward-looking approach of ARI's leadership."

## START

### STUDENT TRAINING IN APPLIED RESEARCH AND TECHNOLOGY

In the fall of 2016, the Applied Research Institute launched the Student Training in Applied Research and Technology (START) program as a way of engaging engineering students at the University of Illinois at Urbana-Champaign in the work we are doing for our clients. The START program forges a collaboration with our industry partners to train the next generation of innovators.



In the START program, ARI leaders and our industry partners collaborate to provide students with opportunities to learn applied research skills, and gain an understanding of the rapidly evolving requirements for the industry partner's technology domain.

The Houston-based FMC Technologies, a large technology company with \$6 billion in revenue in underwater drilling and sensing platforms, was one of our first partners, asking START students to build underwater autonomous vehicles and a new sensing platform design. The program is training students on the R&D process from top to bottom, starting from ideas to proposals to building and testing, led by student trainees.

"FMC Technologies wants to collaborate with University of Illinois and the Applied Research Institute to combine student engagement with innovation and digital transformation. FMC Technologies has been innovating as part of its proud heritage and wants to accelerate its adoption of digital technologies to realize new business markets. FMC Technologies believes that the University of Illinois and ARI, along with bright and energetic students, can investigate and develop new innovative products for the oil and gas business."

William Thomas, manager for  
Multi-Physics Simulations in FMC's  
North American Technology Center

## PROJECT 2026

Project 2026 is a collaborative effort between the Applied Research Institute, other regional centers of applied research, and the region's startup entrepreneurs to collaboratively solve national problems. Project 2026 is building a collaborative network to transfer technology emerging from ARI, Argonne National Laboratory, and other centers of applied research to startup entrepreneurs capable of commercializing their research in the market.



In ten years, 2026, the United States will celebrate our 250th birthday. Before that historic day, the Midwest's applied researchers and entrepreneurs can collaboratively build a thriving startup economy in strategic sectors. Project 2026 aims to lead that collaboration.

In October of 2016, Project 2026 published its Asset and Strategic Review, an extensive document that assesses the Midwest region's unique economic capacities,

and generates a strategy for collaboratively solving national problems with research and entrepreneurship. Researchers, entrepreneurs, venture capitalists, municipal managers, and federal officials from throughout the region participated in drafting the Asset and Strategic Review. With ARI's leadership, the Midwest region now has a platform for collaboration in driving economic growth through new startups that bring applied research to the market.



# FINANCIALS AND IMPACT



Impact is our watchword, for our clients, for our university, and for our faculty and students. ARI led the way in engaging University of Illinois at Urbana-Champaign faculty in developing a seed-funding program aimed at identifying promising technologies on campus. ARI's leadership has encouraged the ARI staff to work with faculty to help transition technologies to a proof-of-concept level. To date ARI has provided \$556,000 in seed funding to 13 projects on campus, with significant participation from younger faculty who are starting their careers.

**DANIEL VINCENT KROGSTAD**, research scientist at ARI won the Air Force's Young Investigator Research Program (YIP) award in 2016 for the Development of Ordered Nanocomposites through the use of Block Copolymer Self-Assembly and Additive Manufacturing. The project will focus on taking advantage of the unique processing conditions that occur in additive manufacturing to help in the three dimensional microscale ordering of the printed nanocomposites. This approach is needed in order to reach the fullest potential of nanomaterials.



**Dr. Daniel Krogstad**

Research Scientist,  
Applied Research Institute

**NICK LANNAN** is a Marine and veteran of multiple combat tours in Iraq and Afghanistan. Now he's a student at the University of Illinois. He participated in an Office of Naval Research-funded project with MIT Lincoln Laboratory to deliver new technologies for battlefield, and he's recruiting student-veterans at the University of Illinois to join the START program.

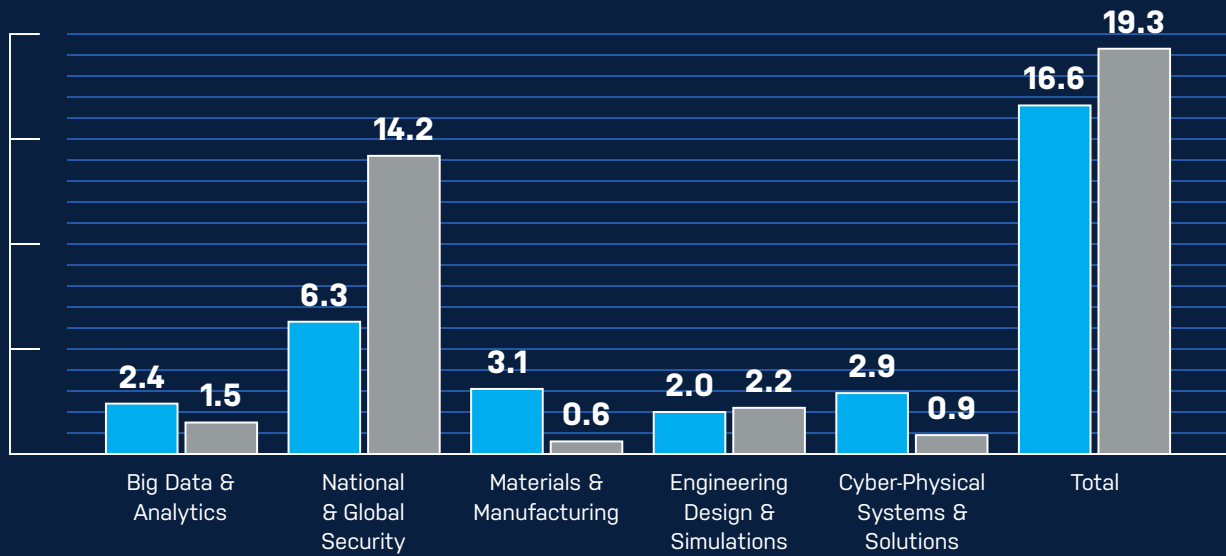
**CARL REMLER** is a senior in Mechanical Engineering at the University of Illinois at Urbana-Champaign. He

is leading a START student team to work with FMC Technologies in Houston, Texas. The team explores new technologies with underwater autonomous vehicles, focusing on collecting energy and data from subsea equipment. FMC Technologies is supporting the START program students with training materials and software to help build a prototype, while the university offers them laboratory facilities and materials.

For Carl, the START program provides an opportunity to build engineering skills in an inter-disciplinary environment, and learn how to apply his classroom training to applied research. "I'm looking to build a career from the newest developments in manufacturing intelligence and automation," Carl said. "The START program has exposed me to the most critical needs for the sensing and control of subsea equipment. Also, it has given me access to the research and facilities that must be leveraged to address these needs. With the START program, I have the ability to solve tomorrow's problems and grow my career in the process."

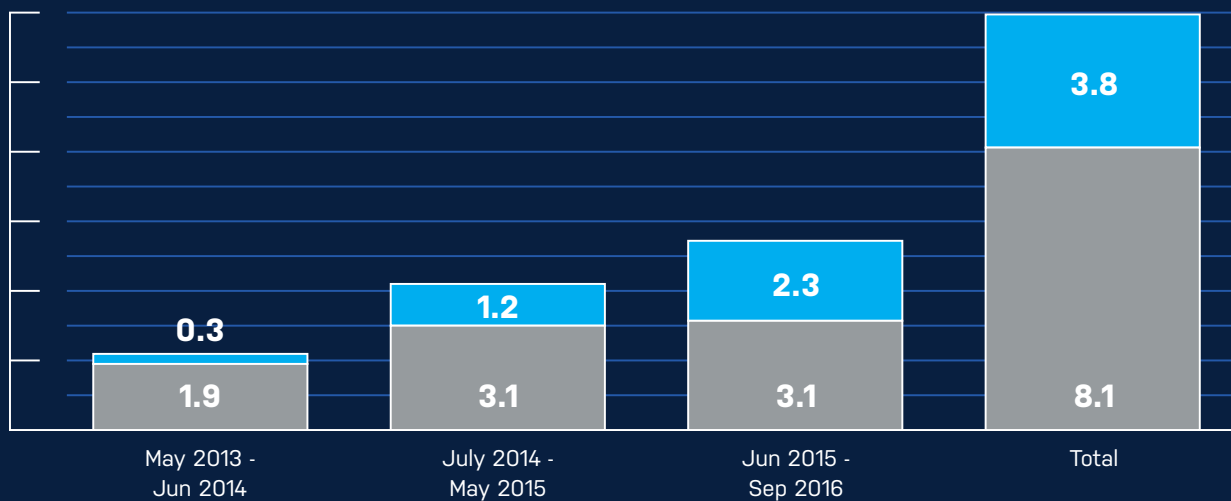
### ARI Research Funding by Thrust (\$ M)

■ Awarded ■ Pending



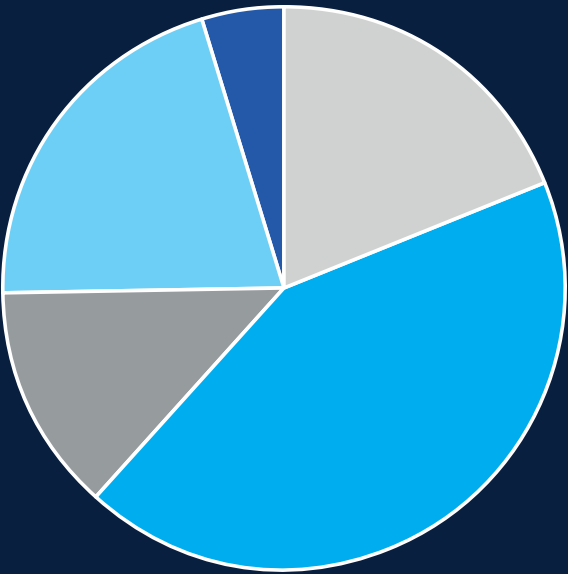
### Research Expenditure and Growth (\$ M)

■ University ■ External



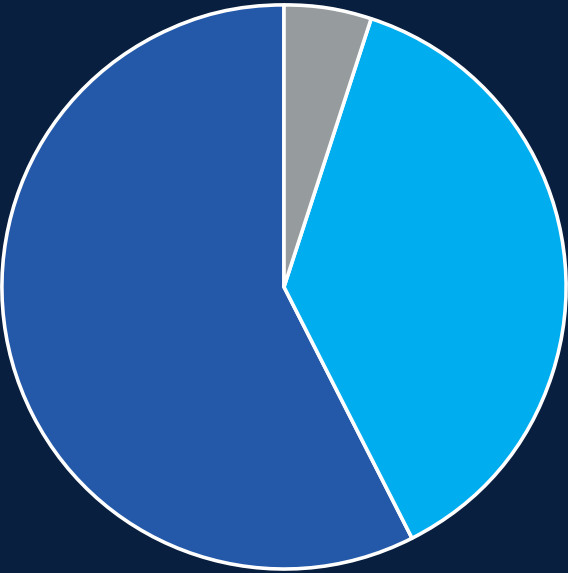


Research Expense (\$ M)



Salary - External Funds	\$2.27
Salary - Internal Fund	\$5.12
Research Expenses - External	\$1.56
Capital and Operational Expenses	\$2.45
Seed Funding to Campus	\$0.56
<b>Total</b>	<b>\$11.95</b>

Research Funding and Impact (\$ M)



ARI Share	\$22.18
Campus Share	\$34.12
External Share	\$3.06
<b>Total</b>	<b>\$59.36</b>

ARI

# LEADERSHIP



**DR. JEFFREY BINDER** is the founder of the Applied Research Institute. Before launching the Applied Research Institute, Dr. Binder spent much of his career in the national laboratory system, both at Argonne National Laboratory in Illinois and Oak Ridge National Laboratory in Tennessee. From 2011 to 2013, Dr. Binder was the associate laboratory director for nuclear science and engineering at Oak Ridge National Laboratory. He holds a doctorate in nuclear engineering from the University of Illinois at Urbana-Champaign and a MBA from the University of Chicago's Booth School of Business.



**DR. MAGDI AZER** is the associate director for Manufacturing Science at the Applied Research Institute. He came to the Applied Research Institute from General Electric, where he led business development, leading partnerships with government customers, developing teaming arrangements and competitive R&D proposals for federal support. In his role at ARI, Dr. Azer leads a team focused on implementing applied research, development and engineering in digital manufacturing, intelligent machining processes, smart factory applications, and defense systems. Dr. Azer holds a M.S. and a Ph.D. in mechanical engineering from the University of Illinois at Urbana-Champaign.



**DR. MARK C. PETRI** is the director of the Critical Infrastructure Resilience Institute. Prior to assuming this role, Dr. Petri had served as the director of Iowa State University's Iowa Energy Center, a research center that designs alternative energy and energy efficiency technologies, and spent 23 years at Argonne National Laboratory.



**DR. SANTANU CHAUDHURI** is a principal research scientist at the Applied Research Institute leading engineering design and simulations effort. His areas of research interest include material design, heterogeneous catalysis, polymers and coatings, and energetic materials research for aerospace and defense applications. Before coming to ARI, Dr. Chaudhuri spent eight years as an associate professor and senior scientist at Washington State University in Pullman, Washington, and led their Applied Sciences Laboratory's effort in transforming science into solutions.



**COLLEEN BUSHELL** is a senior research scientist at the Applied Research Institute. Her work is in the area of data science, specifically visual analytics and information design. She focuses on developing techniques and software tools for analyzing and presenting genomic and health data. Prior to her current role, Colleen directed the Students Pushing Innovation (SPIN) program at the National Center for Supercomputing Applications (NCSA).

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# ARI STAFF

The ARI provides the University of Illinois with a formalized conduit for collaborating on open, proprietary, or classified projects. With a staff of over 25 employees, the ARI is rapidly expanding its ranks to perform specialized research in areas such as advanced materials and manufacturing, communications and cyber security, biotech, and Big Data.

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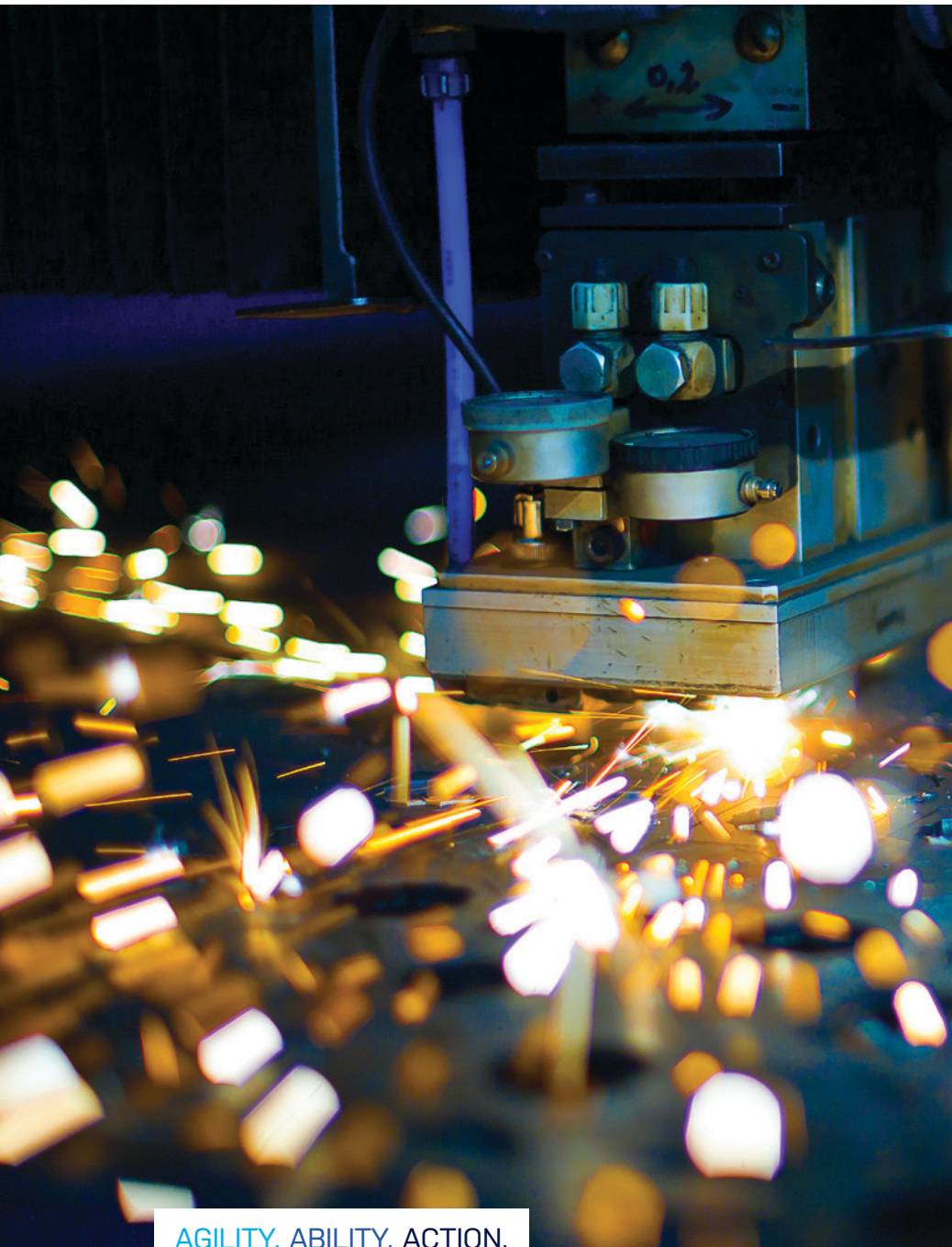


Applied Research  
Institute staff at a  
retreat in 2015.









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2100 South Oak Street, Suite 206, MC 628  
University of Illinois at Urbana-Champaign  
Champaign, Illinois 61820

T 217.300.3162

F 217.244.2705

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