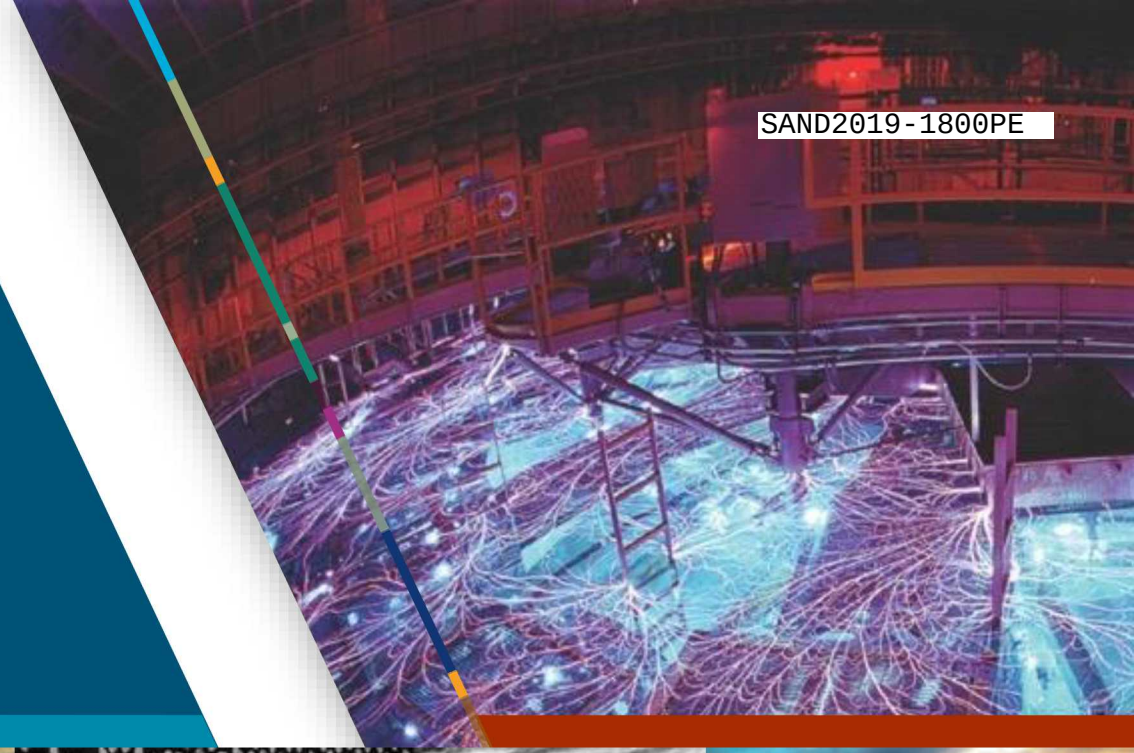
Sandia National Laboratories

Exceptional service in the national interest



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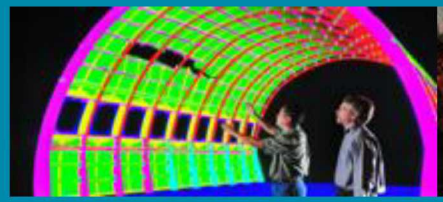
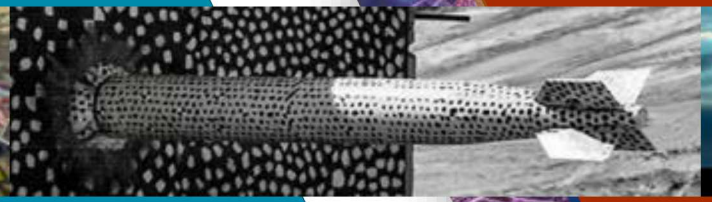







Dr. David Schoenwald
Electric Power Systems Research Department
Sandia National Laboratories

Lecture on Technology Transfer at Sandia National Labs
EMGT 533/633 – Portland State University
February 19, 2019

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.
SAND 2019-XXXXPE

Outline of Today's Lecture

1. History and Overview of Sandia National Labs

2. Technology Transfer Mechanisms at Sandia National Labs

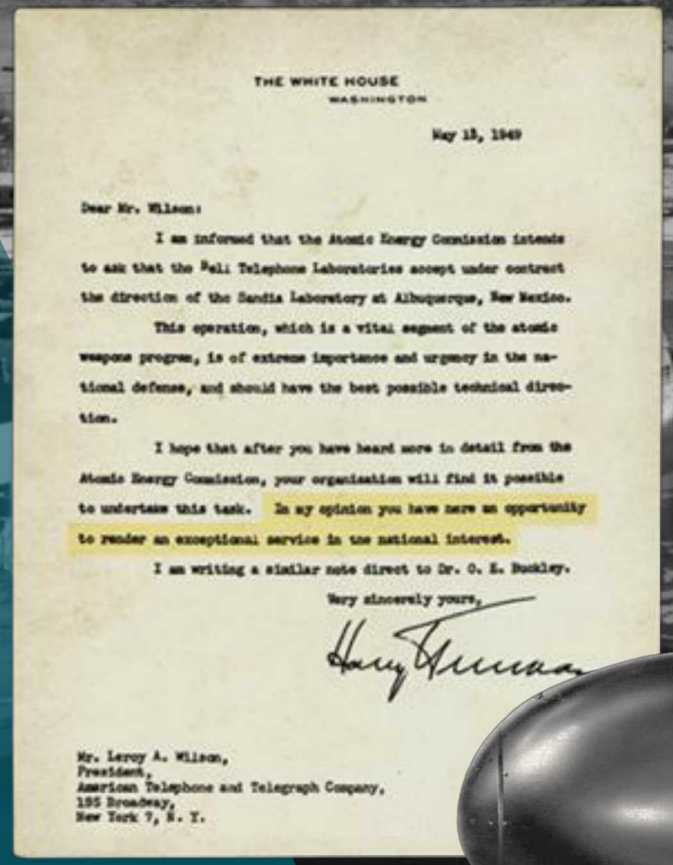
3. Example Project

4. Conclusions

SANDIA'S HISTORY IS TRACED TO THE MANHATTAN PROJECT

…In my opinion you have here an opportunity to render an exceptional service in the national interest.

- July 1945
  Los Alamos creates Z Division
- Nonnuclear component engineering
- November 1, 1949
  Sandia Laboratory established
- AT&T: 1949–1993
- Martin Marietta: 1993–1995
- Lockheed Martin: 1995–2017
- Honeywell: 2017–present



THE WHITE HOUSE
WASHINGTON

May 13, 1949

Dear Mr. Wilson:

I am informed that the Atomic Energy Commission intends to ask that the Bell Telephone Laboratories accept under contract the direction of the Sandia Laboratory at Albuquerque, New Mexico.

This operation, which is a vital segment of the atomic weapons program, is of extreme importance and urgency in the national defense, and should have the best possible technical direction.

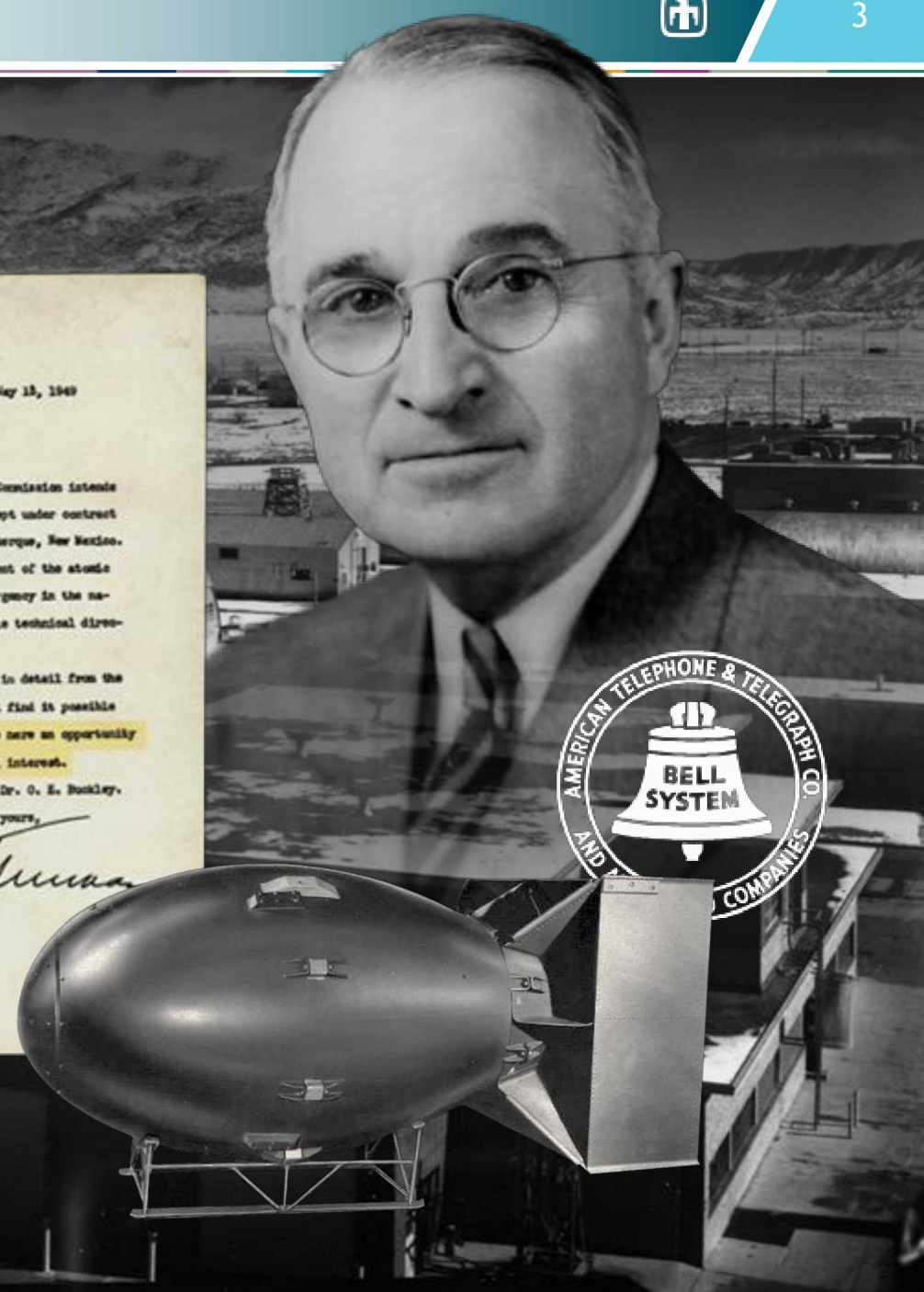
I hope that after you have heard more in detail from the Atomic Energy Commission, your organization will find it possible to undertake this task. In my opinion you have here an opportunity to render an exceptional service in the national interest.

I am writing a similar note direct to Dr. O. E. Buckley.

Very sincerely yours,

Harry Truman

Mr. Leroy A. Wilson,
President,
American Telephone and Telegraph Company,
195 Broadway,
New York 7, N. Y.



SANDIA IS A FEDERALLY FUNDED RESEARCH AND DEVELOPMENT CENTER MANAGED AND OPERATED BY

National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc.: 2017 – present

Government owned, contractor operated

SANDIA HAS FACILITIES ACROSS THE NATION

Activity locations

- Kauai, Hawaii
- Waste Isolation Pilot Plant, Carlsbad, New Mexico
- Pantex Plant, Amarillo, Texas
- Tonopah, Nevada

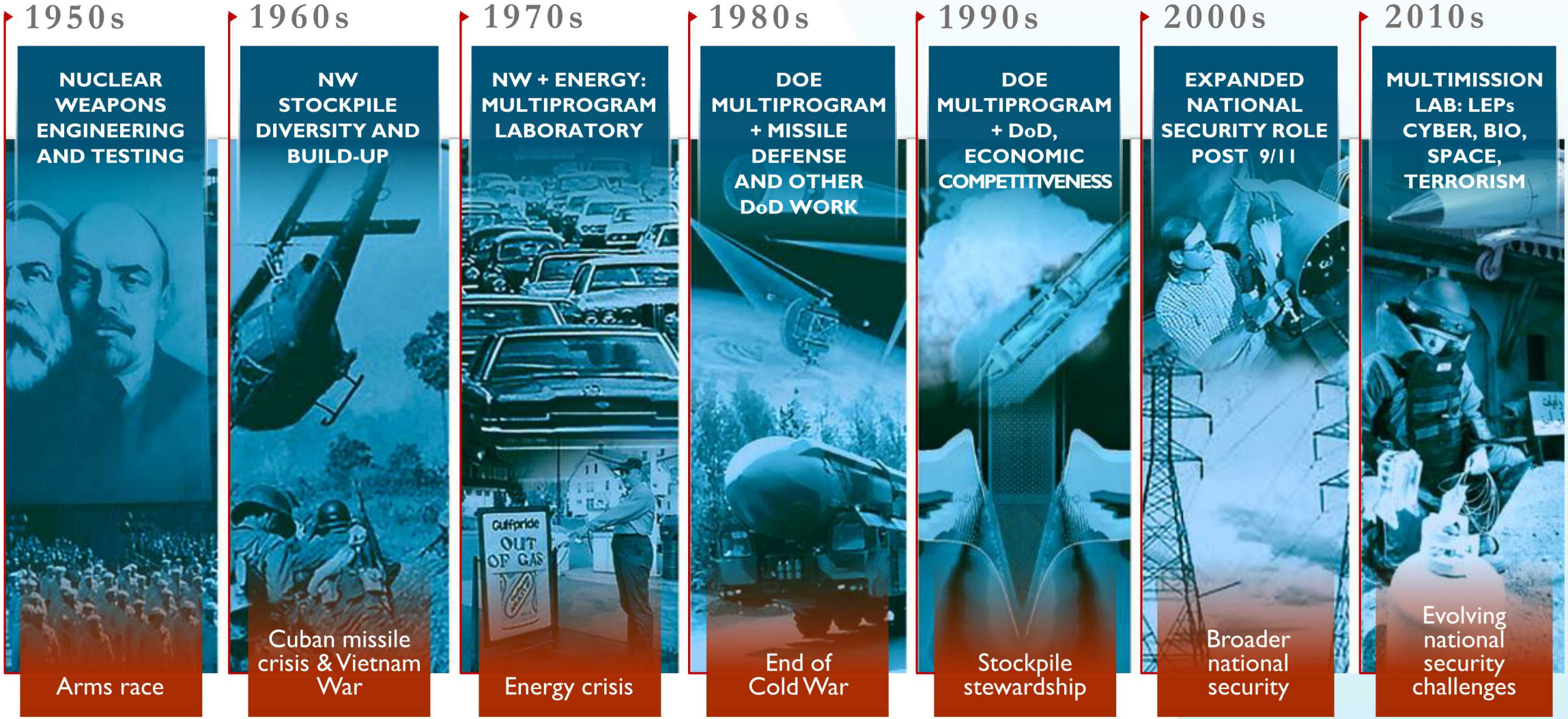
Main sites

- Albuquerque, New Mexico
- Livermore, California

PURPOSE STATEMENT DEFINES WHAT WE DO

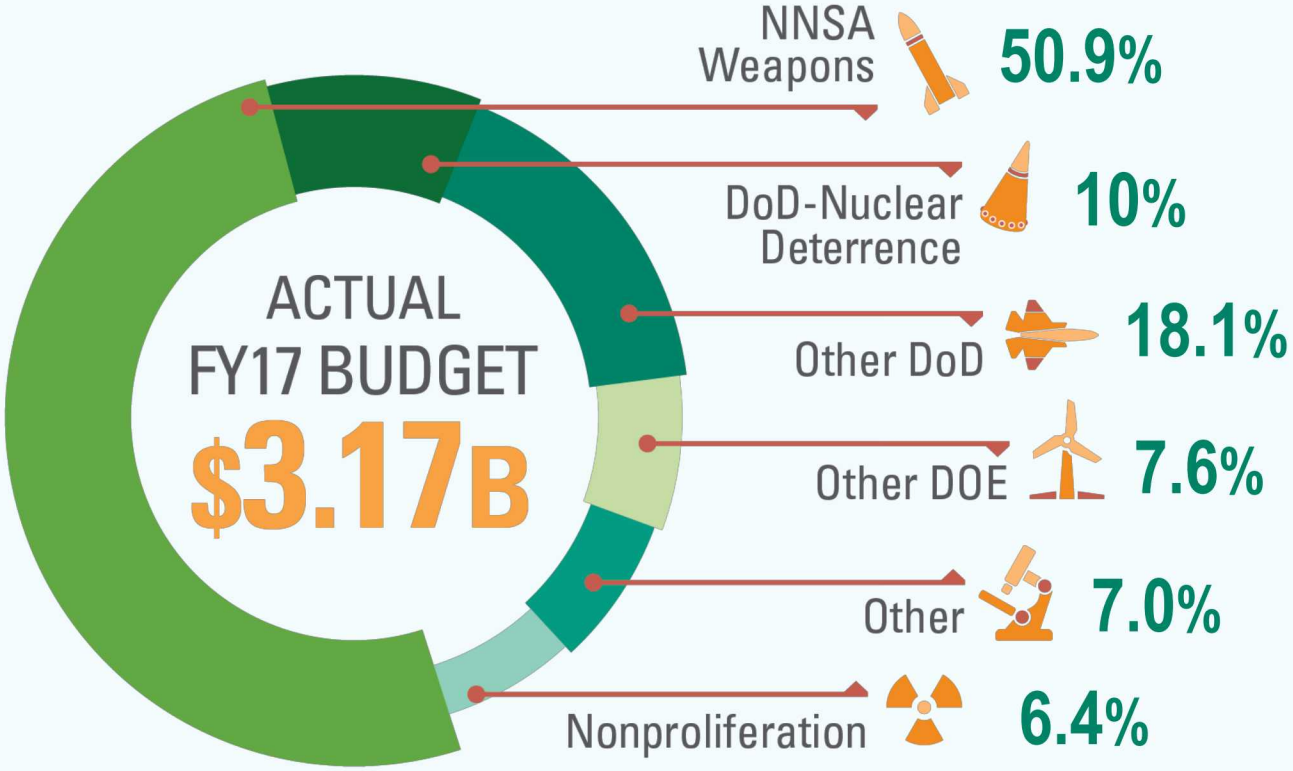
Sandia develops advanced technologies to ensure global peace

SANDIA ADDRESSES NATIONAL SECURITY CHALLENGES



SANDIA HAS FIVE MAJOR PROGRAM PORTFOLIOS

SANDIA'S BUDGET COVERS A BROAD RANGE OF WORK



OTHER

Department of Homeland Security
Other federal agencies | Nonfederal entities
CRADAs, licenses, royalties | Inter-entity work

DoD

Air Force | Army | Navy
Defense Threat Reduction Agency
Ballistic Missile Defense Organization
Office of the Secretary of Defense
Defense Advanced Research Projects Agency
Intelligence Community

OTHER DOE

Science
Energy Efficiency and Renewable Energy
Nuclear Energy
Environmental Management
Electricity Delivery and Energy Reliability
Other DOE

NONPROLIFERATION

NNSA/NA20 | State Department

LABS' SPENDING TOPS $3 BILLION

LABOR AND NON-SUBCONTRACT-RELATED PAYMENTS
$1,858,356,000

SUBCONTRACT-RELATED PAYMENTS
$1,092,155,000

GROSS RECEIPTS, SALES/USE, AND CORPORATE TAXES
$88,072,000

PROCUREMENT CARD PAYMENTS
$85,688,000

SMALL BUSINESS IS A PRIORITY

DISADVANTAGED	$151,638,000
OTHER*	$145,889,000
* Non-minority, non-woman, non-HUBZone, non-veteran owned	
WOMAN OWNED	$98,237,000
VETERAN OWNED	$74,101,000
SERVICE-DISABLED VETERAN OWNED	$48,721,000
HUBZone	$36,497,000
8(a)	$25,915,000

OTHER*	$43,417,000
* Non-minority, non-woman, non-HUBZone, non-veteran owned	
DISADVANTAGED	$26,607,000
WOMAN OWNED	$14,334,000
VETERAN OWNED	$7,738,000
SERVICE-DISABLED VETERAN OWNED	$5,944,000
8(a)	$673,000
HUBZone	$120,000

DISADVANTAGED	$69,992,000
WOMAN OWNED	$66,334,000
OTHER*	$49,685,000
* Non-minority, non-woman, non-HUBZone, non-veteran owned	
VETERAN OWNED	$30,963,000
HUBZone	$22,510,000
8(a)	$14,400,000
SERVICE-DISABLED VETERAN OWNED	$13,541,000

TECHNOLOGY-BASED ECONOMIC DEVELOPMENT

Helping New Mexico companies start up and grow

New Mexico Small Business Assistance (NMSBA)

6,858 new jobs created and retained; all **33** New Mexico counties supported
$57.9M in technical assistance to **2,796** New Mexico small businesses
2017: **$2.4M** in assistance provided by Sandia alone, **188** small businesses in **21** counties

Sandia Science & Technology Park (SSTP)

45 companies and organizations employing **2,059** people
$384.8M of investment
$83K average annual salary, **$4.4B** wages and salaries generated
2017: **6** new companies

Entrepreneurial Separation to Transfer Technology (ESTT)

158 Sandia entrepreneurs have left the Labs
109 companies started up or expanded
2017: **5** entrepreneurs left to start/expand companies

Entrepreneur Exploration (EEx)

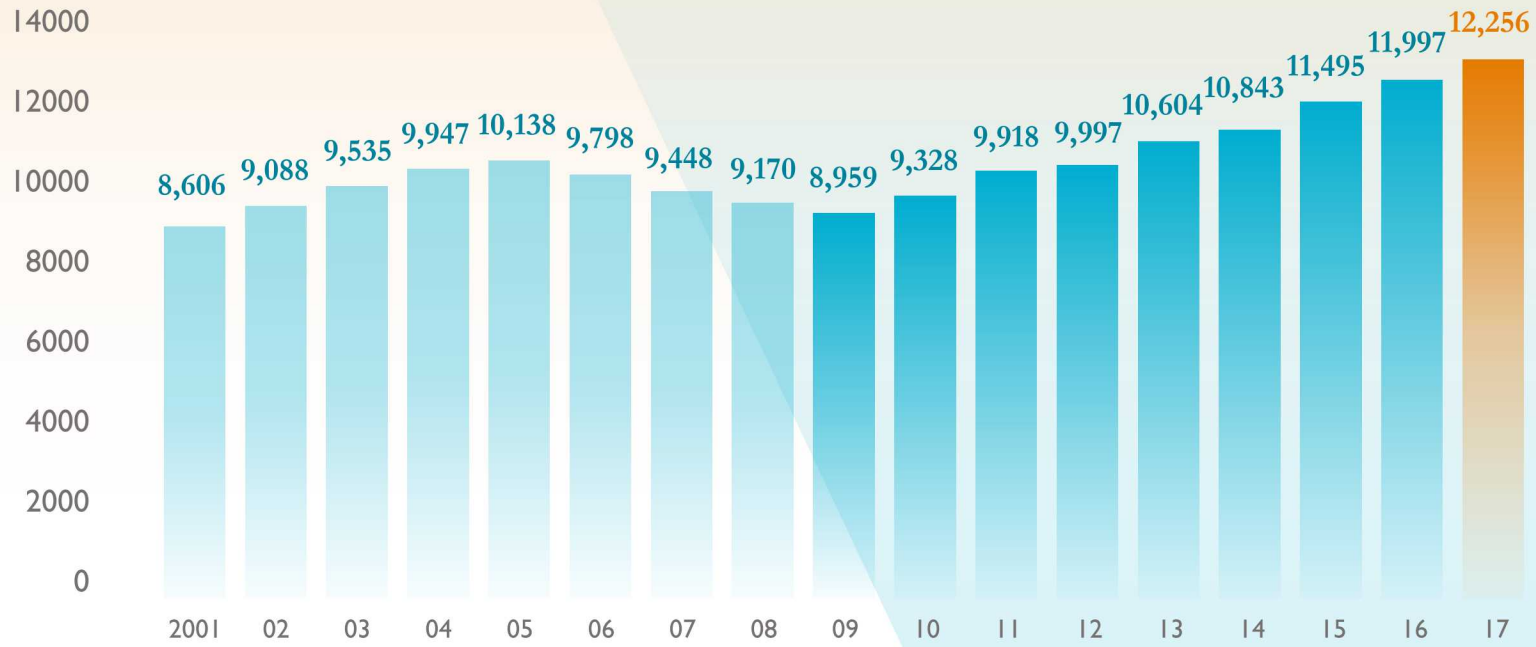
46 events, **2,063** participants
2017: EEx had **20** events with **926** participants

SANDIA'S WORKFORCE IS GROWING

Staff has grown by over 3,000 since 2009 to meet all mission needs

10,940 New Mexico

1,316 California



Mechanisms for Technology Transfer at Sandia

What is Tech Transfer?

The process of transferring our knowledge for the purpose of further development and commercialization...

...for the public good.

Sandia's Objective for IP

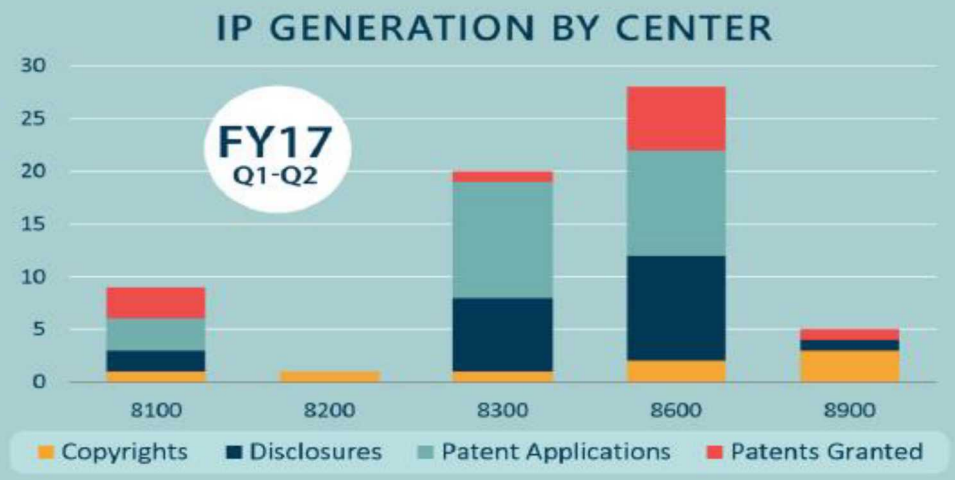
Enable the results of Sandia's publicly funded research and development to be deployed for the US public good

- **Enhance national and local economic development**
- **Further the national security mission(s) of Laboratories by**
  - attracting strategic partners
  - commercializing technologies to enhance national security

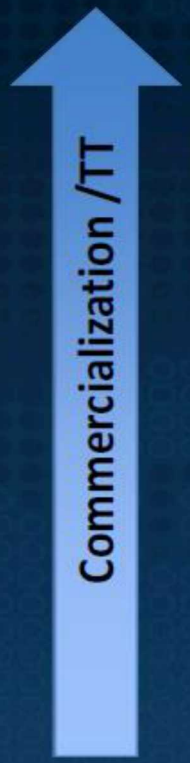
Fulfill Sandia's technology transfer mission by

- enhancing U.S. industrial competitiveness
- commercializing technologies
- providing special consideration to small business

- 8300 and 8600 continue to drive IP generation. As opposed to FY16, 8300 leads patent applications while 8600 leads patents granted thus far in FY17.
- Lab-wide IP trends remain fairly consistent with FY16 numbers.
- Division 8000 IP generation is likely to remain consistent with FY16 numbers, with the exception of copyrights which are likely to exceed FY16 numbers.



Interacting with the Lab takes many forms



- Intellectual Property Licensing
- CRADAs – Cooperative Research and Development Agreements
- Strategic Partnership Agreements (Work For Others)
- Open Source Software/Published Literature

- Entrepreneurial Leave (ESTT)
- LabCorps
- NM Small Business Assistance
- Sandia Science & Tech Park
- Livermore Valley Open Campus (LVOC)

Intellectual Property Licensing

- Commercial Patent License
- Commercial Copyright License (software or design plans)
- Commercial Hybrid License (copyright and patent)
- Test and Evaluation License
- License Option

Cooperative Research and Development Agreement (CRADA)

Definition	Protection of generated information	IP Rights	Industry resource commitment	Lab resource commitment	DOE approval required
Agreement enables non-federal entities to collaborate with the Lab for the purpose of joint R&D	Commercially valuable info generated under a CRADA may be protected for up to 5 years	Negotiable, however, the US Gov. retains a nonexclusive license and march-in rights	Cost shared through contributions of personnel, equipment, services, facilities, and funds	The Lab cost shares (program $) otherwise Sponsor is responsible for full cost recovery	Yes

Strategic Partnership Agreement (SPA) formerly non-fed work-for-others

Definition	Protection of generated information	IP Rights	Industry resource commitment	Lab resource commitment	DOE approval required
Agreement that enables non-federal entities to ask the Lab to perform a defined scope of work or list of tasks that draw upon the Labs capabilities	Negotiable	Rights to Lab inventions generated under the SPA may be available to a Sponsor under DOE's Class Waiver	Sponsor covers the cost of all Lab work to be completed under the SOW	Personnel, equipment and facilities that are used	Yes

Our Vision For The Future

Transform
Research & Technology Showcase
into a year-round function

- More "hot" technologies
- Easy and fast licensing
- Access to research and inventors
- Place to meet and collaborate
- More licensing and collaboration with small businesses
- Medtech and LabCorps as a model

NSF, Energy I-Corps, and NLEAP

CORPS NSF Innovation Corps

- Identify product opportunities that can emerge from academic research
- Gain skills in entrepreneurship through customer discovery

ENERGY I-CORPS U.S. Department Of Energy

- Empowers teams with the tools, resources, and relationships necessary to discover potential market pathways for their innovations.
- Accelerate the transfer of clean energy technologies from national labs to the commercial marketplace.

IPO National Laboratory Entrepreneur Accelerator Pipeline (NLEAP)

Introduces the I-Corps concepts, with a customized focus for the Sandia environment.

Apply concepts to research at earlier stages

Assist in technology transfer of target technologies

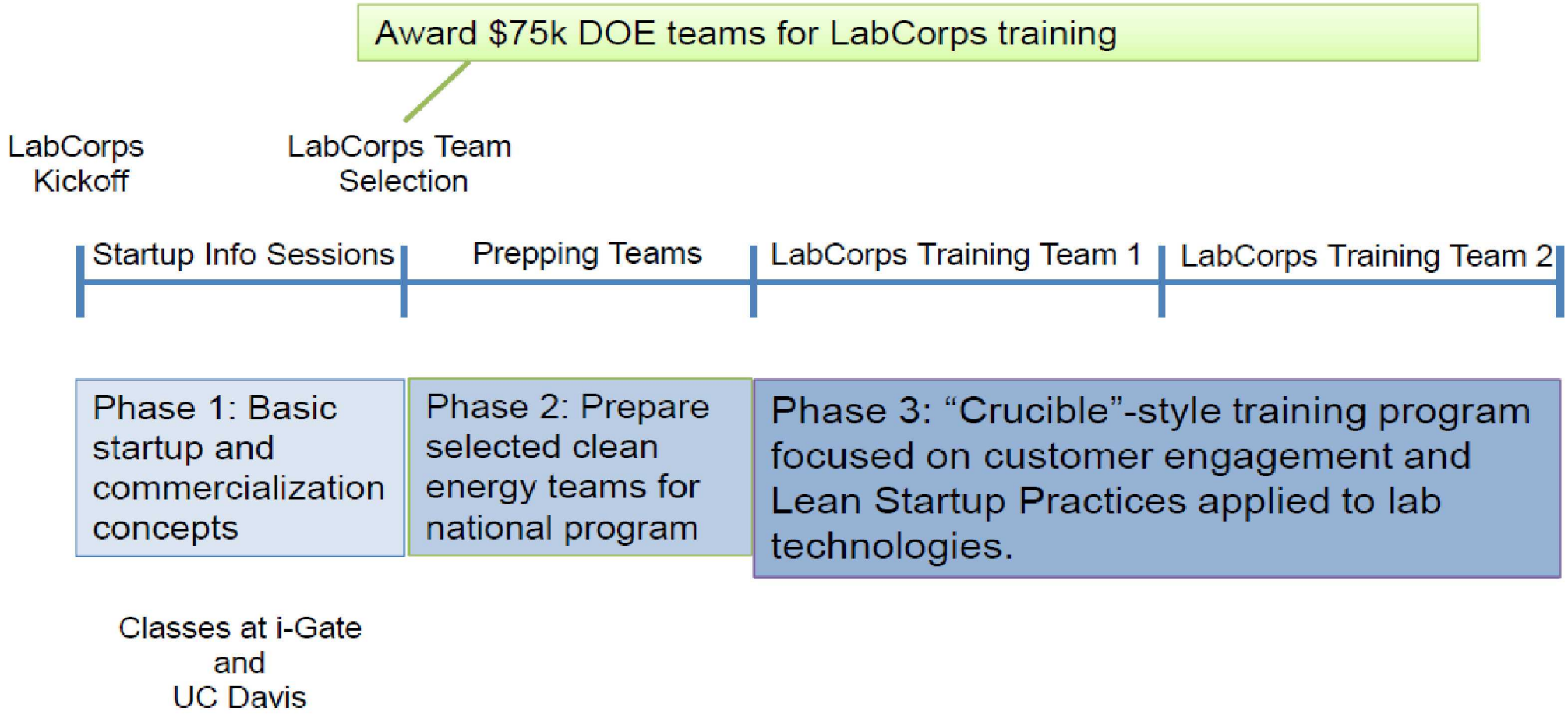
Consider technologies that are not on a path for external commercialization

Provide training to researchers at an accessible pace.

LabCorps Goals

- DOE program based on NSF's i-Corp program. Pilot program was last year with 5 national labs, this year all 17 DOE labs are participating.
- Increase the number of national laboratory-developed technologies that are transferred into commercial development or industry agreements
- Train national laboratory researchers to better understand the commercialization process and private sector needs, even how to start a company
- Transform national laboratory culture to value commercialization and entrepreneurial activities.

DOE LabCorps



ENERGY I-CORPS
U.S. Department Of Energy

8 CLASSES *of* ENERGY I-CORPS

89 TEAMS | 11 NATIONAL LABORATORIES

BRINGING **ENERGY INNOVATIONS** TO

LEARNING FROM

>89 Industry Mentors *and* **5,750** Customer Discovery Interviews with Companies Like:

Hitachi, Lowes, Johns Manville, Lego, US Army, Trane, Tesla, GM, Dow Chemical, Yingli, 3M, Whirlpool, GE, Home Depot, ReMax, Amazon

6 New Businesses

Six teams have launched new businesses based on their Energy I-Corps Technology

$22M Follow- On Funding

Because of Energy I-Corps, technologies have reached a point of commercial viability that has attracted over **$22M in follow-on Funding**

What is NLEAP?

National Laboratory Entrepreneur Accelerator Pipeline (NLEAP) helps participants gain the tools, knowledge, and networks needed to advance their research, ranging from basic science concepts, to applied demonstrations, to final prototype.

NLEAP builds researchers' business skillsets, enabling them to successfully mature their work along the TRL scale and bridge the various "valleys of death".

Nominate participants from each division.

- Early/mid-career staff
- Strategic research topics
- Need for customer engagement

Provide training to build participants' skillsets and enable them to mature their research.

- Monthly training classes and lunch and learn sessions
- Opportunities for networking and collaboration
- Connect to resources

Enable participants to utilize NLEAP concepts in future activities.

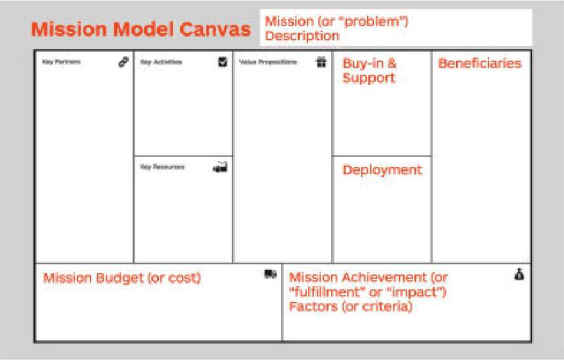
- Advance their R&D with new or existing sponsors
- Form partnership agreements and/or licenses
- Pursue tech transfer opportunities (Technology Commercialization Fund, Pitch Competitions, etc.)

3/26: Mission Model Canvas

Drew Gorham, BMNT

All-Day Course in NM

Lunch and Learn 4/18



5/16: Customer Discovery

Jeff Dorman, JDA International

All-Day Course in NM

Lunch and Learn 5/23

Evaluate how their work ties to mission and create a plan for impactful maturation.

Better understand their customers need for their technology.

Additional NLEAP Training Topics

4/25: Market & Competitive Analysis

IPO: Business and Competitive Intelligence, 1182

6/11: Value Proposition & Market Fit

IPO: Business Development, 1181 and 1184

7/9: Tech Transfer and Commercialization

IPO: IP Management and Licensing, 1182

IPO

Evaluate how their work ties to mission and create a plan for impactful maturation.

Better understand their customers need for their technology.

Communicate the value of their work in presentations, LDRD proposals or other funding requests.

Understand and better utilize the resources available at Sandia.

Consider opportunities for commercialization and tech transfer.

Example Project:

Real-Time Control of Inter-Area Oscillations in the Western North American Power System

Acknowledgements and Contributors

- **We gratefully acknowledge the support of DOE and BPA:**
  - BPA Office of Technology Innovation – TIP# 289
  - DOE-OE Transmission Reliability Program – PM: Phil Overholt
  - DOE-OE Energy Storage Program – PM: Imre Gyuk

- **Bonneville Power Administration (BPA):**
  - Dmitry Kosterev (Tech. POC)
  - Gordon Matthews (PM)
  - Jeff Barton
  - Tony Faris
  - Dan Goodrich
  - Jisun Kim
  - Michael Overeem
  - Sergey Pustovit
  - Greg Stults
  - Mark Yang
  - Steve Yang

- **Sandia National Labs:**
  - Dave Schoenwald (Project PI)
  - Brian Pierre
  - Felipe Wilches-Bernal
  - Ryan Elliott
  - Ray Byrne
  - Jason Neely

- **Montana Technological University:**
  - Prof. Dan Trudnowski
  - Prof. Matt Donnelly

U.S. DEPARTMENT OF ENERGY | Electricity Delivery & Energy Reliability

BONNEVILLE POWER ADMINISTRATION

MONTANA TECH MontanaTech

Sandia National Laboratories

Project Summary

Problem:

- Poorly damped inter-area oscillations in congested transmission corridors can lead to system breakups and widespread outages
- To prevent this, power flows are constrained well below rated transmission limits ➔ inefficient use of expensive capital investments

Solution:

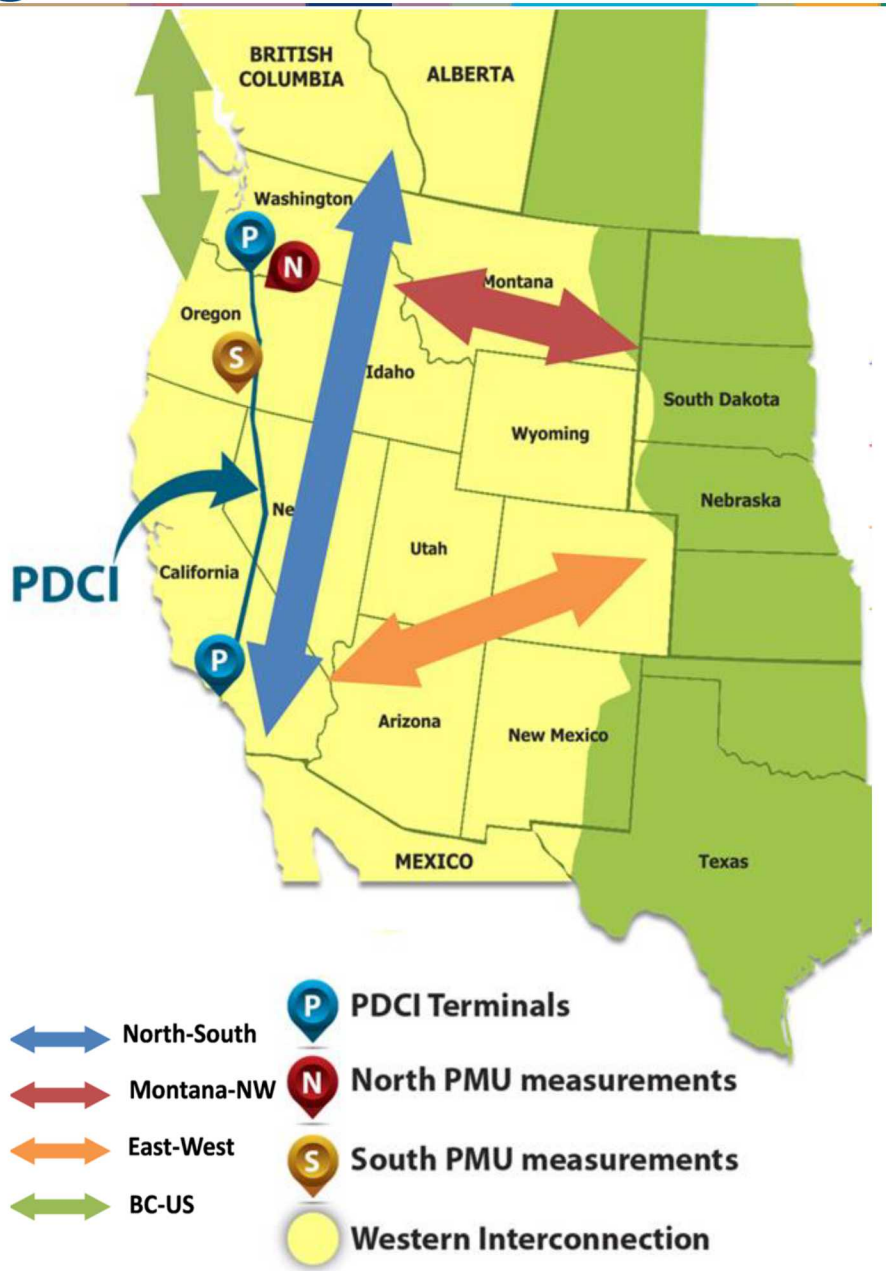
- Feedback control using real-time PMU data: First demonstration of this in North America
- Real power injection by modulating PDCI power
- Supervisory system integrated with controller for ensuring “Do No Harm” to grid

Benefits:

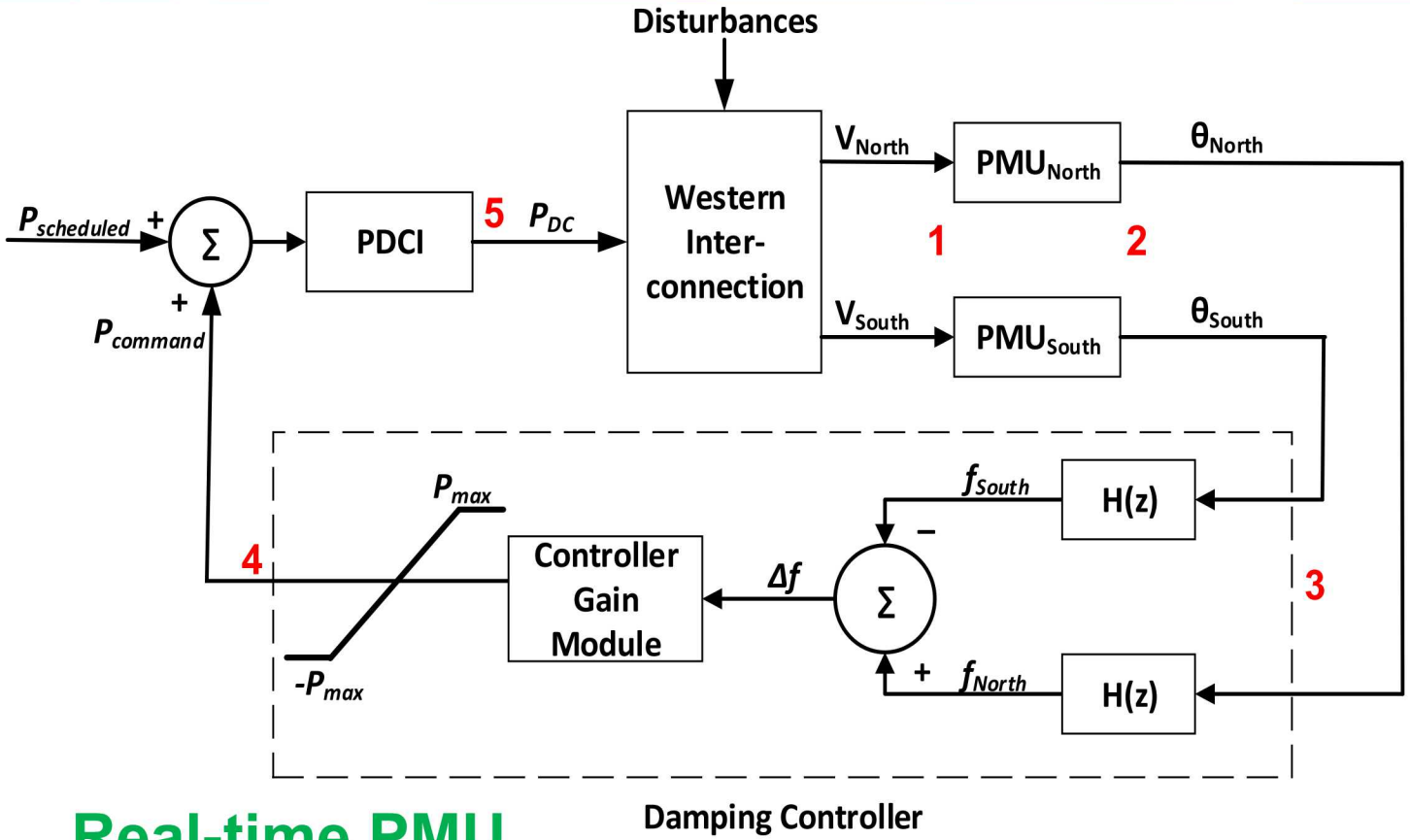
- Improved grid reliability
- Additional contingency for stressed grid conditions
- Avoided costs from a system-wide blackout
- Reduced or postponed need for new transmission capacity
- Enables higher power flows on congested transmission corridors

Project Background

- Based on 1970s BPA experiments on PDCI later shown to have destabilized BC-US mode
- Revived in 2007 – 2012 by BPA with Montana Tech leveraging PMU deployments in WECC
- Current project launched in June 2013 as a collaboration of SNL, MT, BPA, and DOE to develop and demonstrate damping control
- Phase 1 (June 2013 – Sept 2015)
  - Controller design based on extensive simulation studies & eigensystem analysis
  - Open-loop tests – study PMU data quality
- Phase 2 (Oct 2015 – Sept 2017)
  - System install at Celilo in The Dalles, OR
  - Closed-loop demonstration on Western Interconnection using modulation of PDCI
  - Documentation and publishing of results; engagement of power systems community
- Phase 3 (Oct 2017 and beyond)
  - Conduct longer-term tests
  - Study transient stability potential
  - Assess impacts with DC side
  - Explore other sources of actuation



Damping Controller Strategy



Real-time PMU feedback is the key to stable control

$$P_{command}(t) = K\left(f_{North}(t-\tau_{d1}) - f_{South}(t-\tau_{d2})\right)$$

K is a constant gain with units of MW/mHz

1 PMUs take measurements

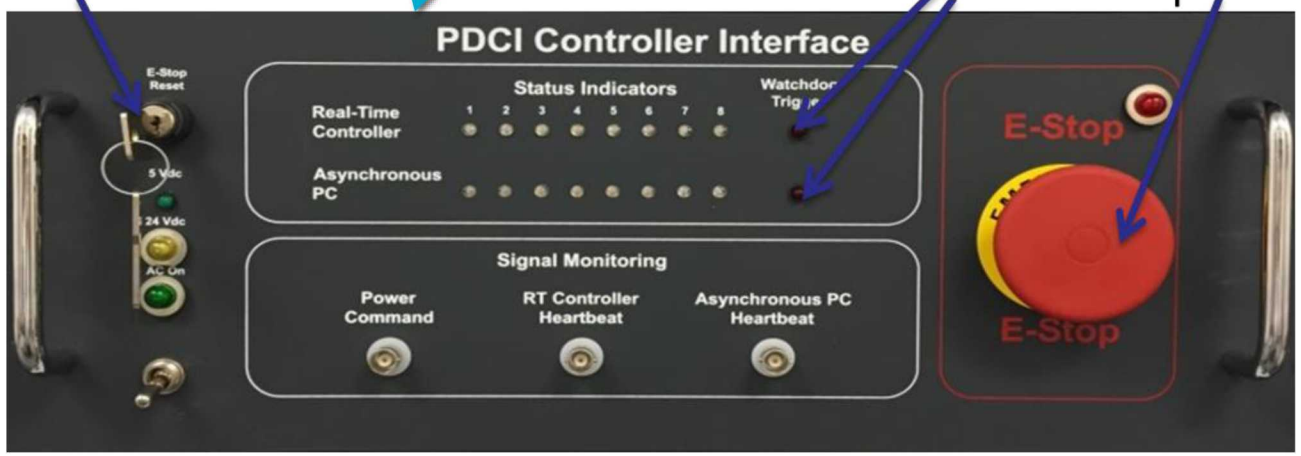
2 PMUs send data packets over network

3 Packets arrive at damping controller

4 Controller sends power command to PDCI

5 PDCI injects power command into grid

Damping Controller Hardware



Watchdog circuit module

Key switch

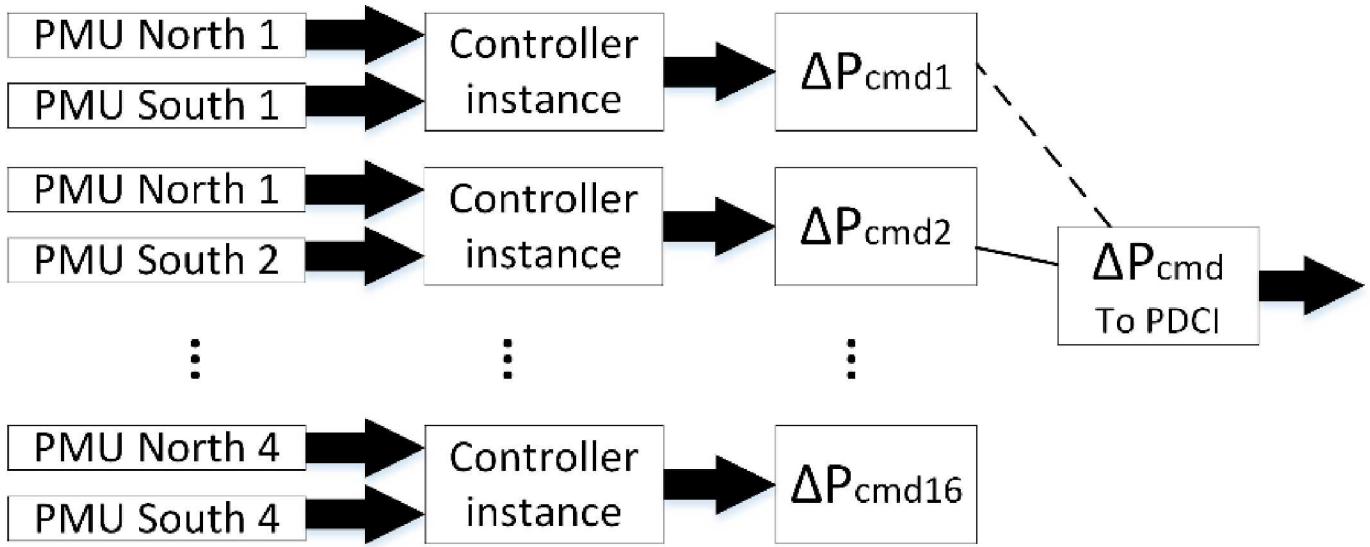
Heartbeat indicators

E-Stop button

Server for select supervisory functions ("Do No Harm")

Real-time Control platform

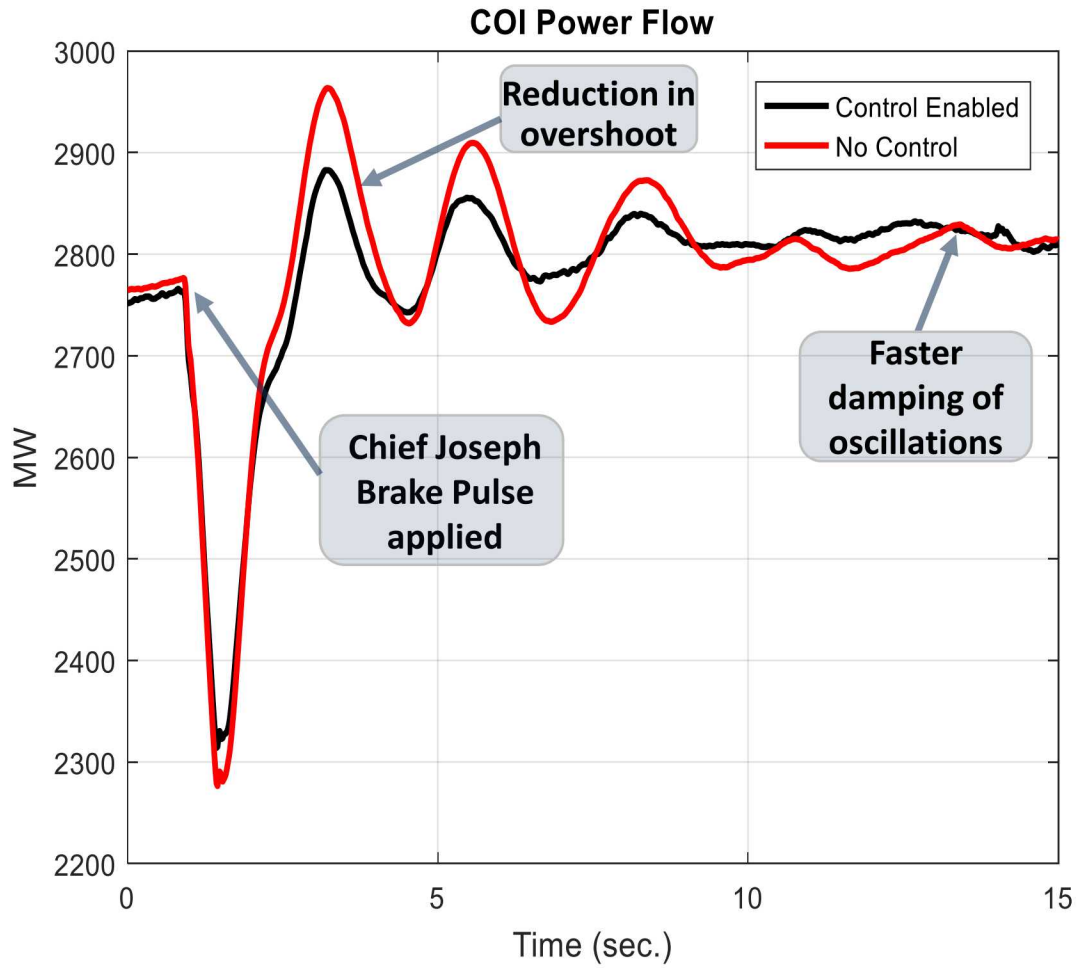
Controller Employs Diversity and Redundancy in Feedback



- Diversity = Geographical Robustness
- Redundancy = Site Measurement Robustness
- Controller evaluates 16 feedback pairs every update cycle to provide options due to any network issues
- Controller seamlessly switches between feedback pairs to avoid injecting step functions into the system

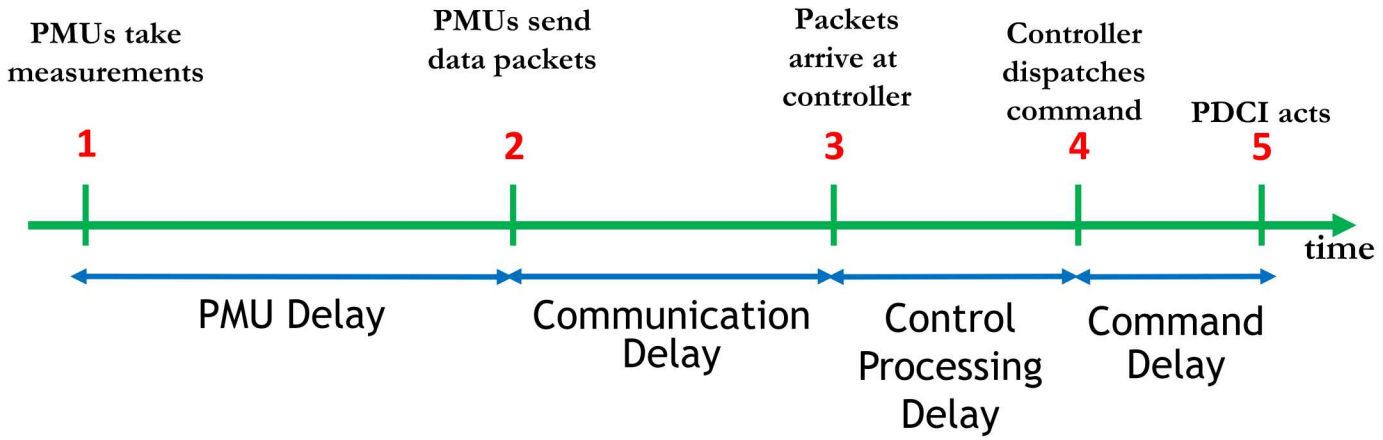
Grid Demonstrations Showed Significant Improvements in Oscillation Damping

Experiments conducted at Celilo Converter Station Sept 2016, May & June 2017, May & June 2018



Chief Joseph brake test	Damping of North-South Mode improved 4.5 percentage points (11.5% to 16.0%) in closed-loop vs. open-loop operation.
Square wave pulse test	Damping controller significantly reduces amplitude of North-South mode oscillations in 15 seconds vs. 23 seconds in open-loop tests for the same reduction.
All tests	Controller consistently improves damping and does no harm to grid.

Communication and Delays



Name	Mean	Range	Note
PMU Delay	44	40 - 48	Dependent on PMU settings. Normal distribution.
Communication Delay	16	15 - 40	Heavy tail
Control Processing Delay	11	2 - 17	Normal around 9 ms, but a peak at 16 ms due to control windows when no data arrives (inconsistent data arrival)
Command Delay	11	11	Tests were consistent, fixed 11 ms
Effective Delay	**82**	**69 - 113**	**Total delay**

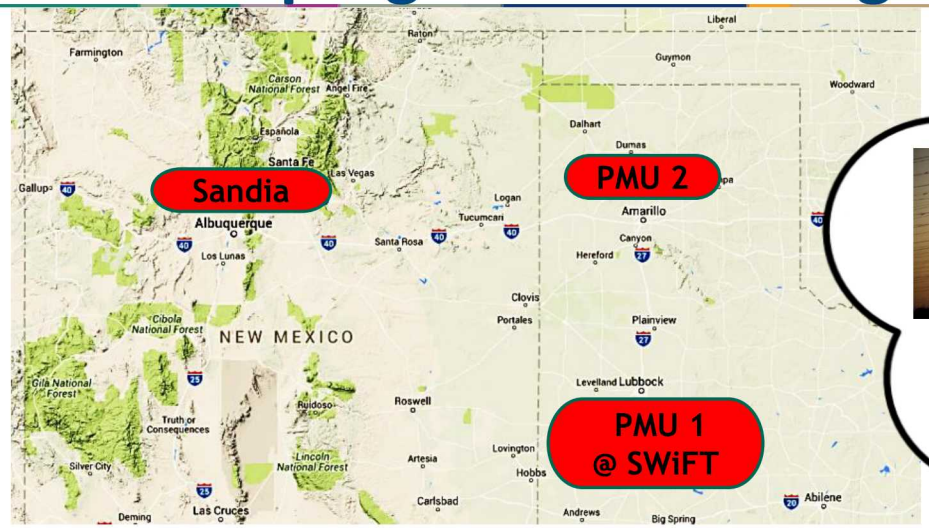
Total time delays are well within our tolerances (<< 150 ms)

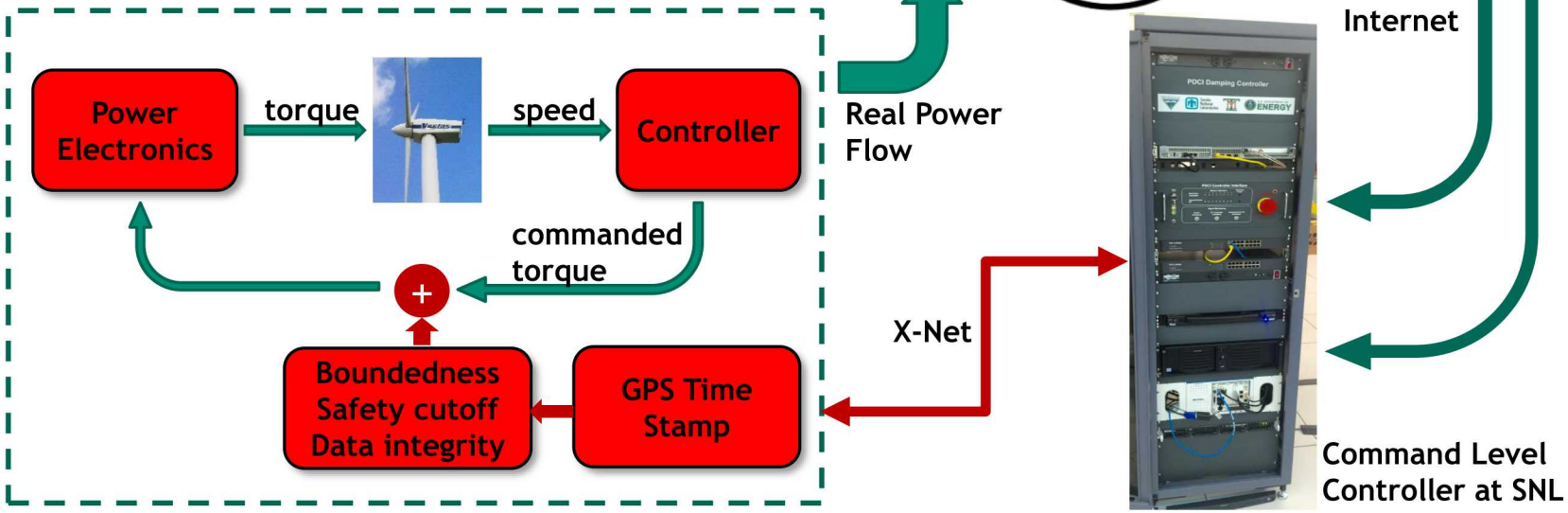
Distributed Control Using Energy Storage Sites

Advantages:

- Robust to single points of failure
- Controllability of multiple modes
- Size/location of a single site not as critical as more energy storage is deployed on grid
  - With 10s of sites engaged, single site power rating ≈ 1 MW can suffice
  - Control signal is energy neutral ➔ storage sites can perform other applications

Damping Control Using Wind Turbines





- PDCI damping controller was modified to modulate the torque command of a wind turbine at Sandia wind facility (SWiFT)
- Actuator (wind turbine) is remote - not co-located with the controller
- Communication channel used the public internet

Key Takeaways from Project

- First successful demonstration of wide-area control using real-time PMU feedback in North America ➔ much knowledge gained for networked control systems
- Control design is actuator agnostic ➔ easily adaptable to other sources of power injection (e.g., wind turbines, energy storage)
- Supervisory system architecture and design can be applied to future real-time grid control systems to ensure “Do No Harm”
- Algorithms, models, and simulations to support implementation of control strategies using distributed grid assets
- Extensive eigensystem analysis and visualization tools to support simulation studies and analysis of test results
- Model development and validation for multiple levels of fidelity to support analysis, design, and simulation studies

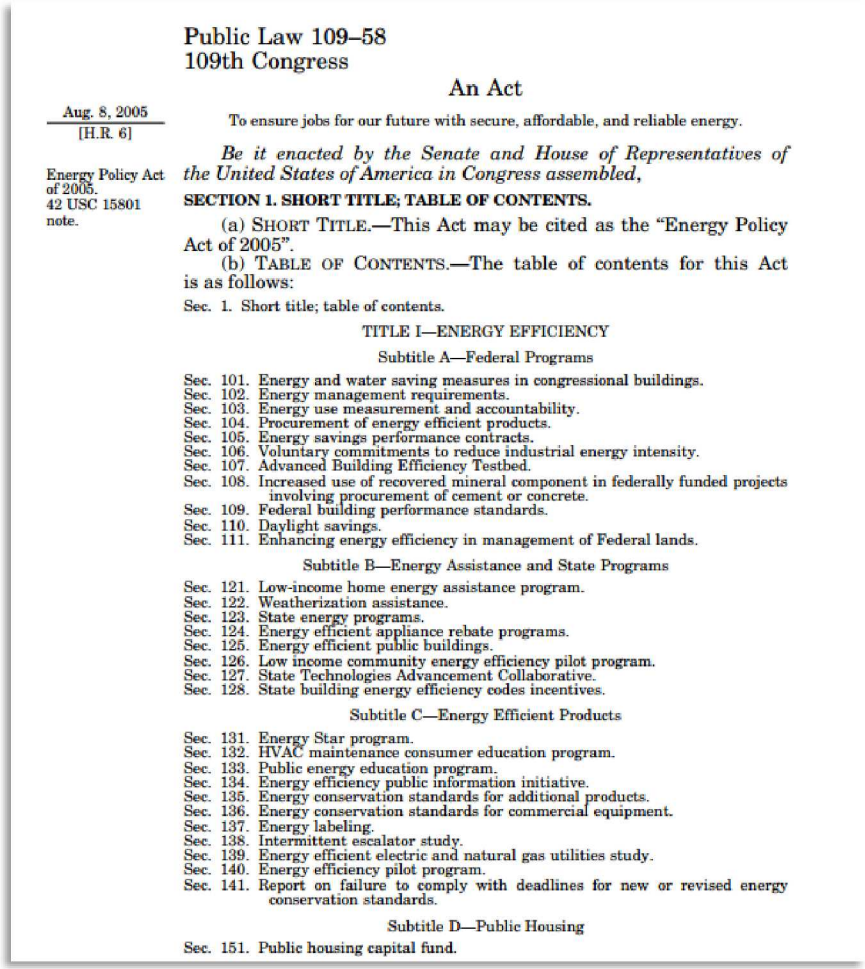
Project Recognition

- First successful demonstration of wide-area control using real-time PMU feedback in North America
- 2017 R&D 100 Award
- 33 published papers (27 conference papers, 6 journal papers, several more journal papers in review process)
- US Patent application filed March 2018
- Commercialization of DCON being pursued jointly with BPA

Current Efforts to Commercialize Damping Controller

What is TCF? Technology Commercialization Fund

- Funding to enable DOE facilities to mature and commercialize energy technology
- Program Goals:
  - Perform technology maturation with the intent of attracting a private partner that is willing to support the technology's commercialization
  - Support cooperative development of technology with a private partner for a specific commercial application



Public Law 109–58
109th Congress

An Act

Aug. 8, 2005
[H.R. 6]

To ensure jobs for our future with secure, affordable, and reliable energy.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

Energy Policy Act of 2005.
42 USC 15801 note.

SECTION 1. SHORT TITLE; TABLE OF CONTENTS.

(a) SHORT TITLE.—This Act may be cited as the "Energy Policy Act of 2005".

(b) TABLE OF CONTENTS.—The table of contents for this Act is as follows:

Sec. 1. Short title; table of contents.

TITLE I—ENERGY EFFICIENCY

Subtitle A—Federal Programs

Sec. 101. Energy and water saving measures in congressional buildings.
Sec. 102. Energy management requirements.
Sec. 103. Energy use measurement and accountability.
Sec. 104. Procurement of energy efficient products.
Sec. 105. Energy savings performance contracts.
Sec. 106. Voluntary commitments to reduce industrial energy intensity.
Sec. 107. Advanced Building Efficiency Testbed.
Sec. 108. Increased use of recovered mineral component in federally funded projects involving procurement of cement or concrete.
Sec. 109. Federal building performance standards.
Sec. 110. Daylight savings.
Sec. 111. Enhancing energy efficiency in management of Federal lands.

Subtitle B—Energy Assistance and State Programs

Sec. 121. Low-income home energy assistance program.
Sec. 122. Weatherization assistance.
Sec. 123. State energy programs.
Sec. 124. Energy efficient appliance rebate programs.
Sec. 125. Energy efficient public buildings.
Sec. 126. Low income community energy efficiency pilot program.
Sec. 127. State Technologies Advancement Collaborative.
Sec. 128. State building energy efficiency codes incentives.

Subtitle C—Energy Efficient Products

Sec. 131. Energy Star program.
Sec. 132. HVAC maintenance consumer education program.
Sec. 133. Public energy education program.
Sec. 134. Energy efficiency public information initiative.
Sec. 135. Energy conservation standards for additional products.
Sec. 136. Energy conservation standards for commercial equipment.
Sec. 137. Energy labeling.
Sec. 138. Intermittent escalator study.
Sec. 139. Energy efficient electric and natural gas utilities study.
Sec. 140. Energy efficiency pilot program.
Sec. 141. Report on failure to comply with deadlines for new or revised energy conservation standards.

Subtitle D—Public Housing

Sec. 151. Public housing capital fund.

TCF Intent is to Bridge the Research to Commercialization Gap

TCF Goals

- Perform technology maturation with the intent of attracting a private partner that is willing to support the technology's commercialization.
- Support cooperative development of technology with a private partner for a specific commercial application.

Key Gaps to Address

- Technology maturation resource gap.
- Forward-looking and competitive DOE approach to CRADAs and partnering agreements.
- Focused outreach and industry engagement to commercialize high-potential energy technologies.

Current Status

- We have a proposal submitted currently under review in the FY2019 TCF FOA
- We are teaming with a software firm to “harden” the software to be operational in a substation environment
- We are leveraging the actuator “agnosticism” to widen the potential commercial market beyond the initial high voltage DC application with BPA
- We are applying for the TCF to enable to “modularization” of the damping controller to be easily adaptable to other environments (energy storage, wind, large PV plants, etc.)
- Interested vendors include ABB and Schweitzer Engineering Labs

Conclusions

- Technology Transfer is a very important mission of the DOE national labs
- Training classes, mentors, funding exist for lab researchers to pursue commercialization of successful research projects
- Many types of partnership mechanisms exist for commercial enterprises, large and small, to participate in the commercialization of lab research
- Experience has shown that the training and DOE funding mechanisms significantly increase the likelihood of eventual commercialization of lab research
- Personal experience has shown that understanding the following is critical to successful technology transfer:
  - ✓ the underlying market(s)
  - ✓ The means by which the potential market(s) and pool of commercial partners can be expanded
  - ✓ the mechanisms for partnership agreements