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# The National Science Foundation
# Industry University Cooperative Research Center Webinar Program

## The Center for Wind Energy, Science, Technology and Research (WindSTAR) and the Center for GRid-connected Advanced Power Electronic Systems (GRAPES)

National Science Foundation
Industry/University Cooperative Research Center (I/UCRC)

# WindSTAR

*Wind-Energy Science, Technology, and Research*
*Industry/University Cooperative Research Center*

Christopher Niezrecki
*Center Director*

I/UCRC Webinar Series
December 12, 2018

Mario A. Rotea
*Site Director*

University of Massachusetts Lowell

UT DALLAS The University of Texas at Dallas

# Our goals are to:

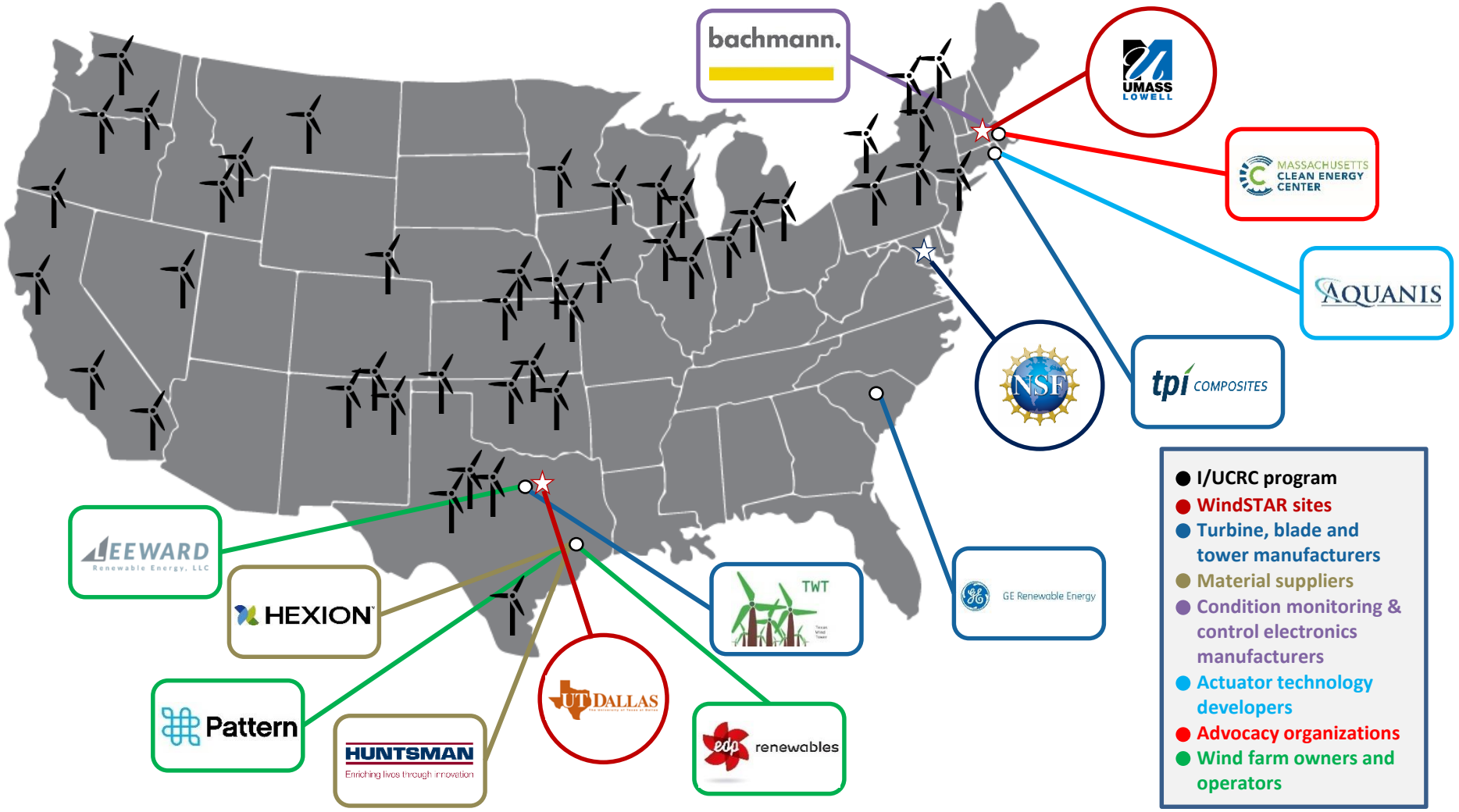
- Conduct research that **benefits our industry members**
- Bring together **university and industry** researchers to conduct basic and applied research on wind energy
- Combine **state-of-the-art capabilities and knowledge** to execute projects relevant to industry partners
- **Train students** in the advanced technologies that are important to industry partners and to have a pipeline of state-of-the-art talent flowing from academia to industry
- Foster a **community for networking, interactions,** and **collaboration**
- Help to make wind energy widespread by **lowering the LCOE**: through increases in performance, improved reliability, material components, and modeling capabilities, as well as reduced capital/operating expenditures of wind turbine systems.

# General info

- Established in 2014
  - Completing NSF I/UCRC Phase I in 2019
  - Planning NSF I/UCRC Phase II for 2019 - 2024
- Major Annual Meetings/Events
  - June Industrial Advisory Board (IAB) Meeting (typically in Massachusetts)
  - January IAB Meeting (typically in Texas)
  - September WindSTAR Day (online webinars for final project presentations)
- Research projects
  - Project year – September 1 through August 31 (typically 1-year duration)
  - To Date, the Center has completed 22 research projects
  - Center has 9 additional research projects underway

**www.uml.edu/WindSTAR**

# Participation



# Center Leadership

## Directors:

**Center Director:**
Christopher Niezrecki, Ph.D.
University of Massachusetts Lowell

**Site Director:**
Mario Rotea, Ph.D.
University of Texas at Dallas

## Operations:

**Assistant Director for Operations:**
Patrick Drane
University of Massachusetts Lowell

## IAB Chairs:

**IAB Chair:**
Nicholas Althoff
GE - Senior Engr. Manager, Wind Advanced Technologies

**IAB Co-Chair:**
Neal Fine
Aquanis - CEO

## IAB Past Chairs:

Stephen C. Nolet (2014-15)
TPI Composites, Inc.

Justin Johnson (2015-16)
EDP Renewables

Stephen Johnson (2016-17)
GE Renewable Energy

Ben Rice (2017-18)
Pattern Operators

# Resources

- Leverage of the resources of two public research universities
  - UMass Lowell focuses on projects that advance the **materials**, **manufacturing**, **reliability**, **testing**, **modeling** and **monitoring** of turbines as well as **energy storage** and **transmission**.
  - UT Dallas focuses on **high-fidelity simulations** of wind power systems and components, **LiDAR measurements** and **analysis** of wind fields for diagnostics and model validation, Boundary layer and subsonic **wind tunnel testing**, **control system design** for wind turbines and farms, **large rotor design**, **grid integration** and **energy storage**.

Together 35+ faculty bring tremendous expertise to the Center:

- Composites, Mechanics, and Materials (8)
- Control Systems & Optimization (5)
- Fluid Mechanics (6)
- Geotechnical Engineering (3)
- Software Engineering (1)
- Structural Health Monitoring, Vibration, Acoustics, and Inspection (6)
- Other Engineering and Business (6)

# Facilities and Laboratories

- Structural Dynamics and Acoustics Systems Laboratory (UML)
- Advanced Composites Materials and Textile Research Laboratory (UML)
- Control Systems Laboratory (UTD)
- Test Bed for Dynamic Visualization of Wind Farms (UTD)
- Access to the NREL/MassCEC - Wind Technology Testing Center
- Wind, Fluids, and eXperiments (WindFLuX) Lab (UTD)
- Boundary Layer and Subsonic (BLAST) Wind Tunnel (UTD)
- High-Performance Computing Centers (UTD & UML)
- Other:
  - Renewable Energy and Vehicular Technology Laboratory (UTD)
  - Security Analysis and Information Assurance Lab (UTD)
  - Renewable Energy Laboratory (UML)
  - Wet Chemistry Laboratory (UML)
  - Thermal Analysis Laboratory (UML)
  - Materials Characterization Laboratory (UML)
  - Processing Laboratories (UML)
  - Composites Engineering Research Laboratory (MCA)

# UTD Mobile Research Facility


## Mobile Research Van

- Dodge RAM 2500 Promaster Cargo commercial van
- Long wheelbase, extra height interior
- Set up for towing, e.g., LiDAR trailer

## LiDAR Trailer

- 14’, extra-height trailer providing safe transport and storage of LiDAR instrument and associated gear
- Carry 4KW power generation capability, tools, support equipment

# UTD BLAST Wind Tunnel

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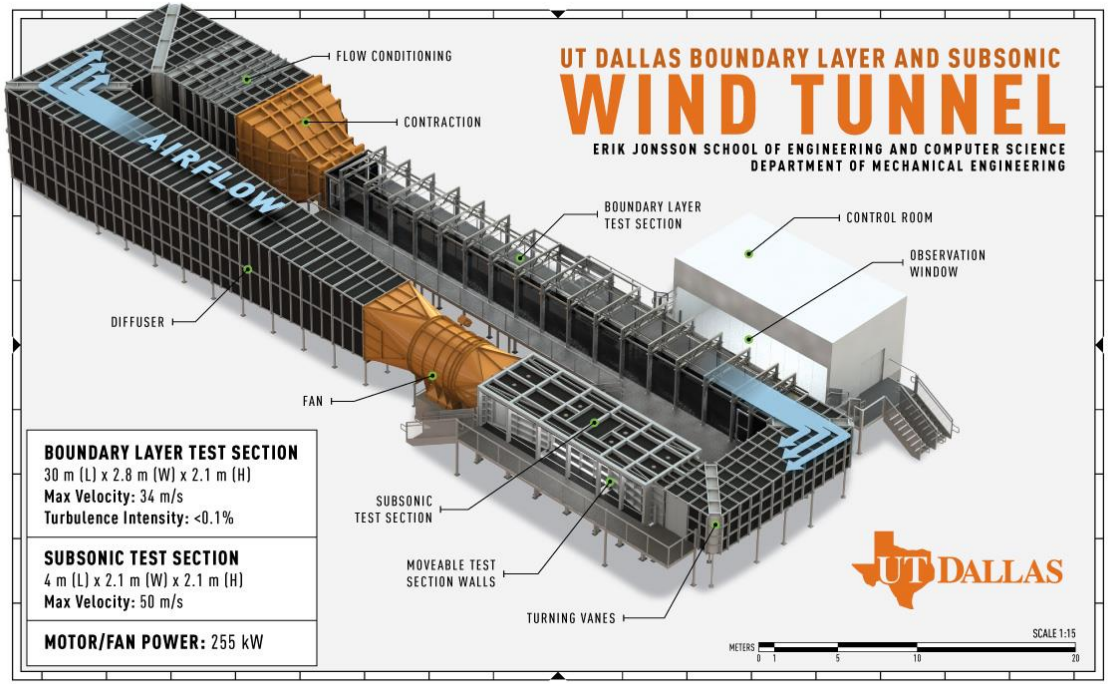



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# Research Thrust Areas

WindSTAR
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Industry/University Cooperative Research Center

## Composites and Blade Manufacturing

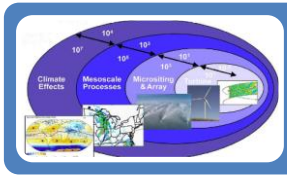
- Design and methods
- Next generation materials

## Structural Health Monitoring and NDI

- Damage detection and prognosis
- Life cycle management

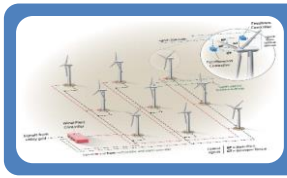
**Snapshot of projects completed in 2018:**

**6 Projects**
**10 faculty members**
**8 graduate students**
**2 undergraduates**




## Wind Plant Modeling and Measurements

- Simulation of power production, power fluctuations and loads
- LiDAR for performance diagnostic and model validation



## Control Systems Wind Turbines and Wind Plants

- Optimization of energy capture and load mitigation
- Wake management

**2 Projects**
**5 faculty**
**4 graduate students**

## Energy Storage and Grid Integration

- Solutions for more reliable, dispatchable and grid-friendly wind energy systems

## Foundation and Towers

- Modeling and costing for higher towers
- Improved ground/soil assessment

**1 Projects**
**1 faculty**
**4 undergrad students**

# Major Outcomes

- 22 Final Project Reports and Presentations to our Members
- 5 Software
- 1 Patent Filing
- 3 Hardware Developments
- 9 Journal Publications
- 2 Masters Theses
- 3 Doctoral Dissertations
- 21 Conference Publications
- IACMI Project Funding
- ARPA-E – $3.5M Funding

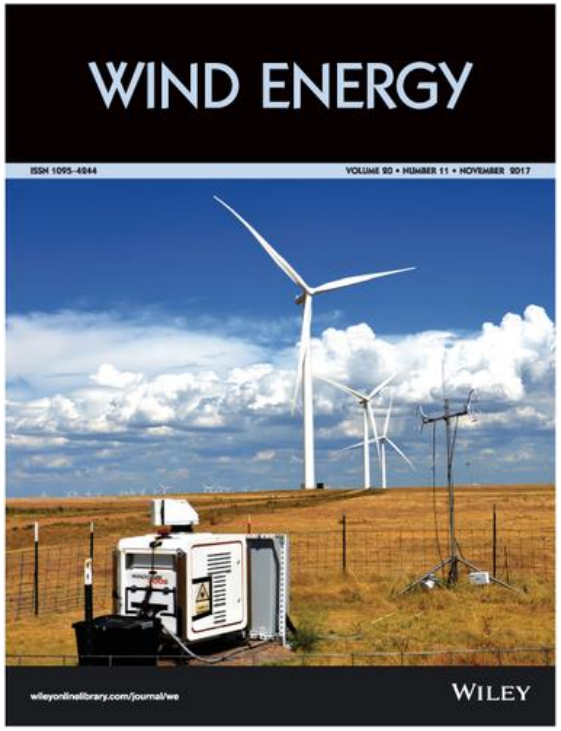



Photo of the deployment of the UT Dallas mobile LiDAR station on the cover of *Wind Energy*, Vol 20, Issue 11, Nov 2017.

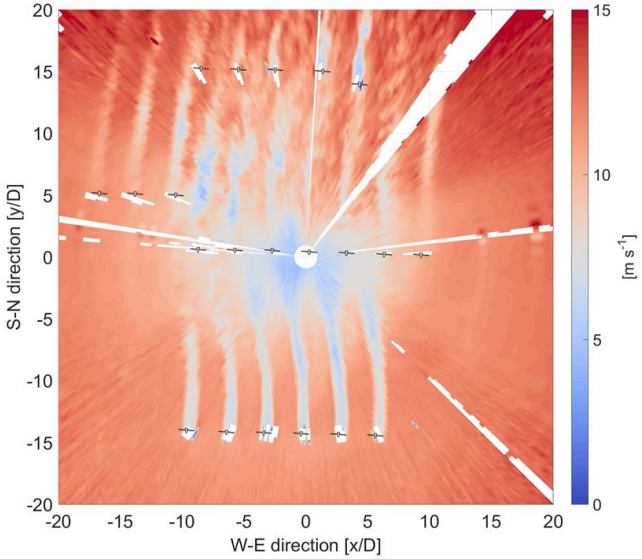
# Wind Farm Model - LiDAR data

PI: G. Valerio Iungo
Valerio.iungo@utdallas.edu

**Objective:** Develop a reduced order model to predict wind turbine wakes and power capture

- Characterization of wind farm performance through SCADA, meteorological and LiDAR data
- Probing wind turbine wakes through LiDAR measurements for different atmospheric conditions and turbine settings
- Capability to predict power production from individual wind turbines, wake interactions and turbine power capture with low computational costs.

LiDAR Measurements




UTD mobile LiDAR station

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# Accuracy Quantification

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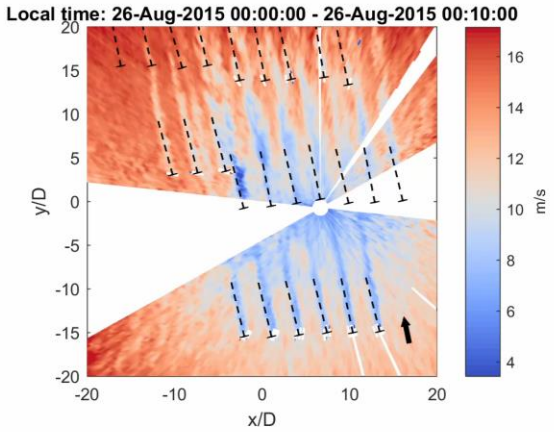
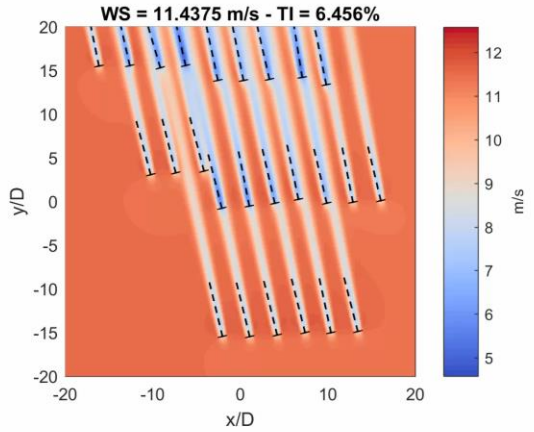
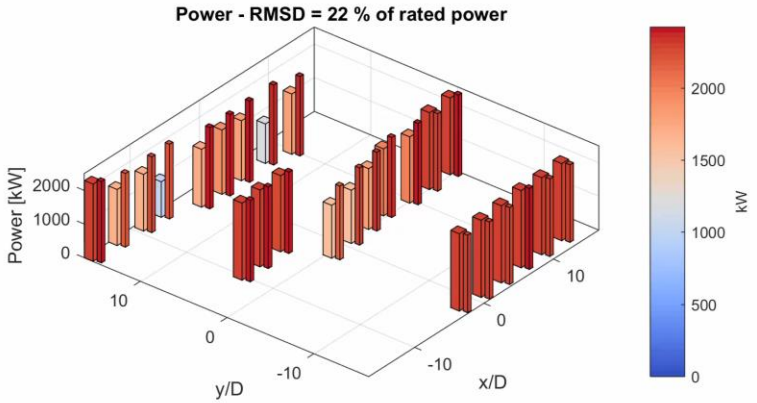
## LiDAR

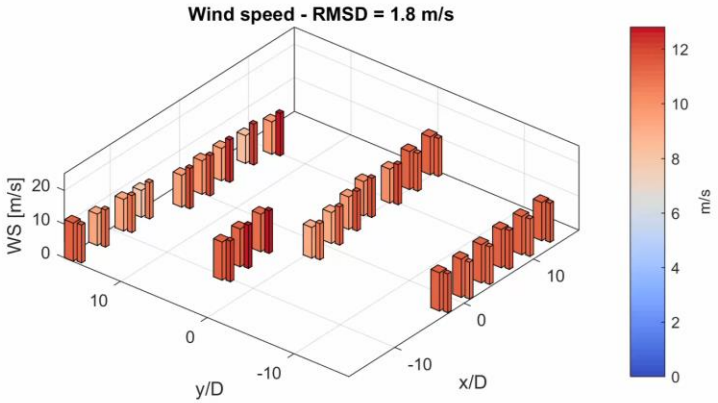



## RANS




**SCADA vs RANS: power**




**SCADA vs RANS: wind speed**

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# Low-cost Acoustics-based Blade Monitoring

WindSTAR
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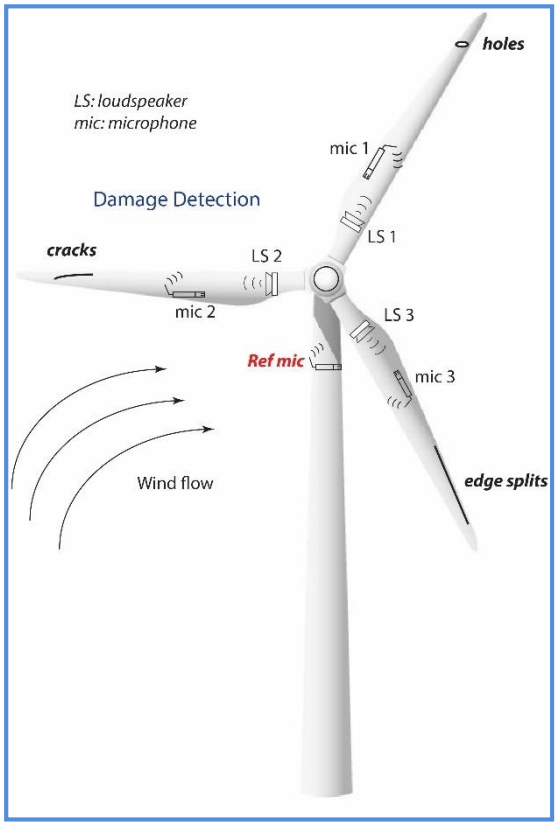
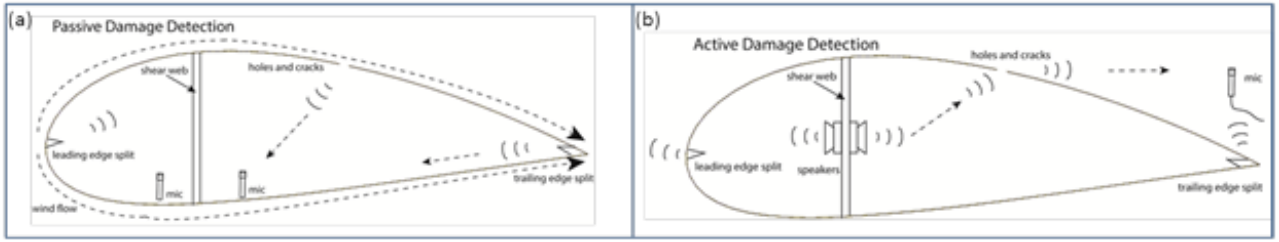
Industry/University Cooperative Research Center

PI: Murat Inalpolat
Murat_Inalpolat@uml.edu

**Objective:** Develop a low-cost monitoring blade monitoring solution that will help reduce O&M costs

- Reduce the need for total blade replacement by identifying issues before they become significant or catastrophic.
- Reduce the need for unscheduled maintenance.
- Improve turbine availability and reduce repair costs.
- Can be used on new and existing turbines (retrofit).
- Can be used both on on-shore and off-shore turbines.
- Costs less than existing monitoring methods.

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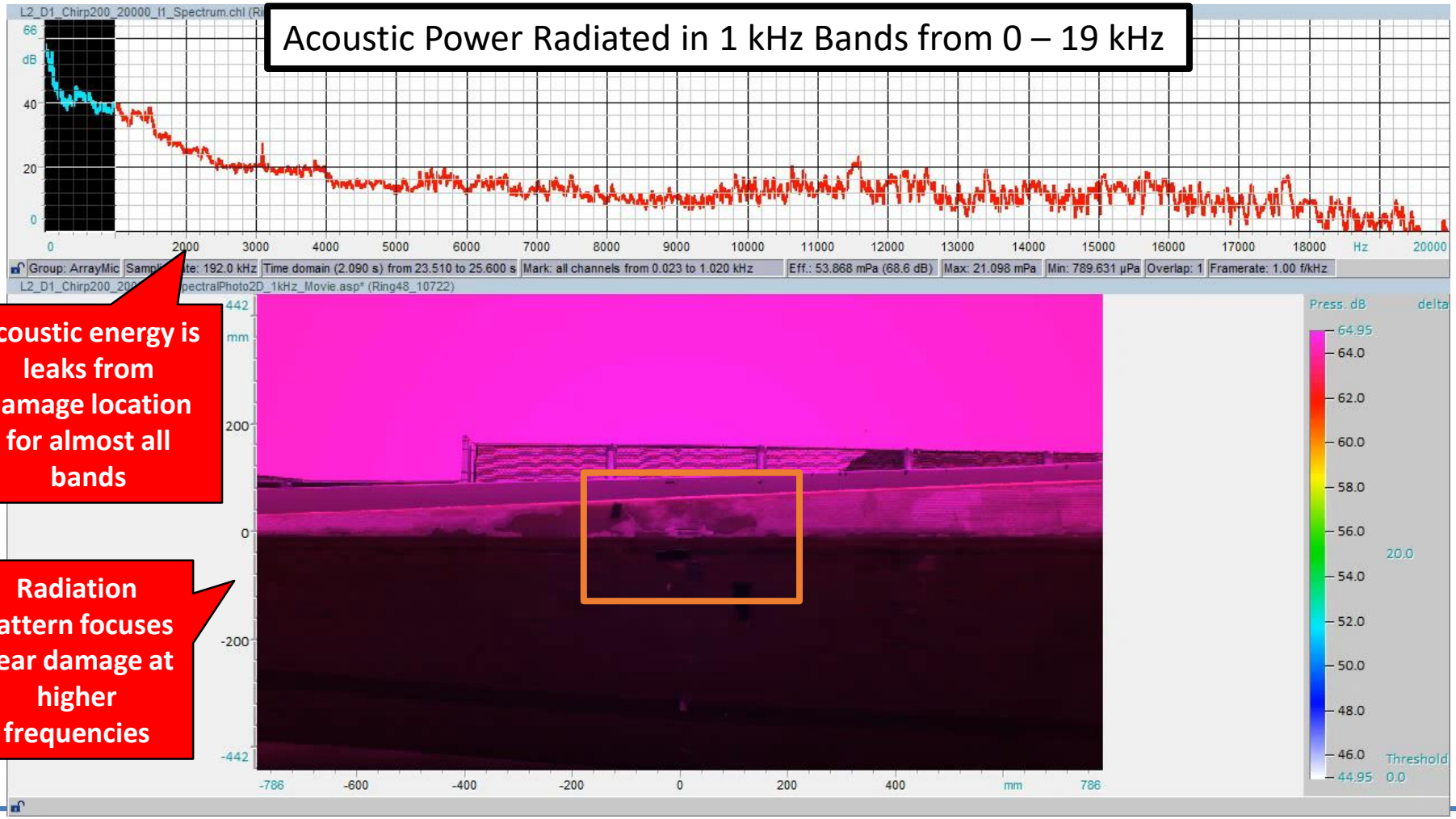
# WTTC Active Detection Tests

## *Acoustic Beamforming Results – Chirp 0.2 to 20 kHz - D1 (2.0”)*

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# Annual Schedule

New industrial members join (Member renewal)

*Typical entry Point*

New topics and opportunities defined

*February - April*

Faculty members

Industrial members

*Faculty and IAB work together to define project topics.*

## Project Proposal Schedule

*May*

Project proposals

*June*

Summer meeting
Project Proposal Ranking by IAB &
Student Poster Presentations

*June*

Projects defined

*July - August*

Students identified

*September*

Projects initiated/continued

*January*

Winter meeting
Progress reported
Student presentations
Evaluations
Project re-direction

## Project Schedule

*September* — Launch

*January* — IAB Meeting Evaluation

*June* — IAB Meeting Review

*August* — Conclude

*September* — Report & WindSTAR Day

Periodic Mentor Review (September – August)

# Membership

- Company joins as a *Full Member* - $42,400/year membership fee, or a *Small Business Associate Member* - $15,900/year
  - NSF supplements may decrease SB fee to $5,000 if member has NSF SBIR

- Pooling money improves **return on investment** in new technology with a ~16:1 leveraging of membership fee and only 10% overhead rate (~60% is typical)
- Industry **members direct** the selection and execution of **research** topics across a broad range of researchers and facilities at multiple universities
- **Sharing risk** at an early stage in research is a good business strategy
- **Royalty-free licenses** to technology generated through the Center and **pre-publication access** to research results
- The Center allows us to pursue other sources of **funding**
- **Student engagement** - resume book and access to graduates who are well trained in the field of wind energy
- **Strategic networking** and synergistic cooperation opportunities with complementary *and* competitor companies

# Member Statements

*"EDPR benefits from the knowledge established within the consortium and shared with the participants. This is **invaluable in assessing and proposing potential improvement initiatives** within the company."*

– Brian Hayes
Executive Vice President
EDP Renewables

*"The center has the **resources** needed to create the right environment for successful research that **benefits the industry**."*

- Nicholas Althoff
Sr. Adv. Mfg. Engineer
GE Renewable Energy

*"They have done a remarkable job in recruiting a cadre of **highly qualified and motivated students** that carry out the **projects essential to driving forward technologies** in the design, manufacturing, inspection and life-time management of critical components for energy generated by wind power."*

- Stephen Nolet
Senior Director
TPI Composites

*"Through the relationships that we have built through WindSTAR, we were able to put together a successful bid for an extremely competitive ARPA-E award. The team, led by Aquanis and supported by UTD, WindSTAR member TPI Composites, and potential member Sandia National Labs, will receive **$3.5M in funding** to develop and test an active load control solution for wind turbines."*

- Neal Fine, PhD
CEO, Aquanis

# Timeline for Joining

- Membership Year Begins in June
  - Mid-year Joining of Center can be negotiated at a prorated Fee under special circumstances.
- Prospective members are invited to attend the next WindSTAR Center IAB Meeting as a guest (single time) to learn about our Center and its operation.
  - Winter at the University of Texas Dallas
  - Summer at UMass Lowell
  - All Guests are required to sign and NDA
- Decide whether becoming a member makes sense for your company and provide a membership fee and sign the membership agreement.
- WindSTAR I/UCRC will execute its next set of research projects starting September 2019.

# For More Information

WindSTAR
Wind-Energy Science, Technology, and Research
Industry/University Cooperative Research Center




**www.uml.edu/WindSTAR**

UMASS University of Massachusetts Lowell

UT DALLAS The University of Texas at Dallas

# www.uml.edu/WindSTAR

WindSTAR
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Industry/University Cooperative Research Center

## For more information, contact:


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E-mail: Christopher_Niezrecki@uml.edu
Phone: 978-934-2963

**Site Director:**
Mario Rotea, Ph.D.
University of Texas at Dallas
E-mail: rotea@utdallas.edu
Phone: 972-883-2720

**Assistant Director for Operations:**
Patrick Drane
University of Massachusetts Lowell
E-mail: Patrick_Drane@uml.edu
Phone: 978-934-2996


## For a WindSTAR reference, contact:


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**Industrial Advisory Board Member:**
Ben Rice
Manager, Operations Engineering
E-mail: Benjamin.Rice@patternenergy.com
Phone: 713-308-4212

**Industrial Advisory Board Member**
Adam Johs
EDP Renewables - Performance Management
E-mail: Adam.Johs@edpr.com
Phone: 361-920-1325

**Industrial Advisory Board Member:**
Stephen C. Nolet
TPI Composites, Inc. - Principal Engineer, Senior Director
E-mail: snolet@tpicomposites.com
Phone: 401-247-4009


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# QUESTIONS?

# GRAPES

GRid-connected Advanced Power Electronic Systems

## *NSF Industry/University Cooperative Research Center*


## *H. Alan Mantooth*

**Executive Director**

**21st Century Research Leadership Chair**

**Distinguished Professor of Electrical Engineering**

**mantooth@uark.edu; 479-575-4838**


***December 12, 2018***

# Mission and Vision

GRid-connected Advanced Power Electronic Systems

***The mission of GRAPES is to:***

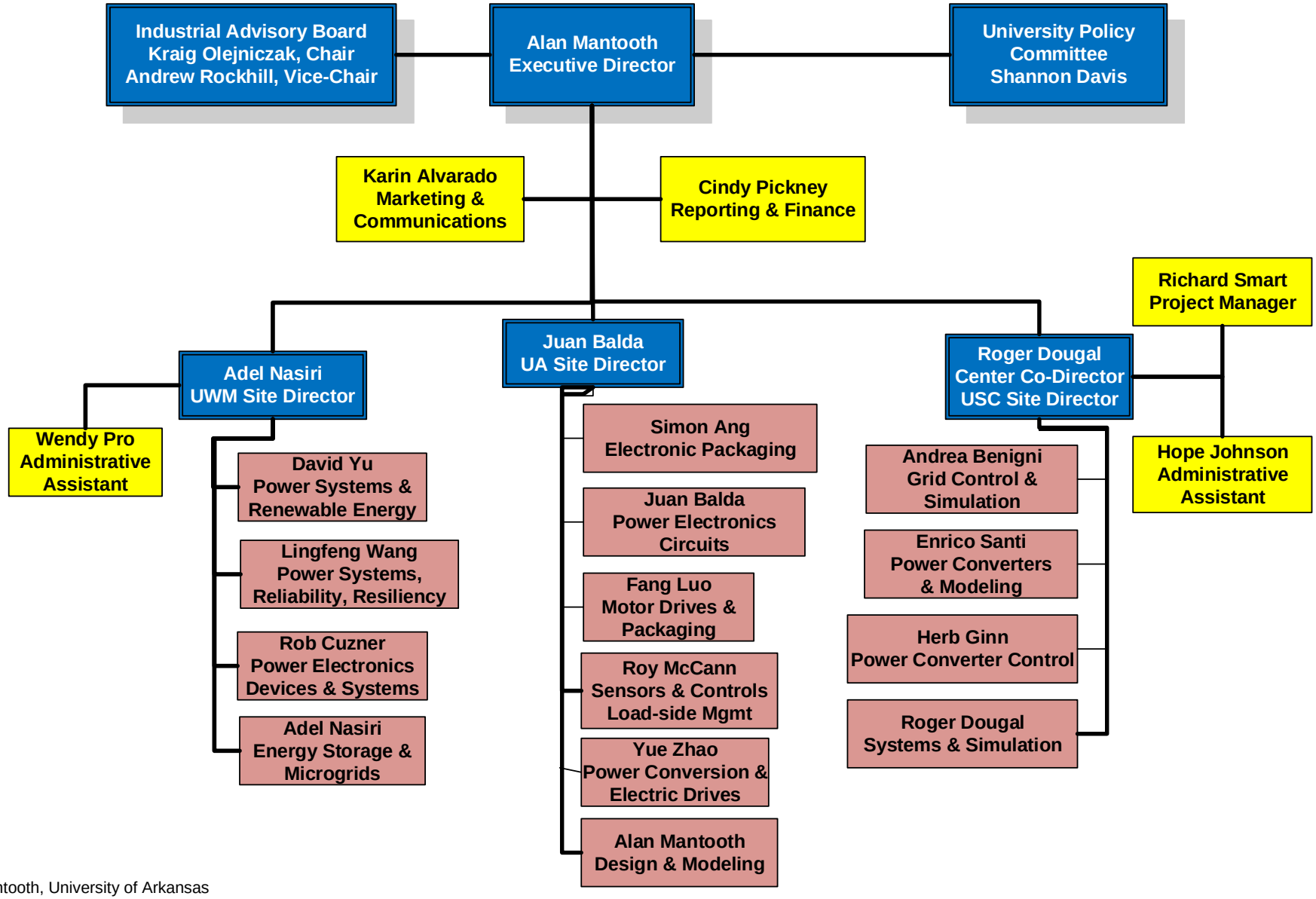
- ✓ ***create a smarter, more resilient electric power grid through power electronics technologies***
- ✓ ***Create and encourage an evolution to revolution!***

***The GRAPES vision is:***

- ➢ ***To be a model industry-sponsored research center***
- ➢ ***To provide member value through advanced technologies in grid-connected power electronic systems***

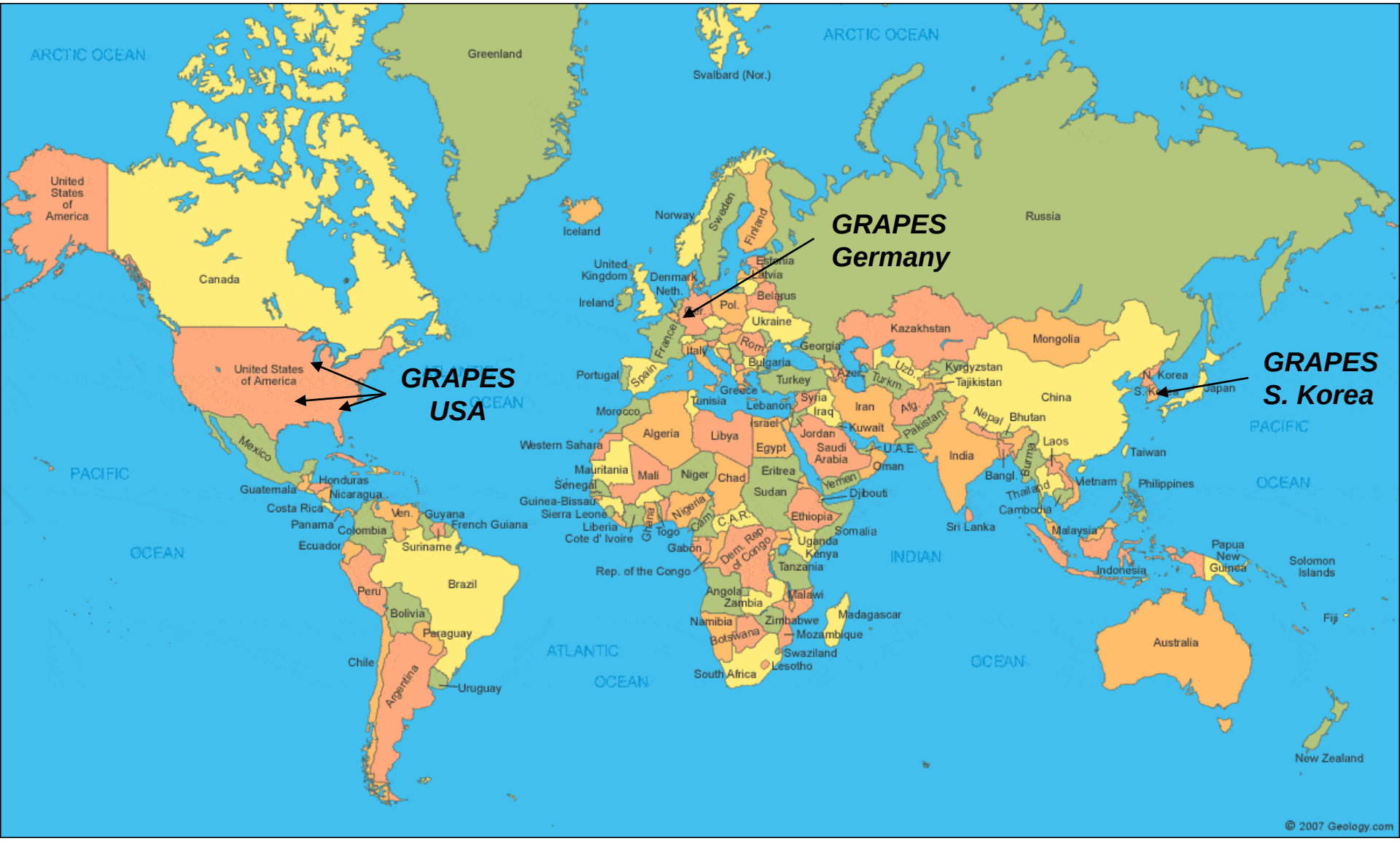
# GRAPES Org Chart

GRid-connected Advanced Power Electronic Systems



# GRAPES Global Institute

GRid-connected Advanced Power Electronic Systems



# Current Center Members



## *18 Member Companies*

- *Members pay a $40,000 annual fee*
- *Small businesses pay a $5,000 annual fee*

SPP Southwest Power Pool

Rockwell Automation

KOONTZ Electric Company, Inc.
OUR POWER IS IN OUR PEOPLE

G&W

ITRI
Industrial Technology Research Institute

Arkansas Public Service Commission

EATON
Powering Business Worldwide

Entergy

Typhoon HIL

Electric Cooperatives of Arkansas
Your Local Energy Partners

Emera

*Schlumberger*

We Energies
Energy You Can Depend On

DRS Technologies
A Finmeccanica Company

Wolfspeed
A CREE COMPANY

m-worc
MID-WEST ENERGY RESEARCH CONSORTIUM

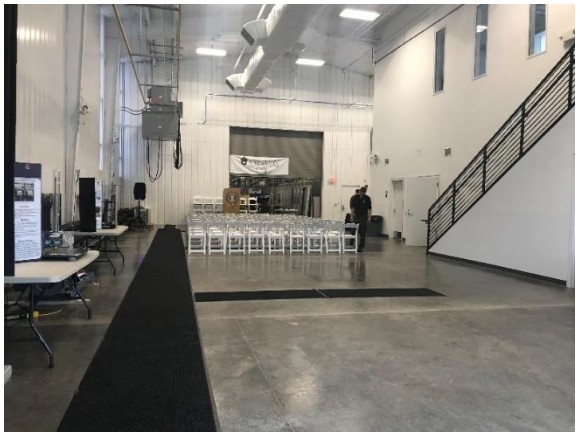
Prysmian Group

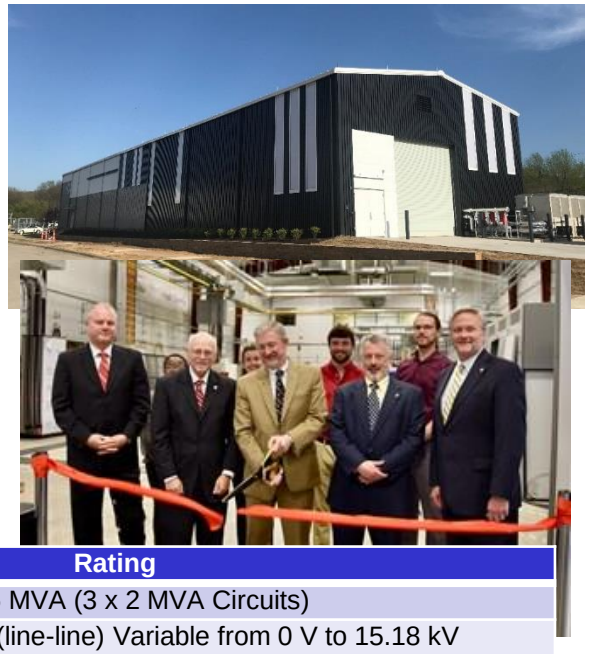
SOUTHERN COMPANY

# NCREPT Facility

GRid-connected Advanced Power Electronic Systems

- **Existing Building**
  - 7,000 sq. ft.
  - 120’ x 50’ + 20’ x 50’ (2nd)
- **Expansion Project Additions**
  - Additional 4,800 sq. ft.
  - 80’ x 50’ + 12’ x 62’ (2nd)
  - 1500 V / 1500 A dc Bus
  - 480 V / 1200 A ac Bus
  - SCIF (Secret Rating) [400 sq. ft.]
  - Office space for students/faculty
  - Server/IT room to support Cyber research
  - 120 ton chiller



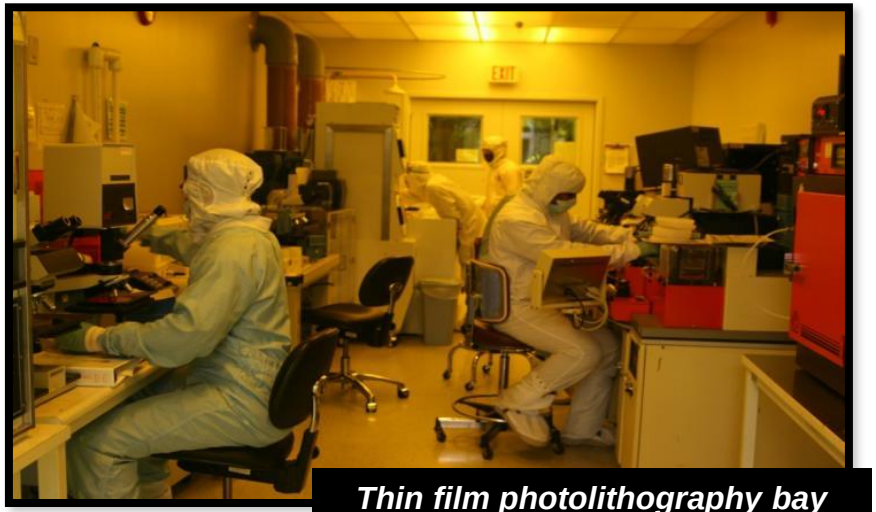


| Parameter | Rating |
|---|---|
| Power | up to 6 MVA (3 x 2 MVA Circuits) |
| Medium Voltage (ac) | 13.8 kV or 4.16 kV (line-line) Variable from 0 V to 15.18 kV |
| Low Voltages (ac) | 480 V (line-line), Variable from 0 V to 528 V |
| Frequency | 40 Hz to 70 Hz<br>Values outside this range (up to 400 Hz or down to 20 Hz) are possible, but require de-rating |
| Currents (ac) | 300 A at 13.8 kV<br>1,000 A at 4.16 kV<br>2,500 A at 480 V |
| Loads | Active loads fully programmable; Test energy is recirculated<br>700 kW Resistive Load Bank<br>Various Passive Components Available |
| Active Cooling | 120 ton Chiller (420 kW Heat Rejection) |
| DC | 2.25 MW (1500 Vdc / 1500 A) [Construction In Progress]<br>750 kW (660 Vdc / 1.1 kA) |
| Dynamometer | 100 kW with Overload Capability<br>6,600 rpm @ 220 Nm |

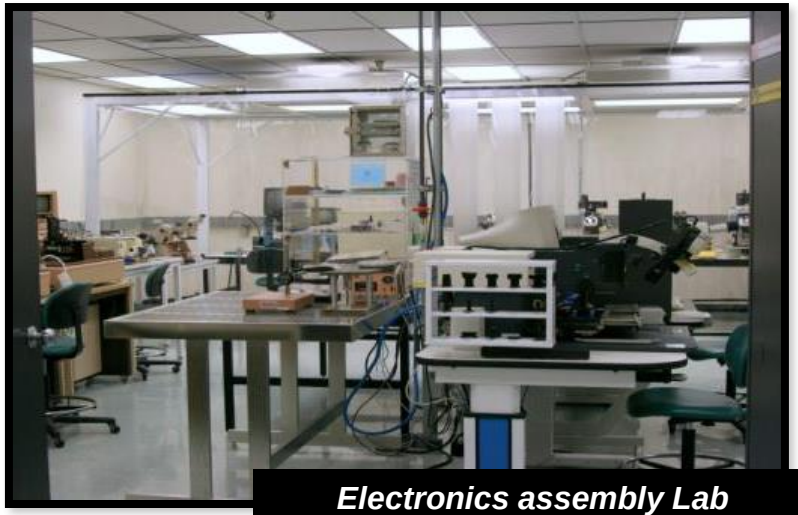
GRAPES
GRid-connected Advanced Power Electronic Systems

# HiDEC Laboratories

GRid-connected Advanced Power Electronic Systems



*Thin film photolithography bay*



*Electronics assembly Lab*

*Low temperature co-fired ceramics lab*

# GRAPES and Related Projects



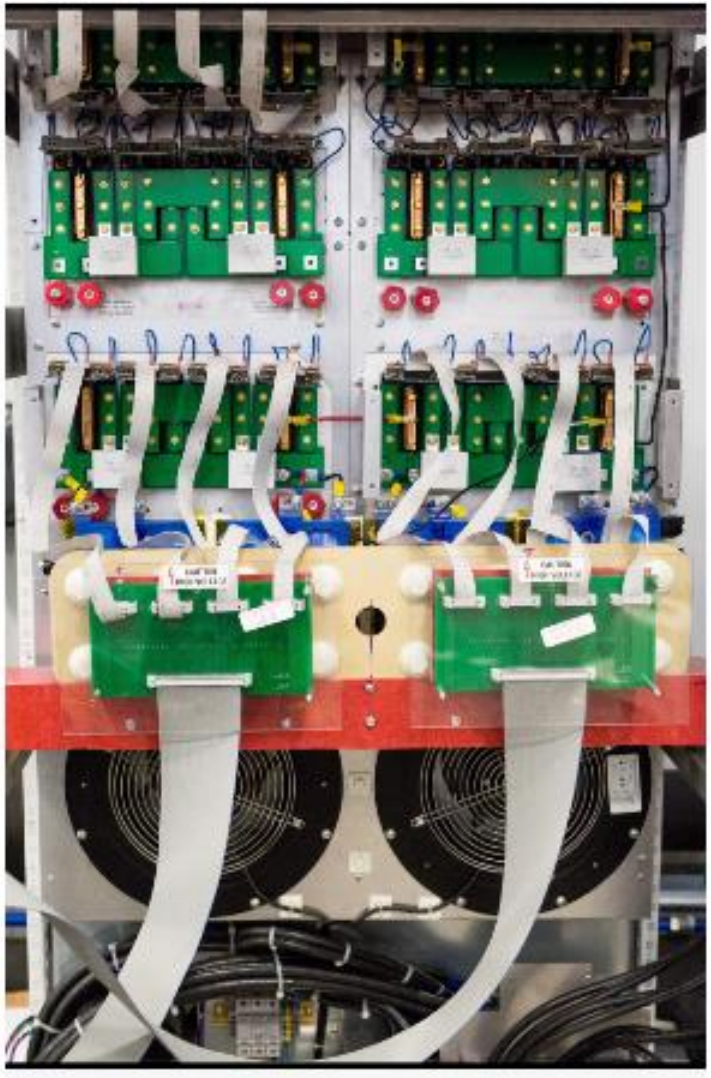
- Residential Power Router => Scalable to MW
- Transmission Load Flow
- Microgrid Research
- Wind Farm Power Quality
- Next Generation Electronics Technologies for PE
- Electric Vehicle Charging
- Energy Storage Electronics
- Grid Protection & Resiliency Devices
- Solar Inverters
- Additional projects funded by:
  - Army Research Lab
  - ARPAe
  - DoE
  - NSF
  - Industry directly

# SiC-Based Power Electronics for Battery Energy Storage Interface into Medium Voltage Distribution Systems

GRAPES
GRid-connected Advanced Power Electronic Systems


*Medium Voltage Cabinet Level Prototype*

- Integrating a battery energy storage into a medium voltage distribution system (13.8 kV) without a bulk step-up 60 Hz transformer



*Nine Level Cascaded H-Bridge*

- Using ≥ 6.5 kV SiC modules for power electronics interface
- Minimizing the number of modules and complexity

# Optimized Gate Drivers for High-Voltage Power Devices

GRid-connected Advanced Power Electronic Systems

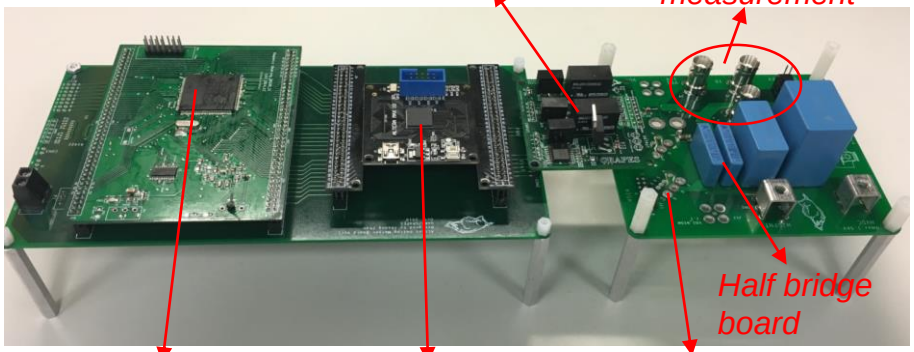
## Background and Major Challenges

- *Design an intelligent gate driver board for 1.2 kV and 10 kV SiC MOSFET*
- *Suppress the high EMI noise of SiC power device*
- *Provide isolation capability for the high voltage (1.2 kV and 10 kV).*
- *The protection of the SiC power MOSFET.*

## Main Approach

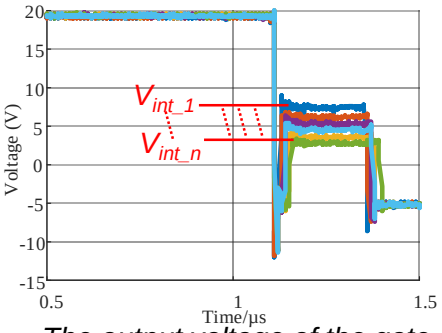
- *A novel switching profile to suppress dv/dt and di/dt without increasing switching delay time*
- *Novel circuitry for multi-level active gate driver*
- *Model predictive control for the switching transient process*

## Prototype of Active Gate Driver for 1.2 kV SiC Device

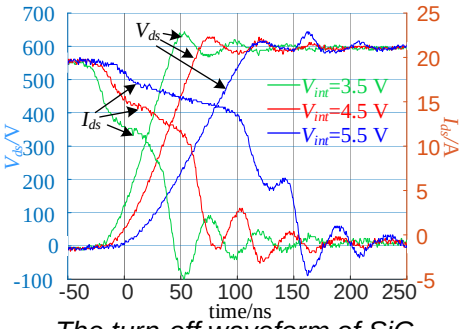



## Experimental Results

- ✓ *Super accurate: 64 levels voltage adjustment.*
- ✓ *Super fast: 10 ns adjustment speed.*
- ✓ *Super smart: With switching process optimization to maximize the performance of SiC power devices*



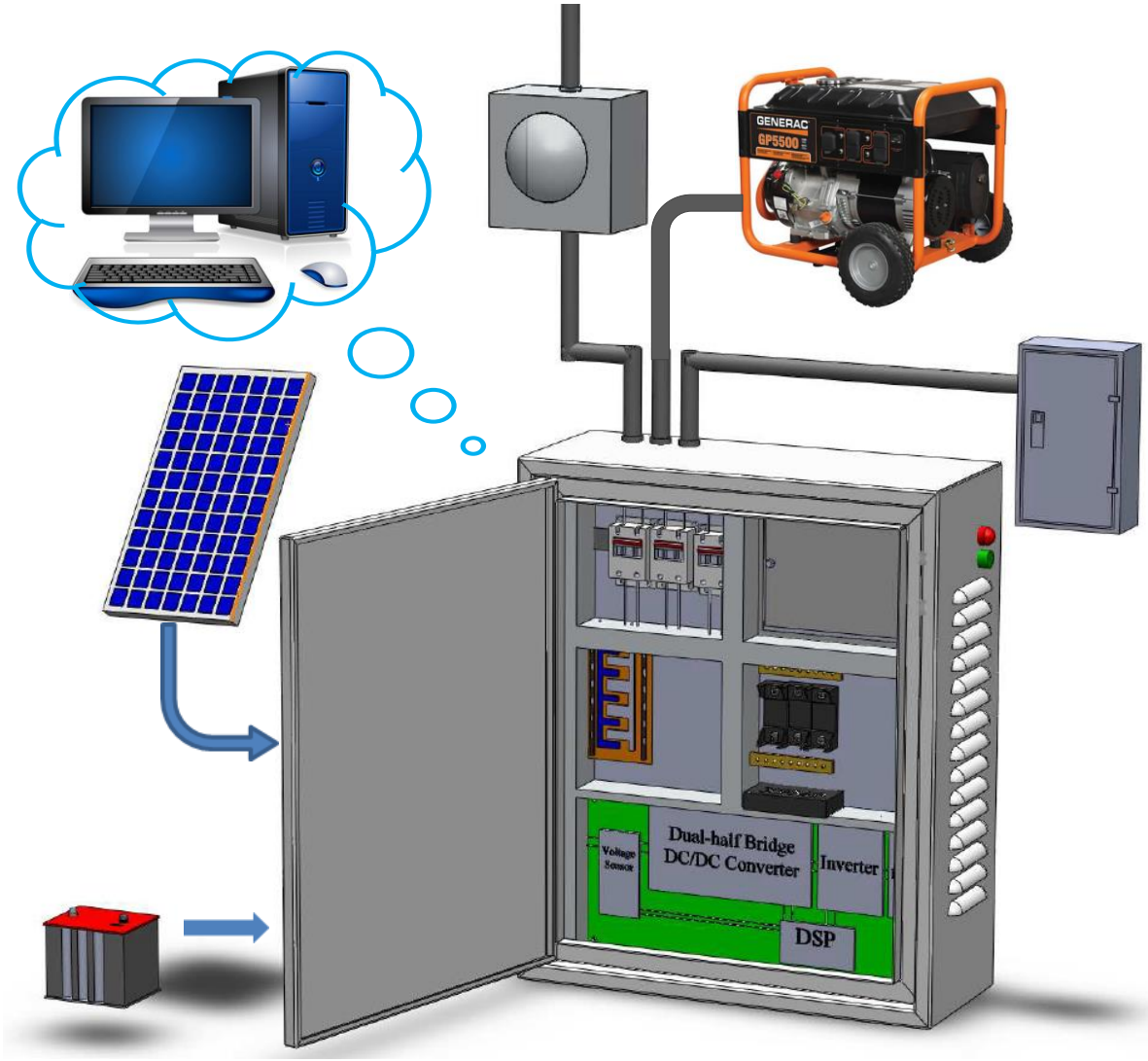

*The output voltage of the gate driver at multi-level turn-off.*




*The turn-off waveform of SiC power MOSFET under different $V_{int}$*

# Residential Power Router



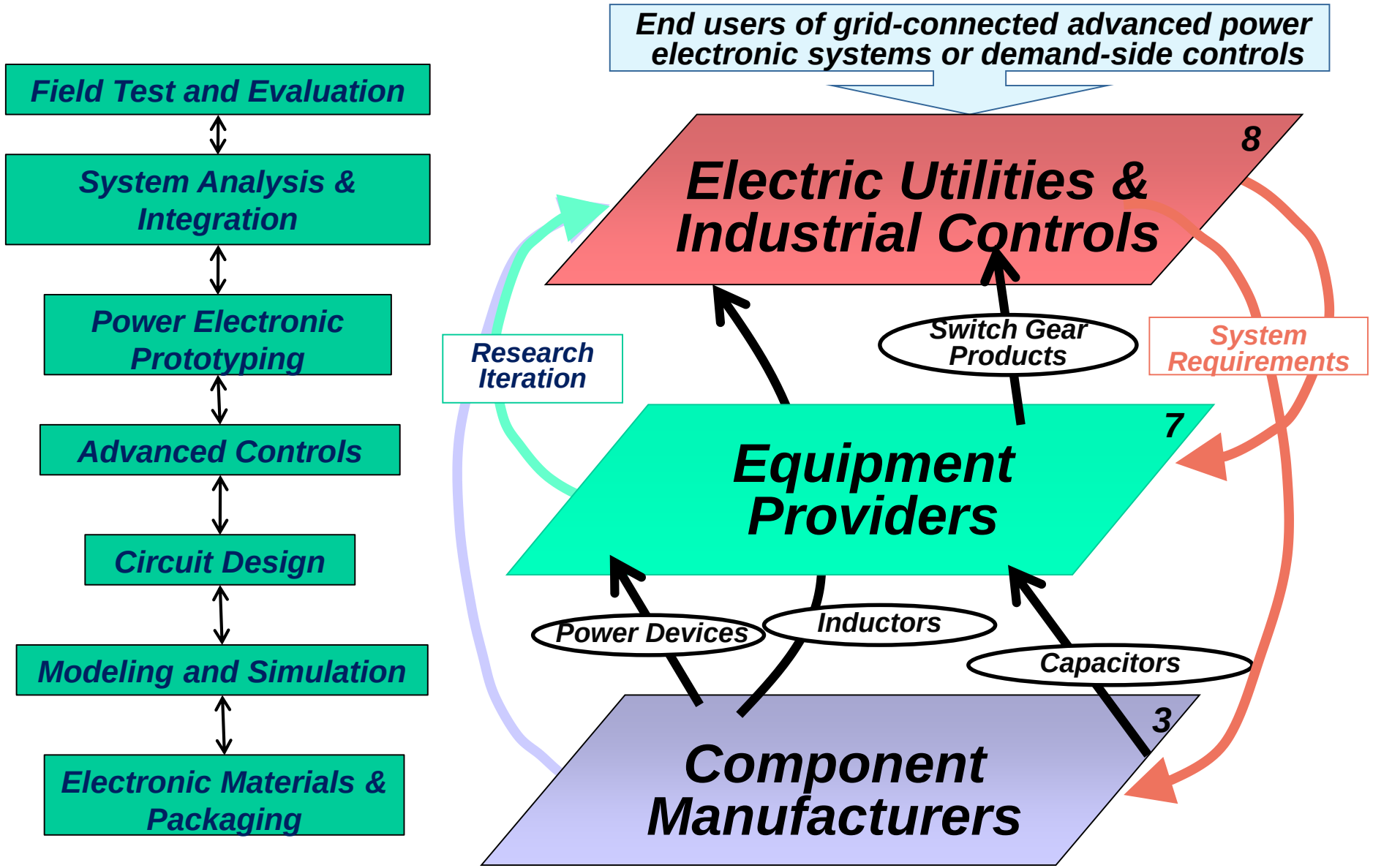



***Intelligent Power Router:***

- ***Takes in weather and time of use pricing data***
- ***Directs power from grid or other assets such as solar, storage, generator***
- ***Sits between meter and breaker box***
- ***Operates in islanded or grid-connected mode***
- ***Prototyped and tested***
- ***Available for licensing***

# The GRAPES Solution

GRid-connected Advanced Power Electronic Systems



# Industrial Advisory Board

GRid-connected Advanced Power Electronic Systems

- Has voting and non-voting members
- Paying members have voting privileges for project selection and shared IP rights
- Reviews project proposals and recommends funding choices to Directors
- Monitors progress of projects => best way to ensure value to your company is to be involved in the projects! (webinar series, reports, strategic planning groups, nuggets)
- Advises Directors & Staff on Center Operations

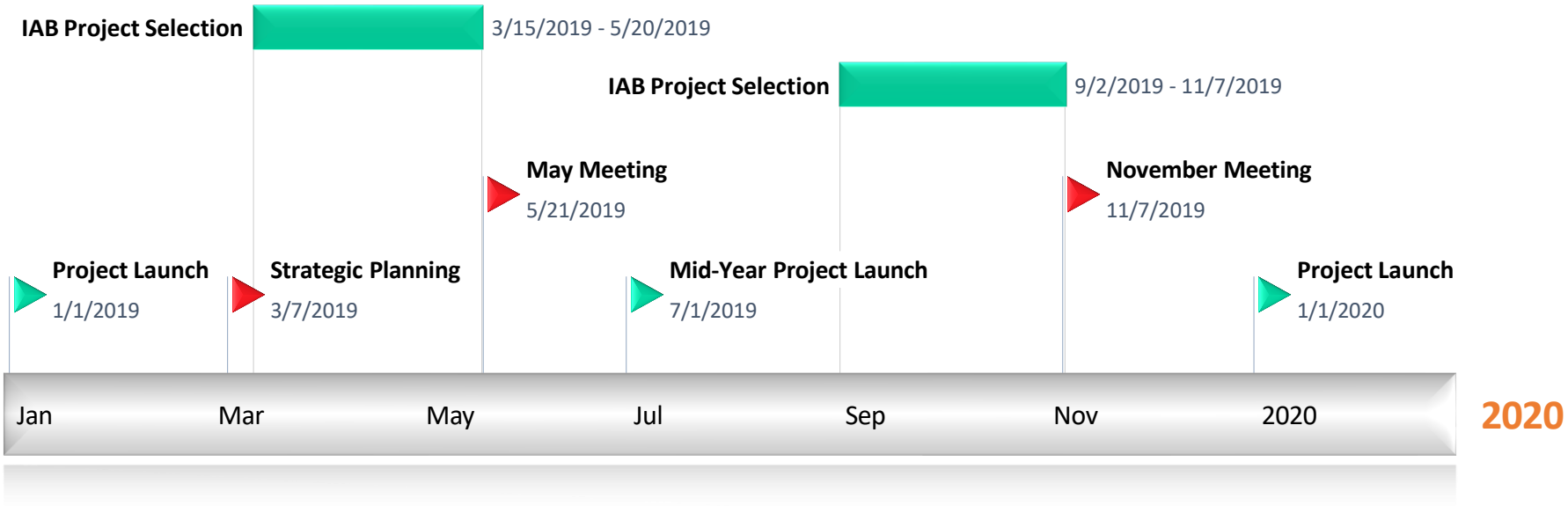
# Operations – Project Selection

GRid-connected Advanced Power Electronic Systems

1. GRAPES faculty present project proposals at one of two semi-annual meetings
2. Members vote on projects of interest (40 votes per full membership; 5 votes for small membership)
3. Highest voted projects are discussed in the IAB against available budget to finalize recommendations to Directors
4. Each project lead will submit a detailed budget and SOW to Center Directors within 21 days
5. Directors will review, consolidate budgets, send to IAB for information by e-mail within 10 days

# Project Timeline





# Value Proposition Summary



- A graying workforce and evolving electric power grid needs well-educated talent
- GRAPES provides access to unique expertise
- GRAPES provides access to unique facilities
- Research is award-winning and widely recognized
- Research is industry-driven from concept to prototype
- Research is pre-competitive; shared IP model
- Center model customer-supplier oriented and collaborative
- Membership is cost-effective

# Financial Details

GRid-connected Advanced Power Electronic Systems

- For a $40,000 annual fee, members leverage a $10-20 million dollar research institute!!
- GRAPES has received ~$2 million in NSF funds; ~$6 million in industry funds; ~$10 million in university support
- GRAPES has or is leveraging a research agenda of over $10-20 million per year in external funding domestically and another $10-20 million through international sites!
- GRAPES began operation in Jan. 2010
- GRAPES is up for renewal in 2019; moving from Phase II to Phase III

# Seeing is Believing!



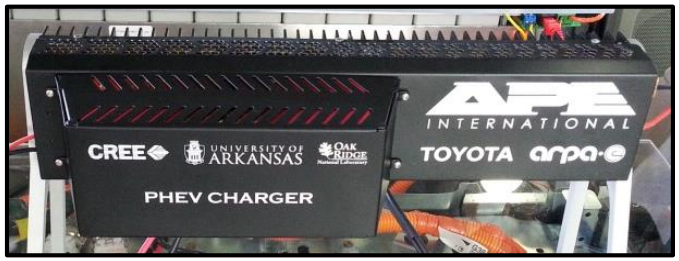
- **Upcoming meetings:**
  - **May 20-22, 2019 in Milwaukee, Wisconsin**
  - **November 6-8, 2019 in Fayetteville, Arkansas**
- **NDA is required to attend as a guest**

**Join us as we transform the electric power grid!**

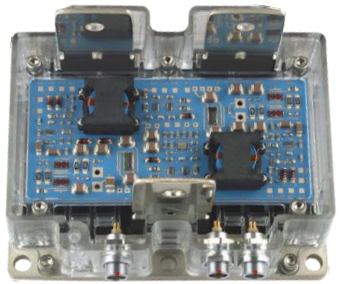
# Award-Winning Research

GRid-connected Advanced Power Electronic Systems

- **3 R&D 100 Awards since 2009 – given for top 100 worldwide innovations that year**






# GRAPES

GRid-connected Advanced Power Electronic Systems

## *NSF Industry/University Cooperative Research Center*


## *H. Alan Mantooth*

**Executive Director**

**21st Century Research Leadership Chair**

**Distinguished Professor of Electrical Engineering**

**mantooth@uark.edu; 479-575-4838**


***December 12, 2018***

# QUESTIONS?

# Interested in university-industry partnerships?

Sign up for information about UIDP news, webinars, projects, and more at uidp.org/newsletter-signup.

Strengthening University-Industry Partnerships

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