



Overview

Kevin Tomsovic
Center Director



NSF-DOE Site Visit
November 9, 2020
Virtual



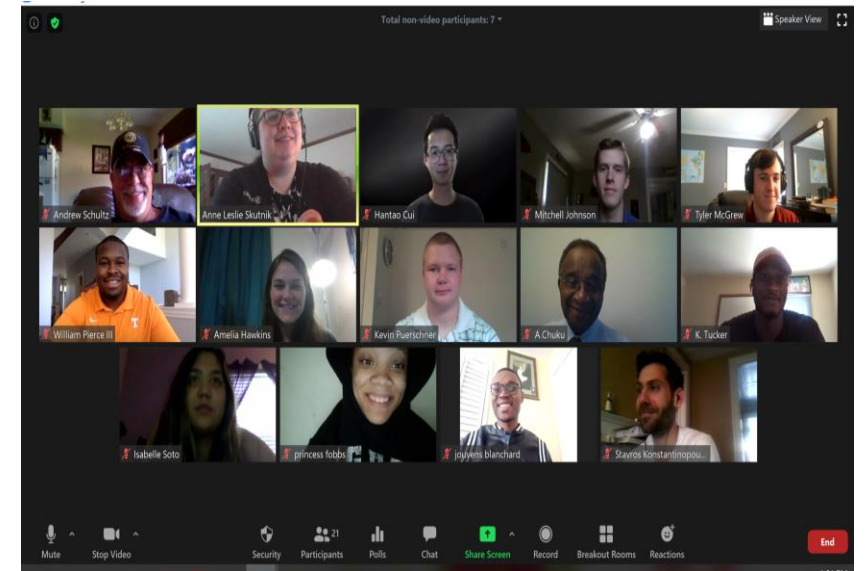
Some Recent Highlights

• Education and outreach

- Virtual summer program with 13 REUs and 3 RETs. There were two cross-center REU projects this year, including a large collaboration between RPI, TU, and UTK.
- Three undergraduate students published with faculty and graduate students.
- Joe Chow hosted the RPI Solar Build workshop for 25 high school students as part of the 11th Annual International Conference on Energy and Power Systems Operation and Planning (ICEPSOP) in Abuja, Nigeria.

• Diversity and Culture of Inclusion

- CURENT continued working with Pope Consulting to provide coaching for the leadership team. This training was extended to student leaders in Year 9.
- The number of domestic graduate students has increased from 21 in year 4 to 39 in Years 8 and 9.
- Underrepresented groups in the undergraduate program was at 26% URM and 24% female.



Some Recent Highlights

- **Awards and Recognition**

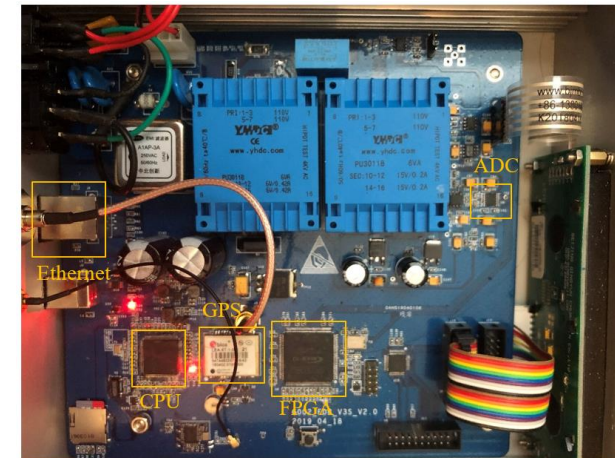
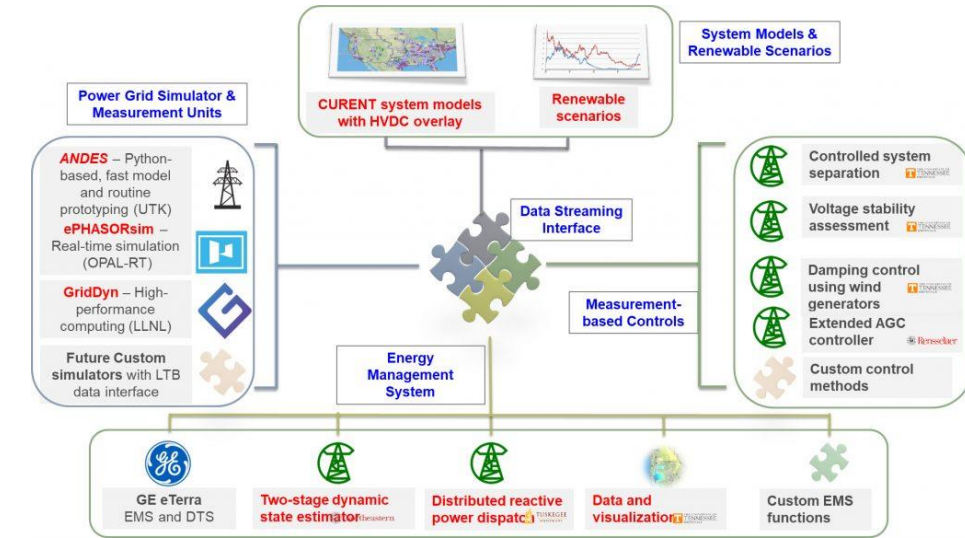
- LTB was a R&D 100 winner.
- Deep Convolution Neural Network for N-1 was R&D 100 finalist.

- **Research**

- Funding of over \$8M
- 79 journal publications and 66 conference publications

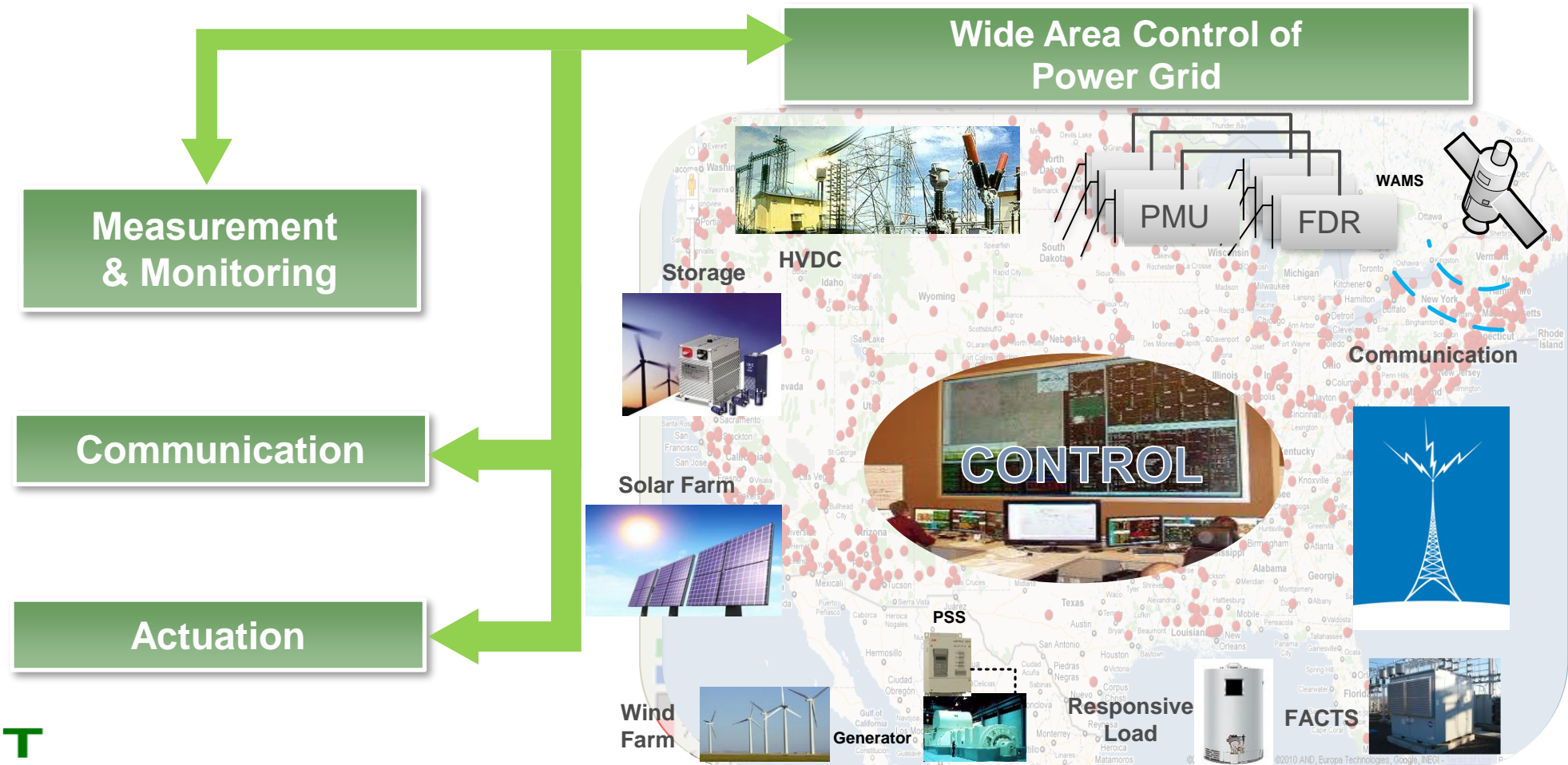
- **Industry and innovation**

- 35 industry members, of which are 11 at the principal and 12 at the full level.
- There were 14 invention disclosures. One provisional and five full patents were filed using IPPF funding.
- Four patents were awarded.



CURRENT Vision

- A nation-wide transmission grid that is fully monitored and dynamically controlled for high efficiency, high reliability, low cost, better accommodation of renewable sources, full utilization of storage, and responsive load.
- A new generation of electric power and energy systems engineering leaders with a global perspective coming from diverse backgrounds.

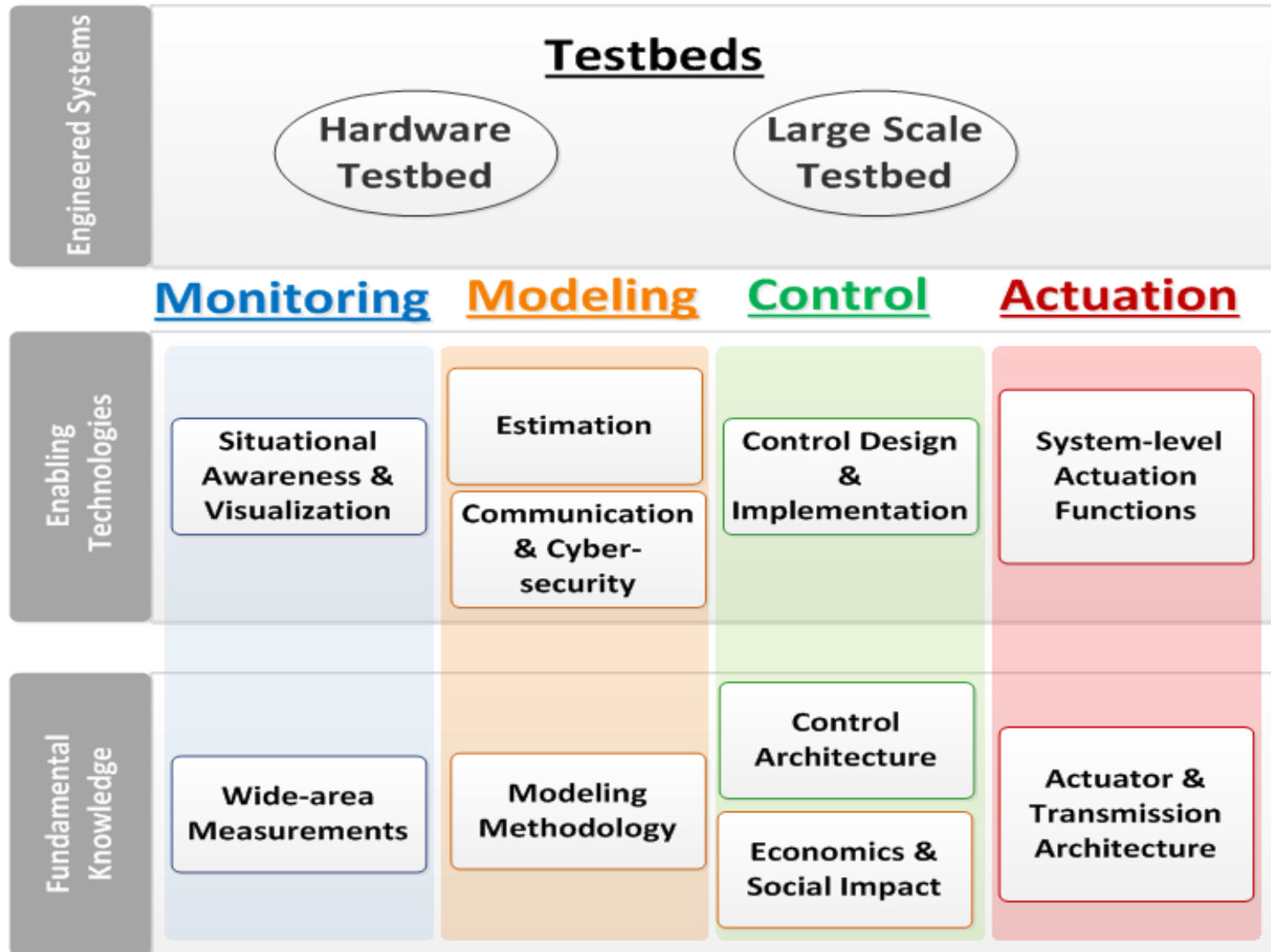


Changing Electric Power System

- Large central generation
- Rotating machines
- Passive transmission
- Small number of asynchronous sensors
- Hierarchical communications
- Costs driven
- Reliability focus considering equipment outages

- Small distributed generation
- Inverter interfaced
- Actively controlled T&D
- Ubiquitous synchronized sensing
- Open network
- Market (transactive) driven
- Reliability and resilience focus considering a wide variety of disturbances

Three-plane Diagram



Objectives

Real-time wide area control using extensive synchronized monitoring and advanced actuators to facilitate renewable integration

Research Focus

- Develop wide-area control concepts and architectures
- Develop measurement technologies
- Develop actuation methodology and architectures to provide system support
- Develop dynamic modeling and estimation methods
- Demonstrate interoperability in an integrated platform

CURRENT Control Architecture

Resilience and scalability by

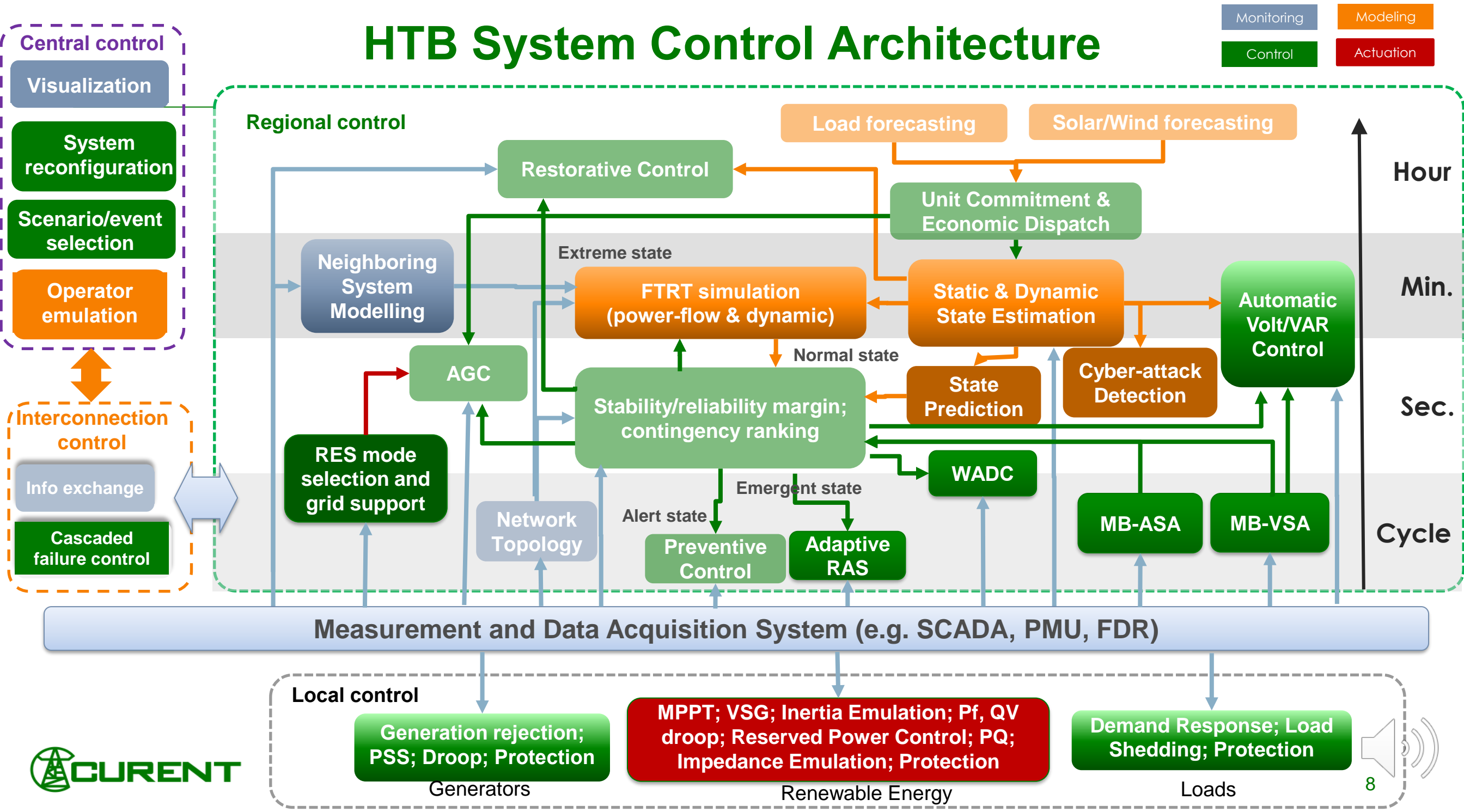
- Distributed controls – renewables, grid, storage, and demand as active control participants
- Synchronized measurements – learning and adaptive, data-driven
- Modular and hierarchical architecture – global signals distributed with context
- Shared resources – reduced impact of uncertainty

Figure 1: NIAC Resilience Construct



HTB System Control Architecture

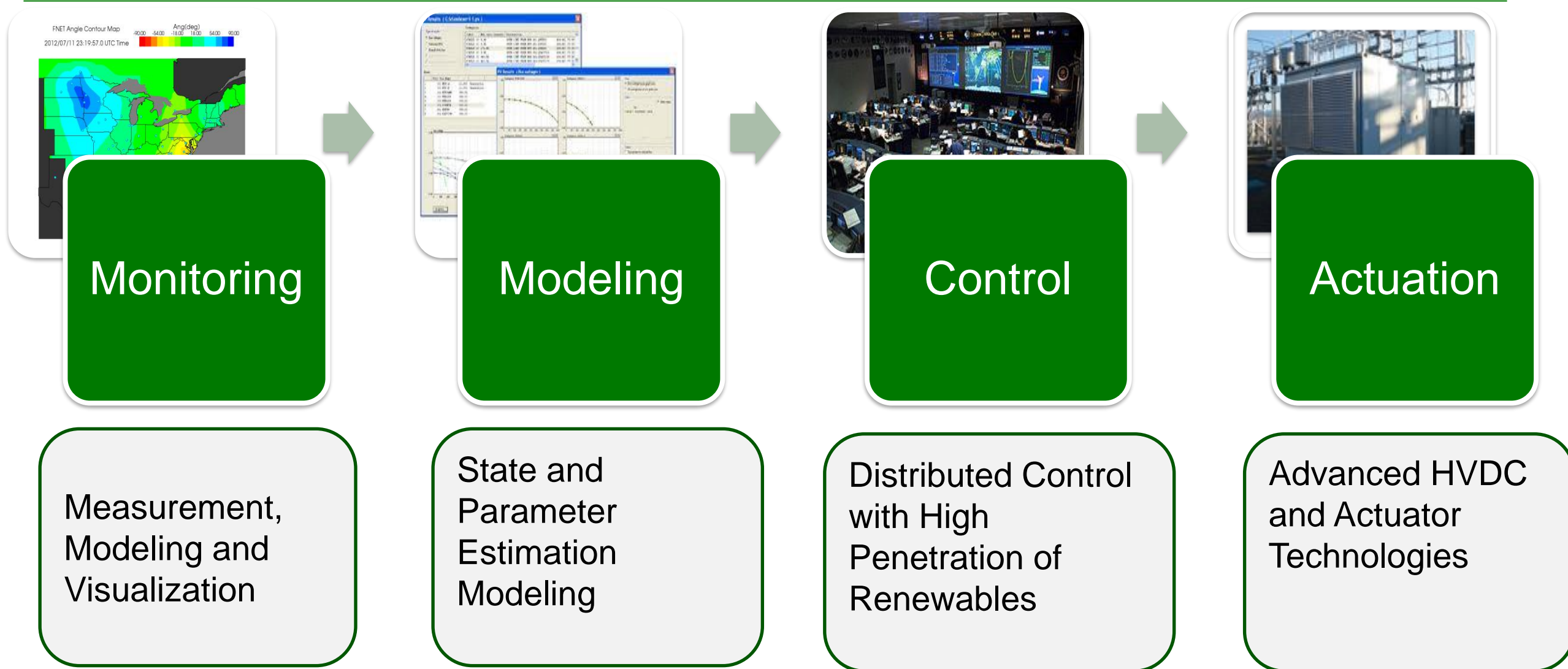
Monitoring (Blue)
 Modeling (Orange)
 Control (Green)
 Actuation (Red)



Research Roadmap

Year 1~3	Year 4~6	Year 7~10
Generation I	Generation II	Generation III
Regional grids with >20% renewable (wind, solar), and grid architecture to include HVDC lines	Reduced interconnected EI, WECC and ERCOT system, with >50% renewable (wind, solar) and balance of other clean energy sources (hydro, gas, nuclear)	Fully integrated North American system with >50% energy (>80% instantaneous) inverter based renewable resources (wind, solar) and balance of conventional (hydro, gas, nuclear)
System scenarios demonstrating a variety of seasonal and daily operating conditions	Grid architecture to include UHV DC lines connecting with regional multi-terminal DC grids, and increased power flow controllers	Grid architecture to include UHV DC super-grid and interconnecting overlay AC grid and FACTS devices
Sufficient monitoring to provide measurements for full network observability and robustness against contingencies, bad topology or measurement data	System scenarios demonstrating complete seasonal and daily operating conditions and associated contingencies, including weather related events on wind and solar	Controllable loads (converter loads, EV, responsive) and storage for grid support
Closed-loop non-local frequency and voltage control using PMU measurements	Full PMU monitoring at transmission level with some monitoring of loads	Fully monitored at transmission level (PMUs, temperature, etc.) and extensive monitoring of distribution system
Renewable energy sources and responsive loads to participate in frequency and voltage control	Fully integrated PMU based closed-loop frequency, voltage and oscillation damping control systems, and adaptive RAS schemes, including renewables, energy storage, and load as resources	Closed loop control using wide area monitoring across all time scales and demonstrating full use of transmission capacity and rights-of-way
		Automated system restoration from contingencies

Year 9 System Level Projects by Primary Thrust



Sample of Associated and Sponsored Projects

\$3M in Year 9

- Actuation

- A Smart and Flexible Microgrid with a Low-cost Scalable Open-Source Controller
- Digital Gate Driver for Next Generation SiC Based Motor Parts
- Multi-functional High-Efficiency High-Density Medium Voltage, SiC Based Asynchronous Microgrid Power Conditioning System Module
- SiC Based Modular Transformer-Less MW-Scale Power Conditioning System and Control for Flexible CHP System
- DOE Wide Bandgap Power Electronics Graduate Student Traineeship

- Control

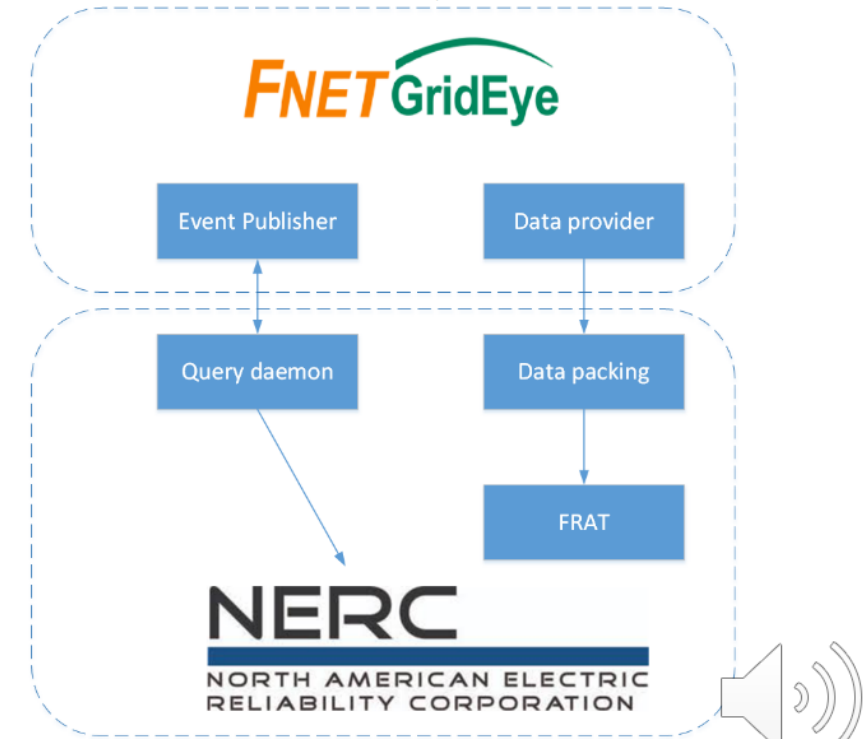
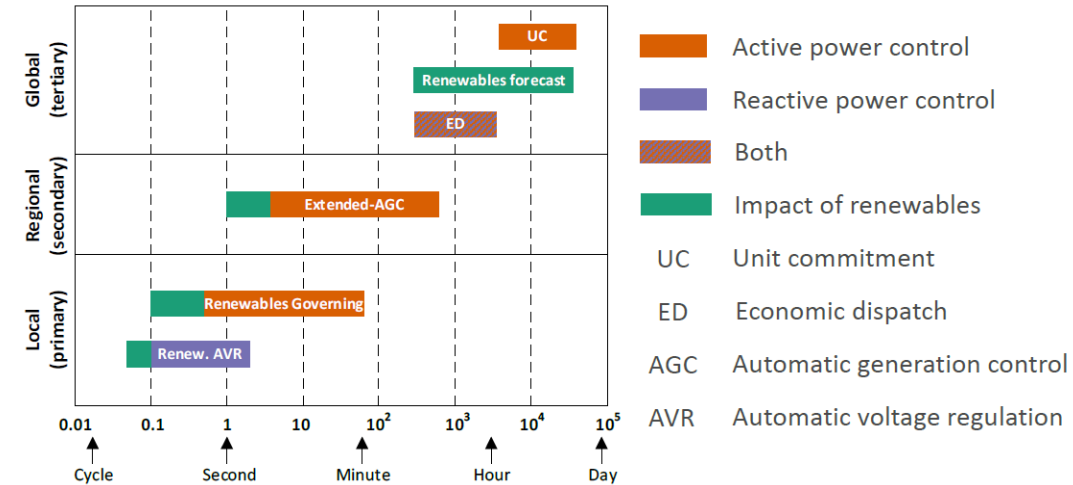
- Continuously Variable Series Reactor (CVSR) for Distribution System Applications
- Control Equipment Performance Monitoring Using Synchrophasor Data
- Ensuring Resilient Operation of the Future Power System with High Levels of Renewals Using Switched Mode Devices
- Using Transactive Control to Optimize Peak Load Reduction

- Modeling

- Analyzing the False Data Injection Attack on the Multistage State Estimation
- Graph-Computing Based State Estimation for Large-Scale Hybrid AC/DC Systems
- Robust Distributed State Estimator for Interconnected Transmission and Distribution Network

- Monitoring

- FNET/GRIDEYE Frequency Transmission and Visualization (Associated Project - translational research)
- Measurement-Driven Approach for Wide-Area Oscillation Damping Controller Design (Associated Project - translational research)



Research Plan for Year 10 and Beyond

	Years 10+
Predominantly inverter-based systems	<ul style="list-style-type: none">• Multiple control region coordination using wide-area monitoring across multiple time scales• System level actuation functions for inverter-based resources to enhance stability• Protection designs using dynamic state estimator and point-of-wave monitoring
HVDC overlay	<ul style="list-style-type: none">• Extension of LAV SE for AC/DC systems• System level HVDC design for frequency control, inertial response and coordinated wide-area damping control design
Coordination extended into distribution	<ul style="list-style-type: none">• Distributed coordinated controls for active distribution grids• Three-phase distribution system state estimator under high levels of PV
Pervasive controllable loads	<ul style="list-style-type: none">• Cybersecurity and data authentication• Actuation and controls to allow resilient microgrids and distribution grids• Demand response and control architecture for large numbers of small loads and mobile storage

Workforce Development Roadmap: Highlights

Year 1~ 3	Year 4 ~ 6	Year 9 Results	Year 7 ~10
Generation I	Generation II	Generation III	Generation III
45 total REUs Grad & UG ratio ~ 3.0	100 total REUs Grad & UG ratio ~ 2.0	133 total REUs Grad & UG ratio at 2.6	140 total REUs Grad & UG ratio < 2.0
Create Young Scholars summer program	Reach 80 YSP participants	Reached 107 YSP participants by Year 9	Reach 120 YSP
Create additional summer programs for girls and students from diverse populations	Continue to recruit middle school girls and students to Smart Grid camp and Adventures in STEM	RPI Solar Build workshop in Nigeria Collaborated with NIMBioS for middle school girl workshop	Pre-College programs institutionalized at respective schools (e.g. RPI Solar Camp, CURENT RET at UTK)
Create and disseminate curriculum related to CURENT	Work with RET teachers to create/share curriculum (website)	Shared ebook and lesson content online Pre-college outreach reached one of the highest	Continue to work with educators to disseminate ebook, solar modules, and other curriculum content



Virtual Young Scholar Program (YSP)

Research Training

- Programming and research skills
- Basic power & energy engineering knowledge
- Interdisciplinary aspect of energy

Research Projects

- One-on-one mentorship
- Team projects
- Poster and presentation sessions

Career Knowledge

- Industry and academic career awareness
- Professional training

YSP projects:

- Human Factors and Ergonomics to Combat Covid-19 in Workplaces
- Perceived Energy Use and Personal Norms during COVID-19
- Analysis of Multi-Faceted Factors Influencing Solar Energy Adoption from an Interdisciplinary Angle
- Following your Heart(beat)

Virtual Research Experience for Undergraduates (REU)

Research

- One-on-one mentorship
- Research paper and poster presentation
- Graduate school information

Technical training

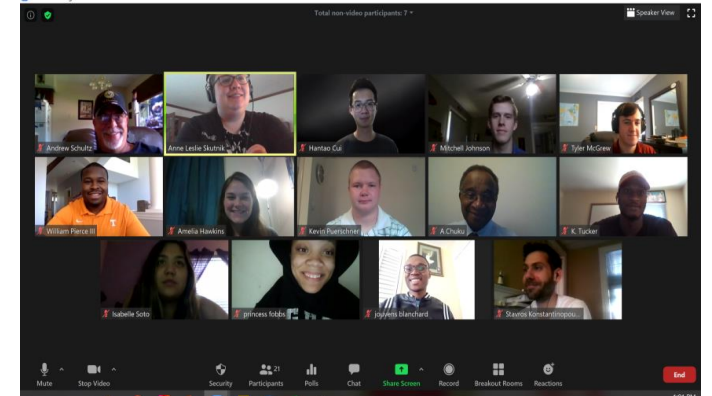
- Power engineering seminar series
- Workshops (e.g. Python,, literature reviews)
- Training from mentors on technical programs and software

Professional skills and culture of inclusion

- Technical writing and resumes/LinkedIn workshop
- Data visualization workshop
- Inclusion seminars

Industry connectivity

- Presentations from ORNL, EPRI
- Graduate school readiness talks

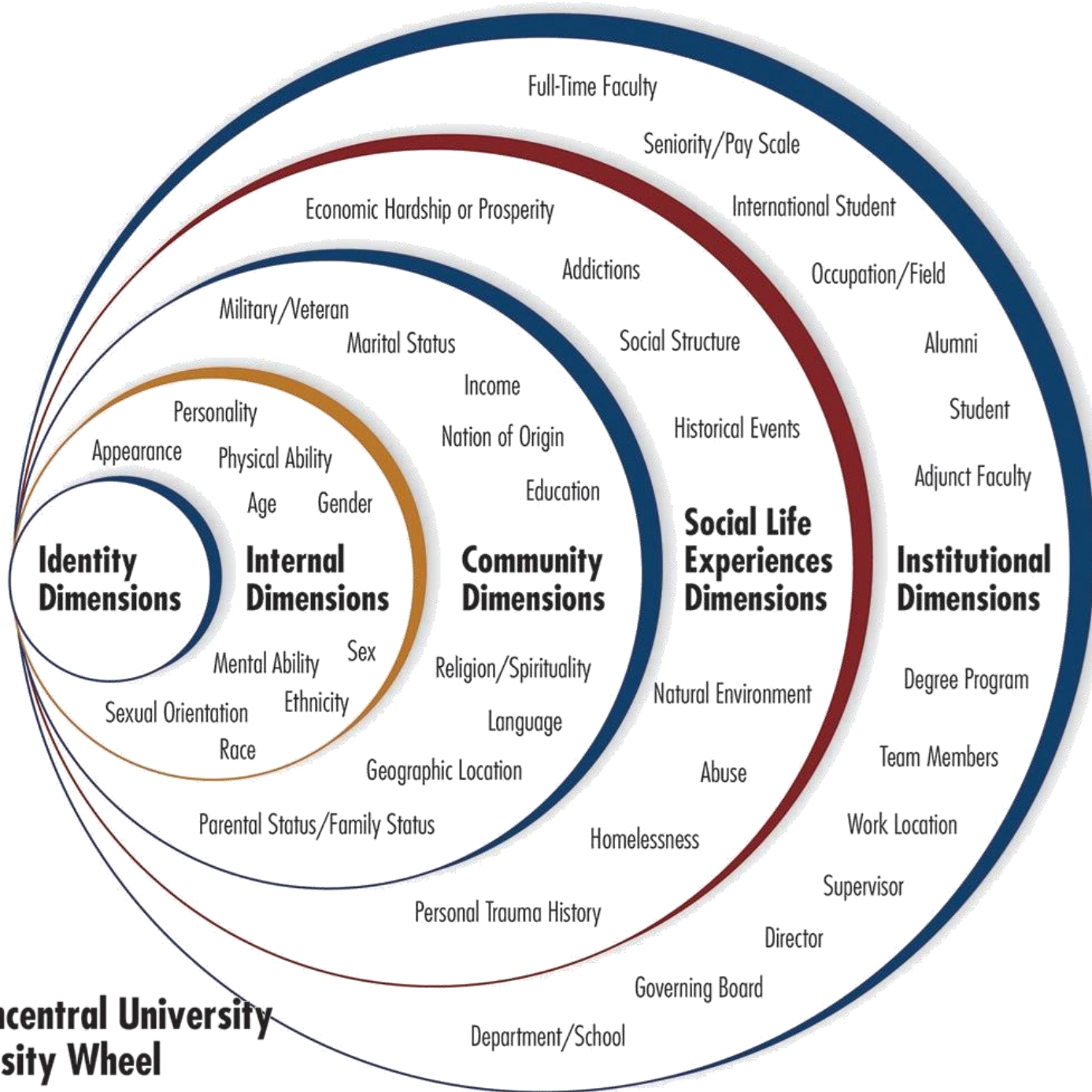


Some of CURENT REUs, Mentors, and Staff on Zoom July, 2020

Additional Highlights:

13 REU students in Year 9

- 4 TU students participated in cross-campus collaboration
- **50% REUs** were women and underrepresented minorities



- **Diversity** encompasses all facets of identity
- An **Inclusive** environment is one in which
 1. Individuals' differences are recognized and valued
 2. Diverse methods of learning and communication are respected
 3. Communication is open and honest
 4. Policies promote understanding and appreciation of all individuals
 5. Center progress and change is positive
 6. Interactions are respectful, open-minded, and flexible to varying needs
- Inclusion applies to **all members** of CURENT
- Our efforts on Diversity and Inclusion enhance and enable CURENT to **deliver on our mission**

External Consultant

- External consultant through Year 10
 - Report to Council of Deans
 - Examine strategic plan and develop operational plan
- Hired Pope Consulting
 - Contract executed May 2nd 2019
 - Initial reports delivered to Council of Deans



“At Pope Consulting, we firmly believe that diversity and inclusion aren’t just buzzwords. As long as organizations need people to achieve their goals, diversity and inclusion will be either a tremendous source of strength or weakness. They will rarely be neutral.”



Pat Pope (CEO / Co-Founder)

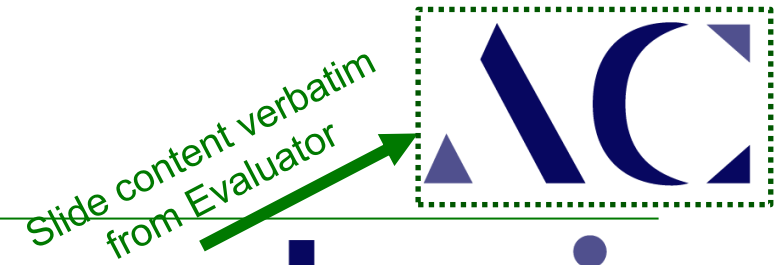
- Coined term “Illusion of Inclusion”
- Developed EDGEAdvantage, Diversity Relationship Indicator™, and Team Inclusion Profile™ (TIP)
- 2011 “Diversity Legend” of The International Society of Diversity & Inclusion Professionals



Samir Gupte (Consultant)

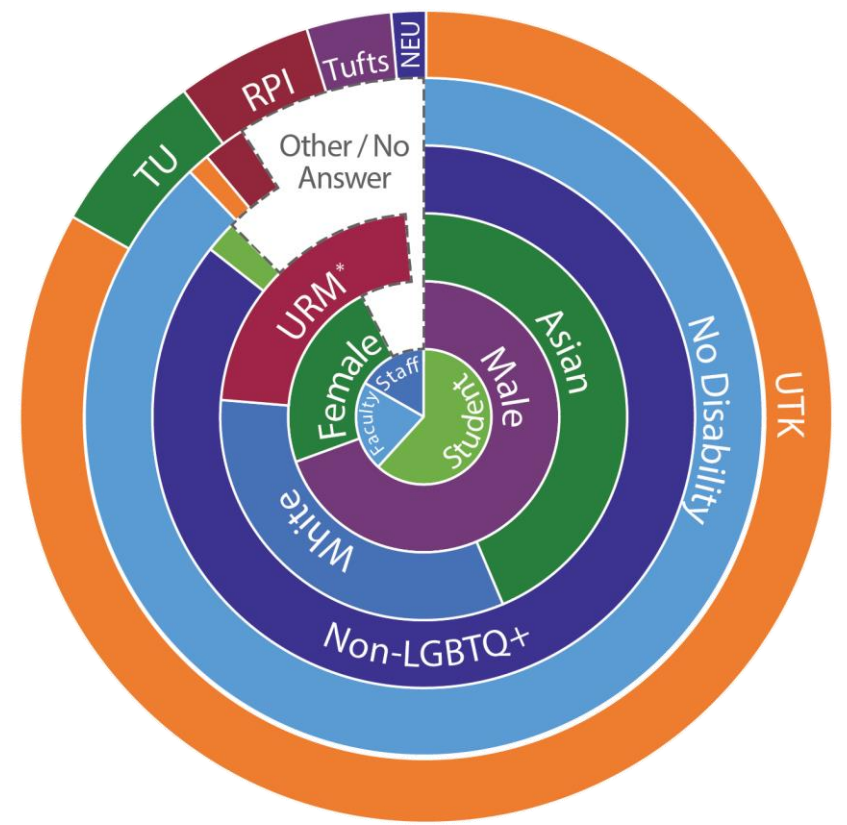
- Prior leadership roles in HR and Operations with 7 firms
- Extensive advisory and service work in academia
- Significant community involvement aiding disadvantaged communities

External Evaluator



- Performed external evaluation of CURENT culture/climate
 - Quantitative/qualitative survey design
- Assessment continuing to gather wider participation
- Survey Design:
 - 54 quantitative questions for all members
 - 5-8 questions for each position (staff, faculty, student)
 - Categories:

1. Belonging	5. Identity
2. Culture of Inclusion	6. Diversity & Inclusion
3. Respect	7. Mindset
4. CURENT Participation	8. General Wellbeing
	9. COVID Impact
 - One open-response per category



Survey demographics (n=97)

External Evaluator: Aggregate Results

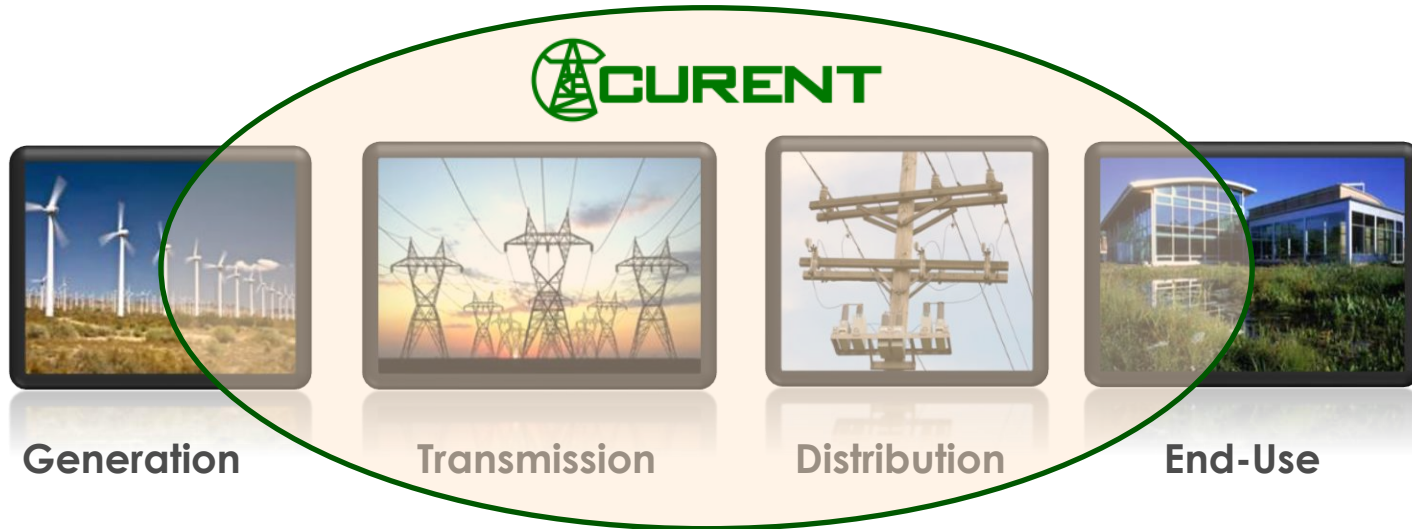


Y7	Y8	Y9	Dimension	Takeaway	Survey Section(s)	# Questions
4.15	4.09	4	Perceived Growth	Respondents feel positively about their advancement potential and career progression	Diversity & Inclusion	10
3.76	4.07	4.04	Growth Mindset	Respondents believe that hard work can influence ability and that they have experienced growth through their CURENT experiences	Mindset section	4
3.93	4.02	4.24	Belonging	Respondents experience a high sense of belonging and respect within CURENT	Belonging Respect	18
3.97	3.92	4.02	Stereotype Threat	Respondents generally believe that others will not judge them based on their performance or specific demographics	Identity	3
--	3.81	4.08	Event Engagement	Respondents generally have good participation in CURENT events; they believe that events are high value	Participation	2
All responses coded so that 5/5 is an optimal response						
3.01	3.76	3.53	Stress	Respondents experience varying levels of stress level	General Well-Being	4

Full report includes ~100 slide breakdown of quantitative and qualitative responses, year-to-year trends, and select disaggregation.



Industry Program



Utilities
RTOs/ISOs



Vendors



Consultants,
Research,
Consortia



Industry Advisory Board



Matthew Gardner
Dominion Energy
Chair



Xiaoming Feng
ABB
Vice Chair



Industry and Innovation Plan Beyond Year 10

Technology Transfer

Establish high-value testing and maintenance services; proof of concept demonstrations, continue annual conference and communications; and complete demonstration/commercialization of prototype software

Research and Development

Continue to build on core competencies in power systems and power electronics, maintain long-term partnerships with organizations of various sizes to expand as needed with technology developments

Innovation

Be a leader in technology trends, publish high visibility white papers, leverage licenses and patents for long term funding

Scientific Advisory Board

These technical experts advise on ERC research program directions. Monthly meetings. We meet once annually and have at least one teleconference per year. The SAB participates in SWOT analysis.



T. Başar
University of Illinois



D. Bertagnoli
ISO New England
(Retired)



T. Boston
PJM (Retired)



C. Clem
TVA



B. Cummings
NERC



J. Giri
GGM Consulting



N. Hingorani
EPRI (Retired)



J. Heydt
Arizona State
University



J. Lyons
Novus Energy
Partners



T. Overbye
Texas A&M University



W. Reder
Grid-X Partners



P. Sauer
University of Illinois

Updates on Responses to SVT

Concerns: Response

- **Fundamental research:** a new methodology named Nonlinear Modal Decoupling (NMD); stability analysis of hybrid systems using time scale theory; intelligent gate drives to deal with fast switching issues of WBG devices among other areas.
- **Recommendation on AAAS' Entry Point! Program:** recruited two students with disabilities into the REU program; one of those students was a veteran.
- **Tuskegee integration:** Implemented new multi-campus program for undergraduates, including joint proposals with Tuskegee faculty and at least one established PI from other partner schools
- **Role of the SAB:** regular monthly SAB meetings began in April 2019. The SAB has been particularly active in suggestions for long term sustainability of the Center.



Acknowledgements



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