# The ERC Program and Wide Area Control for the Future Power Grid

NSF JST DFG RCN Workshop – Washington DC

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# NSF Engineering Research Centers

- Created in 1984. Sought to bring industry and universities together to address US economic competitiveness.
- Funded to date: 61 with 20 still active.
- Broadly breakdown into:
  - Manufacturing
  - Biotechnology and healthcare
  - Energy, sustainability and infrastructure
  - Microelectronics, sensing and IT
- Estimated economic impact 10s of billions USD.

# NSF Engineering Research Centers

- Program of focused research on an engineering problem. Among most significant investments NSF engineering makes in an area with support up to 10 years.
- Program elements include:
  - Outreach (K-12 education)
  - Research experience for undergraduates
  - Entrepreneurship training
  - Industry program
  - Systems engineering approach
  - International collaboration

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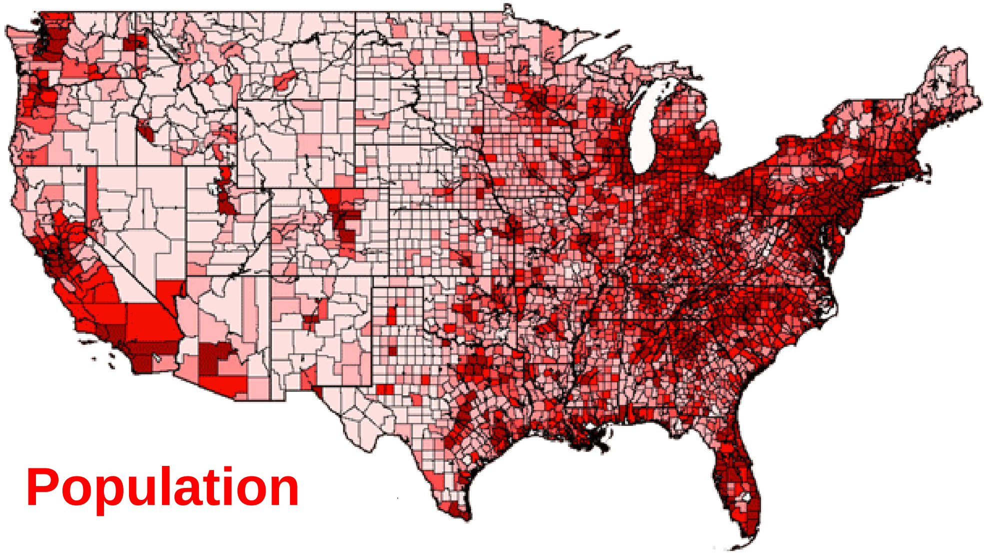
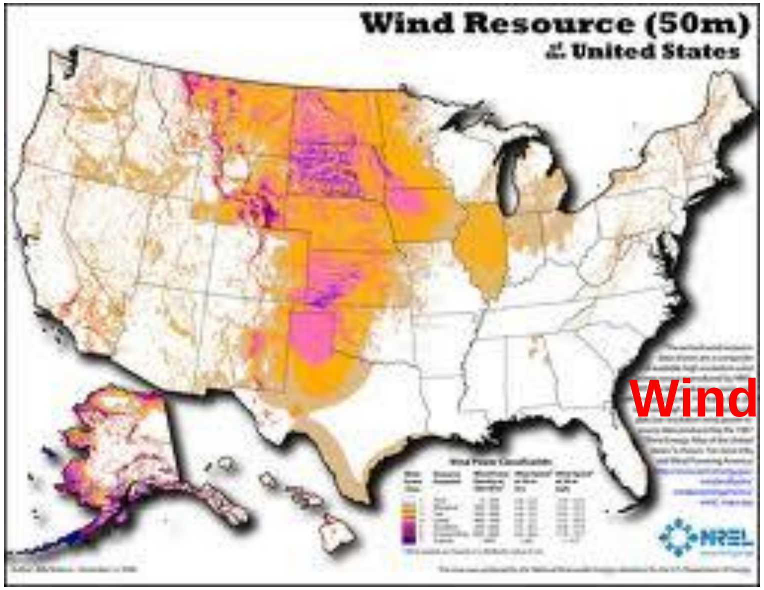
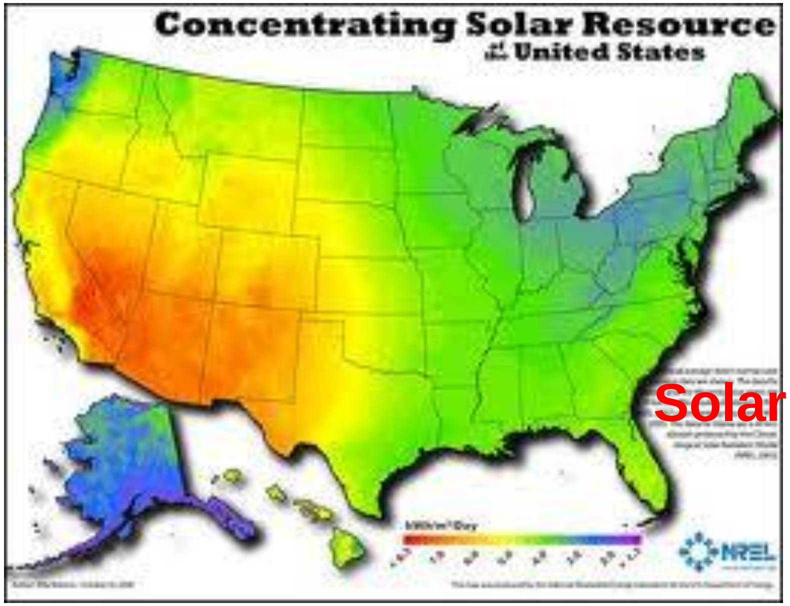
# CURENT – NSF/DOE ERC

- One of only two ERCs funded jointly by NSF and DOE. Core budget: ~$4M/year for 5-10 years but highly leveraged to be able to fully support programs.
- CURENT devoted to wide area controls and one of only two in power systems (FREEDM at NCSU).
- Partnership across four universities in the US and other international partner schools. Many opportunities for collaboration.
- Presently have 26 industry members.
- Center began Aug. 15th 2011.

# US Wind and Solar Resources



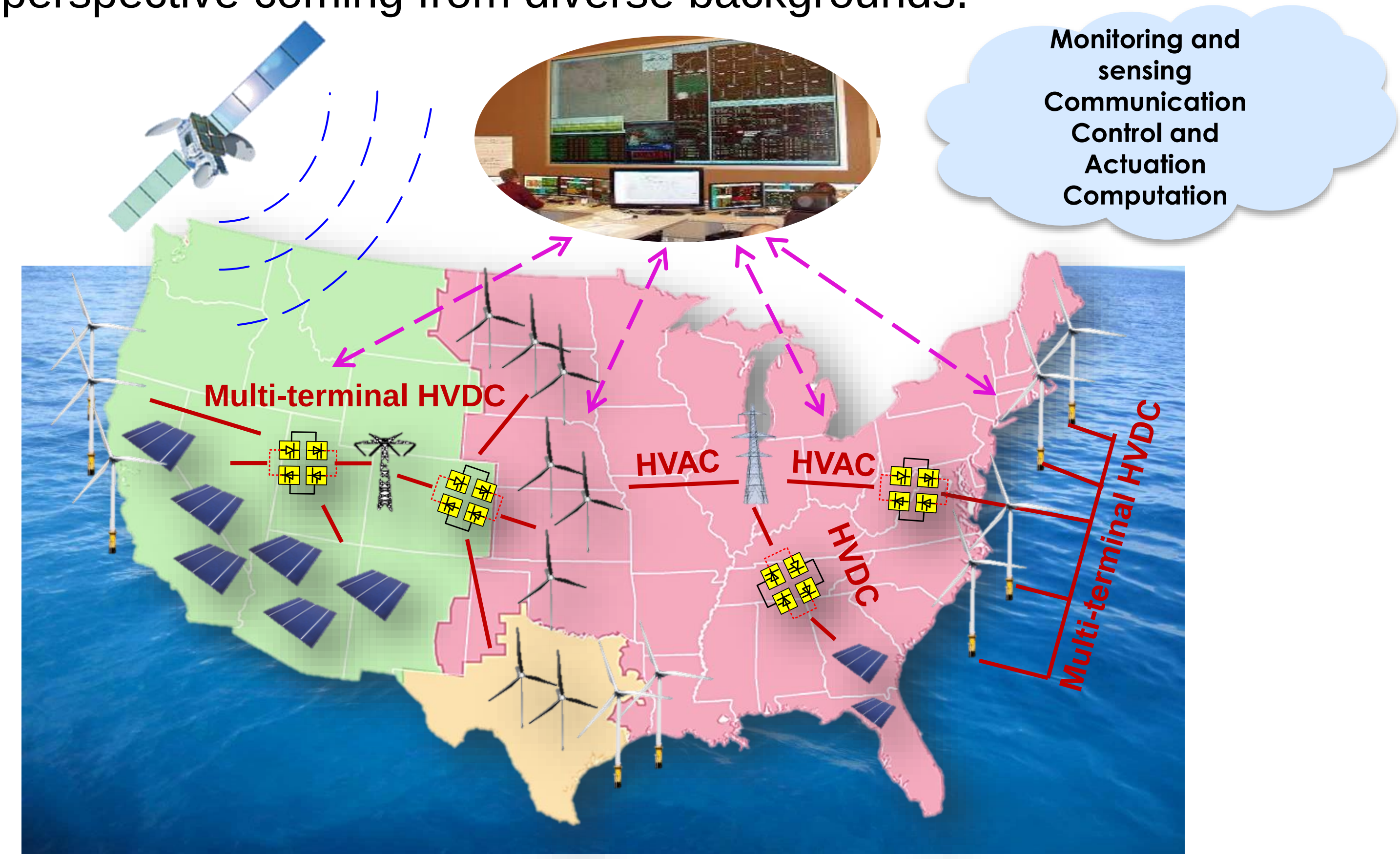

**Best wind and solar sources are far from load centers.**

**Transmission networks must play a central role in integration.**

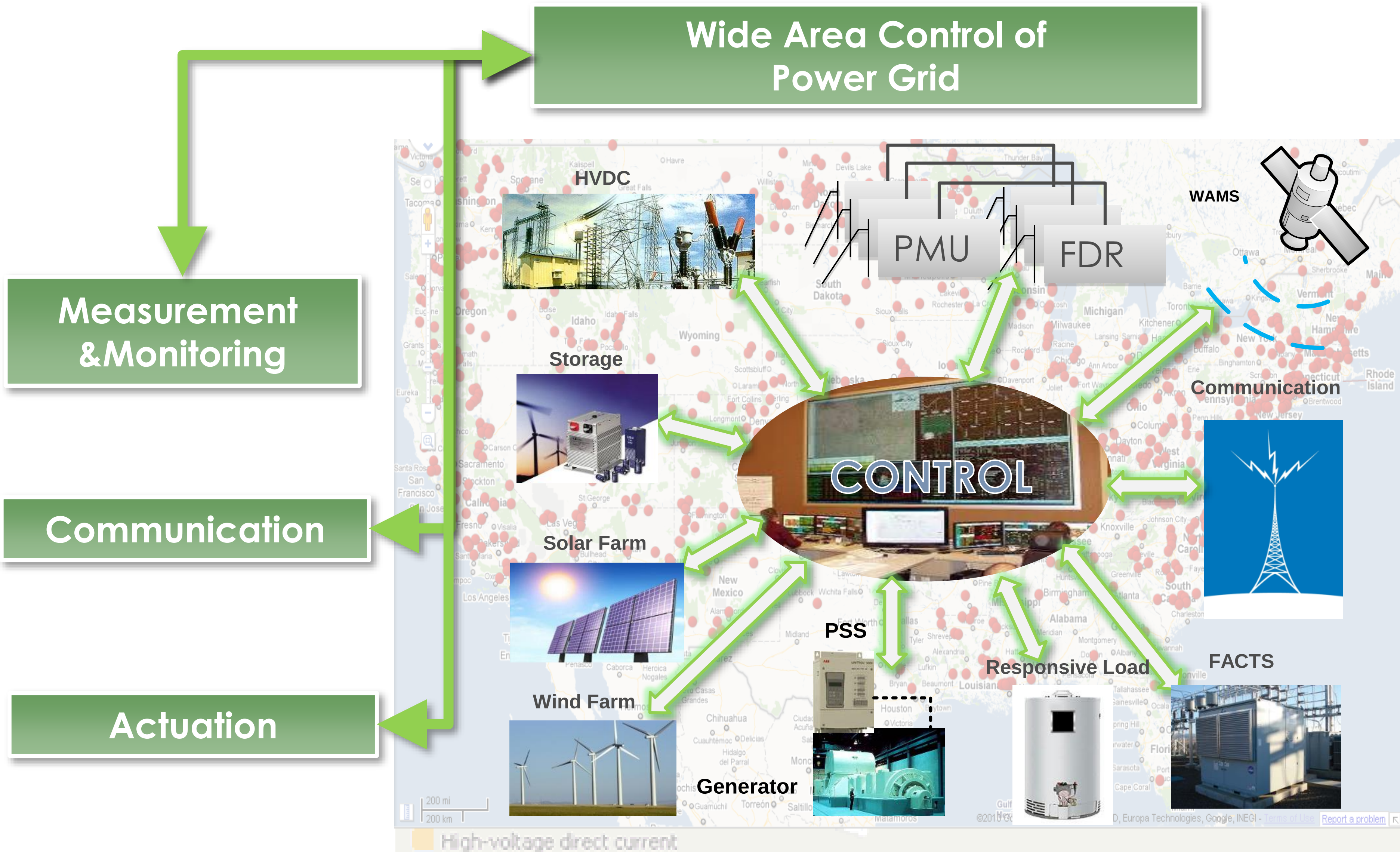
http://www.eia.doe.gov/cneaf/solar.renewables/ilands/fig12.html

# CURENT 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.



# What is CURENT?

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# Example Value of Improved Controls

**Northwest Pacific Intertie**

- Two 500kV AC lines and +/- 400kV DC line
  - Designed for transfer of 2000 MW AC and 1440 MW DC
  - Actual capacity was 1300 MW AC due to instability caused by AVRs
  - Power system stabilizers allowed increase to 1800 MW AC
  - Dynamic brake added at Chief Joe allowed up to 2500 MW AC
- Transmission upgrade – third AC line and DC upgrades
  - AC capacity today about 4800 MW (primarily voltage)
  - DC capacity today about 3000 MW

➔ 1990s work by DOE and BPA on WAMS and WACS a direct result of this type of need for improved controls.

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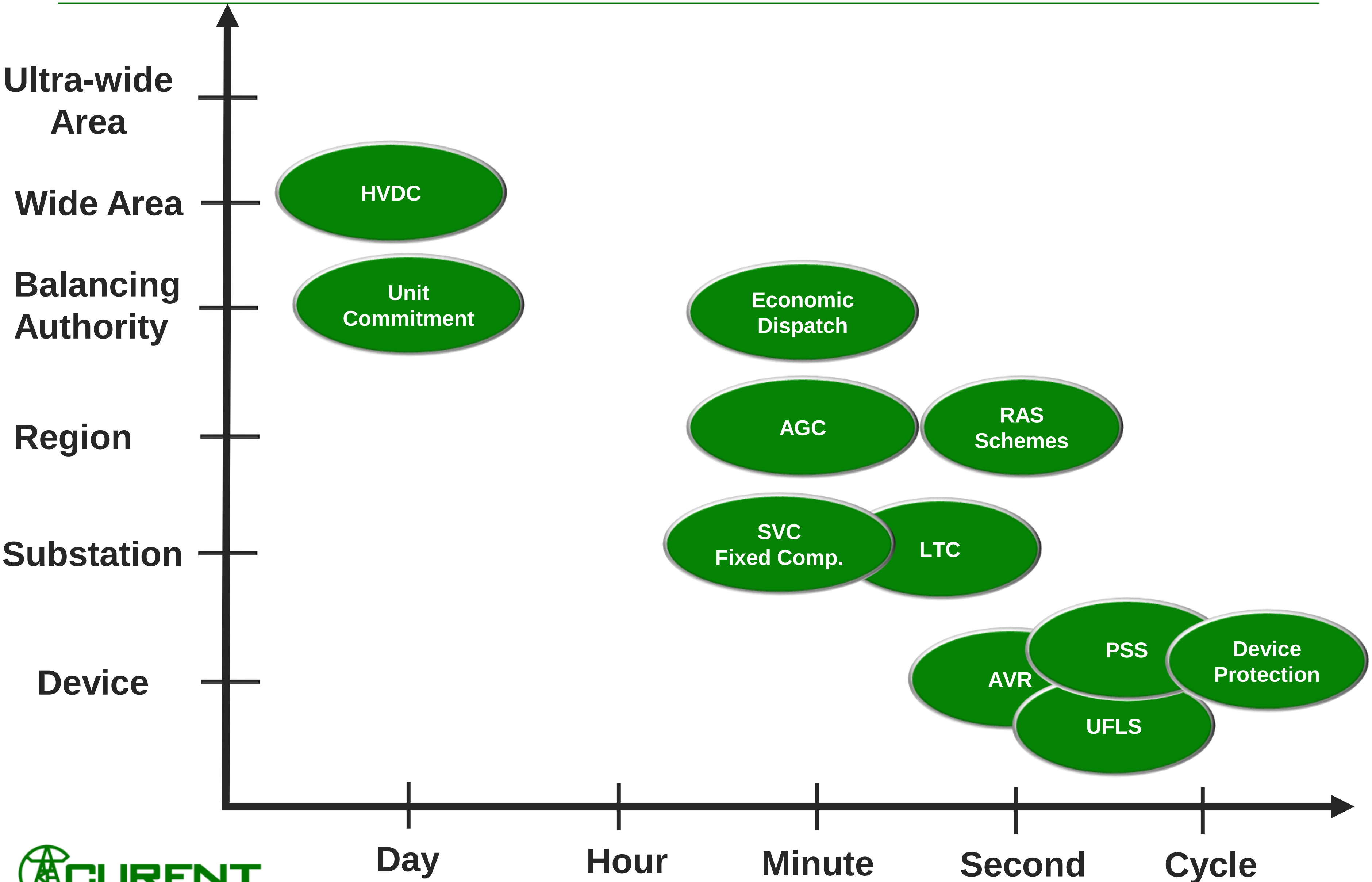
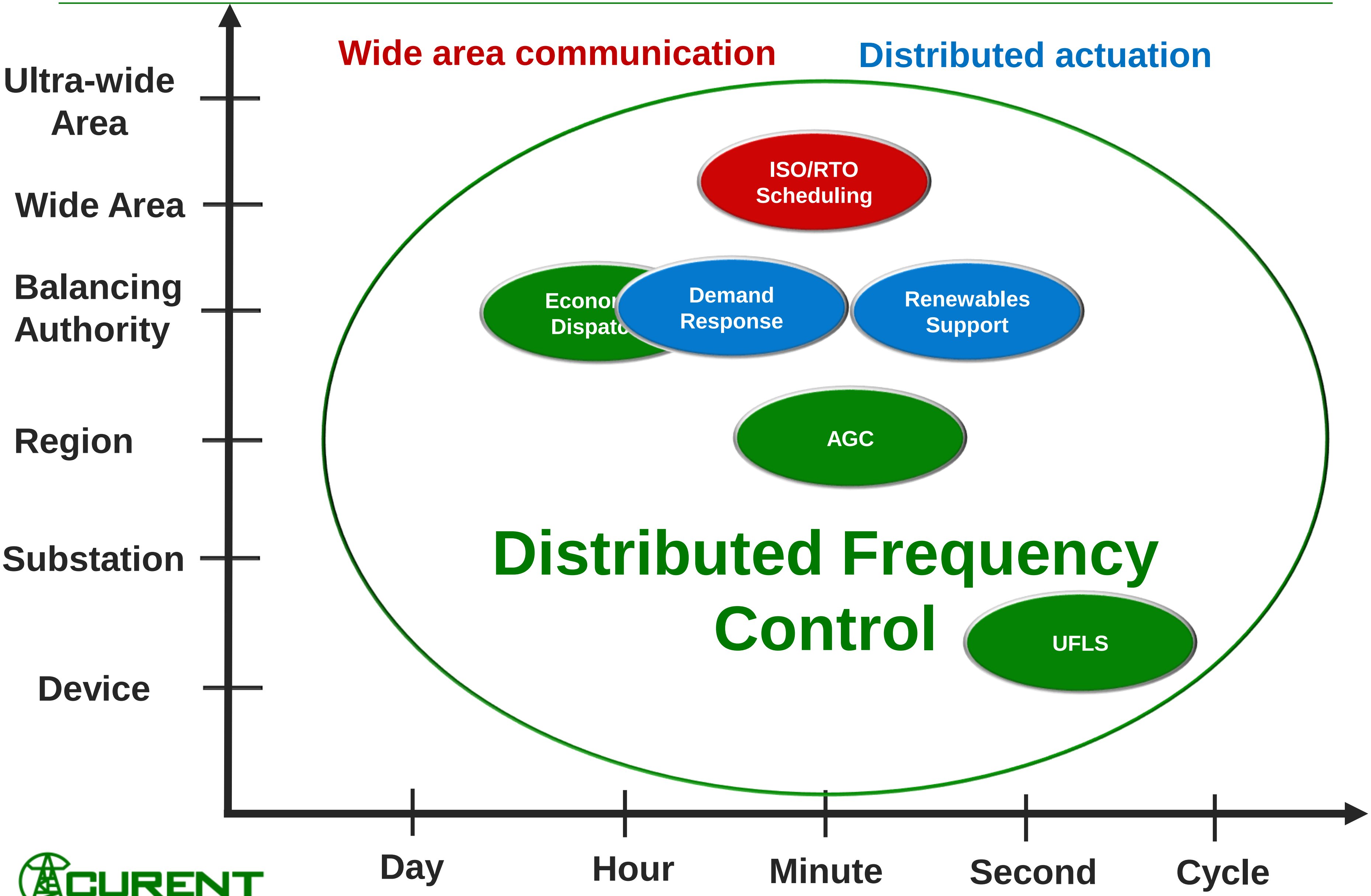
# Today's Controls

## Some wide area and some fast but not both



# Frequency Control

## Wide area with distributed actuation



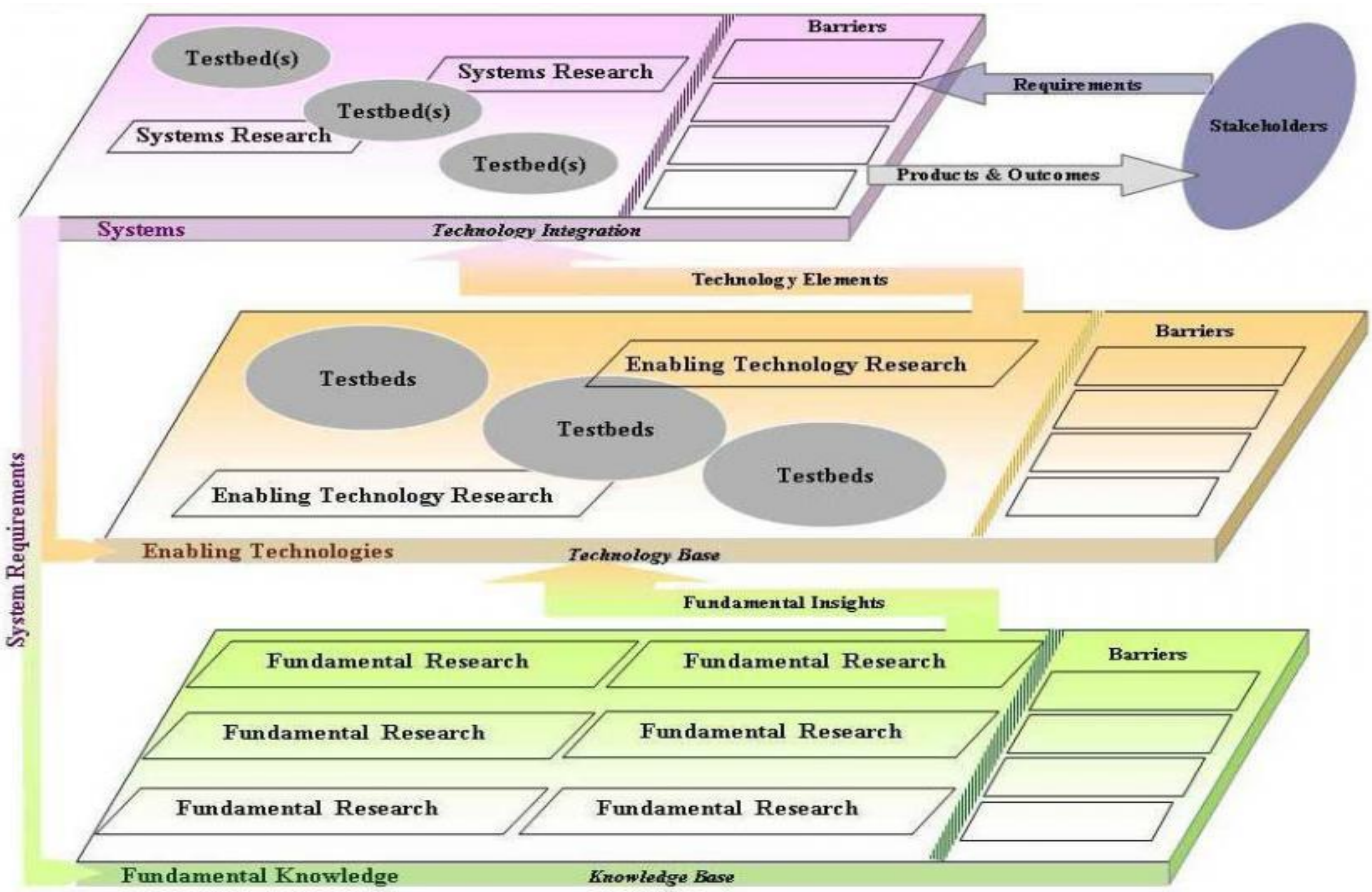
# Major Research Questions

***Future Control Architecture***

- Information flow
  - What information is needed where?
  - How much latency can be tolerated?
  - Trade-off – more information leads to better decisions but slower response
- Control architecture
  - Do all devices contribute to control?
  - For which phenomena do devices contribute (some fast and some slow)?
  - How much contribution is needed to ensure performance?
  - Trade-off – more devices contributing properly expands viable operating region but requires greater sophistication
- Economics and optimization
  - Contributions from certain devices are more cost effective
  - Trade-off – greater optimization leads to lower cost but requires more voluntary sharing of information and more susceptible to market manipulation

➔ Design needs to be a series of trade-offs between communication needs, device sophistication, resiliency, speed of response, economic performance and device reliability vs. system reliability.

# Three-plane Diagram

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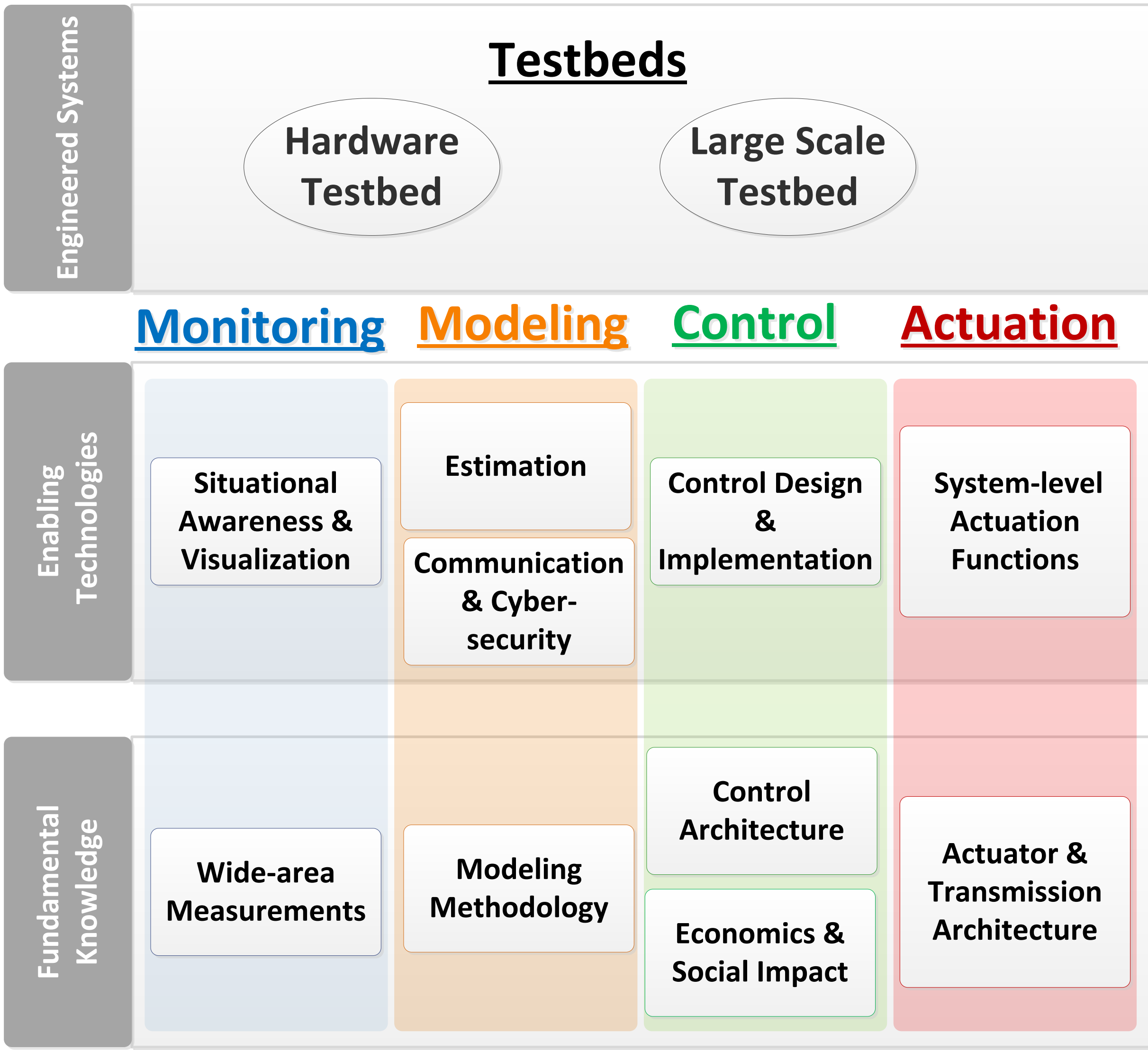
# Three-plane Diagram




*Barriers*
- System complexity
- Model validity
- Multi-scale
- Inter-operability

*Barriers*
- Poor measurement design
- Cyber security
- Actuation & control limitation

- *Barriers*
- Lack of wide-area control schemes
- Measurement latency
- Inflexible transmission systems

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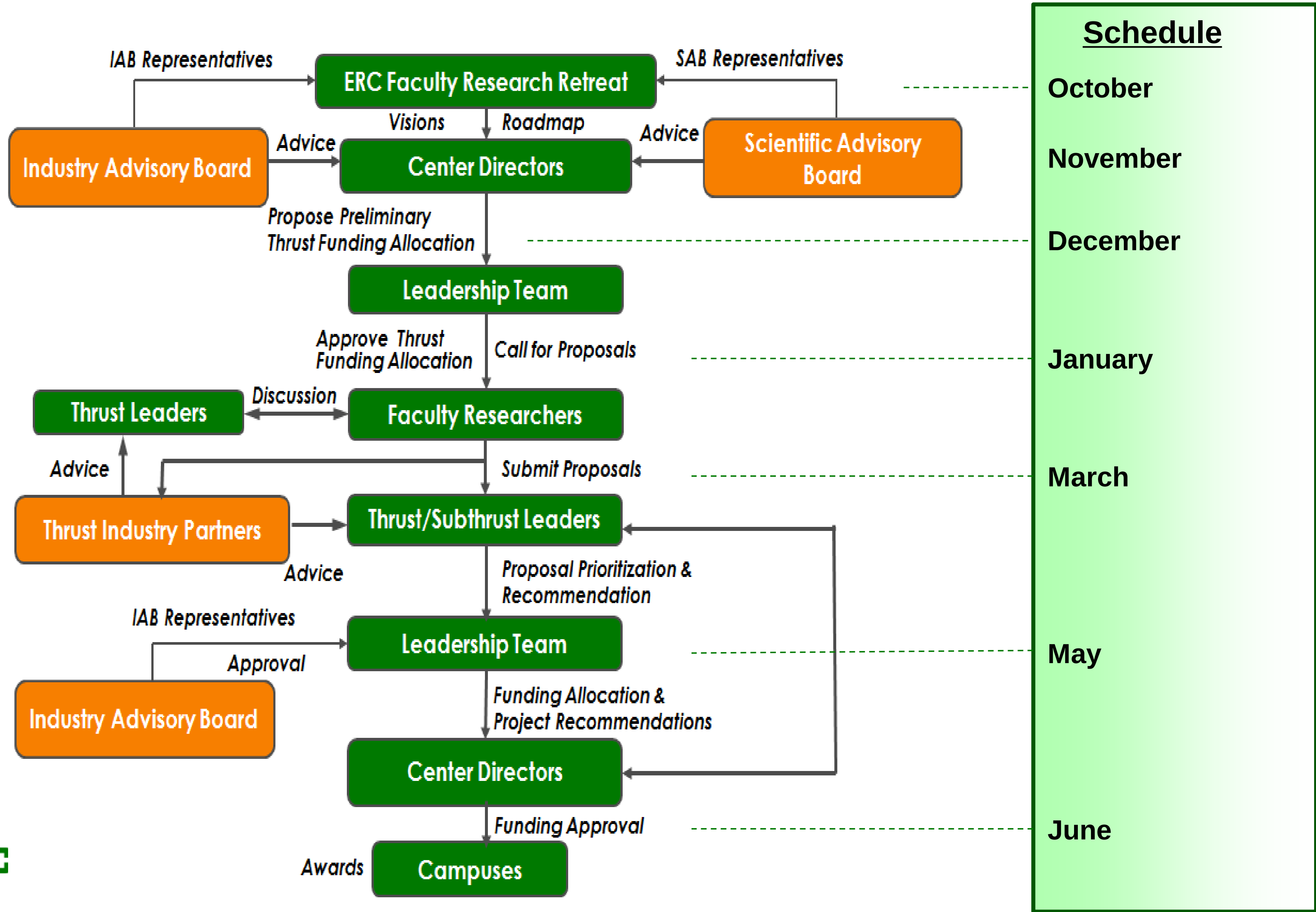
# Three Generations of Engineered Systems

| Year 1~3 | Year 4~6 | Year 7~10 |
|---|---|---|
| Generation I | Generation II | Generation III |
| Regional grid models with > 20% penetration of renewables and HVDC connections. | Reduced North American system model with > 50% penetration of renewables and HVDC connections. | Positive sequence model of North American system with >50% renewables and HVDC connections. |
| Model development for primary and secondary frequency and voltage controls in regional grids. | Extension of frequency and voltage control models to North American grid for damping control and transient stability control. | Fully integrated system model of real time communication, coordinated control, actuators, monitoring and load response. |
| Scaled down system models suitable for testing in RTDS and HTB. | Communication system modeling including cyber attacks. | Scalability of cyber security approaches and resilience to coordinated attacks. |
| Scenario development to include diverse system operating conditions. | Scenario development for North American grid. | Detailed scenarios for contingencies. |

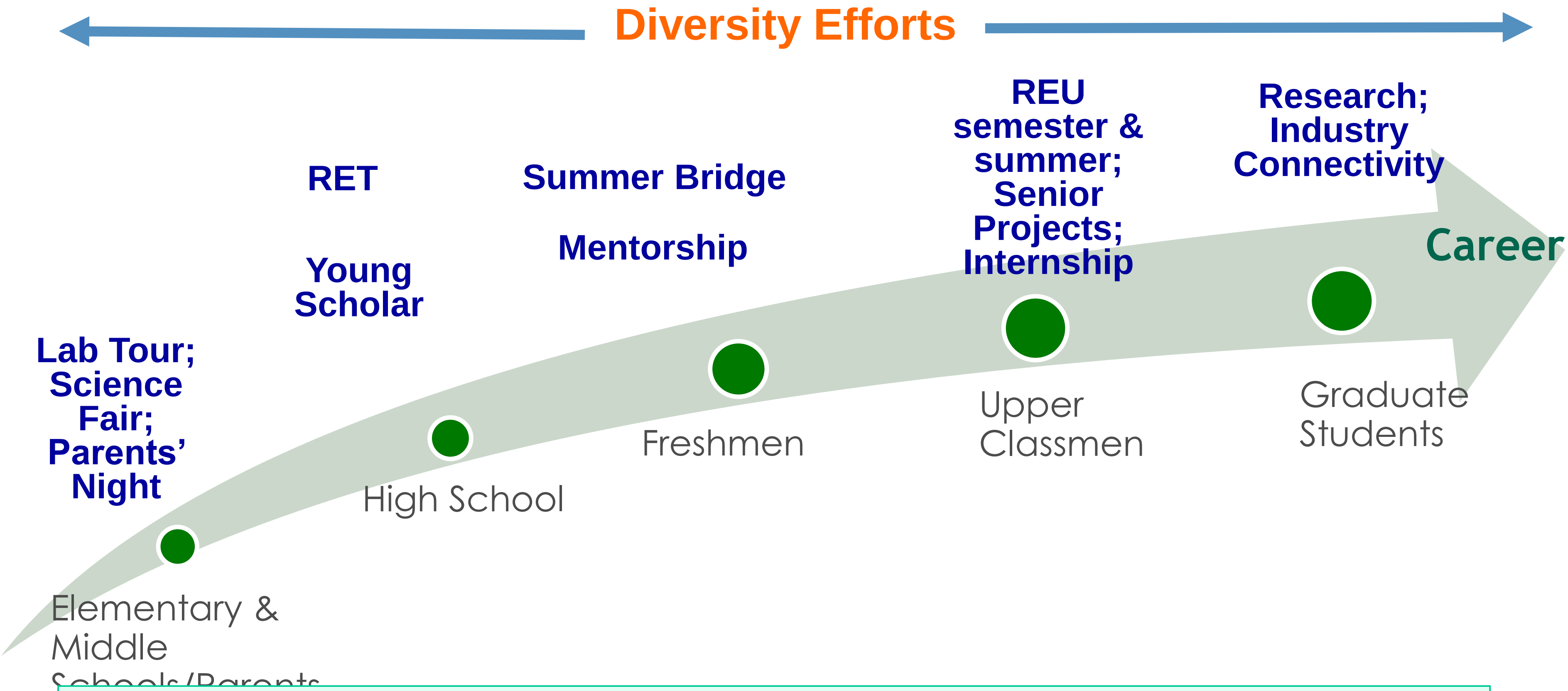
# Industry Collaboration and Innovation

| | |
|---|---|
| **Industry Partnership Program** | • Three tier membership structure<br>• Industry consortium<br>• Industry Advisory Board (IAB) |
| **Research Collaboration** | • Mentors and thrust partner<br>• Sponsored research |
| **Industry Connectivity** | • Industrial residence program<br>• Summer internships<br>• Short courses |
| **IP & Technology Transfer** | • Intellectual Property Protection Fund (IPPF)<br>• Build partnerships with local government<br>• Engage small businesses |
| **Innovation Program** | • Entrepreneurship and IP training<br>• Faculty award for winning SBIR/STTR<br>• Student award for patent |

# Proposal Development



# Education Program Pipeline




- Early intervention
- Operates at all levels (diversity)
- Tailored research opportunity
- Sustained involvement
- Model-based assessment & research

# International Research Collaboration Opportunities

- Incorporate projects into strategic research plan
- **Use of testbeds**
- **Education exchanges – students and researchers**
- Unique aspects of different systems across countries can more fully test new control architectures, e.g.,
  - Japan
    - Multiple frequency system
    - Highly dense urban distribution systems
  - Germany
    - High levels of wind and solar
    - Tight integration with larger continental system
  - Norway
    - High levels of hydro
    - Longitudinal system