Cyber-Resilient Distributed Autonomous Energy Grid

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Cyber-Resilient Distributed Autonomous Energy Grid

Research Aim:

*Develop an **integrated framework for cyber-resilience** in the design and operation of a distributed autonomous energy grid.*

Research Approach:

Advancements in fundamental science and engineering approaches in the field of:

- Cyber-resilient design and control
- Zero trust architecture for autonomous grid
- Autonomy to enhance cyber-resilience

Defining Cyber-Resilience

- The ability of the system to ***prepare, anticipate, defend, withstand, recover,*** and ***adapt*** from an adverse cyber event on the system.

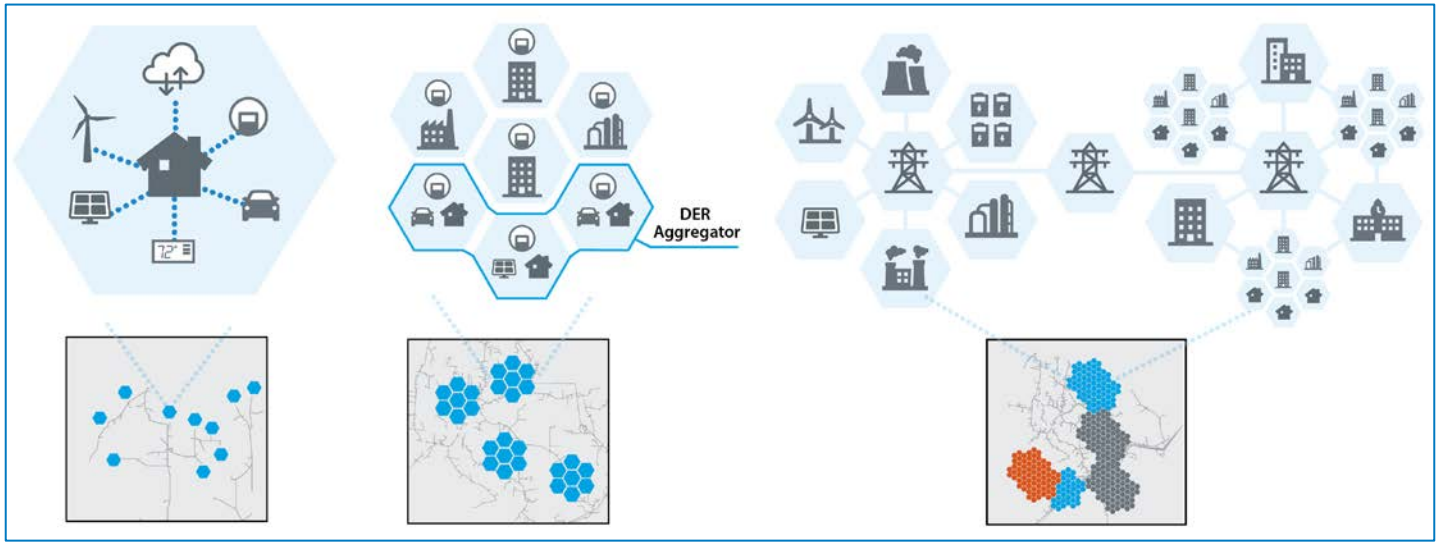
Cyber-Resilience Definitions*

Context	Term	Definition
National Security	Resilience	"The ability to ***adapt*** to changing conditions and ***prepare*** for, ***withstand,*** and rapidly ***recover*** from disruption." [WH 2010]
Critical Infrastructure	Infrastructure resilience	"Infrastructure resilience is the ability to reduce the magnitude and/or duration of disruptive events. The effectiveness of a resilient infrastructure or enterprise depends upon its ability to ***anticipate, absorb, adapt*** to, and/or rapidly ***recover*** from a potentially disruptive event." [NIAC 2010]
Critical Infrastructure Security and Resilience	Resilience	"…the ability to ***prepare*** for and ***adapt*** to changing conditions and ***withstand*** and ***recover*** rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents." [WH 2013]
DoD Cybersecurity	Operational resilience	"The ability of systems to ***resist, absorb,*** and ***recover*** from or ***adapt*** to an adverse occurrence during operation that may cause harm, destruction, or loss of ability to perform mission-related functions." [DoD 2014]

* "Cyber Resiliency FAQ" MITRE, Available online: https://www.mitre.org/sites/default/files/PR_17-1434.pdf

Future Grid Challenges

Features of future grid		Cyber-Resilience challenges
Distributed (Authority)	→	Distributed attack surface
Interconnected (Communications)	→	Multiple attack entry points
Hierarchal and Coordinated (Design & Operation)	→	Cascading impacts and failures
Autonomy (Control and Operation)	→	Autonomous Decision Making



Research Approach

Cyber-Resilient Design

Emerging Features of Future Grid
Highly distributed

Emerging Cyber-Resilience challenges
Distributed attack surface

Approach:

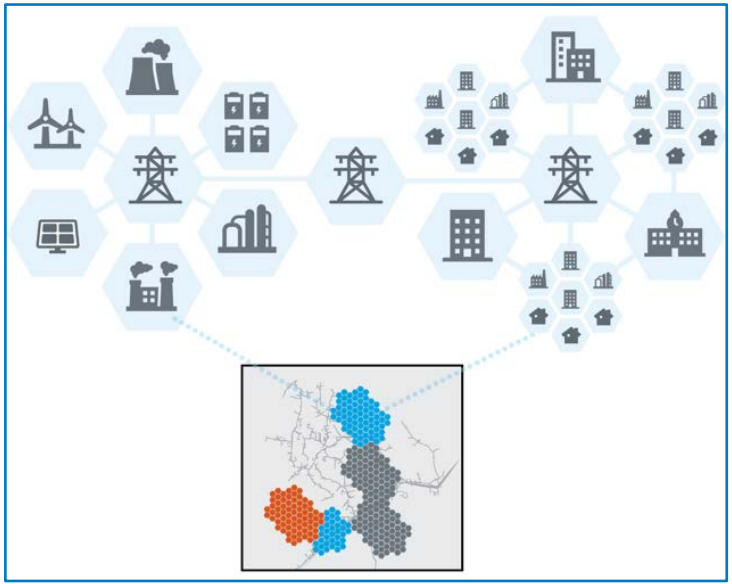
- Development of ***novel cyber-resilience metrics for cyber-physical systems***
  - Highly distributed and autonomous
- Development of ***novel Graph Neural Net approach*** to analyze and search for a more resilient cyber-physical topology

Innovation:

- Mathematical quantification of the impact of system topology on resilient operation of a distributed and autonomous grid
- Novel graph embedding techniques for combined cyber-physical networks

Impact:

- Bake-in security the design instead of bolt-on security
- Leverage topology for developing cyber attack response
- Determine future security investments



Cyber-Resilient Controls

Approach:

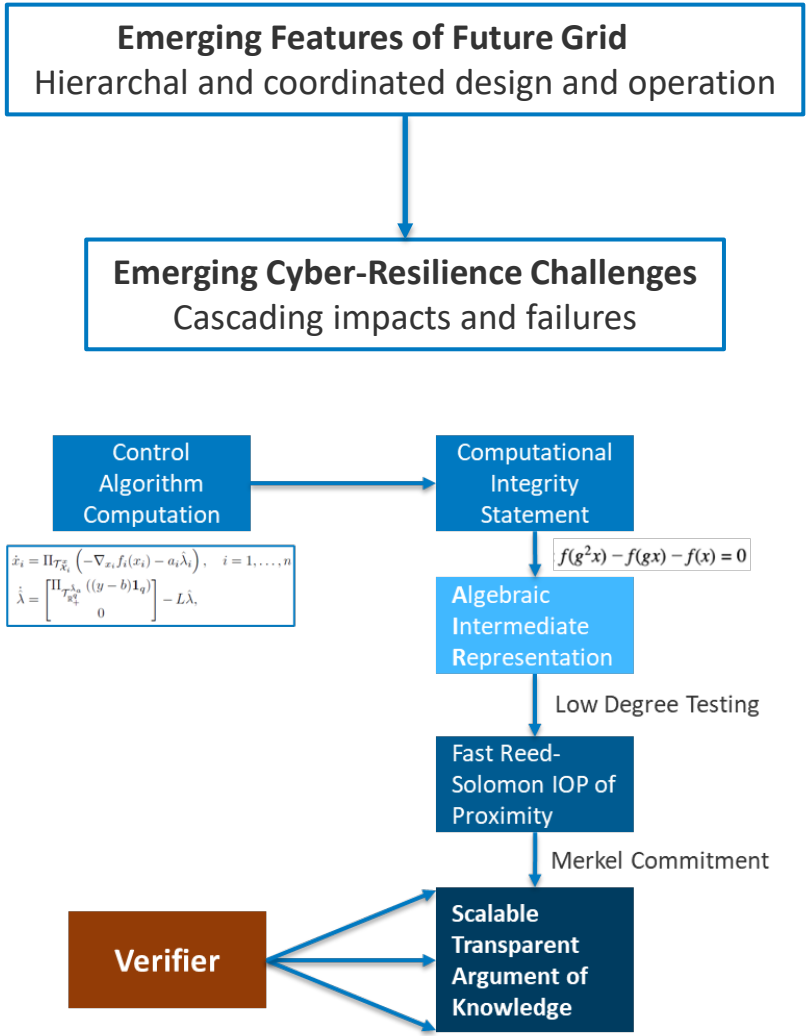
- ***Proof of computational integrity for the grid control approaches*** leveraging zero-knowledge proofs
  - Zero knowledge - Succinct Transparent Arguments of Knowledge (zk-STARK)

Innovation:

- Computational integrity versus just data integrity
- Transparency: Trust towards none, integrity for all
- Scalable and efficient
- Post-quantum secure (plausibly!)

Impact:

- Attack resilient control schemes
- Not reliant on novel encryption or access control schemes
- Forms a last line of defense



Zero Trust Architecture for Autonomous Grid

Emerging Features of Future Grid
Highly interconnected

Emerging Cyber-Resilience Challenges
Multiple attack entry points

Approach:

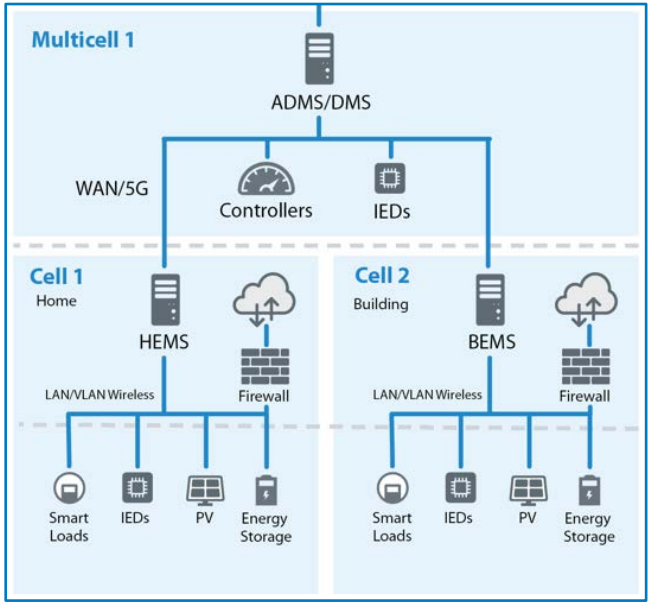
- ***Formally verifiable approach to developing zero trust architecture for operational technology (OT) systems***
  - Formal specification language for a cyber physical system
  - Physics informed machine learning for verification of data flow

Innovation:

- Bringing formal methods approaches to OT security
- Formal proof of minimum protect surface for OT system
  - Adequate, consistent, unambiguous, and complete

Impact:

- Move the challenge from inherent trust in the system to a quantifiable confidence.



Autonomy for Cyber-Resilience

Emerging Features of future grid
Autonomous Control and Operation

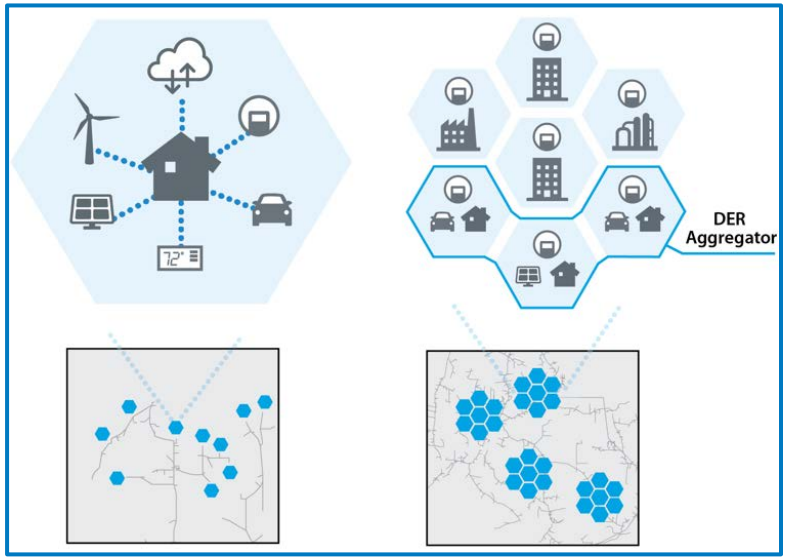
Emerging Cyber-Resilience challenges
Autonomous Decision Making

Challenge:

How to perform ***autonomous decision making*** in an environment that is governed by ***autonomous controls*** to ***withstand and recover*** after a cyber attack?

Approach:

- **Autonomous Decision Making = Autonomous Response in light of cyber threat intelligence**
  - Develop self-healing and self-optimizing techniques for communication systems for autonomous response to withstand and recover from a cyber-attack
  - Develop novel techniques for cyber deception and decoy in real-time OT environments that can help gather cyber-threat information



Areas of Research:

Graph Theory

Optimization Theory

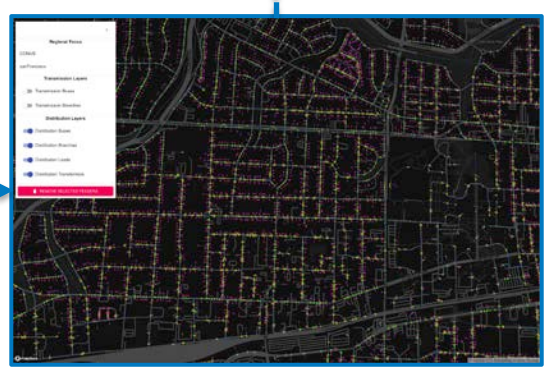
Complex System Theory

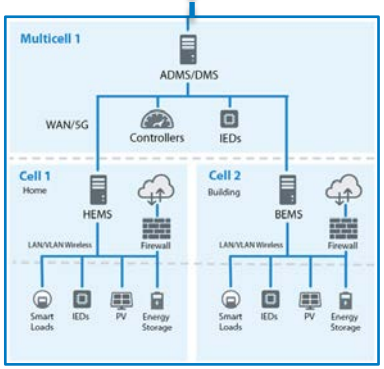
Game Theory

AI/ML Based Approach

NREL Cyber Range

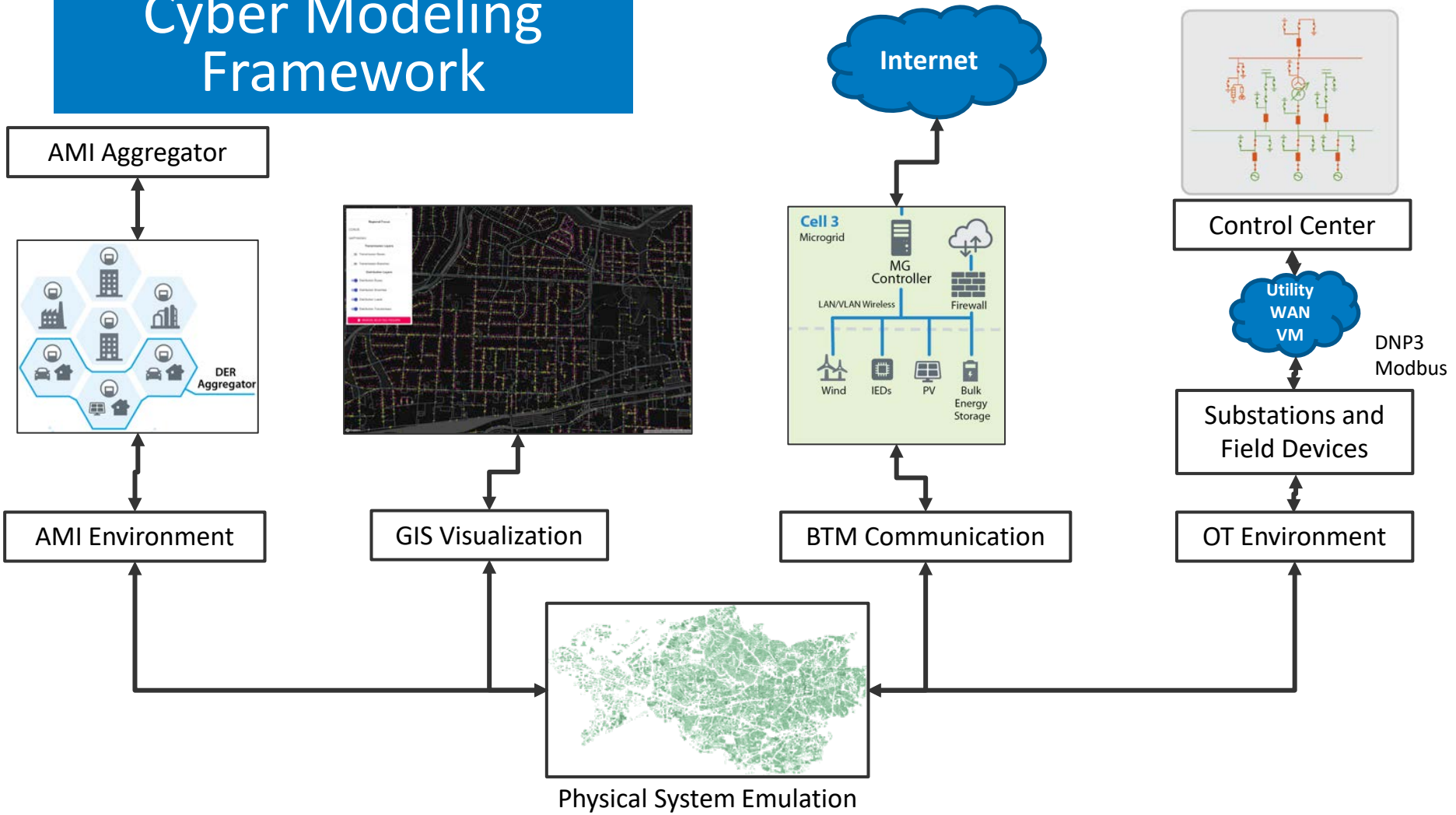
In minutes instead of Months.





- **Scale + Complexity**
- Dynamic orchestration
- Protocol Fidelity
- AMI Network emulation
- GIS visualization
- Policies and Procedures

Cyber Modeling Framework



Summary

- ***Enhance secure and resilient integration of renewable energy resources at scale***
  - Advance the science of cyber-resilient OT system design
  - Secure and resilient grid control schemas
  - Move OT security from implicit trust to explicit verification
  - Enable autonomy and deception to stay ahead of the threat curve

Acknowledgement

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