### Problem Statement
To translate current state-of-the-art centralized processing algorithms for wide-area monitoring and control of large power grids using large volumes of Synchrophasor data to a completely distributed attack-resilient cyber-physical architecture.

1. Centralized versus distributed power flow oscillation monitoring following critical disturbances
2. Applying distributed algorithms for ensuring resiliency against cyber and physical attacks
3. Experimental verification using federation of DETERLab and RTDS-WAMS testbeds

### Theoretical Approach
State-of-art Centralized Processing Architecture:
1. Regional PMU data sent to regional PDC
2. Independent local analysis and storage
3. Regional PDCs send data to super-PDC for archival

Proposed Distributed Cyber-Physical Architecture for PMU-PDC Communication:
- Centralized Recursive Least Squares (RLS)
- Distributed Subgradient Method
- ADMM and other convex algorithms

Compute power flow oscillation frequencies (eigenvalues), mode shapes (eigenvectors), damping, residue, participation factors, and mode energy of electro-mechanical swing dynamics from PMU measurements.

Pose a least-squares estimation for transfer function parameters:
\[
\min_{\theta_k} \sum_{i=0}^{K} (\theta_i - \theta_k)^2 + (\theta_k - \theta_o)^2 R_k(\theta_k - \theta_o)
\]

### Goals
Our team is advancing the science and technology for cyber-physical power systems by developing transformative algorithms for wide area monitoring and control of next-generation smart grid networks.

**Key Elements**
We are performing a set of interconnected activities in the following areas:
- Enabling facility integration by leveraging existing testbed infrastructure across different institutions.
- Advancing the underlying experimentation technologies to increase the scale and the scope of the evaluation of wide area CPS monitoring, control, and security algorithms.
- Providing technologies to extract and maintain the theoretical and empirical understanding of stability and control algorithms in wide area CPS scenarios.
- Developing tools and methods that can be used for experimentation by experts and non-experts in addition to applications-specific and domain-specific support tools.

### Experimental Approach
DETERLab and RTDS-WAMS tools to create several what-if scenarios for evaluation.
1. Emulate real-time dynamic models of power system coupled with representative wide area topology
2. Orchestrate traffic and faults that impact monitoring and estimation
3. Compare impact of communication bottlenecks on the convergence of the estimation
4. Collect data and visualize results

**Impact on CPS Community**
- Increases the technology readiness through rigorous evaluation and validation
- Facility integration provides an interdisciplinary training and educational platform for power engineering and computer science

**Facility Integration**
Verification and validation of distributed algorithms for wide-area stability monitoring and control using real world communication protocols implemented over a nation wide network.

1. High-fidelity dynamic models of IEEE 39-bus New England instantiated across three facilities
   - PMU-based hardware-in-loop simulation testbed at NCSU
   - Federated with DETERLab and ExoGENI
2. Create at-scale scenarios to explore resiliency of distributed algorithms
3. Test fault tolerance and accuracy in the presence of communication failures and cyber-security incidents

### Design and Analysis of Wide-Area Resilient Control Algorithms for Large-Scale Power Systems: Theoretical and Experimental Methods

Alefiya Hussain (USC/ISI) and Aranya Chakrabortty (NC State Univ)

Team Members: Prateek Jaipuria, Vineet Ghatge, Terry Benzel (USC/ISI), Jianhua Zhang (NC State), Yufeng Xin (UNC Chapel Hill)