Cloud Hosted Linear State Estimator

Proof-of-Concept

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Outline

- Background and business needs

- Proof-of-Concept Cloud WAMS

- Conclusions and future work

PMU Infrastructure at ISO New England

- \>100 PMUs in New England and constantly growing per OP-22

- Full observability of 345 kV with some redundancy

- Operational since 2013

- Selected external PMU data from NYISO, PJM, MISO, SPP, Southern Company and TVA via EIDSN

- Also share PMU data with other RCs
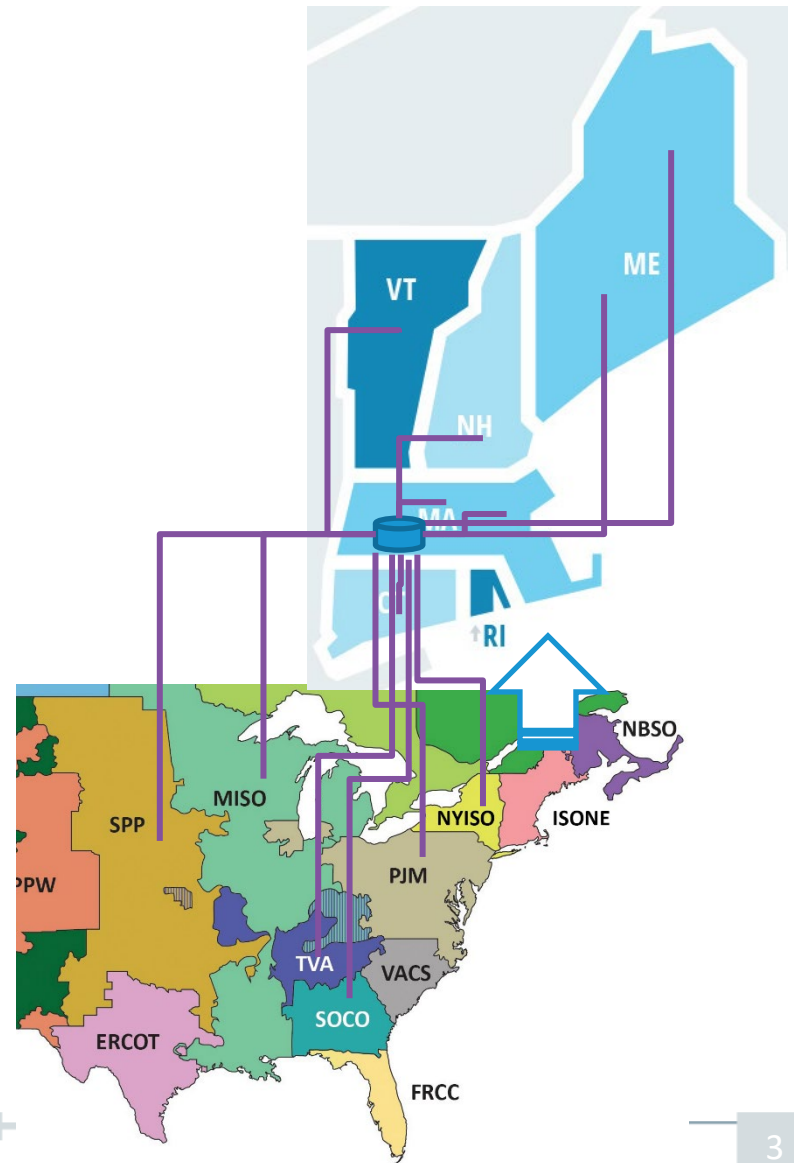
Key PMU-based Operational Processes

- Data Quality Monitoring System (DQMS)
  - ✓ Online detection, reporting and diagnose of "bad" PMU data

- PhasorPoint Application
  - ✓ Main application for visualization, event detection & analysis, and historian

- Online Oscillation Management
  - ✓ Oscillation detection, source location, notification

- Automatic Power Plant Model Verification (APPMV)
  - ✓ Event verification, phasor-based playback simulation, result analysis, notification

- M/LCC-21
  - ✓ Backup ACE calculation, generation dispatch when SCADA/EMS is lost

- Linear State Estimation (PoC)
  - ✓ Backup for a regular State Estimation

ISO-NE 2024 Synchrophasor Scorecard

- Secure the Synchrophasor Infrastructure
  - Emerging Work Request (EWR) to develop a roadmap and bring synchrophasor infrastructure into CIP

- Further Enhancement of Business Applications
  - Oscillation Source Location (OSL)
  - Redesign Control Room PMU Situation Awareness Displays

- Streamline PMU Support and Maintenance Processes (including TOs) to Ensure Data Quality

Business Needs for a Better WAMS

- PMU Data Exchange
  - Today: multiple bilateral data exchange via EIDSN for predefined data points.
  - Need a simpler solution with more flexibility
  - Need an EI-wide PMU registry for easy metadata access
  - Need to access external historical data on demand
    - Without streaming and storing predefined data points.

- Online Operator Collaboration
  - Today: each RC has its own version of software, configured and visualized differently.
  - Need an EI-wide WAMS fed by data from most if not all RCs
  - Need to speak the same language as the neighboring RC operators
  - Potentially eliminates the need for raw data sharing at all

Why the Cloud?

- Cost-effective, readily available and scalable infrastructure

- Logically centralized, physically distributed computing
  - Best of both worlds

- Platform ideal for multilateral data/results exchange
  - Getting data from everywhere and delivering to everywhere
 - Hosting applications online

Proof-of-concept Cloud-hosted WAMS

- Project collaborations among ISO-NE, NYPA, Cornell University and Washington State University, back in 2014/2015

- Objective: demonstrate a cloud-hosted distributed platform for real-time PMU data collection, storage, processing and dissemination to achieve wide-area monitoring

- Technical Aspects Evaluated:
  - Security
  - Network latency
  - Fault tolerance and recovery
  - Data consistency

Overview of the Cloud-hosted WAMS
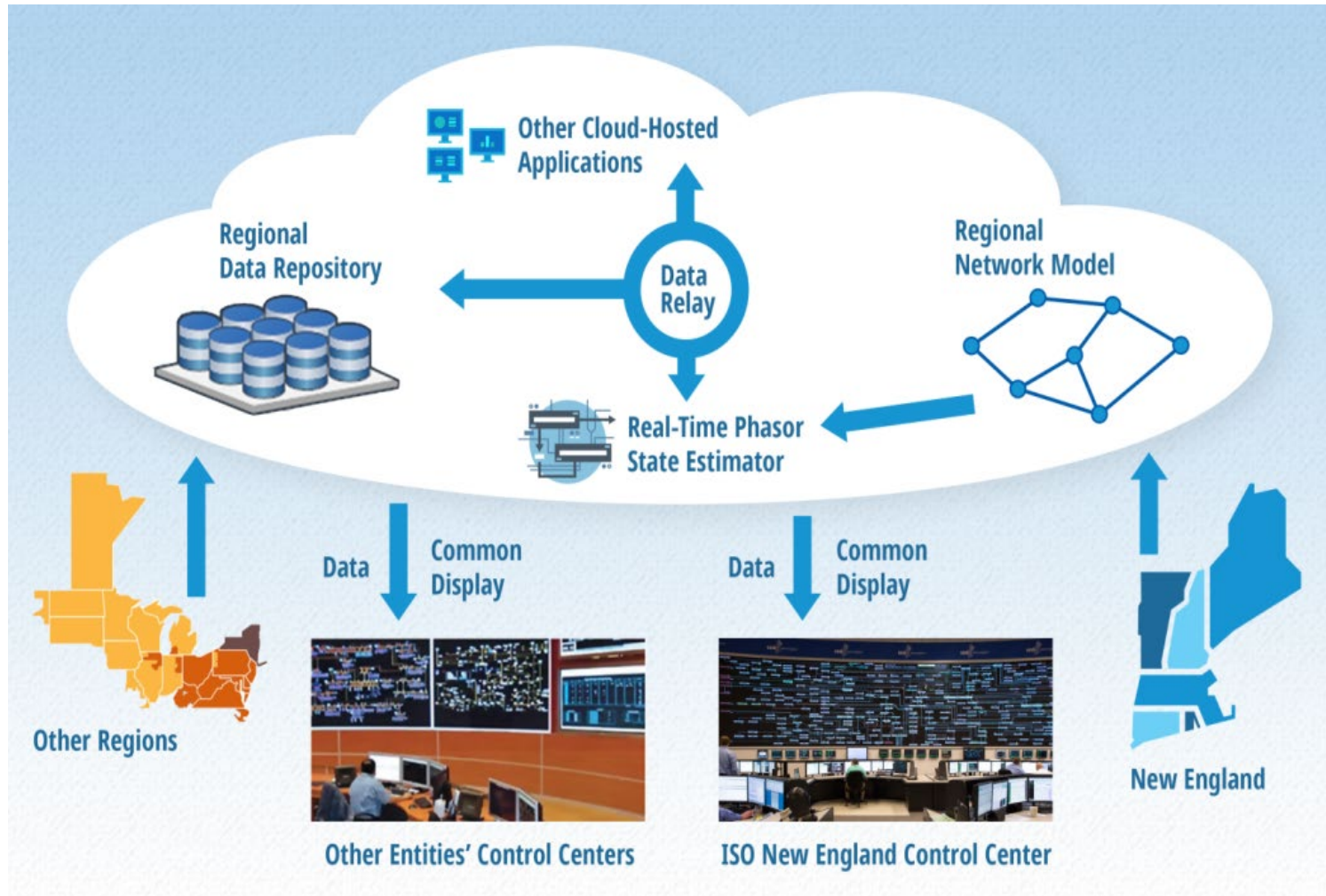
Security

- Amazon **Virtual Private Cloud** (VPC)

- **SSH** Tunnel for data stream
  - Loop playback 60 minutes of PMU data from ISO-NE and NYPA

- Cloud Data Storage
  - Encrypted using a **key**
    - Generated by and stored in Amazon AWS
    - Managed by users

Latency

- EC2 Latency:
  - Average Round Trip Time (RTT) = 245ms
  - 1st Percentile = 211ms
  - 99th Percentile = 255ms

- VPC Latency:
  - Average RTT = 261ms
  - 1st Percentile = 228ms
  - 99th Percentile = 270ms

- Delta is approximately +15ms

- These numbers do not include SE compute time (75ms-100ms)

- Adding SSH tunnels added less than 2ms to RTT

Operating Cost

Instances	Type	Number	Price	Total
Cloud Relay	C3.large	1	$0.11	$0.11
Cloud Manager	C3.large	1	$0.11	$0.11
Visualizer	C4.largeWin	1	$0.19	$0.19
LSE	C4.xlargeWin	1	$0.39	$0.39
Raw Archiver	C3.xlarge	3	$0.21	$0.63
LSE Archiver	C3.xlarge	4	$0.21	$0.84
Forwarder	C3.large	2	$0.11	$0.22
Total		13		**$2.47**

- Optimizing cost was not a major objective for PoC
  - Prioritized convenience & repeatability

- An overall cost savings compared with the on-premises IT investments required for similar performance
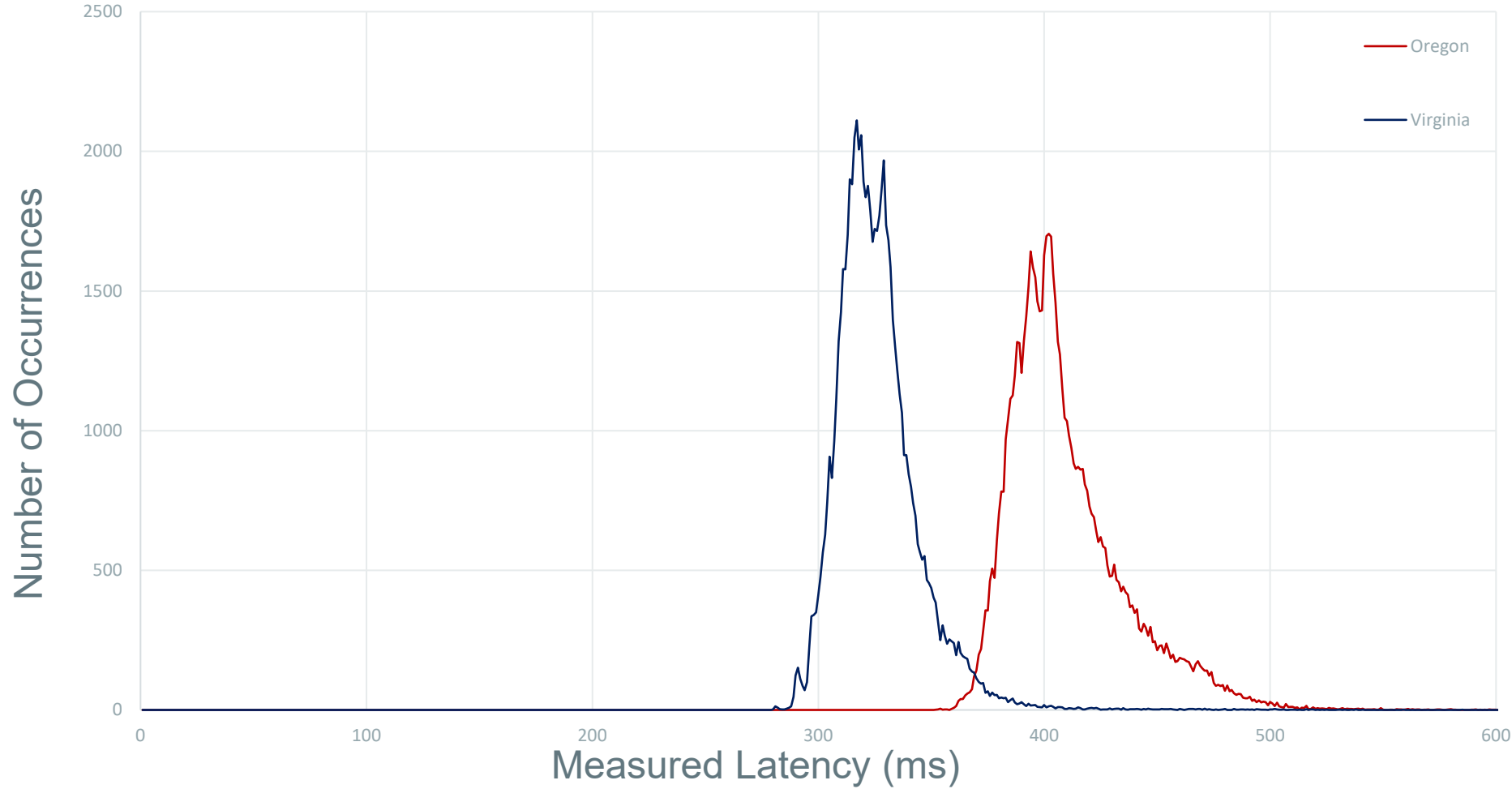
Histogram: Raw Data Round Trip Latencies

Graphs: Number of times a particular latency occurs

Raw Data Round Trip Latency
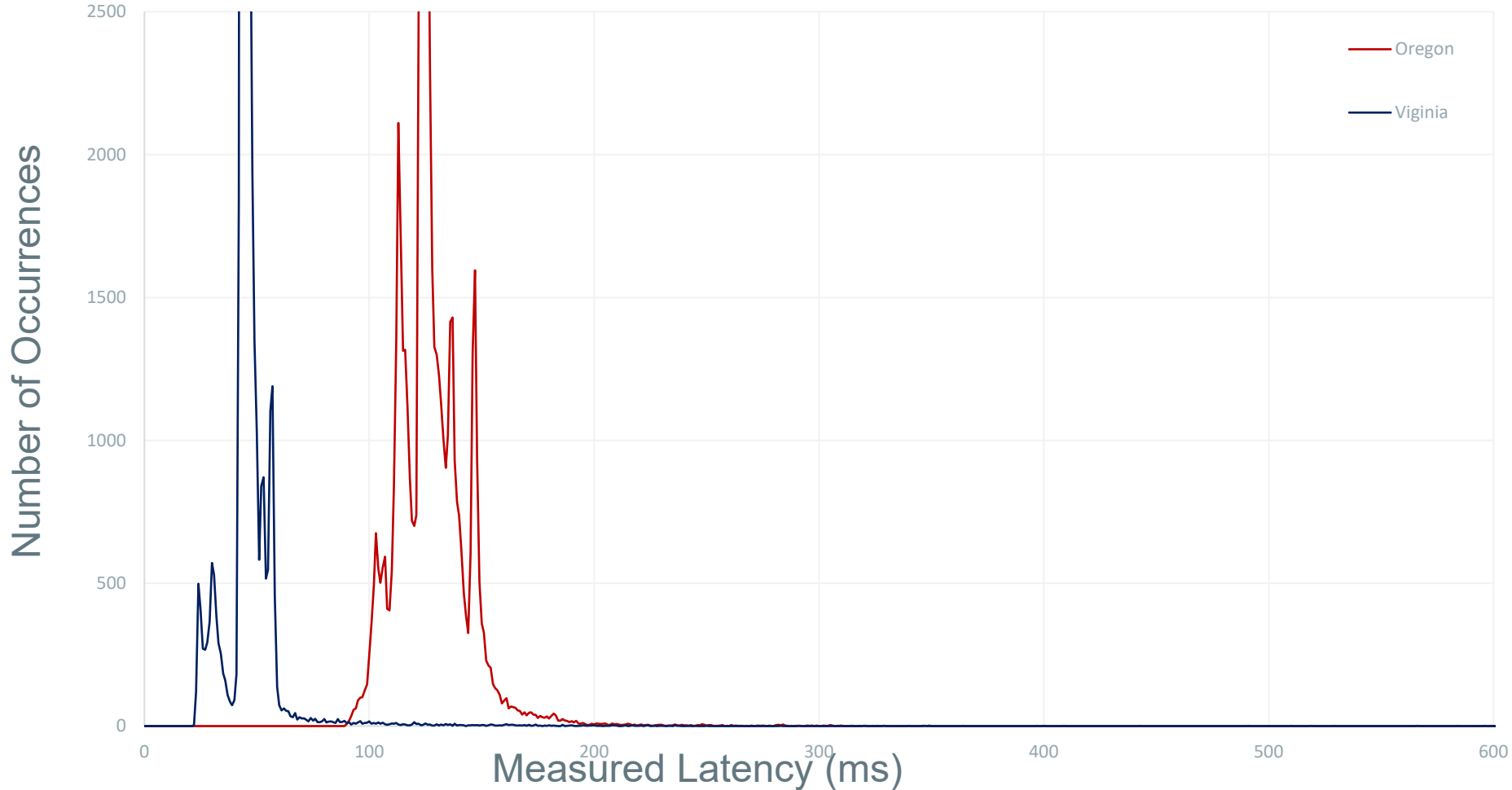
Histogram: LSE Results Round Trip Latencies

Graphs: Number of times a particular latency occurs
SE Results Round Trip Latency

Other Performances

- Fault Tolerance & Recovery
  - Two parallel systems
  - Independent
    - Manual redundancy
  - Restarting a data center
    - Needs ~500 s

- Consistency
  - No raw data loss
  - Few SE data loss
    - Due to replay looping
  - Within ~100 ms
    - End users have consistent data/results from both data centers

Conclusions from the PoC project

- Cloud is a feasible "central" platform for PMU-based Wide Area Monitoring

- Security, Latency, Fault Tolerance, Data Consistency performances meet expectations

- Benefits:
  - Eliminate the need for multiple bi-lateral data exchange
  - Only need to configure and maintain one copy of application
  - Same real-time visualization, no discrepancy during collaboration
  - Flexible and scalable
    - Easily adaptable to changes in business needs, technical requirements, data volume increase, participant changes, etc.

Future Work

- Eastern Interconnection Situational Awareness Monitoring System (ESAMS)
  - Host by PJM between June 2021 and March 2022

- Potentially to host ESAMS on the cloud

- Collaboration among ISO-NE, PJM, AWS, PNNL, LBL, and EPG for demonstration

- Proposal submitted to DOE in August

Questions