



**26**<sup>th</sup> annual **INCOSE**  
international symposium

Edinburgh, UK  
July 18 - 21, 2016

# Modeling-Simulation-Analysis-Looping: 21st Century Game Changer



The things that matter in Information Age

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# Co-Authors

- Jeff Schmitz, PhD, Principal Investigator,  
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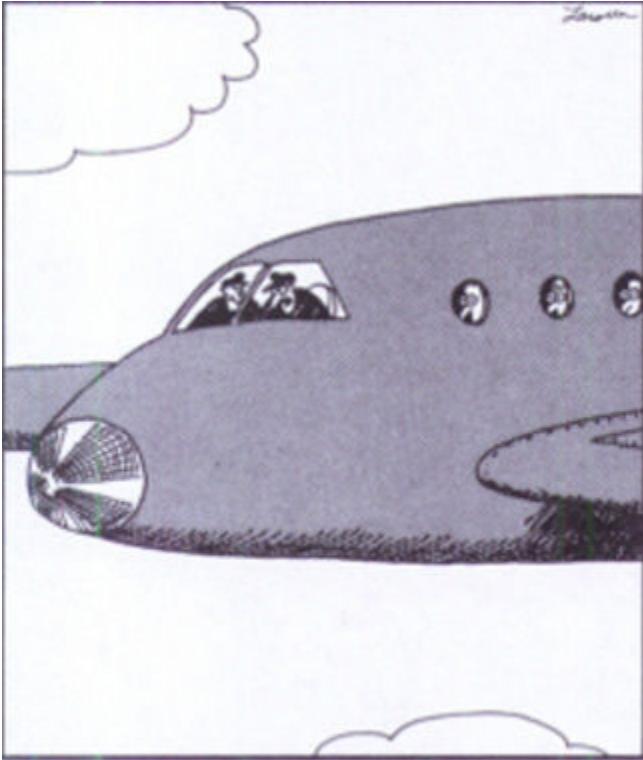
» Senior Scientist ,Principal Investigator and Software Engineer with background in defense systems, semiconductor fab, and academia. Jeff's objectives are to research, evaluate, develop and transition novel algorithm approaches from academic research into operational deployment.

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» Software Engineer with background in defense systems, and commercial logistics software applications. Research and Development

# Background



"The fuel light's on, Frank! We're all going to die! ...  
Wait, wait. ... Oh, my mistake—  
that's the intercom light."

# What We are trying to do?



Develop and demonstrate Uncertainty Quantification (UQ)  
capabilities for complex system  
Modeling and Simulation (M&S) environments.

# What We are trying to do?

UQ is the identification, characterization, propagation, analysis and reduction of all uncertainties in M&S\*



\*Center for Applied Scientific Computing, "The PSUADE Uncertainty Quantification Project," Lawrence Livermore National Laboratory, US Department of Energy

# Uncertainty Defined

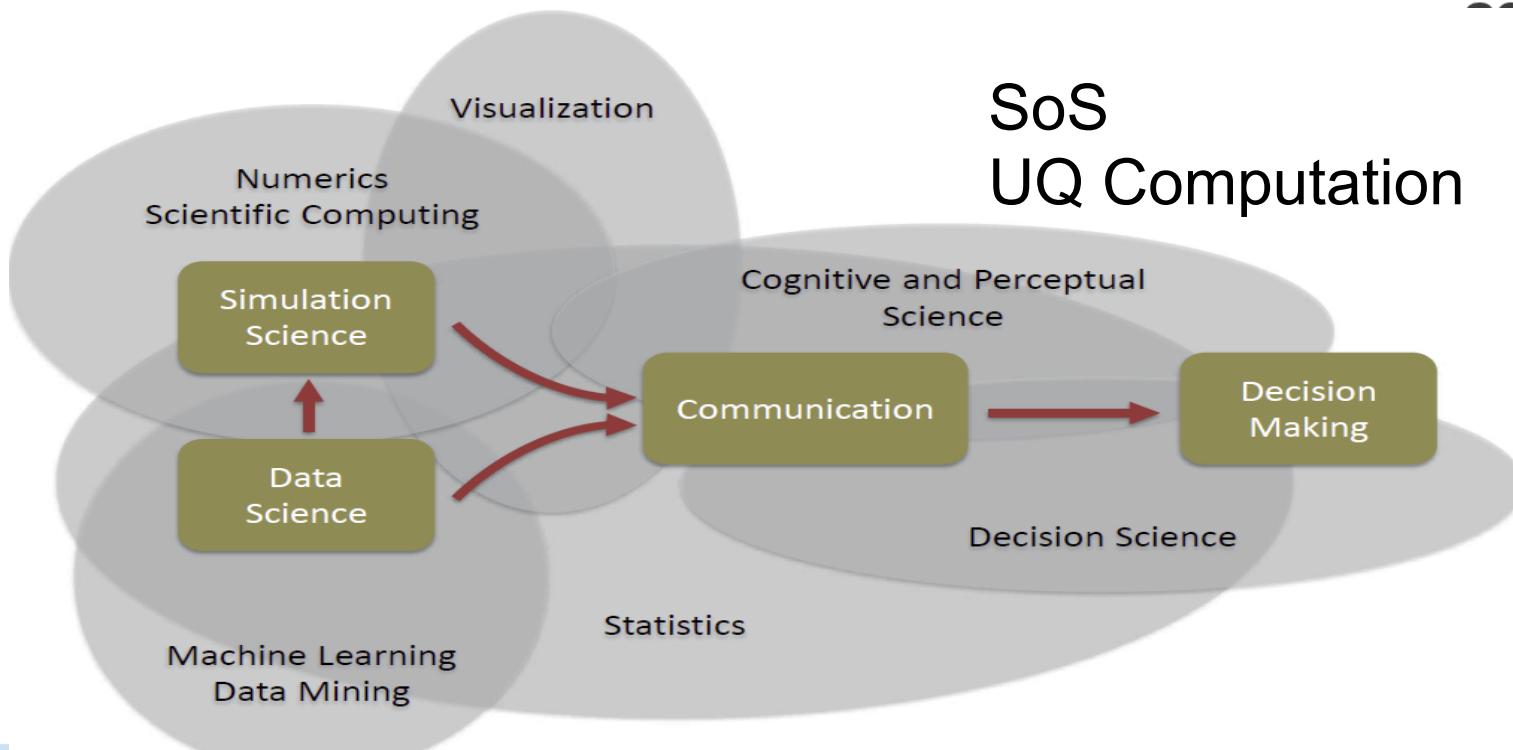


- Uncertainty is a measure of the error associated with Modeling and Simulation (M&S) of the real world
- M&S abstractions of the real world introduce intrinsic uncertainties and errors into the calculation of outcomes
- Consequently, M&S outputs contain:
  - uncertainties in inputs
  - intrinsic errors in algorithms (model form)
  - errors in software or data (“bugs”)
- Uncertainty Quantification (UQ) is the business of understanding, communicating and using this information about errors in decision making

# Challenges

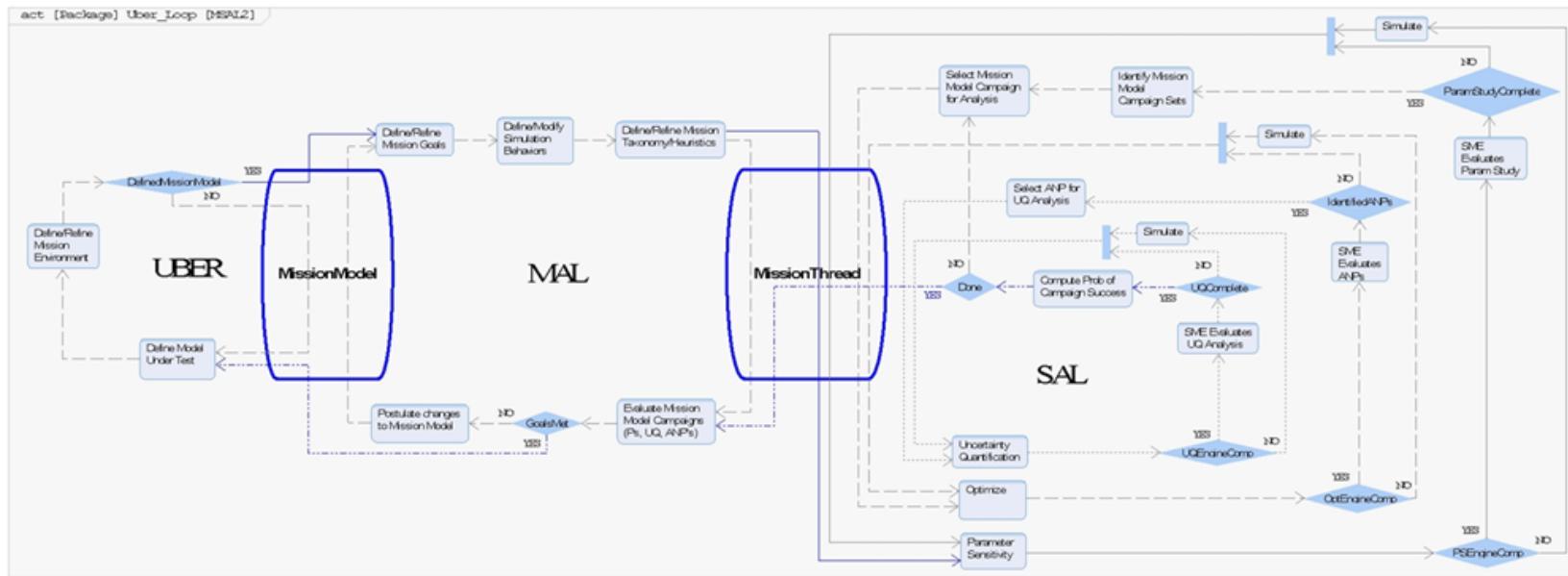


# SoS UQ Computation



# What we Did

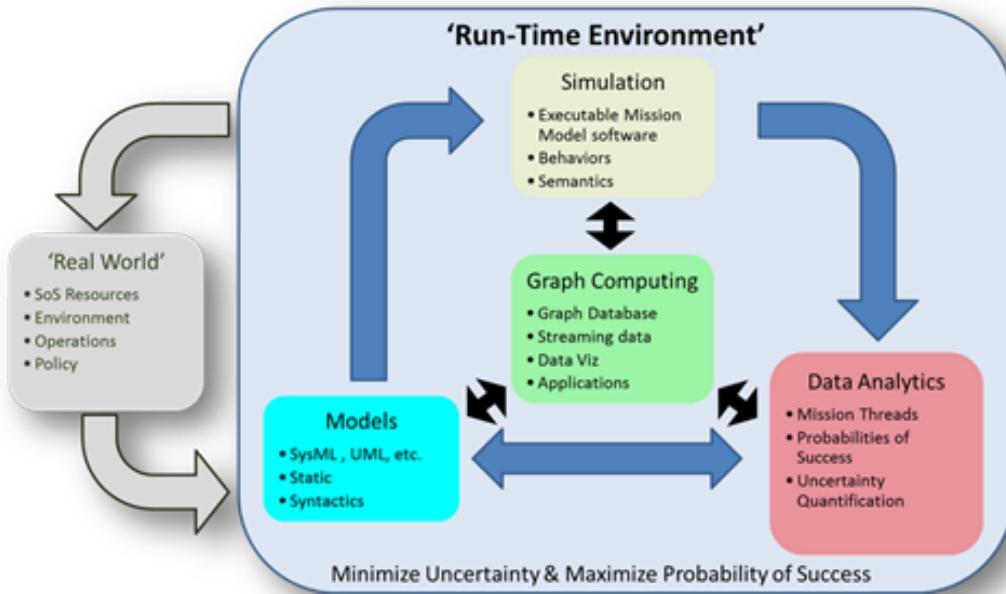
## Use SysML to design our approach



# Modeling-Simulation-Analysis-Looping (MSAL)



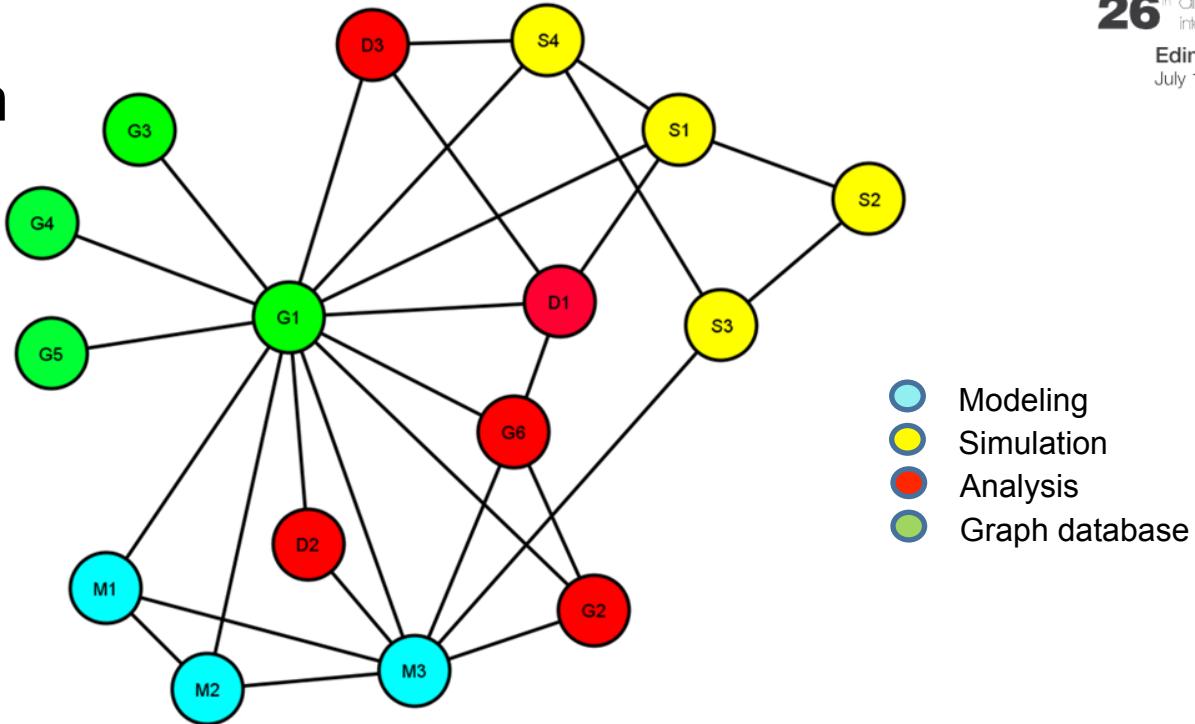
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Mapping activities to events (nodes) and data flows (edges)..

# Graph Design

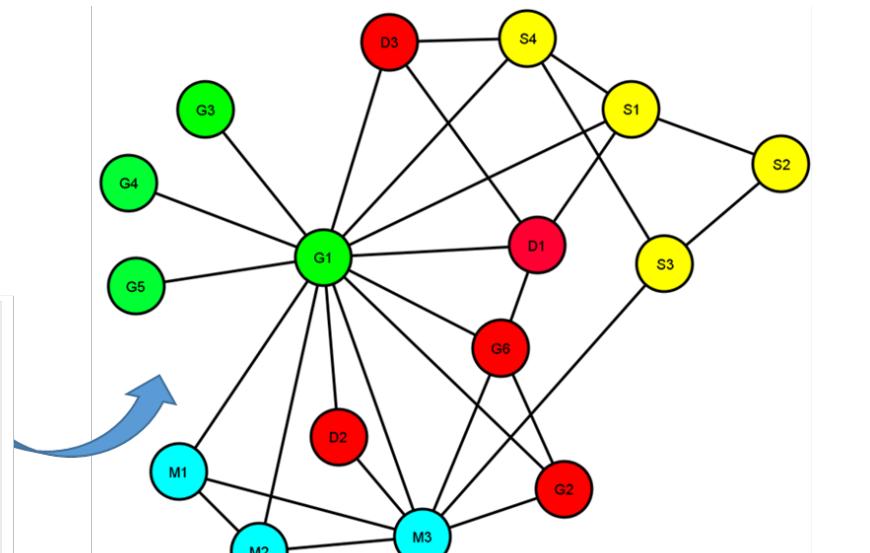
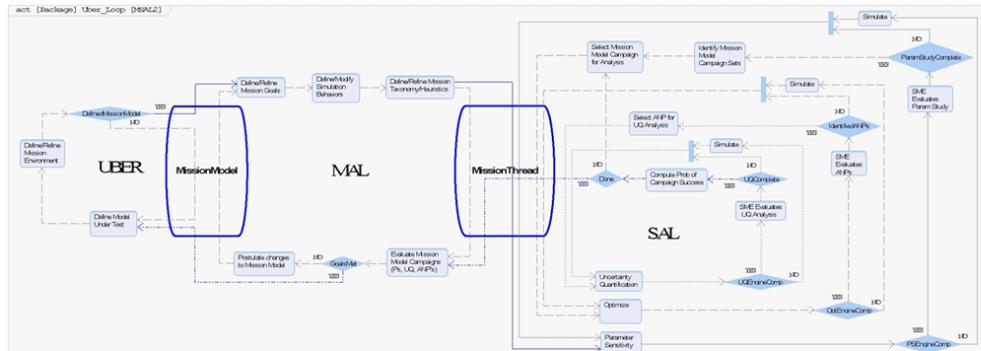
Creates a graph



# MSAL Design

Graphs are everywhere and a more Accurate representation of real-world System interactions

System Modeling Language (SysML)  
Understand structure, components  
And interrelationships



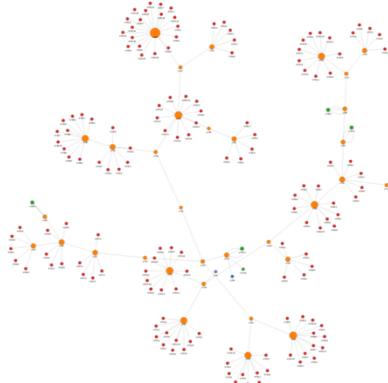
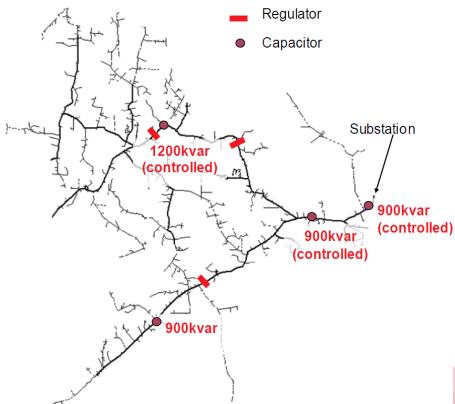
Graph databases facilitate the representation of model components and data relationships of complex system behavior



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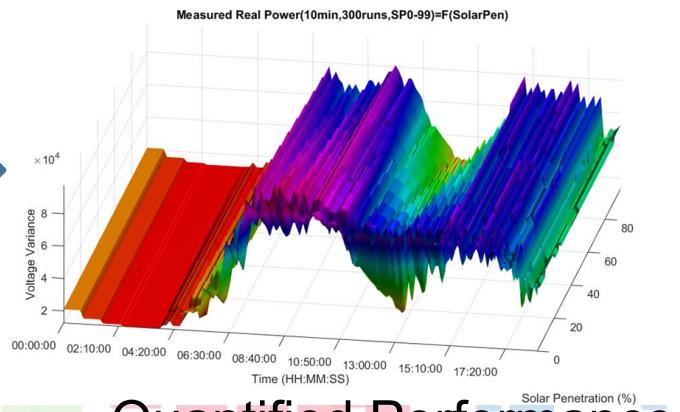
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# Rapid System Analysis using Graphs Power & Energy Use Case



Real World System

Graph Model



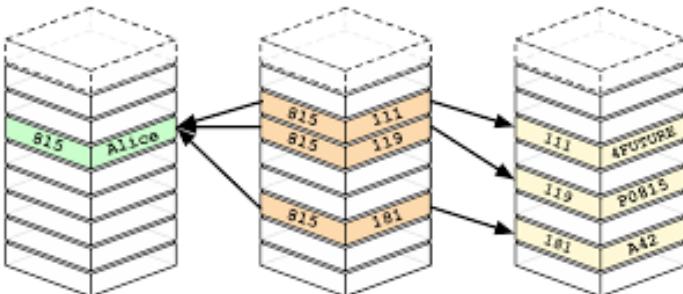
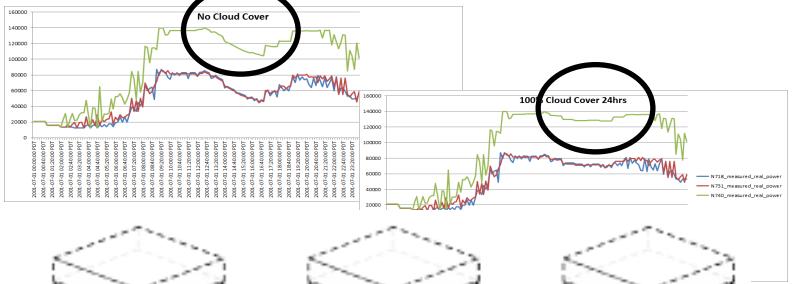
Quantified Performance

# Getting at complex relationships



# MSAL

## Voltage Variance – Time – Solar Penetration



# Relational Databases

# Connected Graph Databases



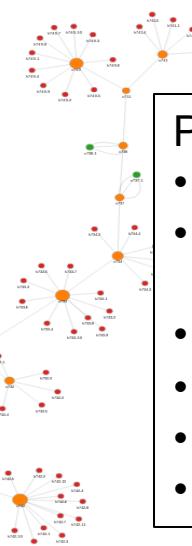
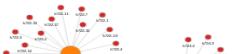
# Results - Power & Energy Use Case

MSAL helped us organize parameter and optimization studies

IEEE 37 Node feeder model:

- 162 houses
- Data recorded at ALL houses,
- Data aggregated by transformers, and meters at all 37 Nodes.

Since voltage levels decrease downstream, focus nodes where chosen simply as representative nodes at terminal points across the feeder. We computed voltage variance using only the data from the focus nodes, 718, 731, 740.



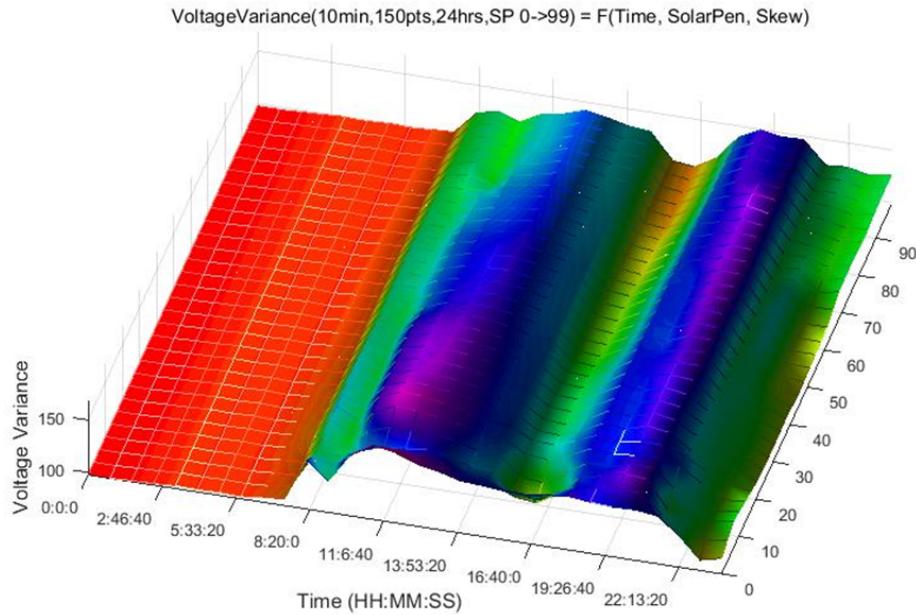
Parameter Studies Included:

- Home Sq Footage (size)
- Air Changes per hour (how airtight)
- Thermostat Cooling Set Point
- Thermal integrity (insulation)
- Solar Penetration
- Solar Panel Area

- Input to Feeder
- Commercial Bldg.
- Transformer
- Home

# Results - Power & Energy Use Case

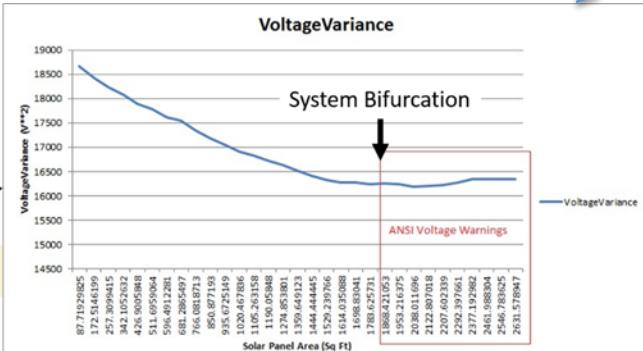
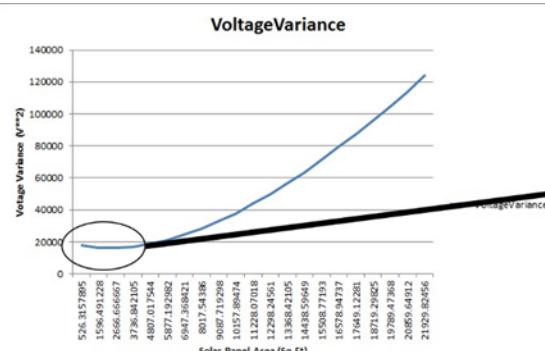
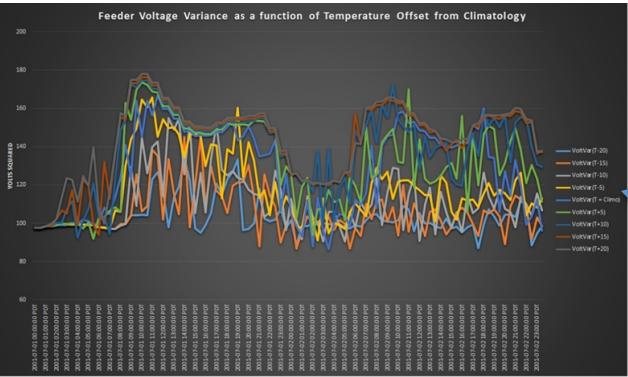
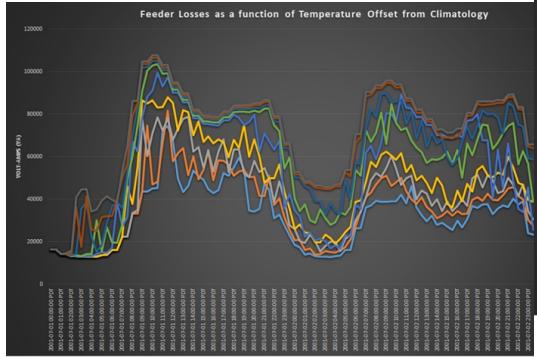
MSAL helped us understand complex system behavior...



solar generation has a stabilizing influence on the grid

# Results - Power & Energy Use Case

But wait..



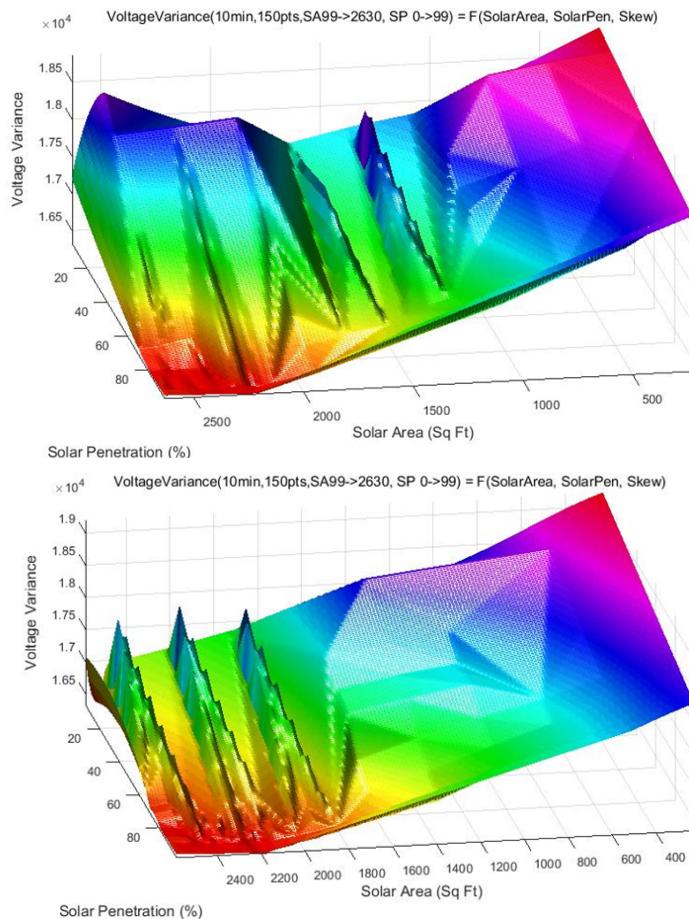
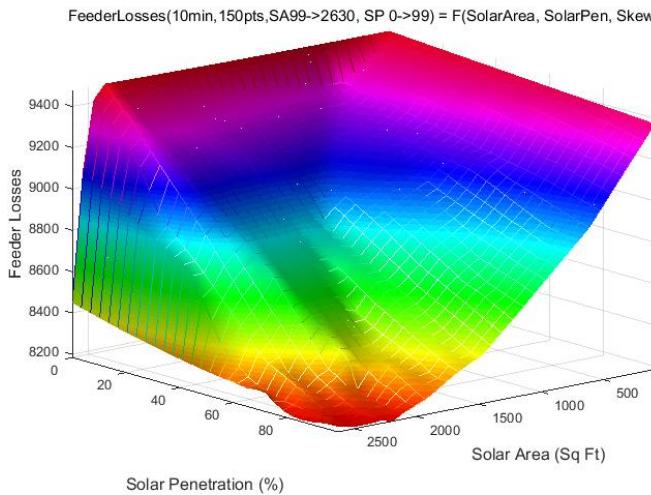
MSAL parameter studies also informed us about:

1. Possible modeling limitations
2. Unexpected system behavior

Structural  
Uncertainty?

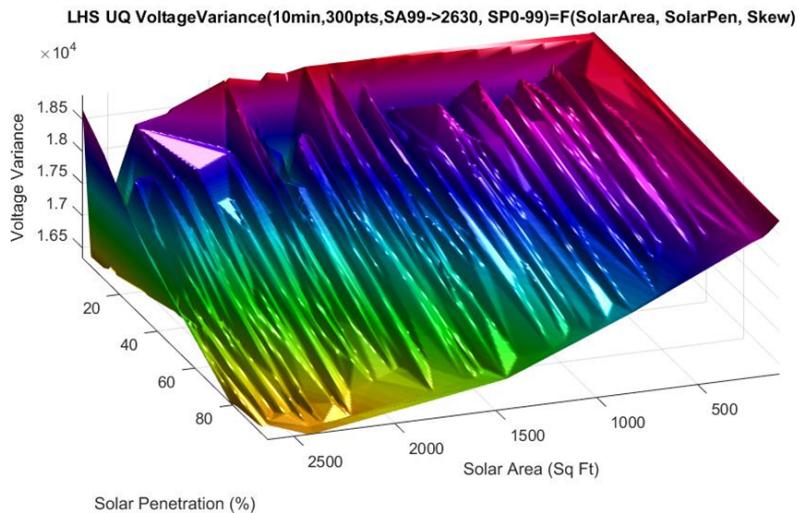
# Results - Power & Energy Use Case

## Optimization Surfaces

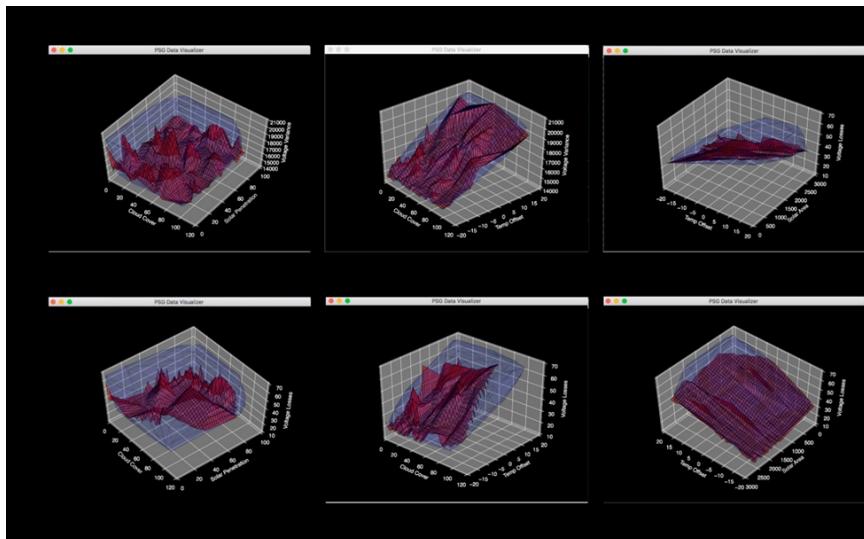


# Results - Power & Energy Use Case

## UQ Studies

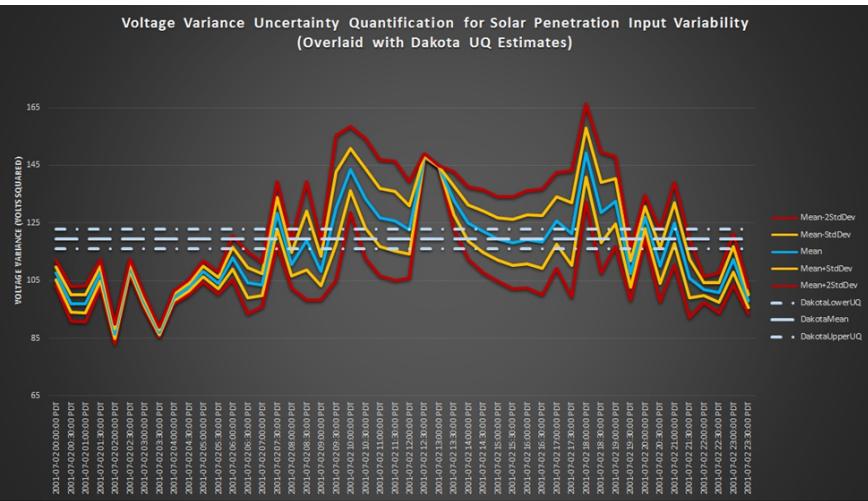
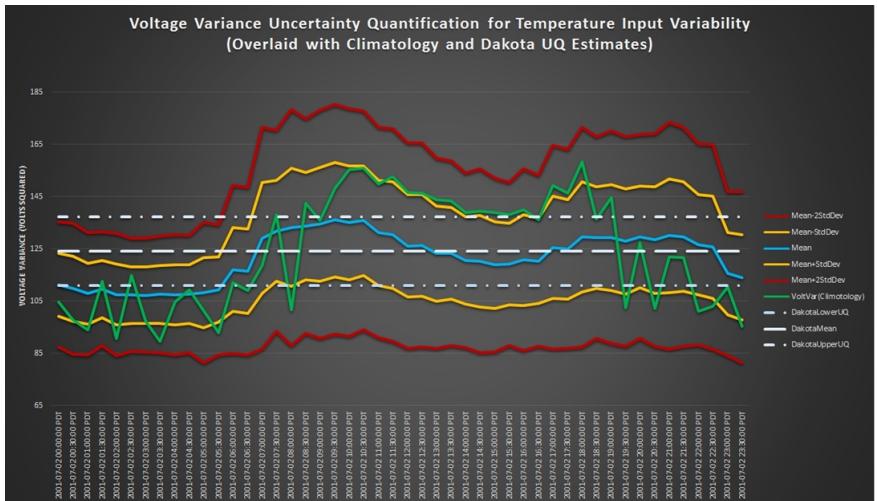


## Aggregate UQ overlaid on Optimization Surfaces



# Results - Power & Energy Use Case

What is UQ good for?



# Summary

- MSAL allows structured approach to parametric and optimization studies
- Basis for UQ studies and foundation for component UQ

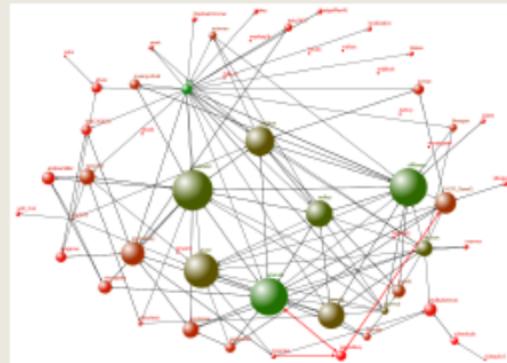


# Summary

## SE Vision 2025

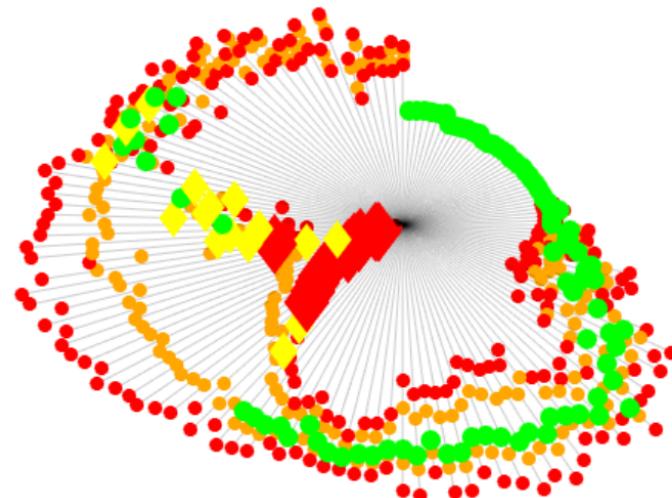
### SYSTEM OF SYSTEMS ENGINEERING PRACTICES

Techniques for analyzing interactions among independent systems and understanding emergent behaviors in SoS must mature and become commonplace (e.g., agent based simulation). New measures will be developed to characterize the SoS and its quality characteristics. SoSE will employ new continuous verification methods as changes occur without central control. Design of experiments is one such methodology for optimizing a verification program with many parameters and uncertainty. Requirements management will evolve to address even more diverse stakeholders, in the face of uncertain organizational authority. Methods for establishing evolutionary interoperability agreements among SoS constituents will become more robust.

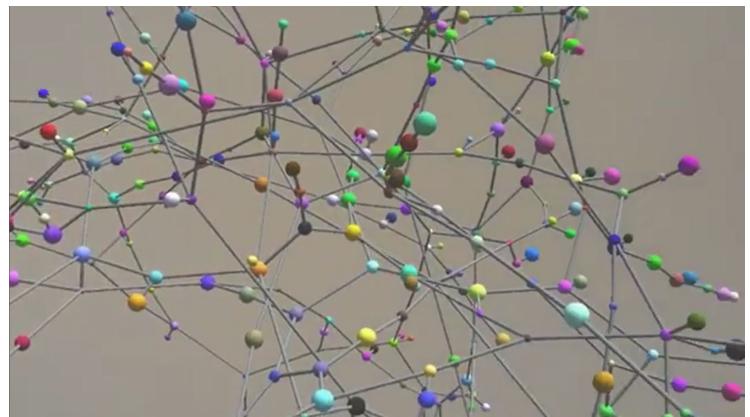
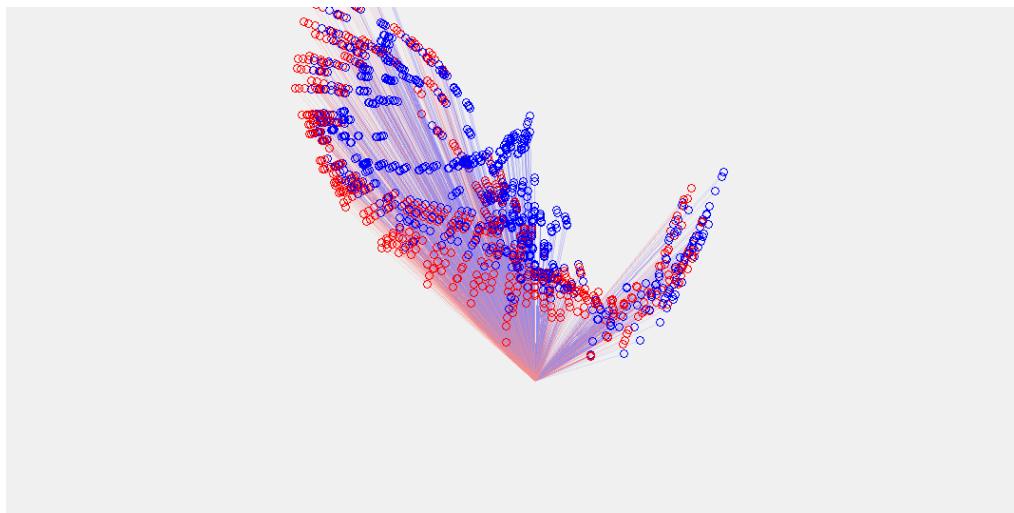


**"A SoS is an integration of a finite number of constituent systems which are independent and operable, and which are networked together for a period of time to achieve a certain higher goal."**

— Jamshidi, 2009



# Visualize



# PII Summary



- Propagation of Uncertainty and UQ studied in the Power & Energy Use Case
- Prototype environment established

Where could this work contribute in DES?

# Counterintelligence Use Case

- Meetings with Phoenix FBI
- Interest in MDA supply chain analysis
  - Web traffic
  - Analytics
- What we want to do:
  - Conduct a test case/proof of concept
  - Evaluate results and determine path forward

# Counterintelligence Use Case



- Test Case approach
  - Obtain sample (real) data
  - Define supply chain data model
  - Ingest into System G graph database
  - Graph Analytics
  - Data Analytics



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