

# Accelerated Infrastructure System Reliability Analysis Using Dimension Reduction

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## INTRODUCTION

### What is hazard reliability?

Hazard reliability for an infrastructure system is defined as the degree of assurance that the system will continue to successfully operate at a desired level of performance during a certain period of time and in a specified environment in the aftermath of a hazard.

### Importance

Assessment of the impact of natural disasters on the infrastructure systems is of importance towards the four main phases of emergency management:



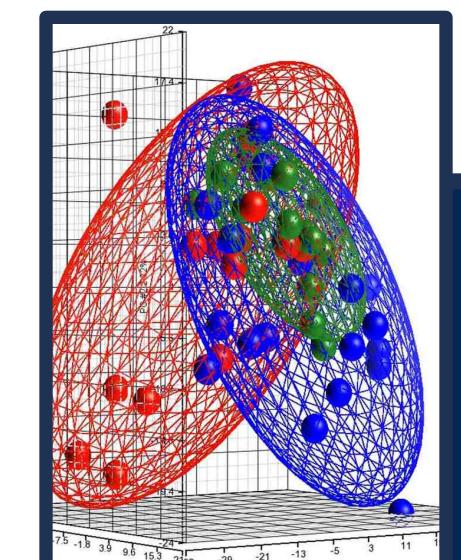
### Challenges

Hazard reliability assessment of the large and complex infrastructure systems is challenging due to:

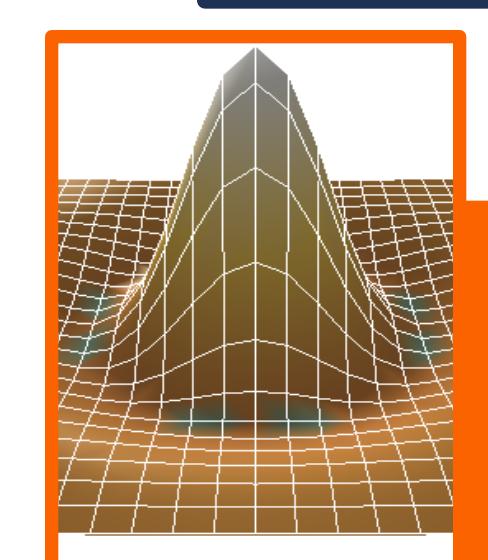
- The large number of network components
- Computational Complexity
- Uncertainties in hazard models
- Complex network topology
- Statistical dependence between component failures

## OBJECTIVE

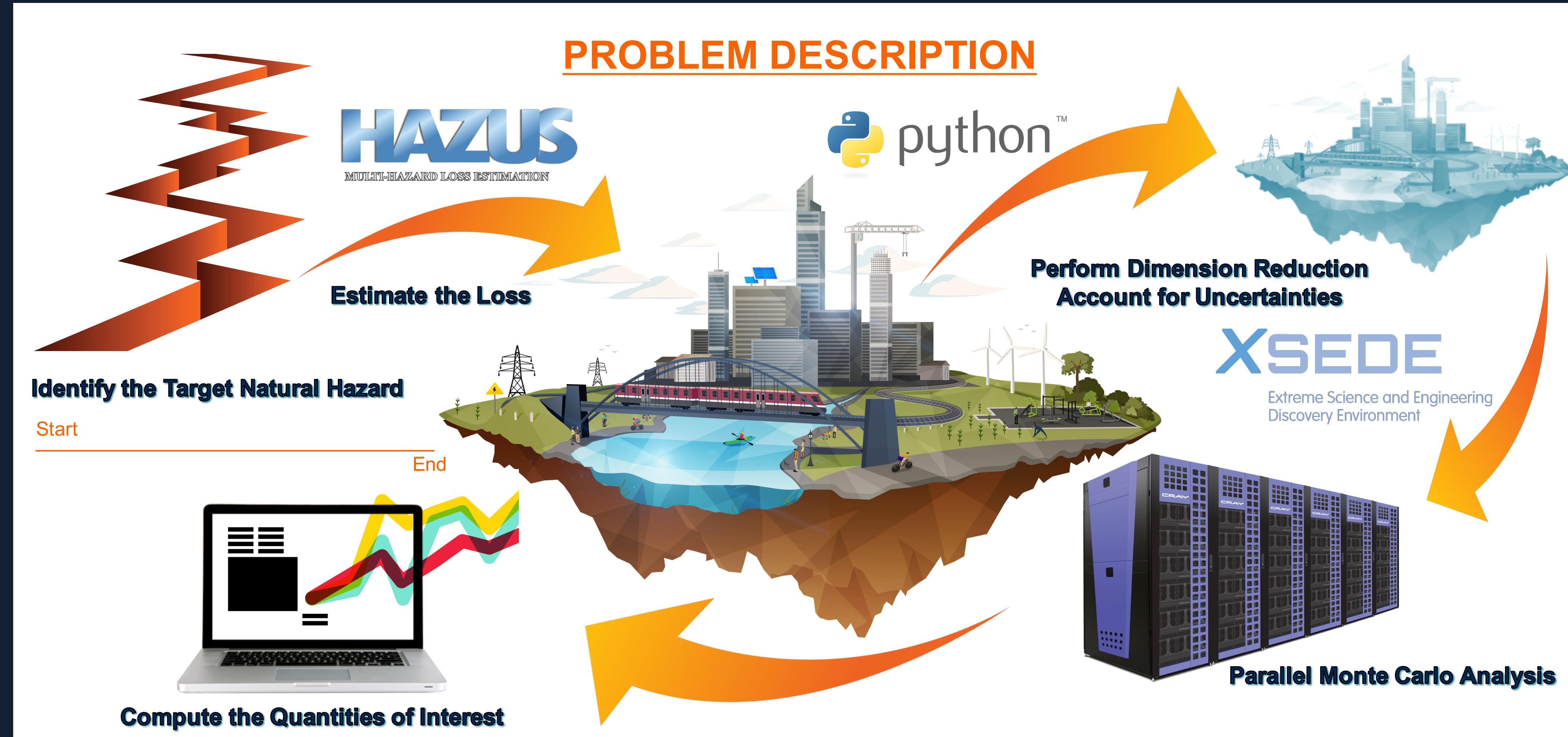
The objective of this study is two-fold:



Accelerate computation of reliability analysis for large networks by reducing the dimensionality of the system.



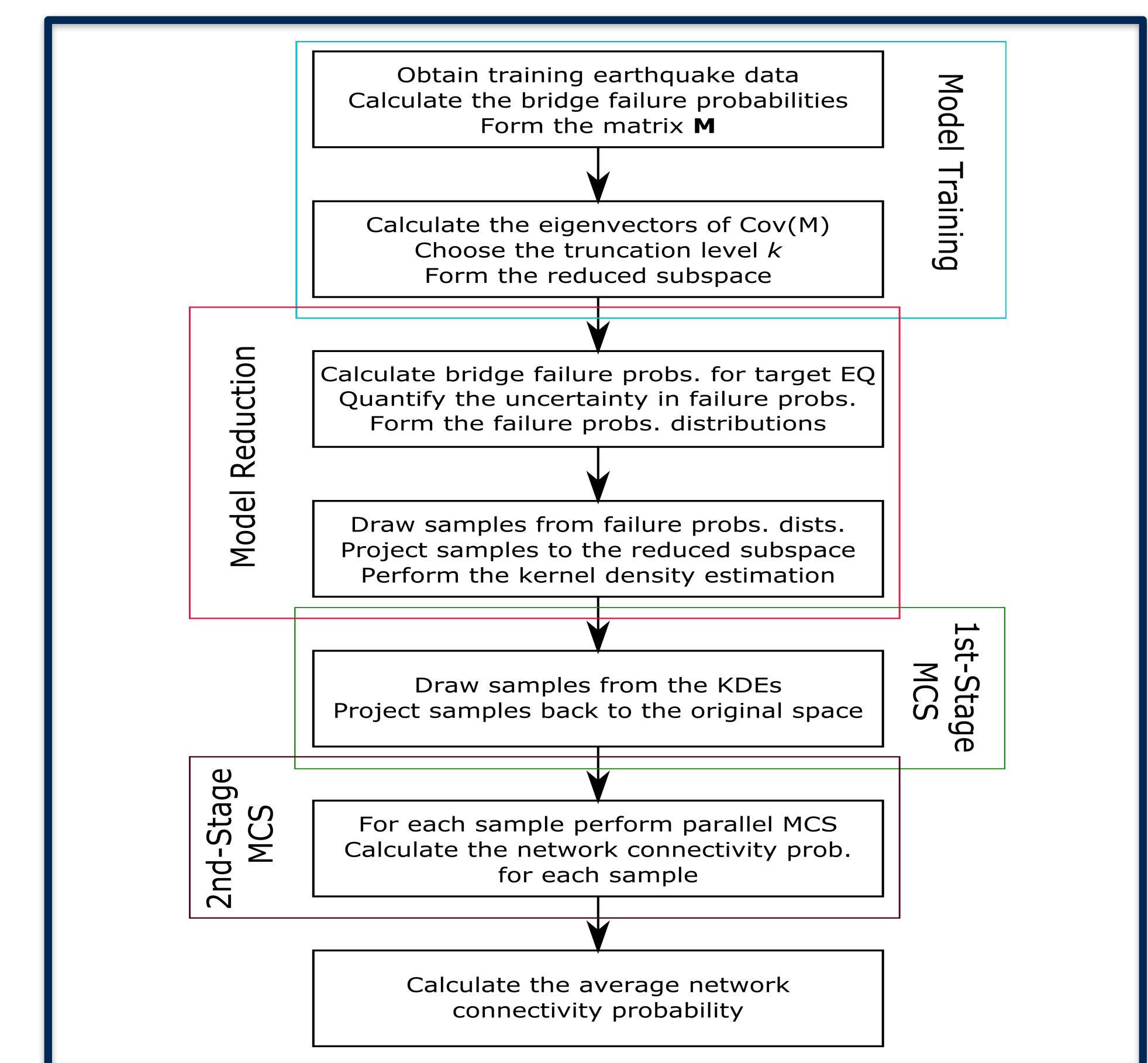
Account for uncertainties in assigning damage state probabilities for network components.



## METHODOLOGY

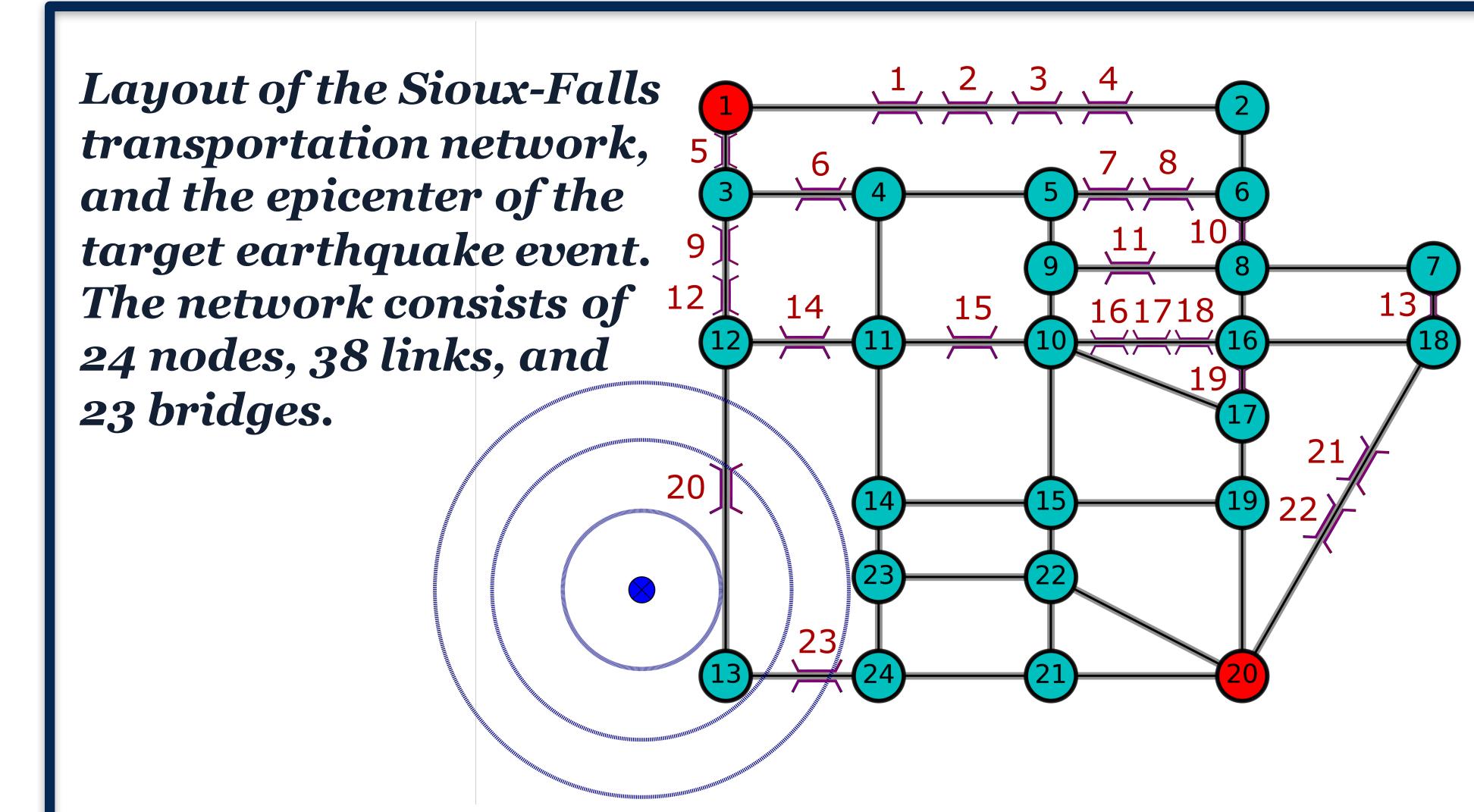
Bridge failure probabilities are inherently correlated as they are likely to share similar characteristics and external loads, such as PGA, soil type, and site conditions. PCA can make use of this correlation structure to compute a set of new orthogonal bases. The distribution of the original random variables can be well represented by a few number of uncorrelated random variables. There are several factors that may cause uncertainties in the calculations of bridge failure probabilities, such as unknown soil conditions and ignoring the effects of liquefaction. To account for these uncertainties, additive mutually independent zero-mean Gaussian noise terms with a known variance are added to failure probabilities.

### Solution Procedure

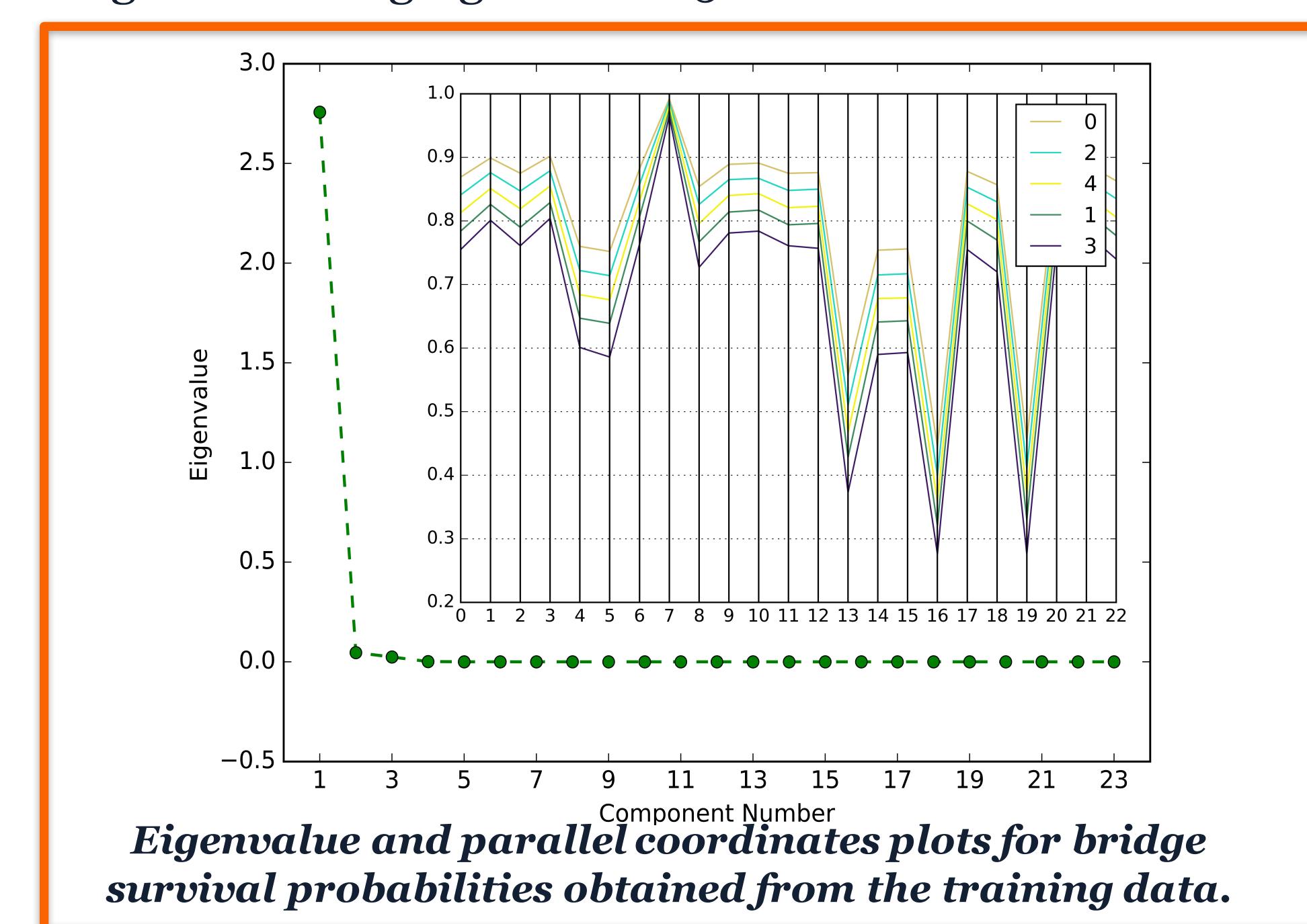


## SAMPLE PROBLEM

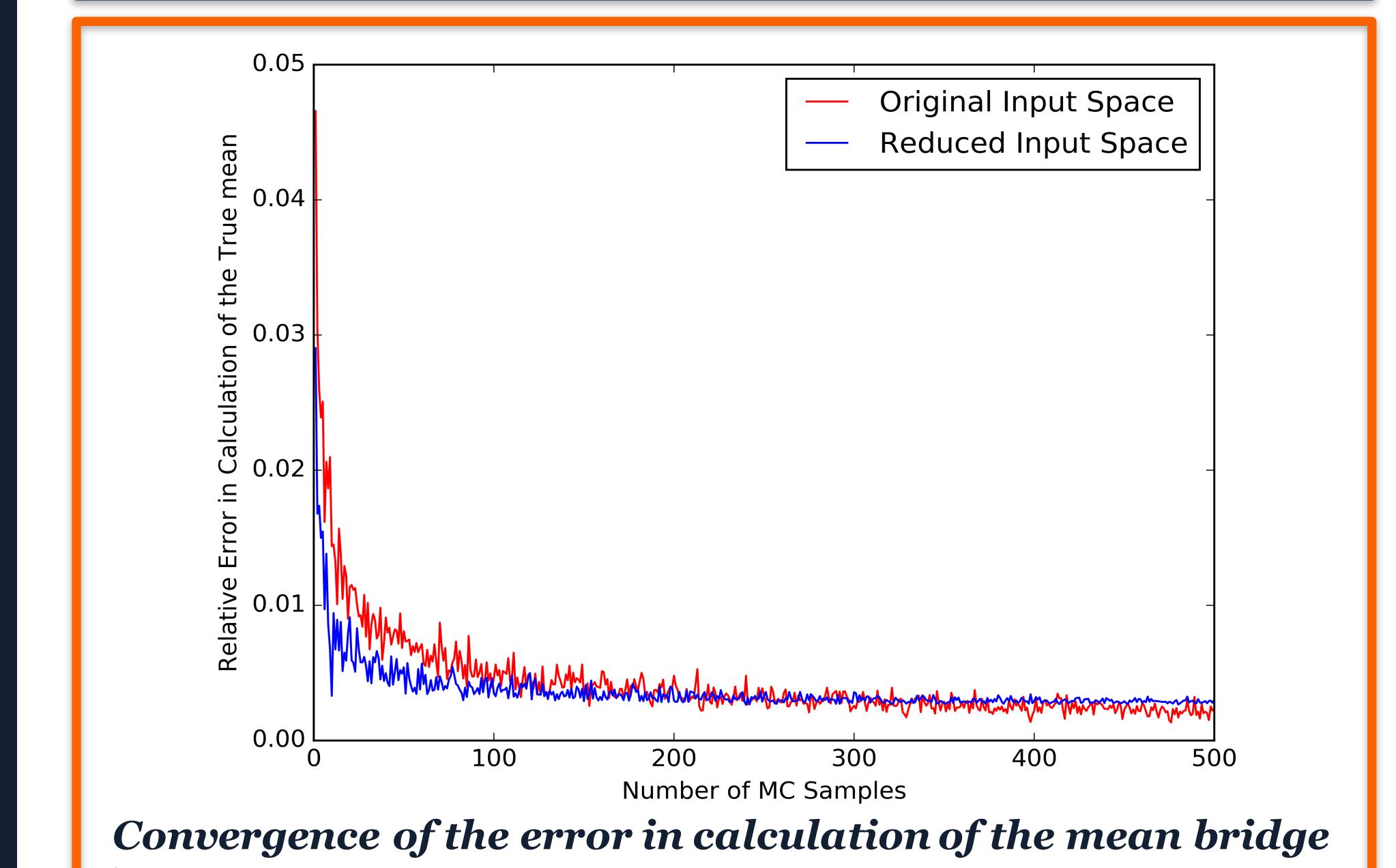
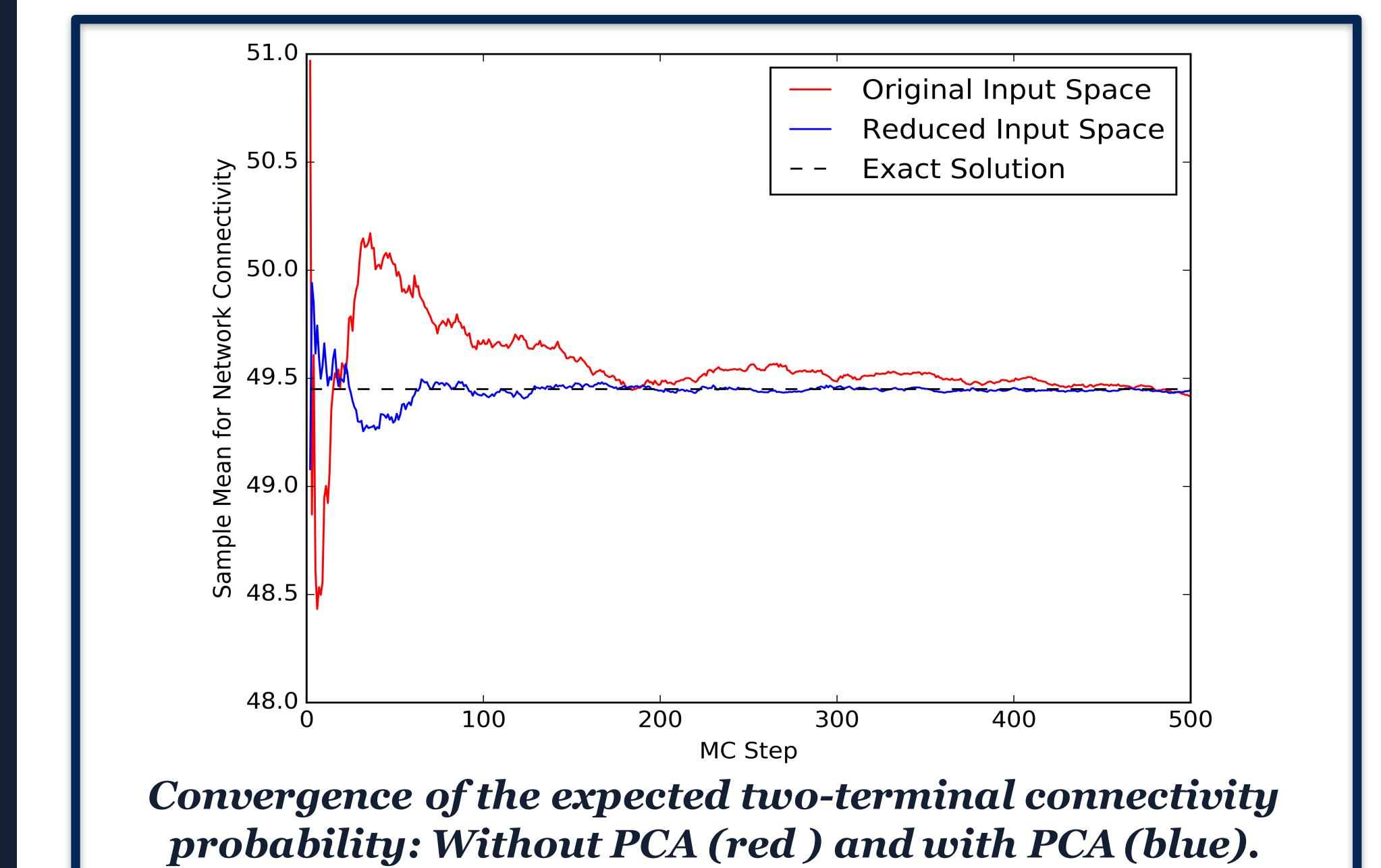
The proposed methodology is applied to the Sioux-Falls transportation network, subject to an earthquake event:



The quantity of interest is the probability that a connection exists between nodes 1 and 20. The target earthquake has a magnitude of 6.8, and a depth of 10km. To identify the principal components, 7 earthquakes with magnitudes ranging between 5-8 MMS are considered.



## RESULTS



## CONCLUSION

This study suggests an approach for accurate and accelerated infrastructure systems reliability assessment. Two major original contributions are made in this study:

1. PCA-based dimension reduction in order to reduce the computational complexity.
2. Quantification of the uncertainties in the existing models for natural disasters.

By applying the proposed approach on a sample problem, it is shown that the proposed PCA-based dimension reduction can help to significantly accelerate the convergence of network performance measure.

## ACKNOWLEDGEMENT

This work used the Extreme Science and Engineering Discovery Environment (XSEDE), which is supported by National Science Foundation grant number ACI-1053575.