Earthquakes and other natural hazards can have devastating impacts on individuals and communities. They can cause extensive damage to the built environment and the infrastructure of a community, widespread injuries and loss of life, and vast losses to a community’s economy and identity throughout the recovery period. Communities can increase their resilience in multiple ways: mitigation measures, policy changes, and community preparedness are all methods that can be used to increase a community’s ability to resist damages and disruptions from a natural disaster as well as speed up recovery time.

Healthcare is a critical component of a community’s overall resilience to natural disasters. The loss of healthcare services can be detrimental in the response phase of a disaster and its public health system during the recovery phase. Recent work at the Sensor Technology and Infrastructure Risk Mitigation Lab at Johns Hopkins University has focused on defining and quantifying the resilience and functionality of communities in terms of the overall community resilience as well as the resilience of systems such as a hospital or a healthcare network. To fully capture the functionality and resilience of a hospital, we consider physical damage to structural and non-structural components, as well as the presence of clinical and non-clinical staff, supplies, equipment, and critical utilities. Over the past year we have been working on disseminating our risk assessment tools to practitioners. We have been working extensively with the Johns Hopkins Medical Institute and the Utah Department of Health to validate our healthcare service fault trees and use these as a training exercise, respectively.

One method of quantifying resilience is through the use of fault trees (Jacques 2014). These fault trees were initially developed based on feedback from hospital personal following earthquakes in Chile, Mexico, and Christchurch. Fault trees were created for different services in the hospital. Initial work to validate the fault trees were done by working with the Johns Hopkins Medical Institute, this consisted of guided interviews with at least one expert from the different hospital services. The interviews focused on the resources required for the service to remain operational during and after a disaster. Resources included staffing, infrastructure, capital equipment, reusable supplies, and interdependencies with other departments or services. Once the fault trees were made, they were presented to the interviewed hospital expects from the different hospital services for review and feedback.

A training workshop and tabletop exercise, sponsor by the Utah Department of Health, was given to facilitate the transfer the fault trees to health care workers and emergency managers. Attendance at the workshop included emergency managers, healthcare workers, public health officials, emergency responders, and practicing engineers. The workshop begin with a brief overview of the historic use of fault trees and the fault trees have been adapted to determine the functionality of a hospital service. The current versions of the fault trees were also presented with an explanation on how the fault trees are used. The workshop concluded with a tabletop exercise.

The tabletop exercise walked the participants through a scenario event and the fault trees for two hospital services to determine if the services would fail. The scenario event was created to model a realistic earthquake in Salt Lake Utah, a 7.0M earthquake in the Salt Lake section of the Wasatch fault line (EERI-Utah 2015). A fictional modern reinforced concrete hospital was used as the subject of the
exercise. The hospital was assumed to have little structural damage, but to have minor non-structural damage on the lower floors, but extensive loss of suspended ceiling tile on the upper floors. Utilities such as power and water were limited to the hospital’s reserved backups. It was also assumed that hospital workers would remain at the hospital until replacements workers arrived. The hospital was expected to get a large influx of patients due to injuries from the earthquake and the closure of other hospitals in the area. To determine if the entire hospital would be functional, fault trees for all the services would have to be evaluated, however, due to time constraints, only two services were considered, the Emergency Department and the Pediatric Intensive Care. Using the fault trees for the Emergency Department and the Pediatric Intensive Care, participants used the predicted failures to the hospital to forecast if the hospital could continue to provide those services. In the initial run-through, both services failed due to the loss of municipal water, limiting the water pressure for fire sprinklers. A mitigation measure of placing large water tanks outside the hospital was added to scenario. With this additional measure, the ER was found to be functional, but the Pediatric Intensive Care was not functional due to the suspended ceiling damage. The tabletop exercise concluded with a discussion of how the fault trees could be improved to capture additional redundancies and how the fault trees could be adapted to additional hospital services.

This poster illustrated the transfer of tools and knowledge from researchers to practicing engineers, emergency managers, and stakeholders. It also shows some of the things learned during the workshop and tabletop exercise to improve the fault trees and the transfer of knowledge.

REFERENCES
