UTC Project Information	
Project Title	Real-time hybrid experimental-numerical simulation of bridge infrastructure subject to cascading earthquake-tsunami hazards
University	Oregon State University
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Funding Source(s) and Amounts Provided (by each agency or organization)	University of Washington PacTrans $40,00 Oregon State University $ 40,000
Total Project Cost	$80,000
Agency ID or Contract Number	69A3551747110
Start and End Dates	August 16, 2020-August 15, 2022
Brief Description of Research Project	This proposal addresses the content area, improving mobility of people and goods, particularly **ensuring reliable mobility** across bridges after tsunami loading. This work also aligns with ongoing interest in tsunami loading on bridges and machine learning applications by the Oregon Department of Transportation and the Pacific Earthquake Engineering Research (PEER) Center. Bridge strength can be significantly compromised when the bridge is subjected to cascading earthquake-tsunami scenarios. However, little data exists to support the simulation of bridges to both earthquake and tsunami loading. Test data under individual earthquake and tsunami hazards is available, but space is limited in wave facilities, necessitating small-scale structural models. Scaling laws then make it difficult to incorporate structural damage from previous seismic loading into hydrodynamic experiments. Real-time hybrid simulation (RTHS) – a testing technique that combines physical experiments and numerical models – can provide data to validate computational fluid-structure interaction (FSI) models. This proposal requests seed funding to develop an RTHS approach to study the vulnerability of bridges subjected to subsequent earthquake-tsunami loading. RTHS virtually extends the Large Wave Flume at OSU, enabling holistic testing of a complete bridge subjected to numerical earthquakes and physical waves.

Describe Implementation of Research Outcomes (or why not implemented) 	While real-time hybrid simulation has been utilized for structures subjected to seismic events for decades, its use in fluid-structure interaction problems is still a novel endeavor. Gathering data for cascading seismic and tsunami events is difficult due to space constraints in existing experimental facilities, complications regarding the application of scaling laws for both the fluid and structure, and limitations of computational software in simulating multiple hazards within the same analysis. To alleviate these constraints, this study demonstrated the feasibility of a real-time hybrid simulation testing method to enhance fluid-structure interaction simulations. A cylindrical bridge pier specimen and three-dimensional numerical bridge model were subjected to cascading seismic and tsunami events within a three-tier real-time hybrid simulation architecture. The domain was partitioned such that the wave-structure interaction was physically simulated and coupled to a numerical model of the remaining bridge. To simulate existing damage, seismic loading was applied in the structural model prior to the wave loading. Textbook short pulse response was exhibited by the specimen, and the results illustrate that a real-time hybrid simulation approach is both feasible and economical for future investigations using this method.
Impacts/Benefits of Implementation (actual, or anticipated)	This RTHS methodology can now be used to characterize the extent to which ground shaking reduces the bridge resistance to subsequent tsunami flow in future studies. While RTHS is not a perfect representation of reality, the abstraction produced by RTHS significantly advances modern simulation of fluid-structure interaction and multi-hazard scenarios. This work addressed the USDOT Strategic Goal, particularly safety and ensuring reliable mobility following extreme hazards. It also addressed efforts by MECHS, MTS, and DOE to extend hybrid simulation to fluid-structure interaction problems. The unique RTHS datasets can be used to validate high-fidelity computational models, develop simplified analytical models for bridge design and retrofit, and improve fragility models for multi-hazard scenarios and regional-scale modeling.
Web Links • Reports • Project Website	Neumann, C. 2021. Fluid Structure Interaction for Cascading Seismic and Tsunami Events using Real-Time Hybrid Simulation, M.S. Thesis, Oregon State University, Corvallis, OR. https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/hx11xp657