Motivation for Study
In numerous recent earthquake events, the damage to nonstructural components and systems (NCs) has exceeded the cost of structural damage in buildings. Nonstructural elements are systems and components within a building either attached to the floors or walls which are not anticipated to be load-bearing. While not intended to be part of the load-bearing system, these components and systems are subjected to the dynamic environment of the building undergoing seismic loading. One common type of NS includes gypsum board partition walls. To understand the behavior of the walls, numerical wall models are calibrated from experimental work and placed into realistic building models to demonstrate their effect on the coupled response (building+partition wall).

Characteristics of Nonstructural Components
NCs within buildings have distinct, but complicated physical and response characteristics making them susceptible to earthquake damage. As a result, NCs and the building should be considered in a combined system to effectively predict response (Villaverde, 2009). Characteristics of NCs include:
- Subject to a building amplified and filtered motion
- Location-dependent as the demands vary within a building
- Mass, stiffness and damping characteristics are small by comparison
- Similar frequencies between NCs and building can produce resonance
- Multiple connection points may induce differential demands
- Interaction between NCs and the building may modify the response

NEES Nonstructural Partition Walls
In the partition wall component assessment for the NEES Nonstructural project, a detailed 50 specimen program was developed at the University of Buffalo (Davies, 2009). The partition walls were approximately 11.5 ft. (L) by 72 ft. (H). The wall specimens were placed in the upper level of the Nonstructural Component System (UB-NCs), a full-scale test frame capable of producing realistic floor motions. The variables considered included:
- Connectivity of the gypsum/studs to the tracks
- Track-concrete fasteners spacing
- Presence of return walls
- Wall intersection detailing
- Attachments of weights
- Height of the partition wall
- Stud and track thickness
- Spacing of the steel studs
- Direction of testing (in-plane or out-of-plane)
- Test type (quasi-static or dynamic)

The loading protocols chosen for this project were developed by Retamales et al (2006). For explicitly evaluating drift sensitive components, such as partition walls without attached masses, a simple quasi-static protocol was used, where the maximum interstory drift imposed is 3%.

Partition Wall Behavior
In the experimental studies, three damage states were identified:

<table>
<thead>
<tr>
<th>Damage State</th>
<th>Description and Repair</th>
<th>Example</th>
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<tbody>
<tr>
<td>Light</td>
<td>Light damage to walls, cracks along corner bendable joint tape, along with screw pullout. Repair requires corner bead and screw replacement with a re-installing techniques.</td>
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<tr>
<td>Moderate</td>
<td>Cracking in wall corner, out of plane bending, damaged boundary studs. Repair requires replacement of gypsum and replacement of boundary studs.</td>
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<tr>
<td>Severe</td>
<td>Track damage (tear, bent), hinges in studs. Full replacement.</td>
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Modeling Platform and Material Modeling
The modeling platform selected to model the partition walls is OpenSees (Mazzoni et al., 2011). OpenSees provides the capabilities to perform modeling and advanced nonlinear time history analysis of buildings. In the methodology chosen for model discretization, a zero-length element is developed with the pinching4 material. Pinching4 is a user-contributed uniaxial material that allows for a "pinched" load deformation response.

Normalized Model Development
To create a simplified modeling approach, the modeling focuses on full-height in-plane walls with full connections. These are the stiffest and strongest type of partition walls. The force normalization is conducted using the sum of the thickness of the stud webs in the lateral direction.

Partition Wall Implementation
The developed partition wall model is lumped between floor levels, to prevent any torsional effect if a three-dimensional model is considered. A zero-length between floor nodes represents the partition wall.

Coupled Model: Building + Partition Wall
Using the developed wall model, it is placed into an existing 8 story reinforced concrete model. Using summary number of wall lengths in existing buildings determined by French and Xu (2010), the range of wall lengths to consider is 56 ft - 10 ft. Using a coupled system model, eigenvalue, nonlinear pushover, and nonlinear time history analyses are conducted. Nonlinear time history analyses were performed using a 2-D single bay model in an incremental dynamic analysis approach with ATC-63/PEER p695 modified.

Key Findings
1. Addition of partition wall into a building model stiffens the model consistently. Up to 9% was noted for this case study.
2. An additional force of 15% was required to produce a roof drift of 3% for a nonlinear pushover in comparison to a no wall case.
3. Initially, up to 60-80% of difference is noted in the max interstory drift and floor acceleration response, where these spectral demands are most reflective of a service level earthquake.
4. As the partition wall degrades, its impact on the response of the building lessens, but can still impact floor levels with softer story stiffnesses.

References