# Title slide

[TITLE] investigates the potential role that an AR system driven by Building Information Modeling data can have on improving retrofitting training. Retrofitting is a process focused on upgrading components or features of a structure that were not part of its initial design and manufacture. Although retrofitting will be key in improving existing building stock and reaching global energy goals, implementing retrofits is often difficult due to tight space and time constraints, so training or re-training existing workers is often necessary.

# Concepts slide

This work combines three core elements, retrofitting, Building Information Modeling (otherwise known as BIM), and Augmented Reality, to create a system to aid in this training process. Obscured building information sourced from a project’s BIM environment is rendered as situated *“X-ray”* style 3D models to provide less cognitively demanding access to building data.

# ‘Holograms’ videos

These models can then be further augmented using visualizations to direct a wearer’s attention to a specific element of their environment or provide a guide a how to interact with building elements.

# Study Design slide

To evaluate the impacts of implementing this system into the training process, we designed a study comparing the required training time, performance consistency, and physical and cognitive impacts of a common retrofitting procedure using our system and a conventional printed documentation set. 64 participants were equally split into the two groups and asked to install an electrical outlet onto a prefabricated wall structure.

# Instructions video

Both groups had access to the same instructions set but accessed in a different manor. Shown here is the virtual instructions interface. Participants can manipulate the interface to fit the needs of their task and embed it in their environment as they see fit.

# ‘Holograms’ videos 2

Obscured building data is visualized to participants and guide-lines are added to simplify the learning process.

# Duration slide

The augmentations resulted in remarkable differences in time for a majority of the sub-tasks required for the installation. Particularly noteworthy was improvements in tasks focused on identifying specific areas or components of the wall structure to interact with, as shown in the graph on the right. Locating the ideal vertical stud to mount the outlet on, identifying the optimal installation height to avoid interior pipes, marking the cutout area of the drywall, and marking the screw holes that will connect the outlet and stud after cutting open the wall. All 4 of these tasks saw a significantly reduced time in AR as opposed to printed documentation and tools.

# Cutout area videos

The AR system was effective in guiding participants towards making more consistent, easy to patch-up, cutout areas during the installation. This is a demonstration of a very common cut made.

# Cutout area slide

When comparing the total area of cuts made, AR participants saw significantly smaller deviations within the group. The higher overall mean cutout area in AR was a product of the system, as the provided 3D visual guides were optimized for comfort during the installation process. When testing with professionals, these values can be reduced to prioritize waste minimization.

# Usability video

Shown here is a typical example of the process participants who were assigned to the conventional documentation group used. A 23 page booklet of complex building documentation was parsed to retrieve essential information, and a stud finder tool helped identify the structural supports of the wall and create a mental image of this information.

# Usability slide

Using a NASA Task Load Index and System Usability Scale, participants reported the AR system to be significantly more usable, and those assigned to it reported significantly lower cognitive, physical, and overall effort required to complete the installation. They also felt more confident in their performance.

# ‘Please see paper’ slide

Overall, our results indicate a very positive future for BIM-enabled AR tools in retrofitting training, and eventually for on-site implementation. For more detailed discussion of our results and methods, please see our paper. Thank you and have a wonderful day.

by reducing time requirements, increasing training consistency, and limiting cognitive and physical costs of training.

and evaluating their performance across key metrics.