

# CPS: Medium: Collaborative Research: Building Information, Inhabitant, Interaction and Intelligent Integrated Modeling (BI5M)

Submitted by [culligan](#) on Wed, 04/24/2019 - 3:58pm

## Project Details

<b>Lead PI:</b>	<a href="#">Patricia Culligan</a>
<b>Performance Period:</b>	10/01/18 - 09/30/21
<b>Institution(s):</b>	Columbia University
<b>Sponsor(s):</b>	National Science Foundation
<b>Award Number:</b>	<a href="#">1837022</a>

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**Abstract:** Each year the nation spends over \$400 billion to power, heat and cool its buildings. Moreover, buildings are a major source of environmental emissions. As a result, even a modest improvement in energy efficiency of the nation's building stock would result in substantial economic and environmental benefits. In this project, the focus is on improving energy efficiency in commercial buildings because this sector represents a substantial portion of the energy usage and costs within the overall building sector. Enhancing the energy efficiency of commercial buildings is a challenging problem, due to the fact that centralized building systems -- such as heating, ventilation and air conditioning (HVAC), or lighting -- must be synthesized and integrated with individual inhabitant behavior and energy consumption patterns. This project aims to design, analyze, and test a cyber-physical and human-in-the-loop enabled control system that can drive sustained energy savings in commercial buildings. It brings together expertise in computational building science, eco-feedback, network theory, data science, and control systems to integrate physical building information and inhabitants with cyber (building-human) interaction models to enable intelligent control of commercial building systems. Specifically, this project will: 1) design an integrated cyber-physical system (CPS), called Building Information, Inhabitant, Interaction, Intelligent Integrated Modeling (BI5M), aimed at reducing energy usage in buildings; 2) assess the complex inter-relationships between and across physical building and inhabitant models, cyber building-human interaction and intelligent control models related to energy conservation behavior; and 3) empirically test and validate modules and the overall BI5M system at test-bed buildings on Stanford's campus and Google's office park. This research incorporates measurement (geospatial

building data, energy use data), dynamics (inhabitant social networks), and control (enhanced user control of: plug-load devices, HVAC, lighting) into the BI5M system. The BI5M system is centered on a cyber Building Information Management (BIM) model of the building, and will encompass rigorous systems engineering that will explore relationships across the cyber-physical domains and develop new insights for how the scientific principles of cyber-physical systems can be used to influence the energy efficiency of commercial buildings through both occupant behavior and intelligent control. By integrating physical building information and inhabitants with cyber interaction modeling, the research aims to introduce an integrated human-in-the-loop control paradigm for commercial buildings. In addition to a testbed and validated CPS system for commercial buildings (BI5M), this project targets fundamental knowledge on: ontological components required to integrate dynamic data streams and control information into static building models; complex socio-spatial structures of inhabitants; insights into how building-human and human-human interactions impact inhabitant consumption behavior; and new control models that leverage input on the energy usage, spatial, social and behavior dynamics of inhabitants. The educational impacts of this project will extend to participants (students, faculty, Google employees in the test-bed buildings), as well as a broader student population through the integration of key insights from this work into courses/projects at all three collaborating universities (Stanford, Georgia Tech, and Columbia). The project team will also disseminate results to practitioners/policy-makers working in the building management space through an Outreach Workshop. Additionally, this project will broaden participation in computing fields through a diverse team and by partnering with the Girls Who Code nonprofit to integrate project data sets and tools into their activities.

## Related Artifacts

### Posters

- [Building Information, Inhabitant, Interaction and Intelligent Integrated Modeling | Download](#)
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