Project Summary

Conventional construction practices are governed by mechanical stress and cost considerations, and are not geared towards mitigating imminent threats and breach of security. Information technology (IT) has empowered civil and mechanical engineers to initiate a *live design* prototype that alerts civic authorities confronted with manmade disasters to enable optimal rescue. To direct evacuation along the most favorable routes, security conditions, particularly in buildings, are continuously updated using streaming measurements from sensors (e.g., for fire and smoke) and dynamic structural stress-strain data. High-speed large-scale distributed statistical computation of Bayesian updating (of this IT-based decision process) almost instantaneous; hence the paradigm is termed *live design*. Over the course of five years, engineers, architects, computer scientists and lawyers will build, demonstrate and deliver *live design* core methodology on randomly selected office building models. Seamless information augmentation, (e.g., new biochemical detectors and surveillance instruments) allows for an open environment in *live design*. Its nonrestrictive extension in enhancing security for all civil infrastructures (e.g., watersheds and energy systems) supports *live design*'s versatility.

There are three principal parts to this research. The first phase of data acquisition combines the available structural stress analysis response history, building codes, legal requirements, and the online sensor readings. The second stage requires a statistical combination of those indicators to construct threat scenarios. The most fatal combination is assessed from principal component analysis of the statistical computation where interval arithmetic depicts confidence bounds. These scenarios lead to spatio-temporal threat patterns according to fuzzy logic. In the final stage, *virtual reality*-based smart signs of optimal paths in evacuation and rescue are displayed. During all three stages IT engines carry out dynamic searches on the *live design* database. Fatal events are signalled from extreme value statistics whose tight bounds on the confidence interval predict credible threats. Anomalies such as noise are indicated by spreads on the confidence bounds. This self-learning process is continuously fine-tuned by eliminating observed false alarms as statistical outliers and simultaneously discovering yet to be identified ominous impending events.

Economic constraints, construction and architectural practices as well as the legal implications of monitoring and surveillance of private, government and international office buildings will be integrated under the IT-based formal specification. The resultant database will guide a computer-aided design software to produce baseline drafts and three-dimensional animation to facilitate evacuation and rescue. The requested budget, which supports domestic university salaries, government rates for the practitioners and minor expenses for sensor fabrication, and publications, will yield life saving security strategies at a fractional cost of a single building.

MIT researchers will simulate building hazards to collect thermo-mechanical stress values from structural calculations, control measurements, security and surveillance data and wireless sensor responses. Results will be statistically combined by Columbia University (CU) researchers for the team's architects to broadcast optimized rescue and evacuation trajectories as architectural animations voice and text security messages. The legal ramification of human intervention based on such predictions will be assessed by querying another *live design* database developed by the lawyers. CMU will design an XML application and associated tools for the entire IT engine to facilitate organizing all time variant responses and database functions based on deep domain models, and export of results in appropriate formats. Notable computer scientists from foreign universities will co-advise doctoral students.

The intellectual merit lies in embedding the tools of information technology within civil and mechanical system engineering. This novel concept, which has no precedence, is evidenced by the following points:

(i) development of semantically rich formalized versions of IT requirements from engineering and legal viewpoints to facilitate evacuation and rescue;

(ii) advancement of the sensing technology to detect composite effects of security related objects, e.g., thermal stresses and biochemical agents;

(iii) enrichment of probabilistic prediction with interval arithmetic to depict confidence level

(iv) PhD theses to elaborate the fundamentals.

The broader impacts are summarized below.

(i) Civic authorities, aided by IT tools, will be able to enhance the security of physical infrastructure including historical monuments.

(iii) Clinicians will receive a clearer picture of disasters to treat related injuries and trauma.

(iii) Chronology from the self-documenting feature will constitute potential legal evidence.

(iv) Unrestricted distribution of research results will elevate the security consciousness of the public at large.