Proposal for Innovation Funding

Dear Research and Educational Technology Committee:

Thank you for the opportunity to submit this proposal for the UT Smart Buildings Initiative. The Smart Buildings Initiative is comprised of a team of researchers from the **School of Architecture**'s Center for Sustainable Development and the **Design Division, Department of Art and Art History** (College of Fine Arts), as well as engaging students from other college and schools, namely **Computer Sciences** and **Electrical Engineering**. We are requesting funding in the amount of **$95,564** to develop and pilot an innovative technological system that marries building energy efficiency monitoring with indoor localization.

The technological prototype was developed in consultation with the UT Facilities Services Department, to ensure that the technology would be easily deployable and of value to the University. Through the marriage of energy efficiency monitoring with indoor localization, important data can be acquired that informs future renovation strategies, maintenance issues, and even scheduling strategies that maximize the buildings' use for optimal building and human performance.

Other universities, such as the University of Richmond and Oberlin College, have conducted more limited energy efficiency studies that empower the building user to lessen energy usage through education and interface with the technologies themselves, but these projects typically limited the investigation to the scale of the building and focused only on energy efficiency. The study at Oberlin College in 2007 did sample 14 rooms in one dormitory, in an effort to better isolate the relationships between user behavior and energy efficiency. This study showed that when building users were provided general information about the building's collective energy performance, energy consumption was reduced by an average of 32%. This figure jumps to an astonishing 52% when looking at a subset of occupants who were supplied with detailed information about their individual contribution to the building's overall energy consumption.

Our study proposes to engage roughly 300 individuals (students, faculty, and staff) working in Sutton Hall to participate in a study that directly links energy efficiency data with user behavior at the scale of the room, instead of the building. The dean of the School of Architecture has approved the proposed system for deployment in Sutton Hall, so **no additional space is required**.

The project will be administered by the UT Center for Sustainable Development, a transdisciplinary research center based within the School of Architecture with a mission to lead the study and practice of sustainable development in Texas, the nation and the world through complementary programs of research, education, and community outreach. The collective experience of the team below provides a fantastic base for such an interdisciplinary study. Funding from the Longhorn Innovation Fund for Technology would allow the Smart Buildings Initiative to transform itself from a conceptual prototype developed by an industrious team of graduate students to a technological system ready for application across the UT campus and beyond.

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Overview: Describe the problem, need, or opportunity that this project would address.

Over 40% of the nation's energy is consumed by the existing building stock, so efforts to refine the way we retrofit and use our existing buildings can play a huge role in transforming buildings and their energy consumption and comfort. There are roughly 19 million square feet of existing building space at The University of Texas at Austin's main campus alone, and more effectively using this space, as well as other educational and office park campuses across Texas, would have a significant positive effect on climate change and efficient resource usage. Several technologies currently exist that monitor energy efficiency in buildings, but none of the products marry that information with the root cause of energy consumption—people. Understanding how occupants use a building is key to optimizing the efficiency of all energy related systems.

The UT Smart Building Initiative plans to develop an integrated system for understanding the relationship between energy usage and user behavior, and to create a method for sharing that information with facility managers and the occupants themselves. The School of Architecture's Sutton Hall will serve as the test building for the proposed pilot study. The team has identified three main avenues for research. First, an energy monitoring system will be installed in the building to analyze temperature, light levels, relative humidity, air quality and electricity usage. This product will provide base data on the building. Second, relying on a technology called indoor localization, the team will enlist a sample of test users (students and faculty) working in Sutton Hall to opt in to a program the team has developed that can track the location of wireless devices down to a room-level of accuracy. Since most occupants carry either a mobile phone or a laptop computer, indoor localization will allow the research team to create an anonymous, high-resolution image of how the building is actually being used by its occupants in real time. This data has obvious benefits for building operations, as facility managers and course schedulers could employ the data generated by the integrated energy/occupancy monitoring system to control HVAC and lighting systems and to target future efficiency initiatives. The third node of the project involves the development of innovative mobile applications that will allow users to see how much energy they have consumed while in the building. Research studies suggest that making energy visible in this way can motivate behavioral changes that result in meaningful reductions in energy consumption. With funding from the Longhorn Innovation Fund for Technology, the project can seamlessly transition from a nascent research concept to an applied research endeavor.

Innovation Level: Identify what is state-of-the-art or innovative about this project.

The Smart Building Initiative builds on the research already underway in the recently constructed UT Thermal Lab. The applied research conducted through the Smart Building Initiative, which will be integrated into the very fabric of the University itself, will provide UT with recognition as a leader in green building education, research, and sustainable facilities management.

The indoor localization technology developed for the Smart Building Initiative could transform the manner in which buildings are managed and renovated. Currently, facility managers rely primarily on occupancy sensors for analytics on building usage, but the data gathered is relatively coarse, lacking detail in both the volume and specific location of occupants. Occupancy sensors are also passive devices – a missed opportunity to engage with occupants as meaningful stakeholders. Both of these issues are addressed by the indoor localization technology proposed by the Smart Building Initiative.

The University of Richmond and Oberlin University both employed interactive energy monitoring technologies in their dormitories, but no other project has paired their applied energy efficiency research with data on indoor localization. This initiative will be the first research endeavor of its kind to marry energy efficiency, indoor localization and user education in the University setting.

Benefit to UT and Potential Adopters:

From power systems to janitorial maintenance, most of a building's core services are people-centered and people-driven. Understanding the traffic patterns of a building allows for the optimization of energy-related systems, such as lighting and HVAC, but also other systems connected to a building's usage. There are two main user groups benefiting from this system: the occupants and the facility managers of commercial buildings.

Students and Faculty: The students and faculty members participating in and learning from this study are primary stakeholders. There are roughly 600 students in the School of Architecture, with hundreds of other students also

taking classes in Sutton Hall each year. The team hopes to not only engage building occupants through their participation in the study, but also to empower occupants to become more educated about their use of the built environment and their impact on energy consumption.

The parallels between this project and the research conducted throughout the School of Architecture provide unique opportunities for synergy with the academic curriculum. The School of Architecture has recently been ranked fifth in the nation in both its undergraduate and graduate programs, and the graduate program ranking is the highest achieved by a public university. The Smart Building Initiative will capitalize on the capacities of this top-ranking program. Professors in the School of Architecture will be encouraged to engage with the Smart Building Initiative, and courses such as Building Construction, Environmental Controls I and II, and Architecture and Historic Preservation Design Studios could integrate this indoor localization pilot technology into their curricula. In addition, the UT Design Program, housed within the Department of Art and Art History, could benefit from the Smart Building Initiative. The program has approximately 60 students, and has already integrated sustainability into courses program-wide. Design classes that could participate in this Initiative include: Design Technologies, Design and the Social Environment, Design and Persuasion, Advanced Issues in Design, Design Perspectives, and Senior Projects in Design.

Finally, this proposal itself is an example of interdisciplinary curricular work at the University. Originating from research proposed by graduate students in the Department of Art and Art History and the School of Architecture, the technical implementation of the Smart Building Initiative requires resources and skills from mechanical engineering, computer science, mathematics, and business. It is a bellwether for future collaborations and interdisciplinary, research-based course development on campus.

Facilities Management Entities: The University Facilities Services Department has already expressed interest in this project, because of its potential to transform their energy monitoring and building usage analysis strategies (see attached letter of support). Additionally, several outside commercial entities have expressed a strong interest in the proposed technologies, and early discussions with potential commercial users will help the research team tailor its findings to the needs of users for immediate application. The Smarte Building Company, a building energy monitoring company in Austin already working with the University on its Pickle Campus, has already become a supporter and collaborator for the project (see attached letter). The Director of Sustainability at Dell is also deeply interested in adopting a version of this product in their buildings (see attached letter). Hubbell-Automation, a company specializing in occupancy sensors and lighting control, has expressed an interest in sponsoring the renovation of University buildings to incorporate these technologies into the building fabric.

Scope of Project:

The Initiative proposes a pilot project that will accomplish the following:

1. Develop the technology to track Wi-Fi enabled devices to a room-level specificity.
2. Deploy an Environment and Energy Monitoring System in a test building (Sutton Hall).
3. Conduct a pilot study with voluntary beta testers to understand how students, faculty and staff are using the test building.
4. Compare the test building's use with its energy consumption to identify potential energy savings.
5. Provide a case study for how to develop interdisciplinary project-based curriculum.

The project is divided into three phases. Phase One includes the further development, vetting, and deployment of the integrated building monitoring system into Sutton Hall. Baseline data will be collected using Smarte Building's proprietary energy monitoring technology, in combination with Ekahau's indoor localization system or a comparable software package. Monitors will be installed in each room of Sutton Hall to assess the comfort conditions and the correlating energy performance. The monitors will also provide a direct feedback loop to occupants on the environmental ramifications of various actions within the space. In this phase, participating building users will also be recruited and educated on the boundaries and goals of the study.

In Phase Two, indoor localization technology will measure how a sampling of building occupants use energy and space inside Sutton for a period of six months. This project will be visible to users as a mobile application for smartphones, and an online web application will provide users with access to an information dashboard from any

computer. Further, in order to expand the breadth of the public engagement, an LCD monitor showing real time energy use at the building level will be mounted in the lobby of Sutton Hall.

Phase Three includes data analysis, synthesis, and dissemination of results in report form.

Plan for Evaluating Success and Effectiveness:

The project will be evaluated on its utility for two sets of stakeholders. **Building Users**: In order for the technology to be successful, building users must feel engaged and empowered to change their behavioral patterns based on their interface with the technology system. The functionality of the system will be judged using both qualitative and quantitative methods. First, building energy performance data from the test period will be compared with historical energy performance data from the same six months of the previous year. Second, project participants will be surveyed about their experiences with the technology to understand their perceptions as building users. **Facility Managers**: In order to evaluate the content of the data produced by the technology, several tactics will be employed to demonstrate the high traffic areas in terms of occupancy compared with where energy is being consumed in the building. This will allow facility managers to visually identify disconnects between energy consumption and building use. Qualitative data will also be gathered from UT Facilities Services staff, in the form of long interviews and surveys, to gauge their perceived benefit of the technology.

Project Timeline and Milestones

September 2010-December 2010: Project development

- September – select all service suppliers, vendors, equipment, etc.
- October – Alpha version of integrated indoor localization and energy metering system.
- November – Beta version of integrated indoor localization and energy metering system.
- December – Release version of integrated indoor localization and energy metering system and select ~300 participants.

January 2011-May 2011: Execute full-scale pilot project in Sutton Hall tracking the energy performance, the CO2 emissions, and the movement of ~300 participants.

- January – Deploy energy meters and environmental sensors; conduct radio fingerprint mapping of building for indoor localization; and begin testing period in Sutton Hall.
- May – End testing.

June 2011-August 2011: Analyze data and suggest future research/implementation strategies.

Sustainability Plan:

The Smart Buildings Initiative research endeavor outlined above can be fully executed within the proposed timeframe. Support from the School of Architecture, the Department of Art and Art History, and the UT Department of Sustainability has been secured, and participating graduate researchers have already developed the basic technology for the integrated system. The research team will work closely with the UT Facilities Services Department to ensure that the methods employed, data gathered, and reports produced are directly translatable to their practices. The long term goal of the project is implementation campus-wide, with a permanent system that will engage a substantial portion of the student body in energy use awareness and control and provide a framework for future students and faculty to investigate, develop, and implement emerging technologies for engaging students and staff in sustainability issues and practices on campus and beyond.

Budget Requirements

Budget Breakdown

Cost Type	Amount Requested
Salaries/Personnel	$55,789
Permanent Equipment	$19,345
Materials and Supplies	$4,430
Tuition	$16,000
TOTAL	**$95,564**

Justification

Personnel: Ulrich Dangel is an assistant professor in the School of Architecture, with an interest in improving the energy efficiency of existing buildings and educating the general public on low-energy building design. Dangel will serve as **Co-PI** for the project, overseeing monitoring of energy consumption and user behavior, and providing feedback to stakeholders. Funding is requested for one month of his time ($XXX) over the course of the project.

Matt Fajkus is an assistant professor in the School of Architecture. His focus centers upon the balanced integration of natural daylighting and artificial lighting in buildings, and their cumulative impact upon the energy performance. Fajkus will serve as **Co-PI** for the project, overseeing the system set-up and spatial integration, as well as the interface criteria. Funding is requested for one month of his time ($XXX) over the course of the project.

Gloria Lee is an associate professor in the Design Division, College of Fine Arts, with extensive experience in human-computer interfaces design and visual communications. Lee teaches graduate students in the Design Division and will be teaching a course on Design and Persuasion Spring 2011. Lee will serve as **Co-PI** overseeing issues regarding the visual user interface. Funding is requested for one month of her time ($XXX) during the project.

Riley Triggs is a lecturer in Design Division, College of Fine Arts, where he continues to couple his work in emerging personal computing technologies with design for sustainability initiatives for broader culture change. Triggs will serve as **Co-PI** for the project, overseeing systems integrations and personal computing component implementation. Funding is requested for one month of his time ($XXX) over the course of the project.

The UT Center for Sustainable Development will administer the implementation, coordination, and publication of the project. A fee of $5,000 has been included in the budget to fund project administration over the course of the project duration.

Research assistants will serve as the heart of the research endeavor, with **five students** (with backgrounds in Computer Science, Design, Architecture, and Electrical Engineering) funded in the first semester of the project to help develop and deploy the technology. Funding is requested during this fall semester for four research assistants, each working at 20 hours per week for three months (two graduate students at $15/hr and two undergraduate students at $10/hr). The graduate student from the Design Division of the Art and Art History Department who conceived of this idea is budgeted to receive funding for a full year at $15/hr for 20hours per week. This student will lead the team of student researchers in the fall during product development, and will focus on data collection, analysis and publication in the spring semester.

An average fringe rate of 20% has been applied to all personnel costs listed above ($11,160).

Tuition remission has been requested at the rate of $4,000 per semester for the graduate student researchers (x4).

Permanent Equipment requested includes an Energy Monitoring System from Smarte Building ($8,545, plus 5 mts of service at $475/mt); Environmental Sensors ($65/sensor for 120 sensors); and the Public Interface: 24" LCD monitor ($250), computer to run the monitor ($100), and cables, mounting hardware and labor ($275).

Materials and Supplies requested includes Localization Equipment: a Linux Server ($1000), 5 cellular phones of various types ($3,030), and phone service for the three months of technology development ($400/mt)