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Computational Needs for Design, Optimization, Control, and Analysis of Energy Efficient Buildings

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Computational Science Needs in the Design, Optimization and Operation of Energy Efficient Buildings

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NNSA National Nuclear Security Administration

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Stakeholders for Computation Impacting Building Efficiency

- AIE practitioners
- Policy makers
- Regulators
- Researchers
- Building occupants
- Industry
- Utilities
- Manufacturers

GOAL: Design and operate buildings for energy efficiency over lifespan, accounting for:

- Internal energy, air, water, occupant flows
- Building/building and building/environment interactions
- Building structure, usage, and energy supply system evolution
- Real-time forecasts and feedback on multiple time scales

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So Where Do Buildings Come From?

Impacts of computational science:

- **Shorten development time (currently years)**
- **Move toward a more iterative process, reducing late retrofits/recourse**

Developer/Owner
– May Be Public or Private
– Defines Baseline Requirements

Architect
– Designs General Building Form
– Insures Livability, Usability

Structural Engineer
– Designs Structural Systems
– Insures Building Stands Up

EE/ME/CEs
– Designs Non-Structural Systems
– Lighting, HVAC, Water, etc.

Construction Engineer
– Designs Construction Plan
– Oversees Building Realization

These are the professions of *Architectural Engineering*

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Risk Quantification

- Target Audience: Developers and Owners
- Goals of Simulation Tools
  - Predict real-world building performance
    - Permit evolution in use of building over lifespan
    - Include sensitivity to full range of expected conditions in computing estimated costs
  - Convey building performance in relevant terms
    - Quantify initial and operational costs
    - Provide accurate estimates of resource inputs

Optimal Building Design

- Target Audience: Architects and Engineers
- Goals of Simulation Tools:
  - Provide for integrated design of buildings
    - Remove artificial barriers between design stages so that more relevant design space can be considered
    - Facilitate incorporation of energy use as an equal partner to architectural and structural considerations
  - Support optimal building design decision-making
    - Compute financial and resource costs of trade-offs among architectural, structural, and environmental systems design decisions

Building Life-Cycle

- Target Audience: Developers and Architects
- Goals of Simulation Tools:
  - Support agile response to evolution of building function over building's lifespan
  - Permit high-level design decision-making that will insure against costly side-effects developing as the function of a building evolves over time

Model Reduction and Hierarchy

- Target Audience: Architects and Engineers
- Goals of Simulation Tools:
  - Reduce complexity of building models
    - Permit manageable set of parameters for control
    - Permit real-time management of building systems
  - Insure that reduced models are accurate
    - Create hierarchy of models to support adaptive error control in reduced models
    - Provide appropriate measures of uncertainty

Modular Software Design

- Target Audience: All Stakeholders
- Goals of Simulation Tools:
  - Provide for rapid development and revision of all simulation tools used for building design
    - Incorporation of new building technologies requires supporting software be rapidly redeployable
    - Supporting integrative building design will require integration of disparate software components
  - Support appropriate computing platforms
    - Need seamless migration to new HPC architectures
    - Tools must scale down (e.g. embedded intelligence)

Quantifying Optimal Performance

- Target Audience: Developers and Engineers
- Goals of Simulation Tools:
  - Support optimal performance in engineering terms
    - Continuously monitor and compare all aspects of building systems performance to theoretical ideals
  - Support optimal performance in financial terms
    - Aggregate systems-level performance data into relevant form for owners and operators
    - Provide financial and resource data to aid in optimal operational decision-making

Intelligent Control and Data Assimilation

- Target Audience: Building Systems Engineers
- Goals of Simulation Tools:
  - Improve accuracy of building systems models by fusion of simulation and data sources
    - Characterize actual usage patterns over time
    - Develop predictive capacity for resource use
  - Incorporate data into control programs
    - Improve reduced models via incorporation of data
    - Sensor placement to reduce model uncertainty

Energy Portfolio Management

- Target Audience: Developers and Owners
- Goals of Simulation Tools:
  - Aggregate building performance to larger scale
    - Facilitate informed decision-making by quantifying effects of trade-offs among building inventory
  - Support coordinated effort in portfolio management
    - Provide decision-support services for full range of financial and resource inputs
    - Provide for adaptive learning based on integration of performance history data over time