

Building-Related Research at Herrick Laboratories: Past, Present, and Future

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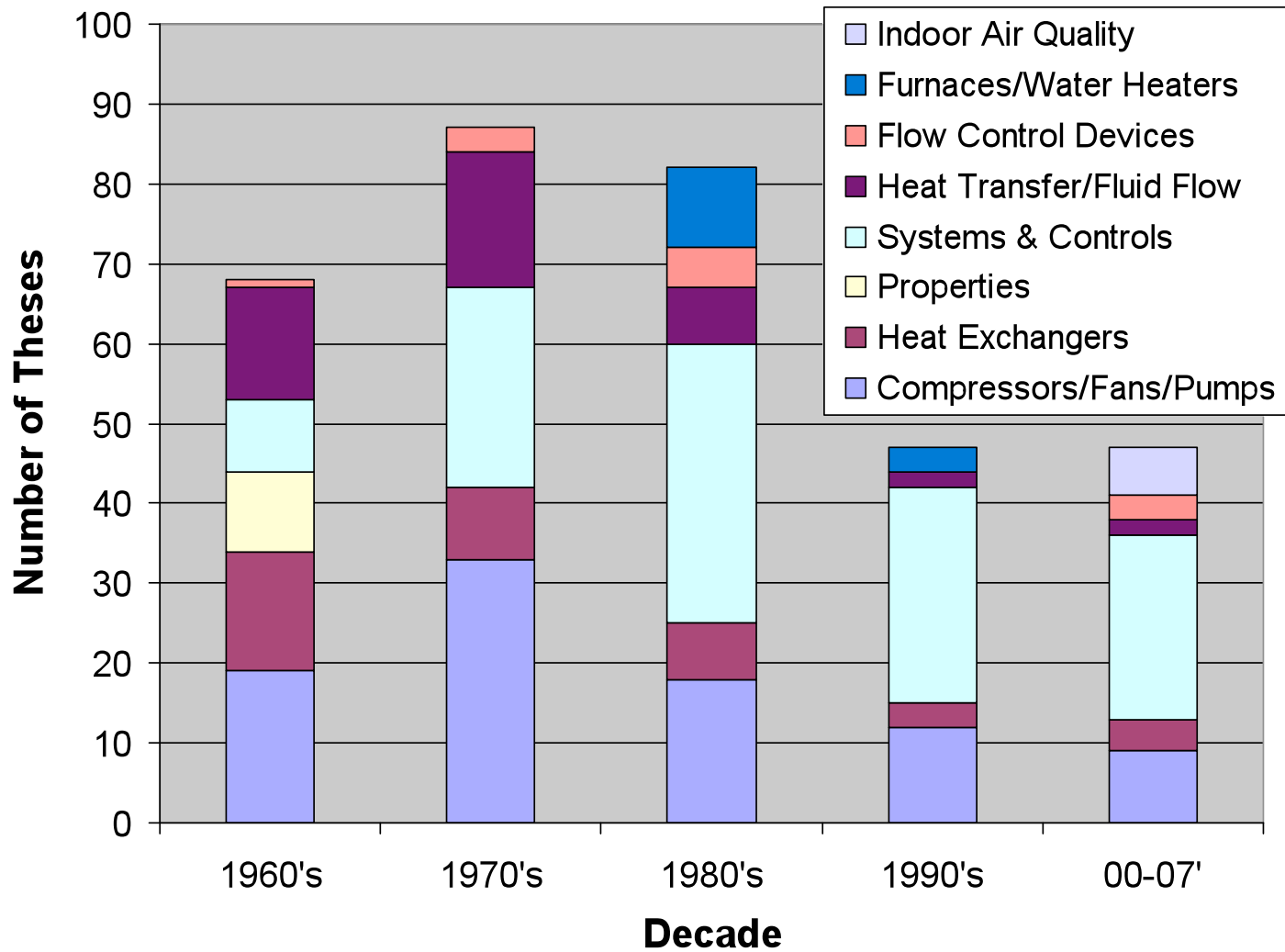
Outline

- History of Buildings' Research at Herrick Labs
- Overview of Current Capabilities and Activities
 - Faculty
 - Research Thrusts
 - Facilities
- Future Research
 - Technologies for Existing Buildings
 - Technologies for New Buildings
 - Research to Technology
 - New Research Facilities
 - Opportunities for Collaboration within Purdue

Herrick Labs History

- Founded in the mid-50's with a grant from Ray W. Herrick, founder of the Tecumseh Products Corp.
- Evolved to do research on
 - refrigerating compressors
 - HVAC&R systems/equipment
 - noise and vibration control
 - electro-mechanical systems and controls (smart machines)
 - building controls and diagnostics
 - indoor air quality
- Strongly connected to industry through research funding, conferences, short courses, employment

Building-Related Research History



Research Evolution

Period	Driving Factors	Research Focus
1960 & 1970's	<p>high-speed computers oil crisis government regulations expanding marketplace size & reliability issues</p>	<p>compressor, heat exchanger, expansion device modeling systems' modeling tools energy analysis compressor reliability</p>
1980's	<p>low-cost micro-computers computerized energy management micro-processor controllers noise issues</p>	<p>transient modeling tools intelligent controls compressor noise</p>
1990's	<p>environmental – ozone depletion worker productivity – comfort, IAQ, noise limited utility capacity reliability expanding service business</p>	<p>Alternative cycles & refrig. IAQ strategies, active & passive noise control thermal storage controls automated fault detection & diagnosis</p>

Current Research Directions

Driving Factors	Research Directions
<p>Global warming</p> <p>Homeland Security</p> <p>Limited generating capacity</p> <p>Information technologies</p> <p>Consolidation of service providers</p> <p>Low-cost sensors & computers</p> <p>Worker Health and Productivity</p> <p>Population Growth</p> <p>Aging Population</p> <p>Global Competition</p>	<p>Building system energy and moisture modeling</p> <p>Equipment modeling and optimization</p> <p>Alternative cooling, heating and power cycles</p> <p>Transport modeling for contaminants</p> <p>Contaminant source identification</p> <p>Optimal ventilation system design</p> <p>Performance monitoring & diagnostics</p> <p>Intelligent controls</p> <p>Human perception and productivity modeling</p> <p>....</p>

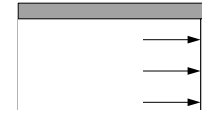
Current Faculty and Thrusts

Professor	Primary Research Activities
Stuart Bolton	Noise control, sound field visualization, wave propagation in structures, noise control material modeling with applications to: Compressor and Fan Noise Reduction, New Insulation Materials
Jim Braun	Modeling, analysis, and optimization with applications to: Intelligent Controls, Automated Diagnostics, Component & System Improvements, Building Simulation Tools
Qingyan Chen	CFD for air flow in & around buildings with applications to: Indoor Air Quality, Homeland Security, Energy Analysis
Patricia Davies	Signal processing, data analysis, and system modeling and identification with applications to: Sound Perception, Sound Quality, Condition Monitoring of Equipment
Eckhard Groll	Experiments and modeling with applications to: Alternative Refrigeration Technologies, Natural Refrigerants, Component & System Performance

Existing Research Facilities

Two Large Environmental Chambers

- Testing of AC, HP and Refrig. Systems
- -20 C to + 50 C, < 5-ton equipment
- Steady-state and cyclic testing of existing, modified, or new equipment designs

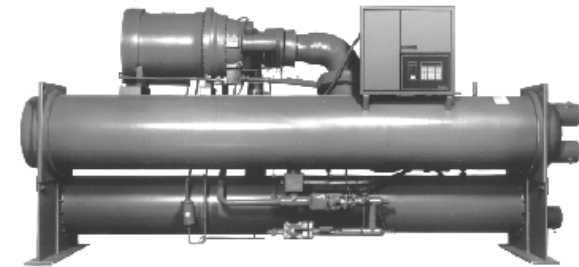


90-ton Centrifugal Chiller

- Automated control of boundary conditions

Heat Exchanger Test Facility

- Testing of cooling coils, heating coils, evaporators, condensers
- Capable of controlled heat exchanger fouling



Compressor Test Facilities

- CO₂, R22, R410a Load Stands
- Compressor Calorimeter

Noise and Vibration Laboratory

- Noise source identification
- Sound quality facility



Existing Research Facilities

Indoor Environmental Chamber



Future Research

- Existing buildings are the near-term opportunity for “greening” technologies
 - 40% of primary energy usage
 - 70% of electrical energy usage
 - Existing building stock will not change very quickly
 - Limited to technologies that can be “easily” retrofitted
- More possibilities for new buildings but a longer time-horizon for potential impacts

Technologies for Existing Buildings

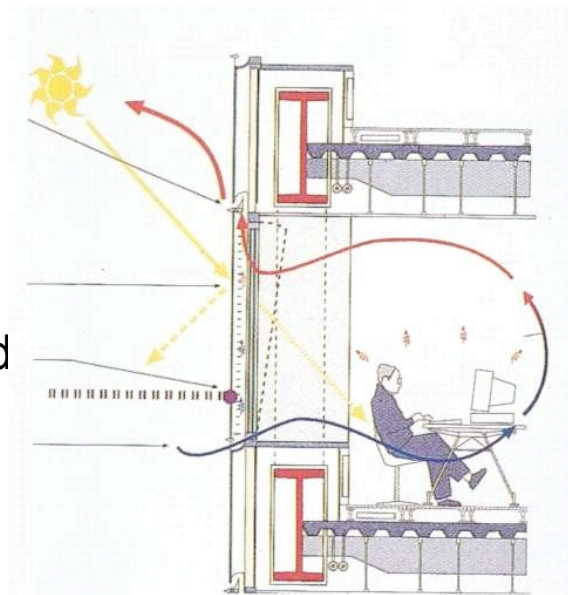
- Performance monitoring & diagnostic technologies
 - Tools for benchmarking the performance of buildings in terms of energy usage, environmental conditions (thermal comfort, IAQ, noise), occupant health and productivity, ..
 - Diagnostic tools for identifying specific problems in buildings (high energy usage, envelope moisture/mold problems, contaminants, noise, ..)
- Retrofit analysis/decision tools
 - Simple, tunable models for analyzing site-specific retrofit opportunities (equipment, ventilation, controls)
- Improved equipment & controls
 - High efficiency HVAC equipment with embedded diagnostics
 - Application of wireless technologies and enterprise networks for low-cost control retrofits (energy management, diagnostics, safety, ..)
 - Optimal control of HVAC system setpoints for minimum energy costs
 - Controlling buildings for minimum net carbon emissions

Technologies for New Buildings

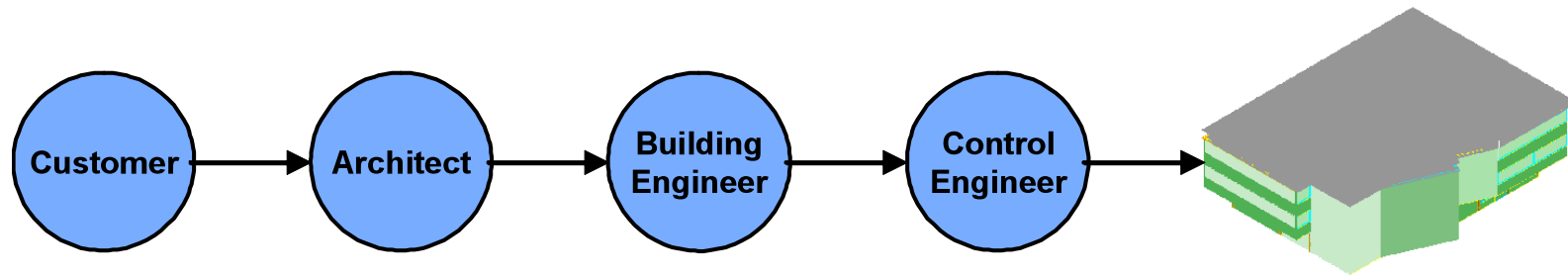
- Integrated Design/Decision Modeling Tools
 - Overall impacts of design choices on energy, CO2 emissions, occupant health and productivity, safety, costs, ...
 - Integration with existing architectural design tools utilizing emerging building information modeling (BIM) protocols
- Equipment
 - Ultra high-efficiency HVAC equipment with environmentally-friendly working fluids
 - “Smart” HVAC components and equipment with embedded intelligence to allow virtual sensing for diagnostics and controls
 - Plug-and-Play comfort delivery architectures and equipment to allow personal environmental control and energy recovery
 - Technologies for on-site combined cooling/heating/power production to enable net-zero energy buildings/communities

Technologies for New Buildings

- Envelopes
 - Integrated ventilation heat recovery in building envelopes
 - “Smart” envelope structures with embedded intelligence to allow virtual sensing for diagnostics and control
 - Integrated photovoltaics in window, wall, and roof elements
 - Optimal envelop constructions for thermal, acoustic, and recycling performance
 - Advanced daylighting technologies
- Operations
 - Plug-and-Play controls for energy cost minimization, diagnostics, safety, etc.
 - Integration of design information into automated operations using BIMs



State-of-the-Art



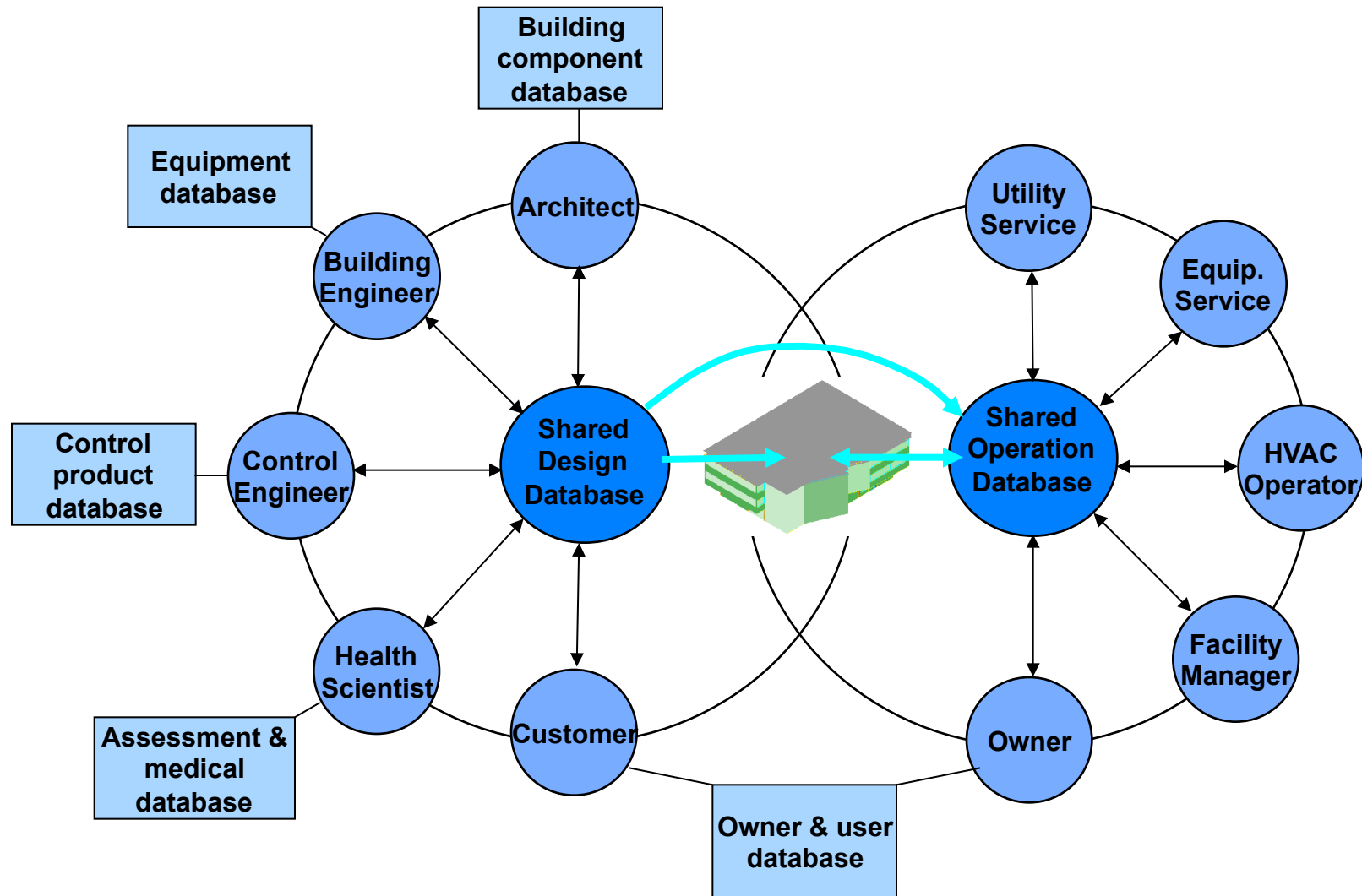
Team work in building industry



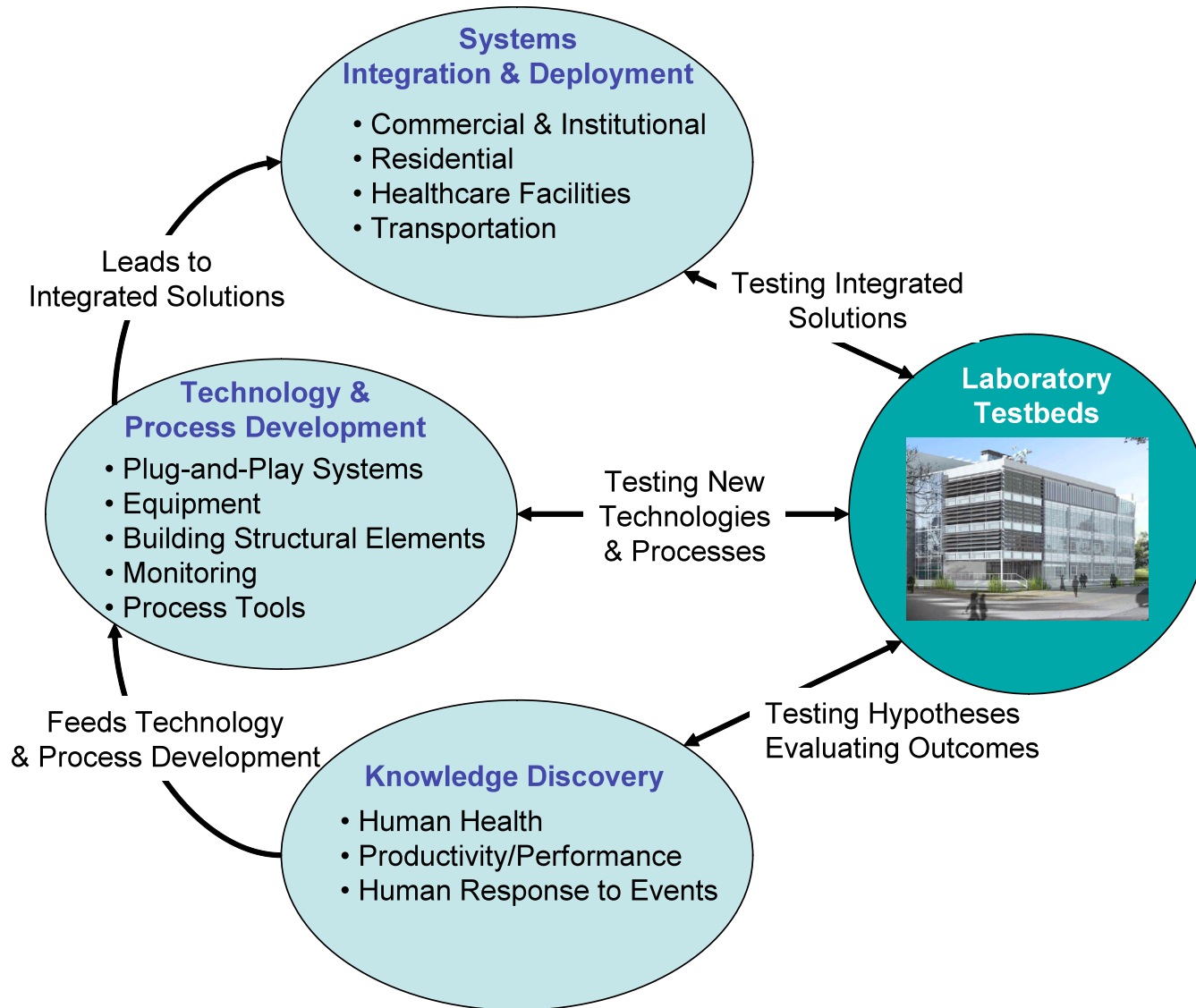
Team work in automotive industry



Integrated Design and Operations



Research to Technology



Multi-Scale Testbeds

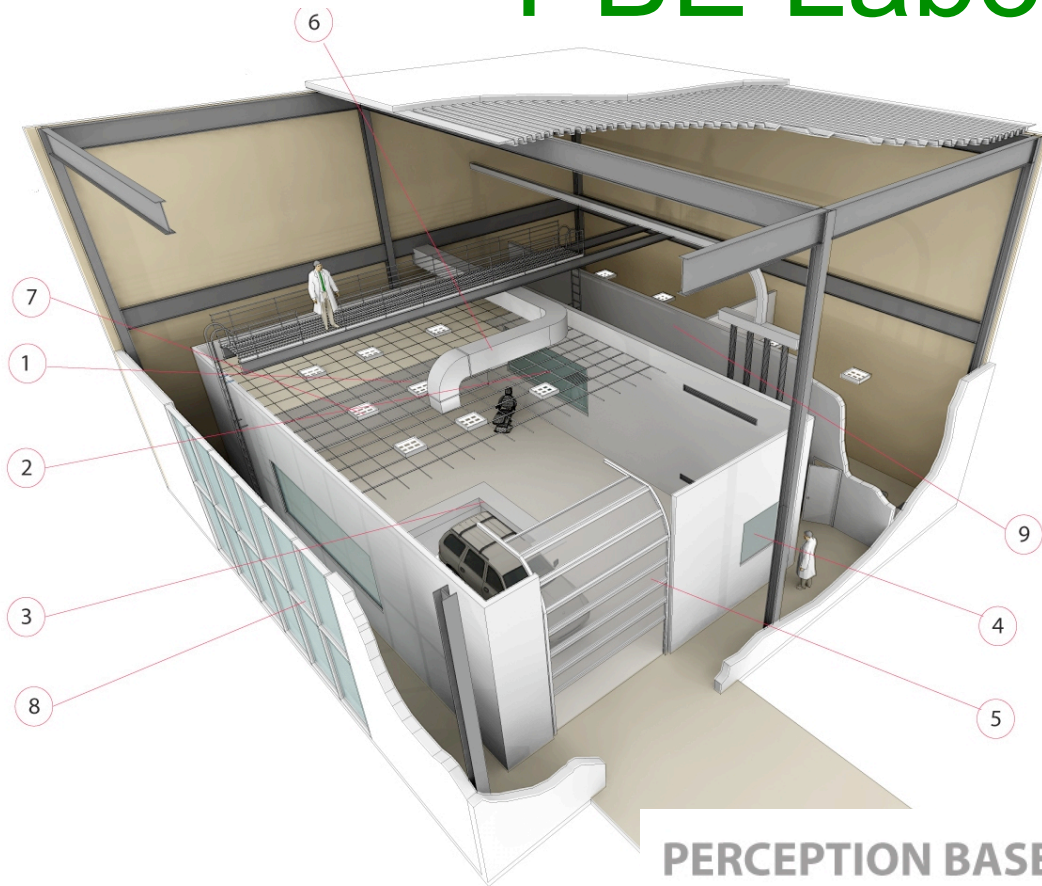
- Laboratory Scale
 - Indoor air quality chamber
 - Psychrometric chambers
 - Wind tunnel, heat exchanger test facilities, compressor calorimeter, etc.
 - Perception-based engineering (PBE) laboratory (planned facility)
- Building Scale
 - Living laboratory section of new HERL (planned facility)
- Community Scale
 - Campus buildings

New Herrick Layout



PLAN ISOMETRIC

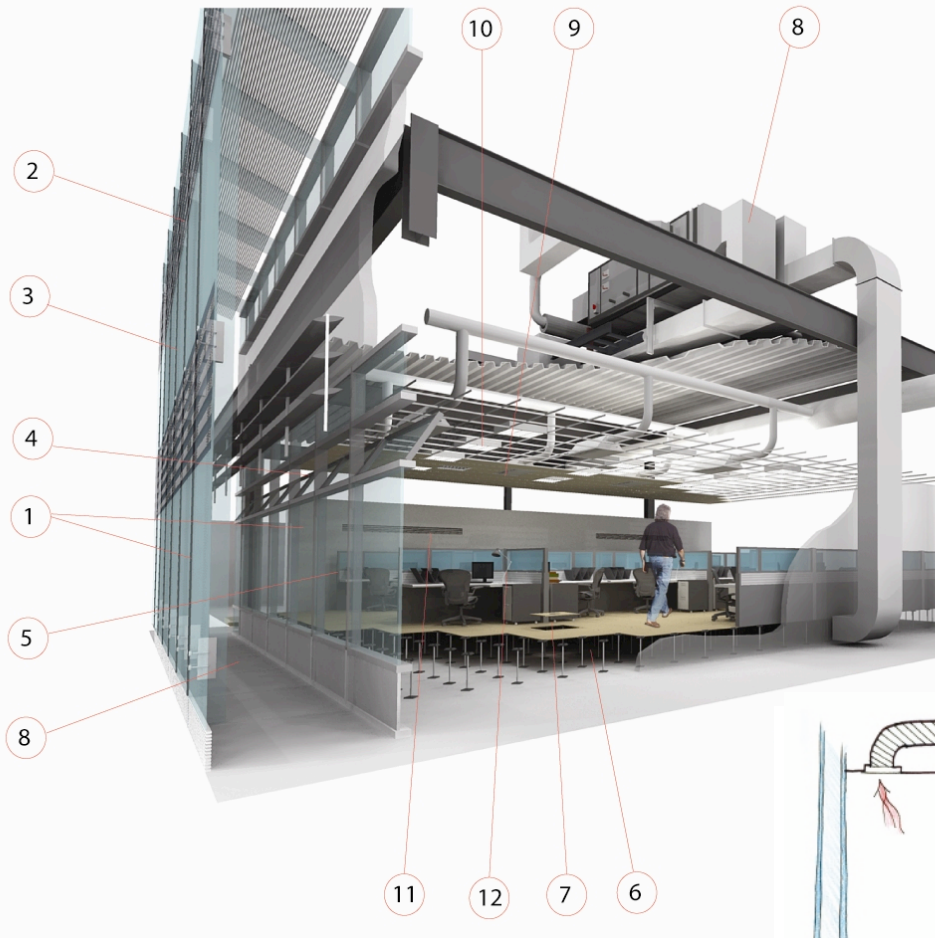
PBE Laboratory



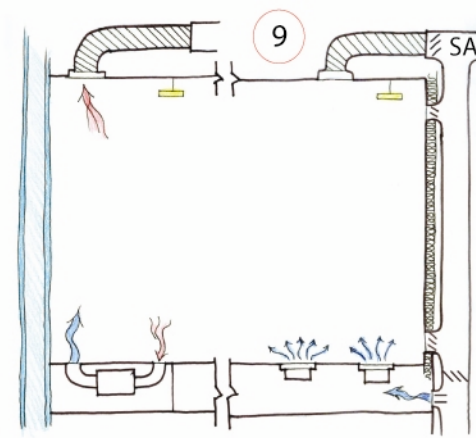
PERCEPTION BASED ENGINEERING (PBE) LABORATORY

1. ACCESSIBLE CEILING
2. OBSERVATION PANEL FOR RESEARCHER'S SUBJECT SUPERVISION
3. COVERABLE, ISOLATED 2-D SHAKER TABLE
4. RECONFIGURABLE WALLS/ROOM
5. OVERHEAD DOORS FOR VEHICLE/EQUIPMENT ACCESS
6. RECONFIGURABLE OVERHEAD UTILITIES
7. RECONFIGURABLE LIGHTING
8. SOUTH FACING DAYLIGHT EXPOSURE ALIGNED WITH CONFIGURABLE WINDOW/ WALL IN LAB
9. CONTROL ROOM AND SUBJECT RECEPTION AREA

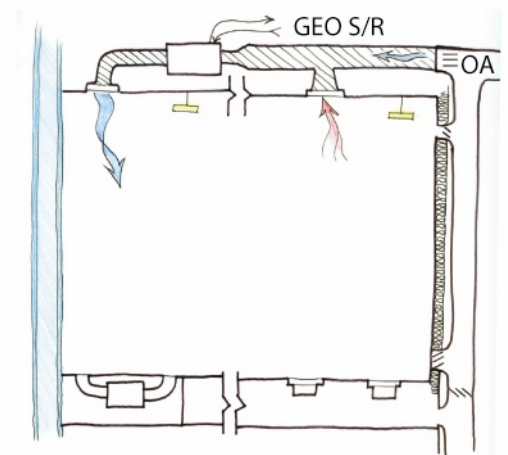
Living Laboratory (Air Room)



- A. RECONFIGURABLE EXTERIOR WALLS WITH OPPORTUNITIES FOR:
 1. DOUBLE SKIN FACADE
 2. INTEGRATED PV PANELS
 3. ADVANCED GLAZING MATERIALS
 4. NATURAL VENTILATION
 5. CONTROLLABLE GLAZING: VISIBLE LIGHT TRANSMITTANCE AND THERMAL PERFORMANCE
- B. AIR HEATING AND COOLING SYSTEM WITH OPPORTUNITIES FOR:
 6. UNDERFLOOR AIR DISTRIBUTION
 7. PERSONAL VENTILATION CONTROL
 8. PRIMARY AIR SYSTEM WITH BROAD DELIVERY RANGE
 9. RECONFIGURABLE OVERHEAD DISTRIBUTION
- C. LIGHTING OPPORTUNITIES:
 10. RECONFIGURABLE OVERHEAD FIXTURES
 11. WALL FIXTURES
 12. TASK FIXTURES

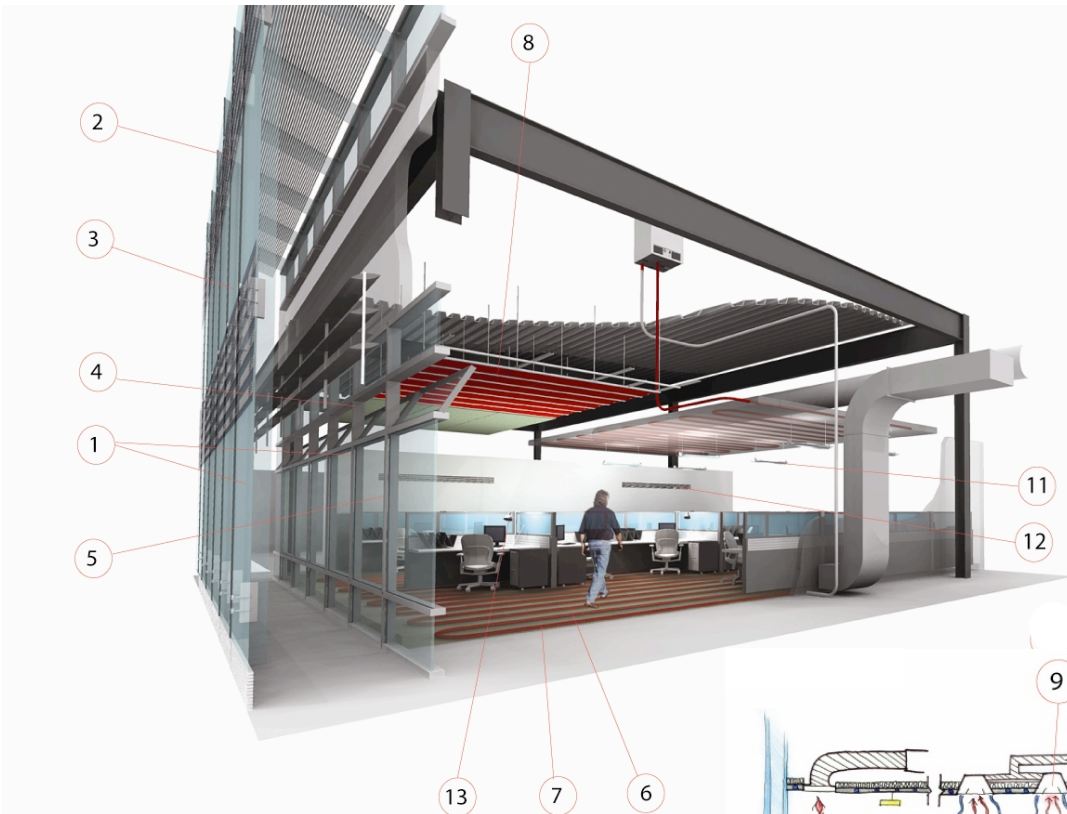


MODE 1A: UNDER FLOOR AIR DISTRIBUTION

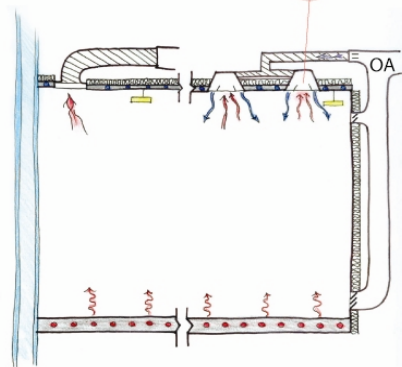


MODE 1B: GROUND SOURCE HEAT PUMP WITH DEDICATED OUTSIDE AIR SYSTEM

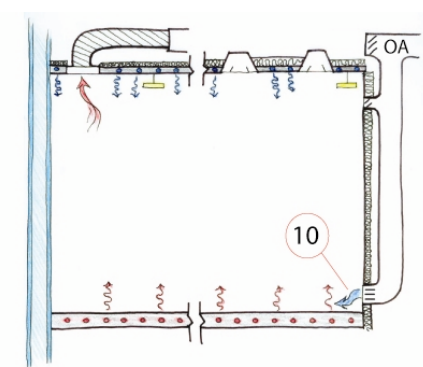
Living Laboratory (Hydronic Room)



- A. RECONFIGURABLE EXTERIOR WALLS WITH OPPORTUNITIES FOR:
 1. DOUBLE SKIN FACADE
 2. INTEGRATED PV PANELS
 3. ADVANCED GLAZING MATERIALS
 4. NATURAL VENTILATION
 5. CONTROLLABLE GLAZING: VISIBLE LIGHT TRANSMITTANCE AND THERMAL PERFORMANCE
- B. HYDRONIC HEATING SYSTEMS WITH OPPORTUNITIES FOR:
 6. RADIANT FLOOR HEATING
 7. INTEGRATED THERMAL MASS
- C. HYDRONIC COOLING SYSTEMS WITH OPPORTUNITIES FOR
 8. RADIANT CEILING PANELS
 9. ACTIVE AND PASSIVE CHILLED BEAMS
 10. DISPLACEMENT VENTILATION
- D LIGHTING OPPORTUNITIES:
 11. RECONFIGURABLE OVERHEAD FIXTURES
 12. WALL FIXTURES
 13. TASK FIXTURES

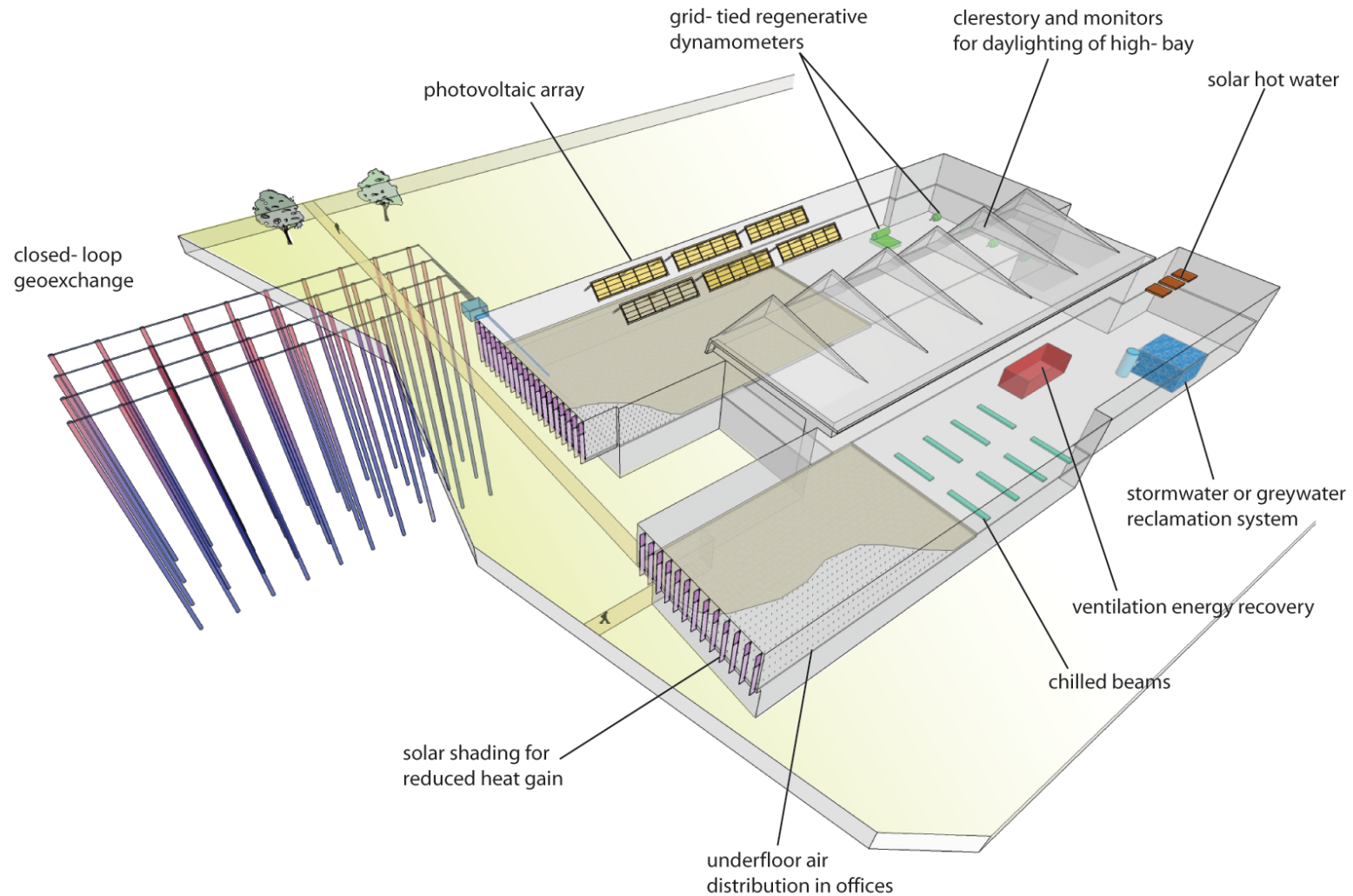


MODE 2A: RADIANT FLOOR HEATING WITH ACTIVE CHILLED BEAM COOLING



MODE 2B: RADIANT FLOOR HEATING WITH RADIANT CHILLED CEILING AND DISPLACEMENT VENTILATION

Whole-Building Energy Features



SUSTAINABLE DESIGN OPPORTUNITIES

Potential Purdue Collaborators

Mechanical Engineering: Indoor Air Quality, Systems Modeling, HVAC&R Equipment, Intelligent Controls and Diagnostics, Acoustics, Sound Quality, ..

Architectural Engineering: Lighting/Daylighting, Building Envelope Modeling, Sustainable Building Design, ...

Electrical Engineering: Wireless sensor networks, intelligent agent controls, ..

Psychology: Human perceptions of indoor climate variables and impacts on productivity

Mechanical Engineering Technology: Technology transfer

Building Construction Management: Process tools

Physical Facilities: Testing of new technologies on campus-scale testbeds

Specific Collaboration Opportunities

- Participation in the development of the new Herrick Laboratory facilities
- Large-scale center proposals (e.g., NSF ERC)
- Specific opportunities arising from the new administration
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