Two Decades of Research Developments in Building Design:
From Specialization to Globalization

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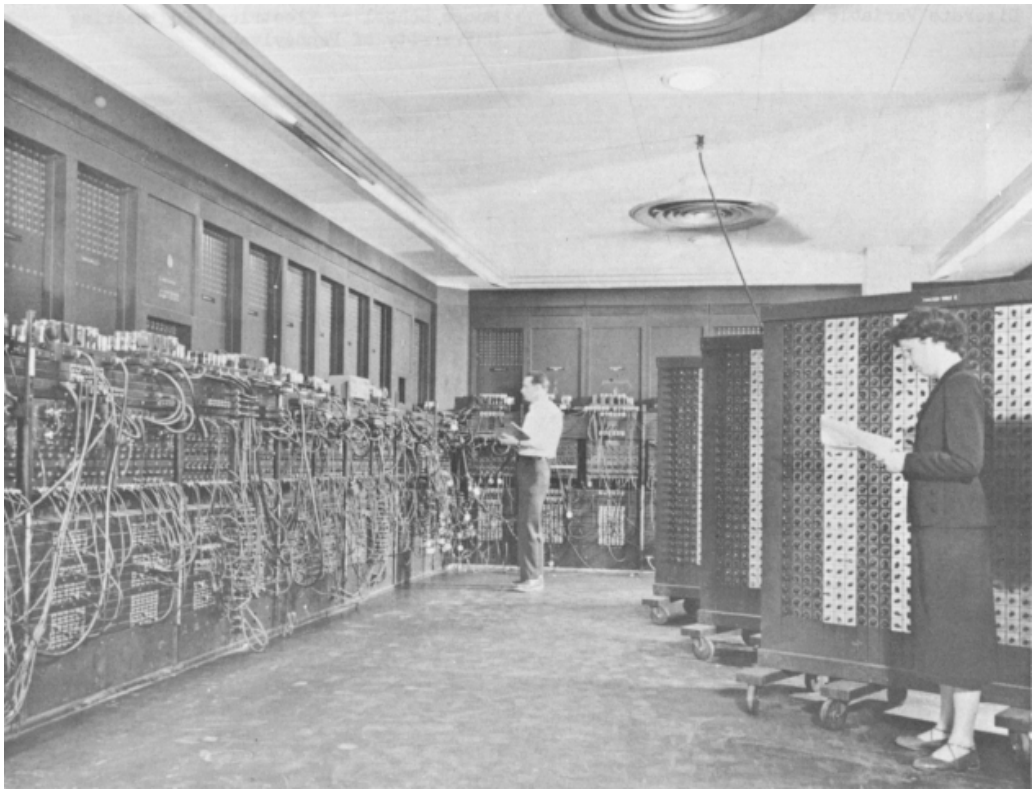
Overview

- Introduction: the early days
- Situation 20 years ago
- Momentous changes
- Research in CABD over the last 20 years
- Current work
- Conclusions: research philosophy
- Future of building design research

Introduction: the early days - From Pascal to PASCAL

- First machines:
  - from Pascal (1640s) through
  - Babbage (1850s) to
  - ENIAC (late 1940s)



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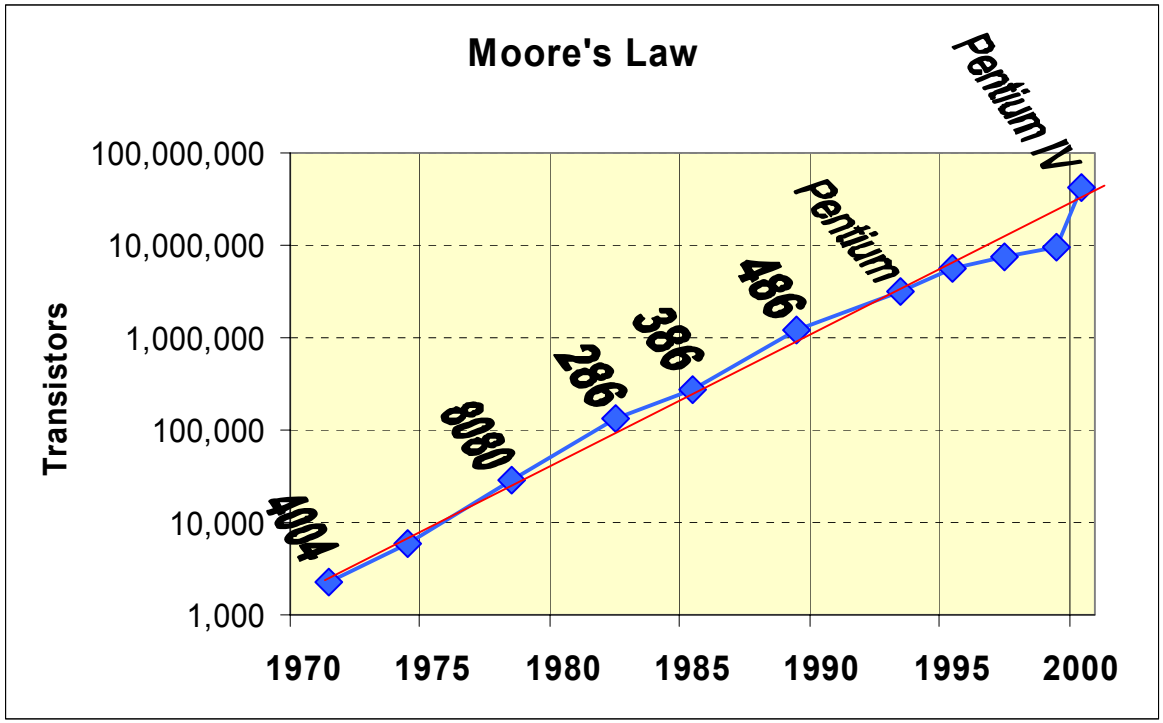
  - matrix stiffness method in structural engineering leads to algorithms coded in programs
- By end of 50s: discretization and programs lead to
  - powerful computational methods e.g. FEM,
  - first application software in construction e.g. COGO, STRESS

Introduction: the early days

- Accelerated developments through 60s and 70s:
  - Hardware (CPU): Moore's law

The number of transistors on a chip ***doubles*** every 18 to 24 months



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  - Successive advances in User Interface
  - Explosion in application software for organized tasks:
    - mostly at the prototype level in construction

Situation 20 years ago

- A 1981 symposium "CABD: Building into the Future":
  - Much emphasis on automated drafting (CAD)
  - Main research agenda items identified in order to realize productivity gains in construction:
    - integration of different specialists during the same project
    - help design as early as possible since the most important decisions over the building life-cycle are taken early
  - Concern about low penetration of IT in construction
    - IT not cost-effective in real projects (prototype applications) and
    - hardware very expensive

Situation 20 years ago

- Situation in building design research around 1980:

  Feasibility of IT tools and techniques clearly established

  BUT such tools remain very specialized and restricted in scope

Momentous changes

- Two main events 20 years ago stimulated CABD research:
  - Advent of PC
    - cheap and easy to use, thus small firms and individuals can buy and use,
    - 2000 survey of Canadian construction industry demonstrates current penetration of PCs in construction firms
  - Research prototypes in AI are shown to be usable in construction, thus IT can be applied to non-algorithmic tasks in construction like design.

Research developments in CABD over the last 20 years

- Note: following presentation by means of projects completed at the CBS
  - projects presented in chronological order
  - projects representative of building design research elsewhere

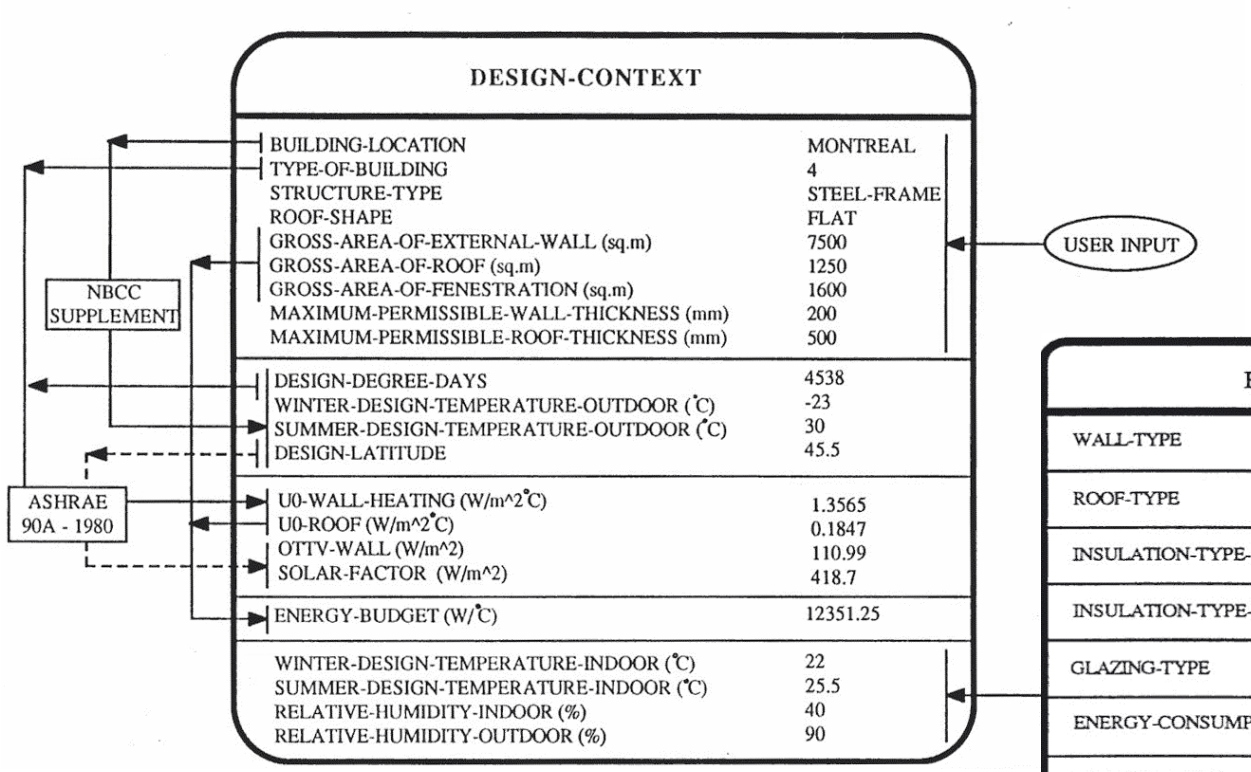
Building envelope design assistant

- Envelope: critical building system, subjected to many factors/influences, responsible for much litigation
- Typical multidisciplinary problem, hence falls outside traditional disciplines
- Design process never before organized systematically
- Approach: prototype KBS "BEADS" developed with mainframe-based development shell using hybrid knowledge representation (frames and rules) and procedural attachments

Building envelope design assistant (cont'd)

- BEADS proved capable of:
  - Design decision-making using knowledge from a variety of sources
  - Maintaining designer's freedom
  - Being used at early stage with little technical knowledge (architect)
  - Making meaningful comparisons among design alternatives

Building envelope design assistant (cont'd)

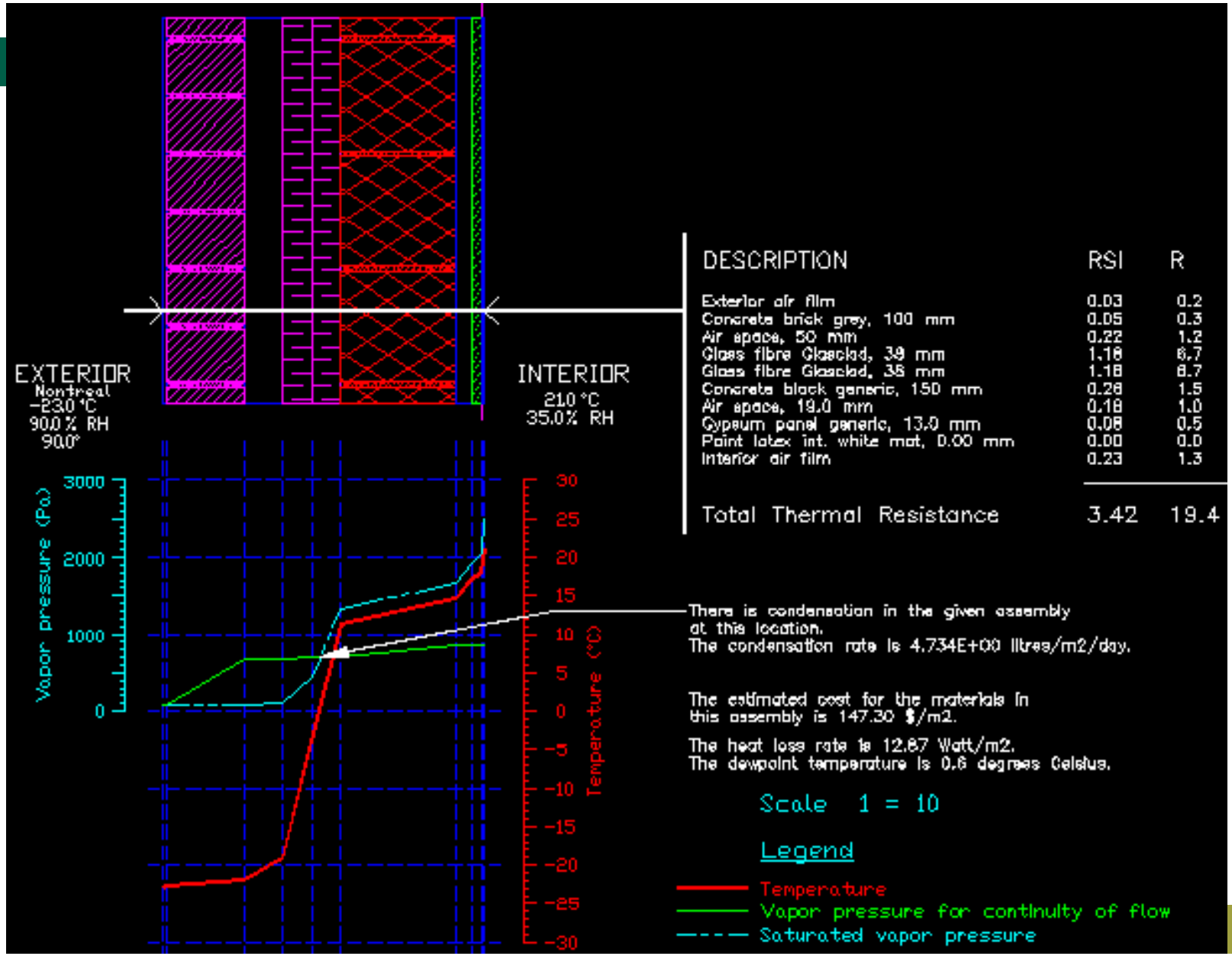


FEASIBLE-ALTERNATIVE-54		
WALL-TYPE	STUCCO-ON-CONCRETE-WALL	
ROOF-TYPE	BUILT-UP-OR-SINGLE-PLY-ON-METAL-DECK	
INSULATION-TYPE-FOR-WALL	GLASS-FIBRE-BOARD	
INSULATION-TYPE-FOR-ROOF	RIGID-GLASS-FIBRE	
GLAZING-TYPE	DOUBLE-GLAZING	
ENERGY-CONSUMPTION	2701.26	(W/ °C)
MATERIAL-COST	594982.0	($)
TOTAL-THICKNESS-OF-WALL	281.5	(mm)
TOTAL-THICKNESS-OF-ROOF	140.0	(mm)
UTILITY-VALUE	32.3 9.8 1.4 10.6 10.5	

Building envelope design assistant (end)

- BEADS remained at the "proof of concept" level only, thus had no impact on practice because of complexity and cost of using development shell
- Spin-off development a few years later:
  - Incorporates part of BEADS in PC-based design environment
  - CONDENSE:
    - add-on to AutoCAD coded in AutoLISP with GUI,
    - proves to be very effective technology transfer to construction industry - more than 1000 copies currently in use across North America

CONDENSE


EXTERIOR
Montreal
-23.0 °C
90.0 % RH
90.0°
INTERIOR
21.0 °C
35.0% RH
DESCRIPTION RSI R
Exterior air film 0.03 0.2
Concrete brick grey, 100 mm 0.05 0.3
Air space, 50 mm 0.22 1.2
Glass fibre Glasclad, 39 mm 1.18 6.7
Glass fibre Glasclad, 38 mm 1.18 6.7
Concrete block generic, 150 mm 0.20 1.5
Air space, 19.0 mm 0.18 1.0
Gypsum panel generic, 13.0 mm 0.08 0.5
Paint latex int. white mat, 0.00 mm 0.00 0.0
Interior air film 0.23 1.3
Total Thermal Resistance 3.42 19.4
Vapor pressure (Pa)
3000
2000
1000
0
Temperature (°C)
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
There is condensation in the given assembly at this location.
The condensation rate is 4.734E+00 litres/m2/day.
The estimated cost for the materials in this assembly is 147.30 $/m2.
The heat loss rate is 12.67 Watt/m2.
The dewpoint temperature is 0.6 degrees Celsius.
Scale 1 = 10
Legend
Temperature
Vapor pressure for continuity of flow
Saturated vapor pressure

Preliminary design of multi-story office buildings

- Design assistant for space layout and floor layout, and development of compatible structural systems
- Approach: frame-based KBS development tool on PC, used multidisciplinary design criteria, assembled knowledge repository from many sources
- Direct validation by two building designers (architect and structural engineer) against projects already completed and built

CABD research projects in wind engineering

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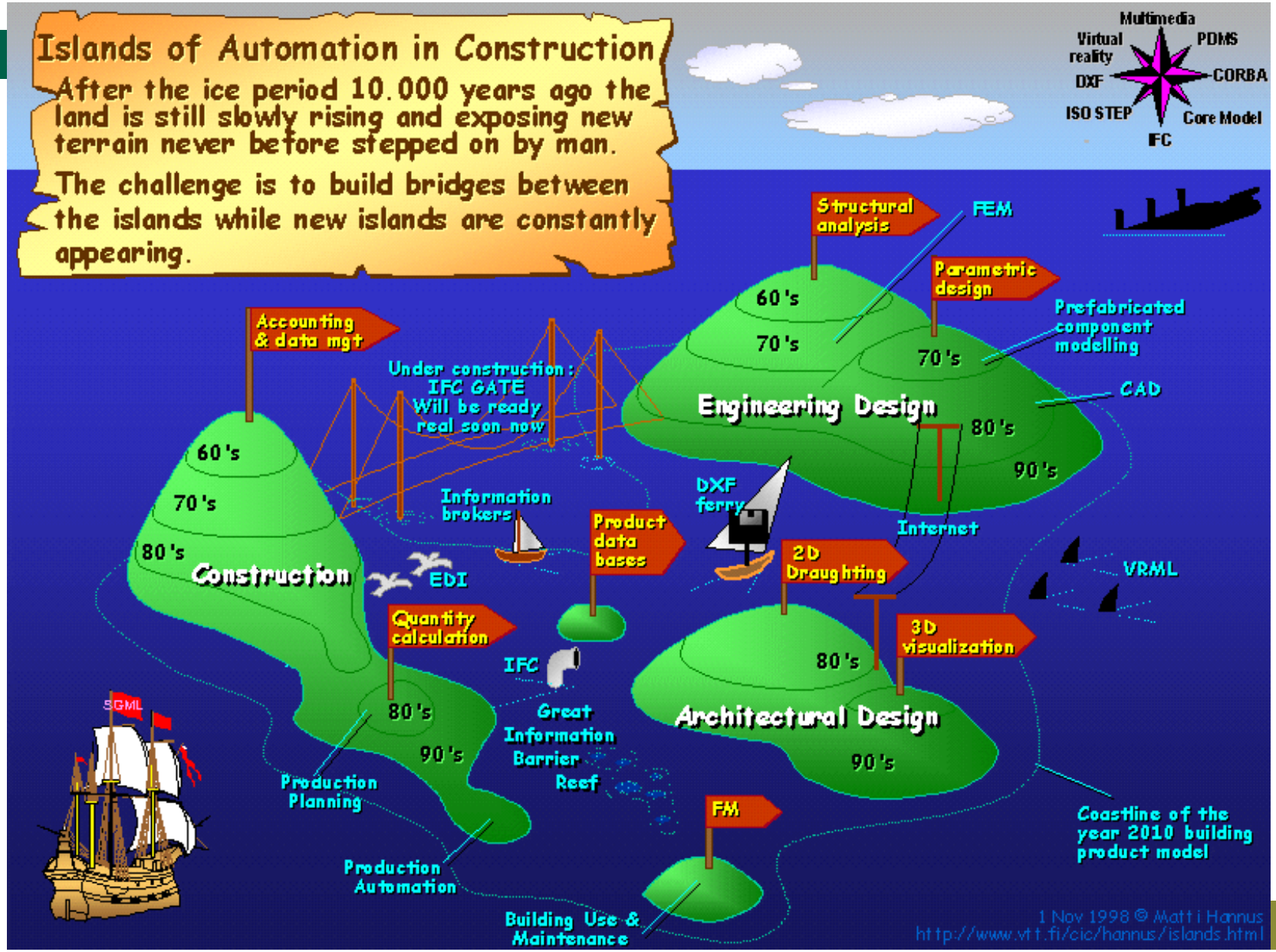
  - and predict wind interference effects in the case of two buildings
  - and predict impact of complex terrain conditions on wind loads

Computer integration of design and construction information

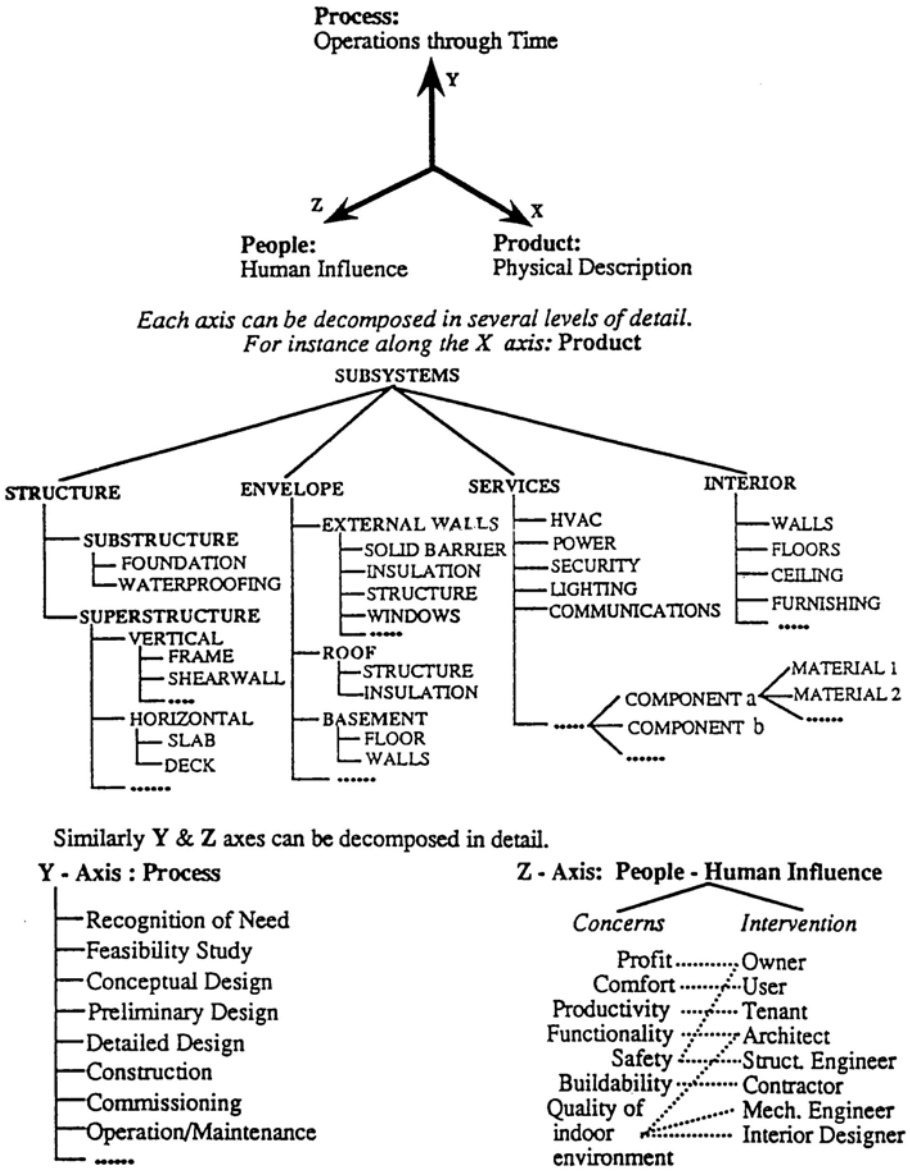
- The construction industry has a level of fragmentation unparalleled in other industries.
- Applications are characterized by islands of automation.
  - Applications are self-contained and unable to communicate among themselves
  - Users must interpret and transfer data manually.
- Much research effort has gone toward addressing this problem.

Islands of Automation



Computer integration of design and construction information

- At the Centre for Building Studies, the integration of the various views of building design has always been of the utmost importance.
- The **'3P model'** was proposed to provide a means of visualizing integration in research.



Computer integration of design and construction information

- An outcome of BEADS was the realization of the lack of shared data representation in envelope design.
- An analysis of the needs during this design process resulted in a representation for the building envelope.
- Expanded later to a more comprehensive representation for conceptual building design:
- This representation satisfied these requirements:
  - integrate multiple views
  - support design evolution
  - provide for design exploration
  - be extensible

Computer integration of design and construction information

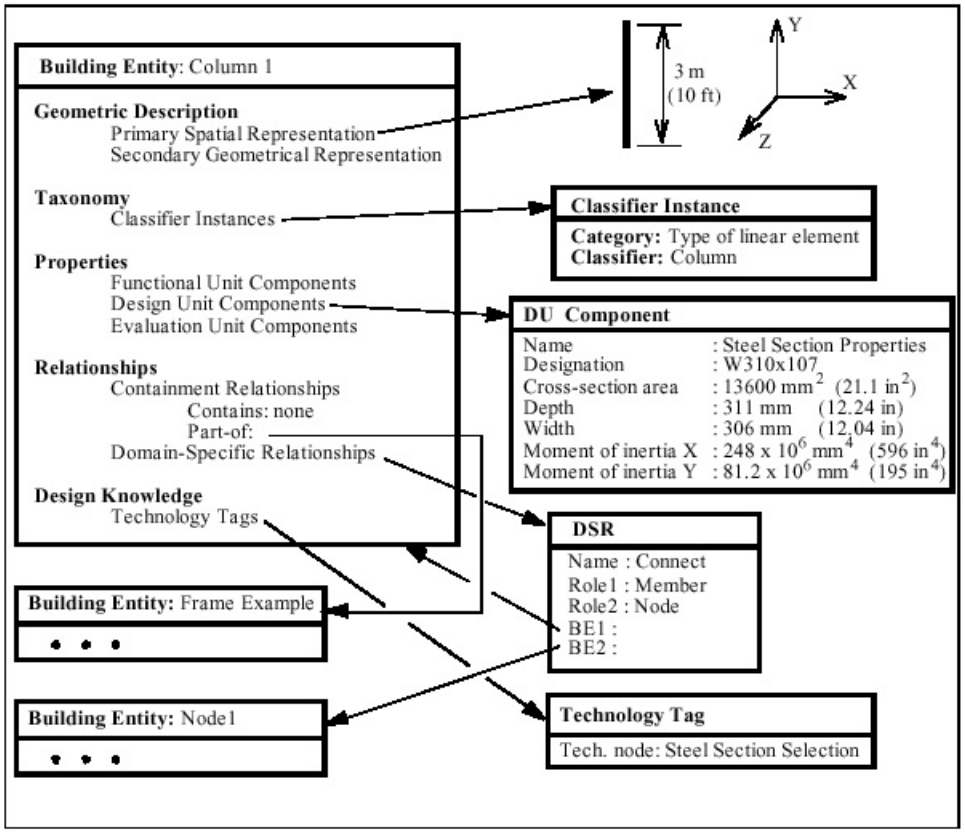


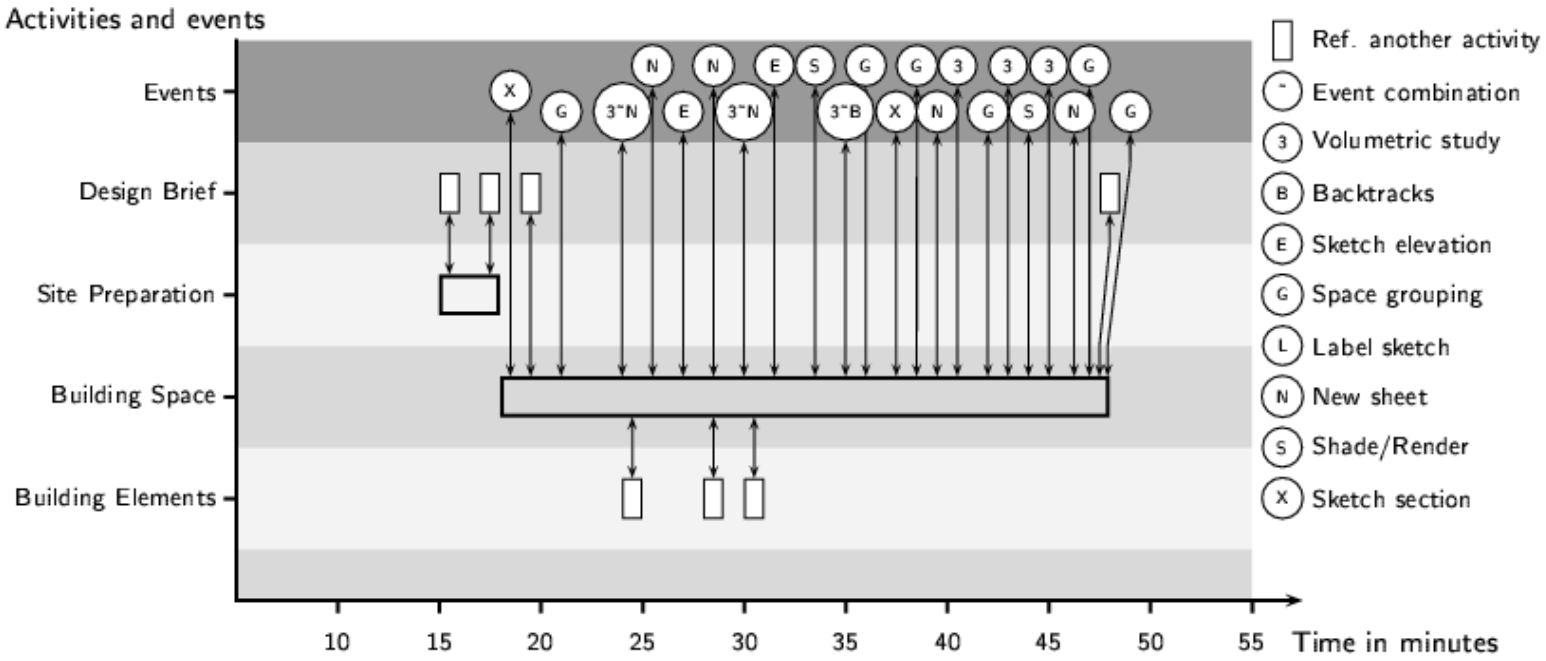
Figure 3. An example of a building entity and a portion of its data.

Current work

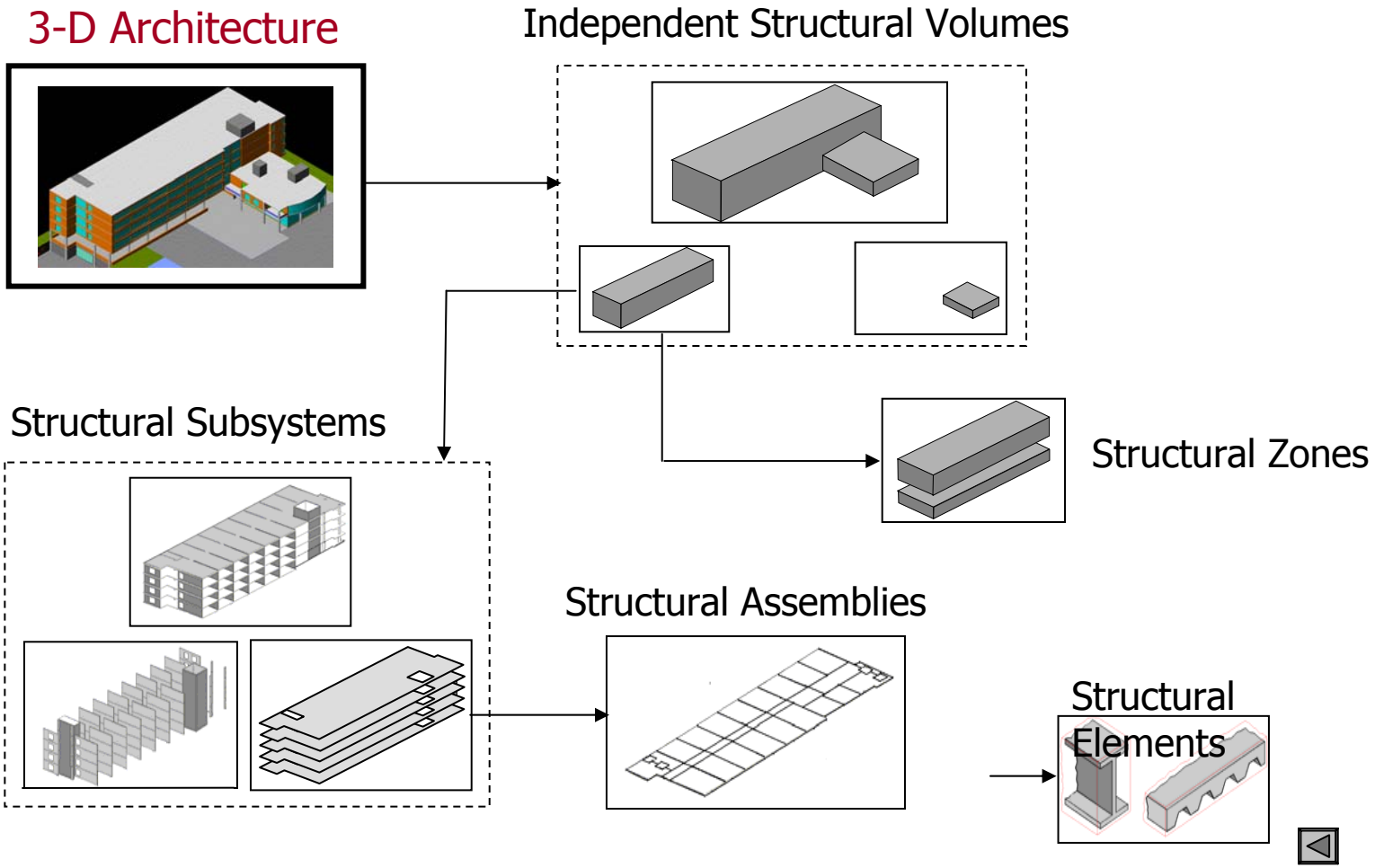
- Computers have become ubiquitous in the industry.
  - But use is mostly dedicated to the later stages.
- Conceptual design is not well supported and designers must resort to sketches for exploring ideas.
  - But, it is during this stage that major decisions are taken with the greatest impact on the final form, constructibility, costs, and overall performance.
- Several efforts are addressing this issue.

Conceptual Design

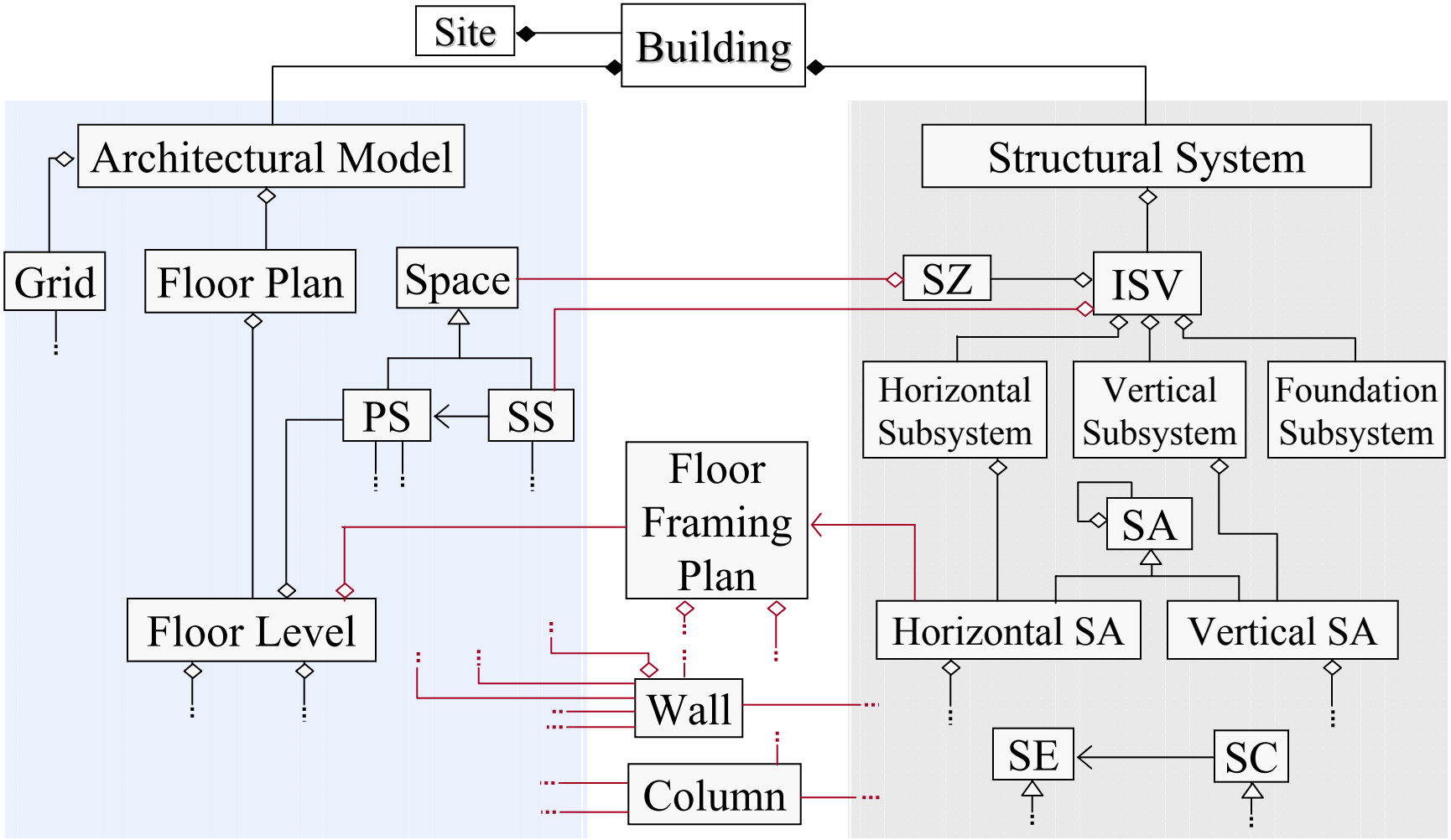
- A study of eight architects at work was conducted.
- Protocol analysis.
- Resulted in a set of specifications for computer tools



Architecture/Structure Interaction



Conceptual Design Representation



Conclusions: research philosophy

- Last 20 years of CABD research as reflected in W78 meetings has reported tremendous developments on hardware and software fronts.
- Trend everywhere has been from isolated and specialized applications to environments capable of communicating with others, performing many tasks, encompassing different concerns.
- In other words, priority research agenda items stated 20 years ago are still perfectly valid

Conclusions: research philosophy

- Our research philosophy is fully consistent with the above agenda.
- long-term goal: **produce better buildings**, hence consider all types of buildings, under all performance conditions, throughout their life-cycle
- primary focus remain
  - integration,
  - enable design decisions as early as possible
- keep designer in charge, solving meaningful problems in a natural way

Future of building design research

- Enable greater integration
- Augment human designer capabilities
- Design for sustainability