Part I: Course Outline
1. Introductions
2. Principles
3. Scope
4. Values to instill
5. Intended Results
6. Course Logistics, Schedule, Grading, etc.

Part II: Development of Construction Technologies
- Innovation in Construction
- Obstacles and Drivers

Part III: Elements of Building
1. Building Systems
   i. Definitions
   ii. CSI Division placement

These notes are a test.
Images:


Part I: Course Outline

Principles

1. **Cultural Context**: Technology exists within a cultural context. Therefore, contemporary building technology derives from a rich historical and cultural evolution of technique and form that augments the ability to design intelligently.

2. **Holistic Building**: Understanding individual building components and the details necessitates understanding the guiding architectural intentions, performance requirements, process of manufacture and assembly, and systematic organization of various building assemblies.

3. **Invention**: Architectural invention is the medium for the determination of form at all scales and permeates the physical architectural result. The making of details is not a deterministic process that seeks to optimize a singular solution. Be careful of optimization. “Il n’y a pas de détail dans la construction”
Scope of Course

1. History and Theory of Building
   Systems and
   Architectural Components

2. Statics of architectural structures
   i. Structural Morphology
   ii. Basic structural elements and
       force systems
   iii. Equilibrium equations
   iv. Material behavior

3. Building Systems
   i. Performance requirements
   ii. Identification and specification of
       elements

4. Sustainable Strategies
   i. Best practice
   ii. Resource efficiency

5. Materials: New and Old

6. Systems Integration
Values to instill

1. Possibility of Invention: both for engineers and architects

2. Craft of New and Old Technologies: good practice and new processes

3. Critical View of Product-Driven Design

Intended Results

1. Familiarity with requirements of architectural assemblies
2. Understanding of broad range of “good” solutions
3. Understanding of contemporary issues in the design of architectural assemblies
4. Understanding of design process
5. Understanding of construction process
6. Identification of opportunities for “invention”
7. The initiation of a career-long study of the expressive potential inherent in the solution of technical assembly and construction situations.
8. Development of strategies for collaboration between disciplines
Course Logistics
Schedule and Grading
Part II: Development of Construction Technologies

Drivers for Innovation: 1900-1980
1. Industrialization and Standardization
2. Modularization of Buildings and Building Components
3. Materials Science
4. Computational Technologies
5. New Structural Morphologies
6. Mathematical Analysis Techniques
7. Systems Isolation and Development

Images:
Jean Prouve
Obstacles for Innovation: 1900-1980

“Fragmented” industry
“Fragmented” process
   Design: the rise of the specialized consultants
   Construction: numerous trades/subcontractors, the rise of the construction manager

Primary Research Interests: 1980
Coordinating resources and interests of fragmented industry
Computational modeling and controls
Technology Transfer from Materials Research
   Polymers (Albert Kahn, Eero Saarinen)
   Composites
   “High Performance” materials
      Alloys
      Ceramics
      Etc.
Successes: 1900-1980

- Polymers (sealants, coatings, membranes, adhesives, nonwoven fabrics)
- Metals (especially thin films, Low-e glass)
- Composites: FRPs, GFRP, CFRP
- Digital Technologies: CAD/CAM, Simulation Software, Project Management, etc.
- Cable net and Fabric Structures (with limited use)

Failures

- Modular Building (except at the very low end of the market)
- Concrete Shells and Hyperbolic Paraboloids (new morphologies)
- “Fordist” Mass production and assembly
- High Performance composites (that is, carbon and glass reinforced materials)

Kresge Auditorium at MIT. Image courtesy of HABS and Structurae
Drivers for Innovation Now

Global Economy
  Competition and Alliances across sovereign borders
  New Markets (esp. China, rest of Asia, and former Soviet Republics)

Sustainable Strategies
  Energy Efficiencies
  Materials Acquisition and Processing (Resource Efficiencies)
  End of Life Materials Reuse (Life Cycle Costing)

Technological Advance
  Improved Technology Transfer (Process Engineering, simulation technologies, Management Technologies etc.)
  Materials Science
  Digital Technologies

Future Developments

Materials
  The integration of various materials together into premanufactured assemblies and composites
  Specification by performance

Processes
  Removing as much specialized “expertise” (knowledge) from the construction site as possible

Morphologies
  Inventing new forms that use materials more efficiently and employ time-saving construction methods (Pantograph example)
  Integrating building systems together in a synergistic way (German Parliament Building)
Obstacles for Innovation: 2001

“Fragmented” industry
“Fragmented” process
    Design: numerous consultants and project components
    Construction: numerous trades/subcontractors
Relatively Low R&D investment by construction related Industries
Continuing underestimation of the level of investment necessary for “real” innovation, proof of concept and market entry
Continuing disciplinary specialization of the various scientific, professional and business interests all involved in the construction process
• Average time period necessary for a technical advance (from lab) to reach market = 17 years in the U.S.

• Easier (in terms of regulatory hurdles) to insert new materials into the human body than into buildings.

• For every $1 of laboratory research conducted, $10 must by spent for proof of concept and product development and, $100 dollars must be spent for industrial retooling and market entry.

• Average level of Research and Development for all U.S. industries approaches 5% of gross revenue.

• The construction industry only invests 0.5% of annual gross revenue.

• Currently the construction industry in the U.S. accounts for 8% of annual GDP.
Energy

Total energy use for buildings in developed nations at an historical high.
Overwhelming reliance on fossil, nonrenewable fuels.
Little domestic incentive to reduce energy consumption by buildings.
Little domestic incentive to increase material use efficiency.

Facts:
Buildings now account for ½ of energy consumption in the western world.
Buildings now account for 1/3 of energy consumption in the entire world.
¾ of the world’s energy output is consumed by ¼ of the world’s population.
70 % of domestic (U.S.) materials consumption attributed to construction industry (by weight).
Materials

Smart and lightweight materials (tessellated fabric example)
Appropriate technologies
Responsive, polyvalent materials
Micro and nano devices and assemblies
Composites (GFRPs, glass laminars, coatings)

Processes

Intelligent tools and systems for improved decision-making processes
Computational and other Digital Technologies
Large Scale Construction Methods
Robotics and Artificial Intelligence

Morphologies

More complex composite and hybrid structures and intricate interior-exterior interfaces (thermal, solar radiation and mass transfer dynamics)
Panel technologies: ultrathin
Integrated structure and exterior wall assemblies
Part III: Elements of Building

1. Building Systems
2. Cost
3. Lifetimes/Durability
4. Performance Requirements
5. Integration of Building Systems

Systems
- Foundations
- Superstructure
- Exterior Envelope
- Interior Partitions
- Mechanical Systems

Image:
Building Systems: Definitions

1. Foundation/Subgrade (SITE)
2. Superstructure (STRUCTURE)
3. Exterior Envelope (SKIN)
4. Interior Partitions (SPACE PLAN)
5. Mechanical Systems (SERVICES)
6. Furnishings (STUFF)

Images:
- Daly, Genik: Valley Center, CA, 2000.

Source: Stewart Brand, How Buildings Learn.
Building Systems: Definitions

1. Foundation/Subgrade (SITE)
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Source: Rush, Richard
The Building Systems Integration Handbook.

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Cost over time

1. Foundation/ Subgrade structure 10%
2. Structure (superstructure) 30-40%
3. Exterior Wall 10-20%
4. Interior Partitions 10%
5. Mechanical Devices 30-40%
Lifetimes

1. Foundation/Subgrade  50-100+
2. Superstructure        50+
3. Exterior Wall         25+
4. Interior Partitions   10-30
5. Mechanical Devices   20

Sir Norman Foster and Partners, Hong Kong Bank. 1995.
Image courtesy of Nicolas Janberg of Structurae
Performance Requirements

1. Foundation/ Subgrade structure
   i. Dead and live load transfer

2. Superstructure
   i. Dead and Live load transfer
   ii. Lateral force resistance and stability

3. Exterior Wall
   i. Maintenance of interior environment

4. Interior Partitions
   i. Programmatic spatial definition
   ii. Acoustic separation

5. Mechanical Devices
   i. Maintenance of interior environment
Integration of Building Systems

1. Foundation/ Subgrade structure
2. Structure (superstructure)
3. Exterior Wall
4. Interior Partitions
5. Mechanical Devices

Six General Performance Mandates

1. Spatial Performance
2. Thermal Performance
3. Air Quality
4. Acoustical Performance
5. Visual Performance
6. Building Integrity

From Rush, *The Building Systems Integration Handbook*
Building Systems: *C S I
Division Specifications

1. Foundation/Subgrade (*SITE*)
2. Superstructure
   (*STRUCTURE*)
3. Exterior Envelope (*SKIN*)
4. Interior Partitions (*SPACE PLAN*)
5. Mechanical Systems
   (*SERVICES*)
6. Furnishings (*STUFF*)

* Construction Specifications Institute
System 1: Foundations/Site

Spec. Divisions
Dependent on material
Div. 2 site work, Div. 3 concrete, Div. 4 masonry, Div. 5 metals, Div. 6 Wood and plastics.

Images:

F.L. Wright: Johnson Wax, 1944
Fabric foundation wall
FRP caisson cover
System 2: Superstructure

Spec. Divisions
Dependent on material
Div. 3 concrete, Div. 4 masonry, Div. 5 metals,
Div. 6 Wood and plastics.

Images:

Eladio Dieste
System 3: Exterior Envelope

Spec. Divisions
Dependent on material, but also identified in
Div. 7 thermal and moisture protection, Div.
8 doors and windows

Images:

Thomas Herzog, Aerogel Exterior
Envelope System
System 4: Interior Partitions

Spec. Divisions
Dependent on material, but also identified in Div. 9 finishes

Image:

Rick Joy House
System 5: Building Services

Spec. Divisions
Div. 11 equipment, Div. 13 special construction, Div. 14 conveying systems, Div. 15 mechanical, Div. 16 electrical

1. HVAC
2. Plumbing
3. Electrical
4. Fire Alarm System
5. Communications/Data
6. Audio Visual