System Architecture
An Overview and Agenda

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With inspiration from:

Rechtin, Maier, Koopman, Hastings, Vetrivius

Today's Topics

- **Objectives and Opportunities**
- **6 Views and Definitions**
- **Architecture Case**
- **Research Agenda**

Objectives

- To develop principles, methods and tools for system architecture synthesis, which:
  - Contain a holistic view
  - Represent emergence
- Insures the delivery of value
- Have utility to real practitioners

Opportunities

- **Expressed need**
- **Great leverage of architecture, and even greater leverage of architecture process and tools**
- **Great room for improvement and addition for rigor**
- **Opportunity for education and organizational change**

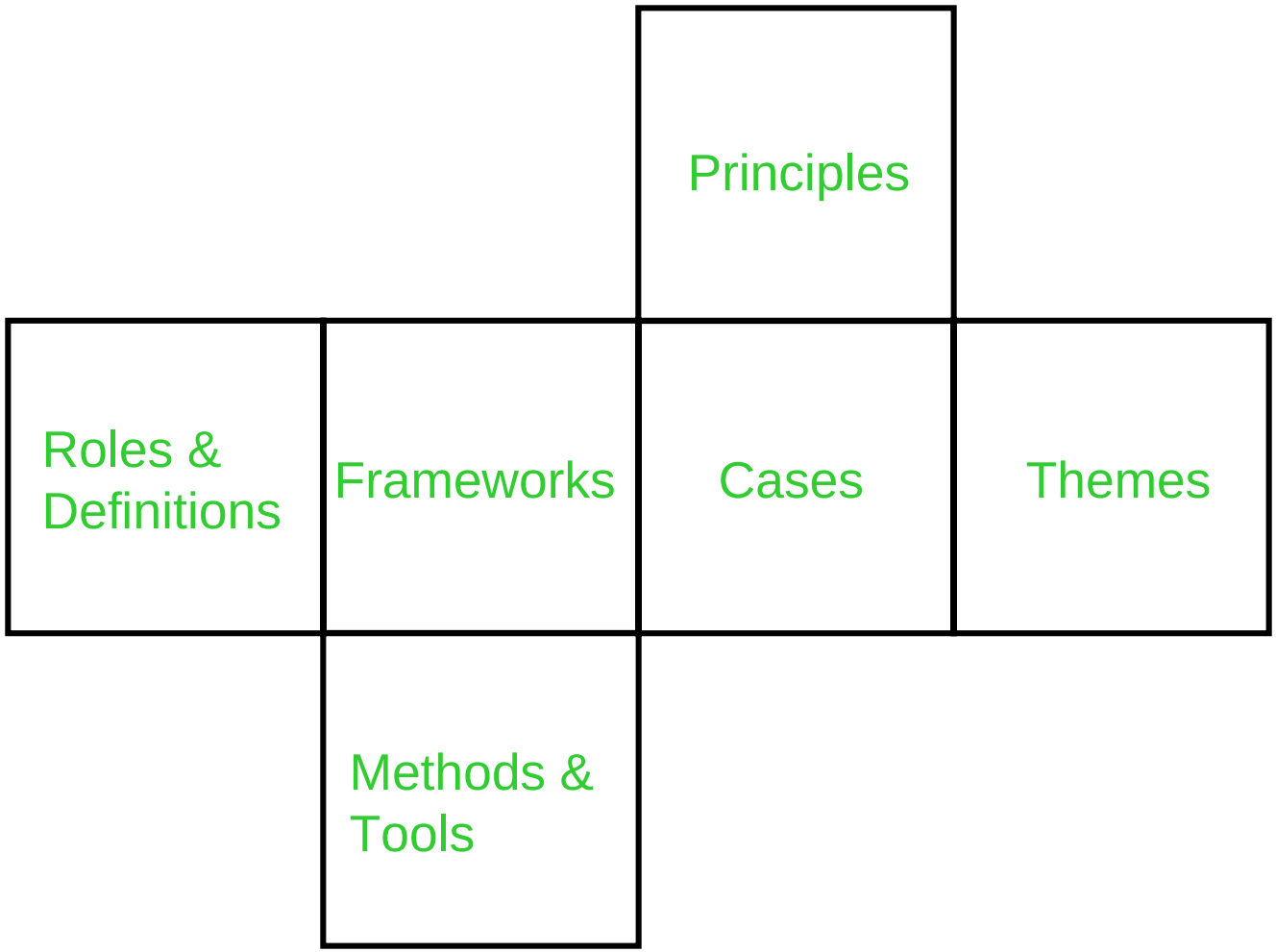
We have to build the intellectual foundation for the field of System Architecture

Progression of a Discipline

- **Observation**
- **Classification**
- **Symbolic representation**
- **Symbolic manipulation**
- **Analysis**
- **Synthesis**

Where are we in System Architecture?

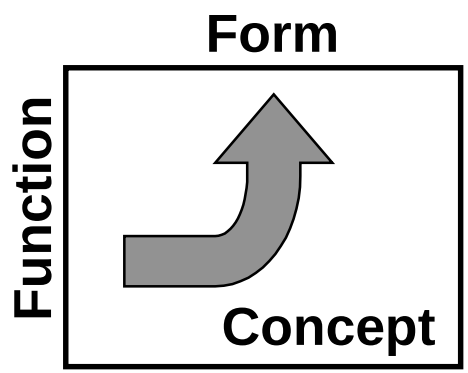
Architecture - 6 Views



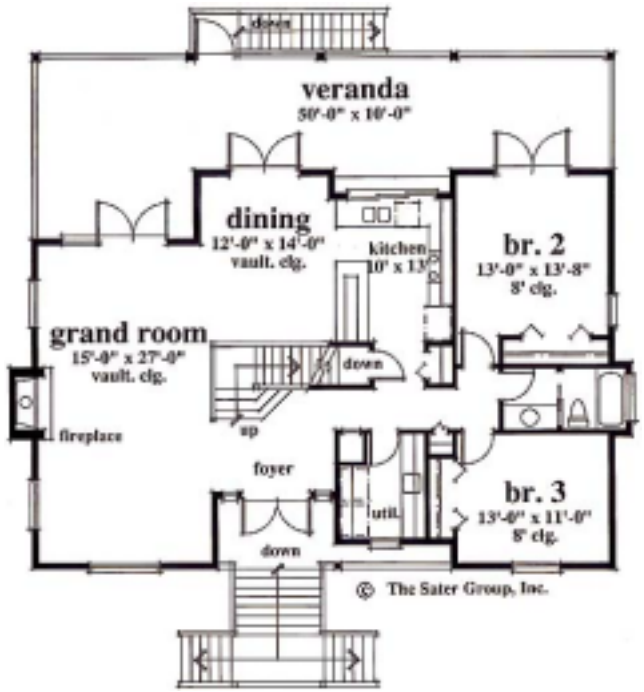
A Definition

- **Architecture**
  - **The embodiment of concept, and the allocation of physical/informational function (process) to elements of form (objects) and definition of structural interfaces among the objects**

- **Consists of:**
  - **Function**
  - **Related by Concept**
  - **To Form**

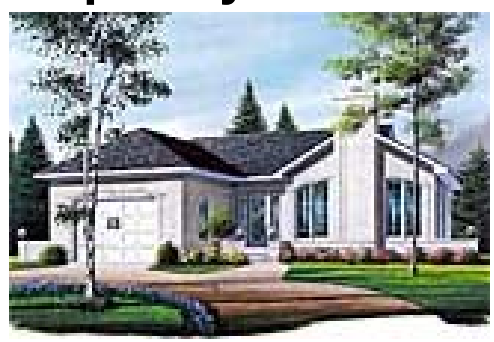


Architecture – Civil



Beach

Contemporary



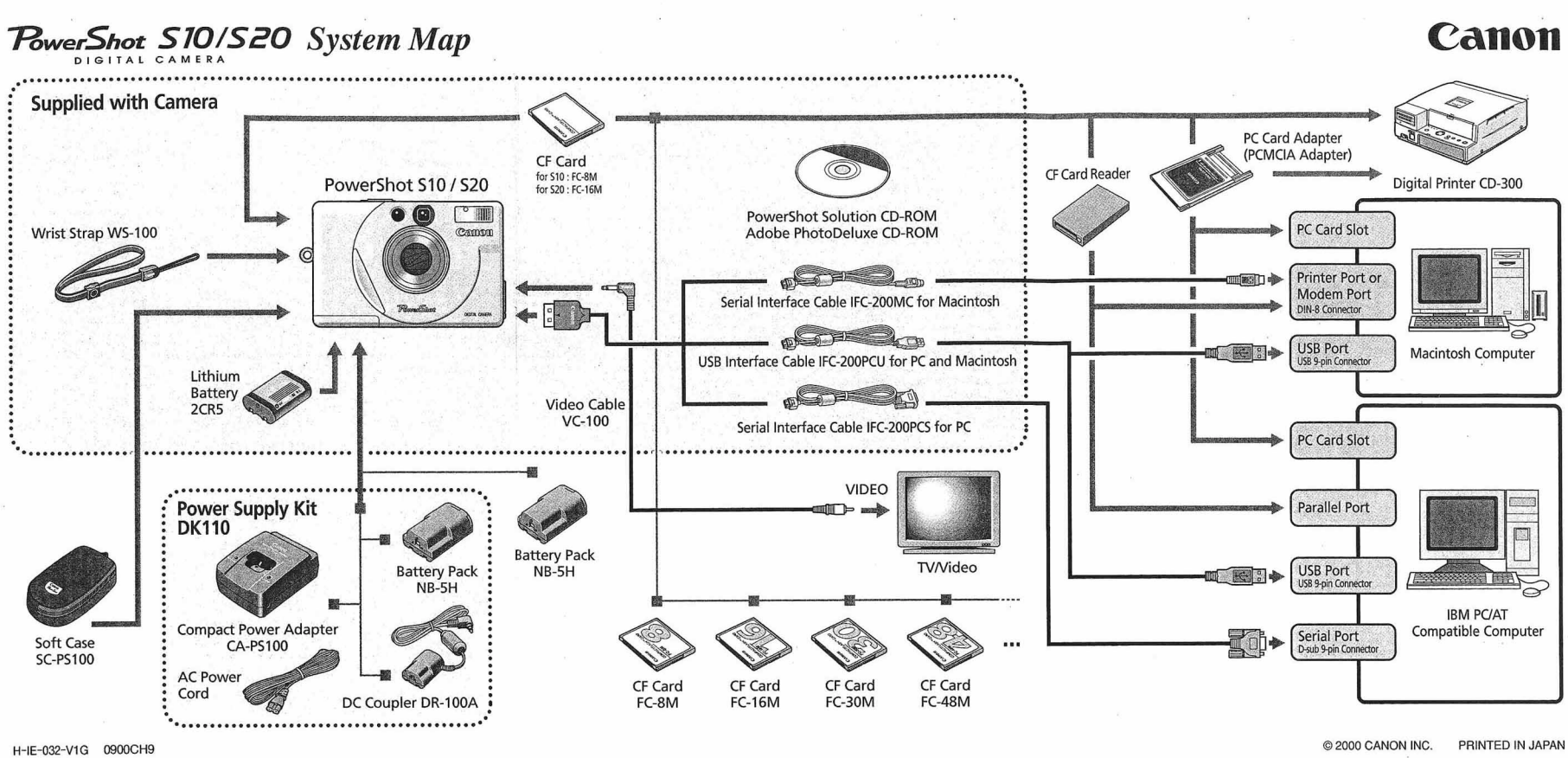
Source - www.coolhouseplans.com

Architecture – Mechanical

Suspension bridge

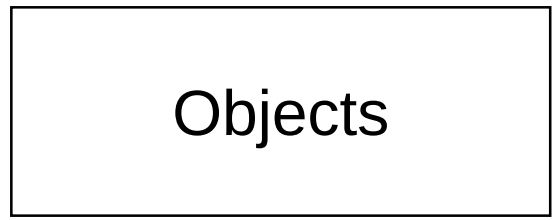
Cable-stayed bridge

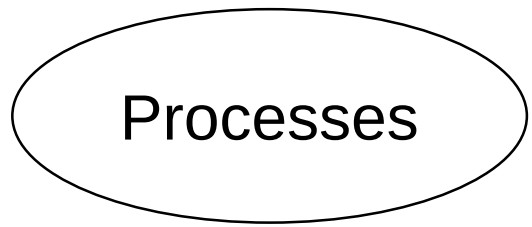
Architecture - Informational



A Tool - Object Process Modeling

- **Object: that which has the potential of stable, unconditional existence for some positive duration of time. Objects have states.**
- **Form is the sum of objects**
- **Process: the pattern of transformation applied to one or more objects. Processes change states.**
- **Function emerges from processes**
- **All links between objects and processes have precise semantics**



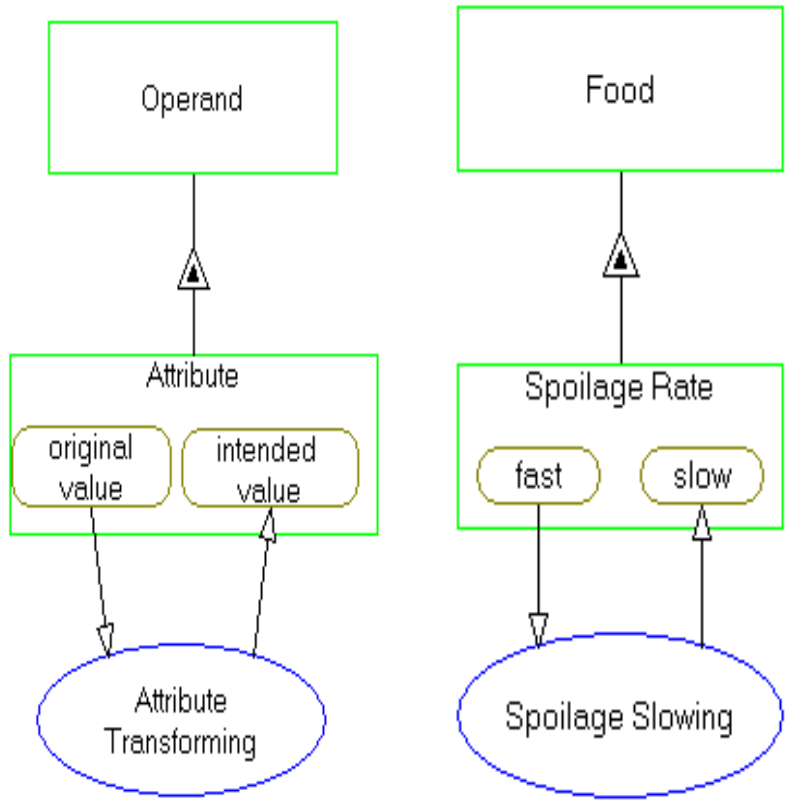


A Case - Refrigerator

- It is essential for ground system architecture in real world strength cases
- Examine the flow of information through three phases:
  - Reducing ambiguity*, by transforming a statement of value to goals
  - Exercising creativity* by defining concept
  - Managing the evolution of complexity*
- * The three themes are pervasive in architecture

Goals

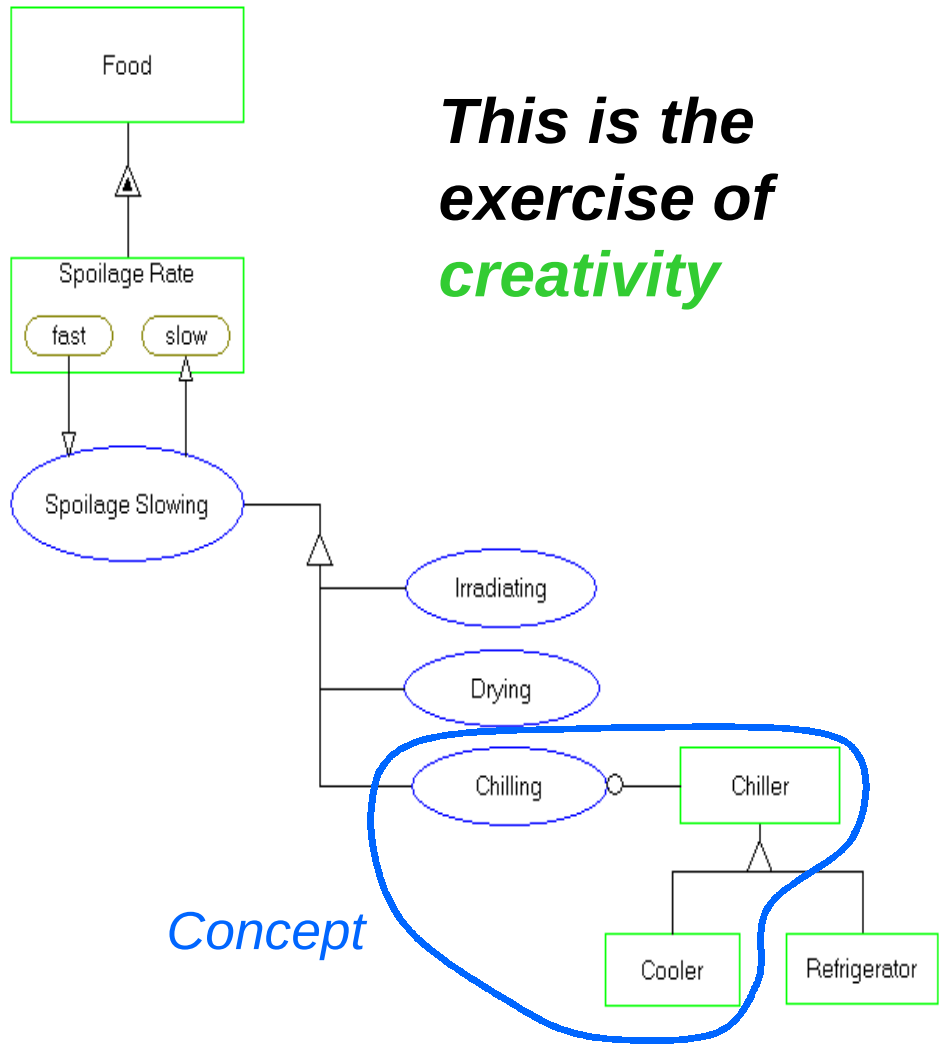
- **Start by examining the operand associated with value**
- **Next identify the attribute of the operand whose change is associated with value**
- **Next define the transformation of the attribute associated with value, in solution neutral form**



This will reduce ambiguity and lead you to a value focused, solution neutral statement of goals on process

Concept

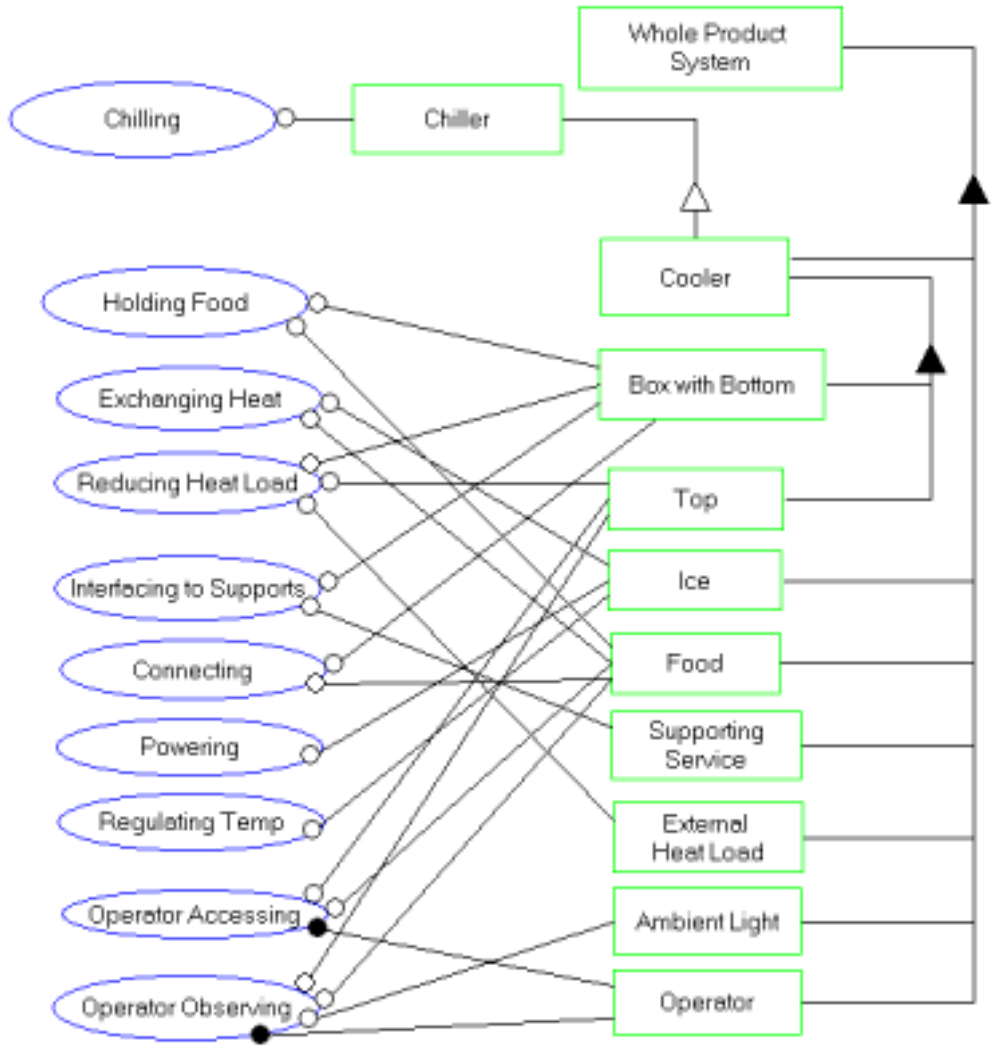
- **Concept: a system vision, which embodies working principles, a mapping from function to form**
- **Choose from among the system operating processing that specialize to the desired solution neutral, value related process**
- **Specialize the related generic concept to the product form**



This is the exercise of creativity

Decomposition of Function and Form

- Identify form of the whole product system
- Zoom the processes of function
- Decompose the form of the product object
- Establish the object process links



Establishing the complexity of the object-process architecture

Framework - Precedence of Processes

- **Sub-processes which support the primary externally-delivered process linked to value**

Then -

- **Other sub-processes linked to other necessary externally-delivered processes**

Then -

- **Interfacing processes**
- **Supporting/connecting processes**

Then-

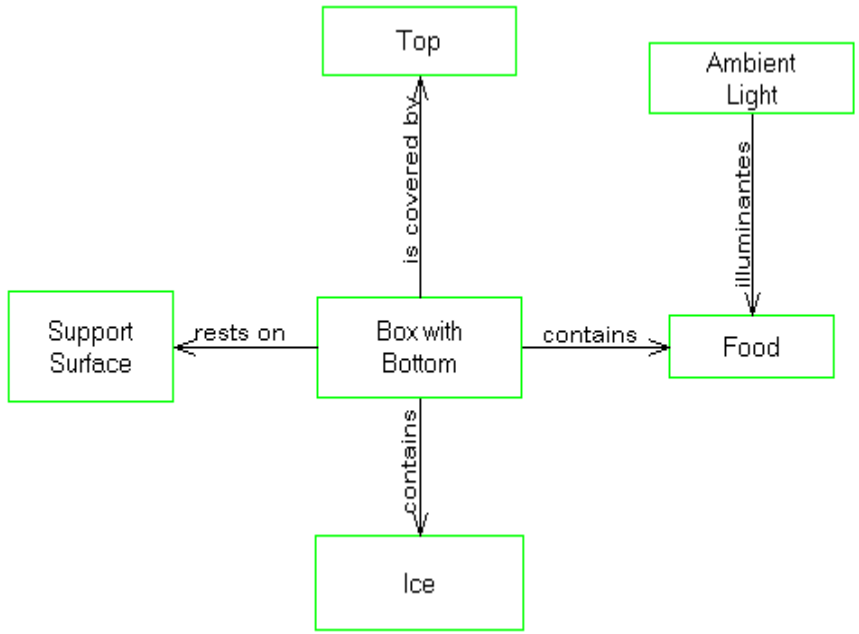
- **Powering processes**
- **Controlling/regulating processes**

Then-

- **Normal operation processes**
- **Contingency/alternative operational processes**

Structure of the Form

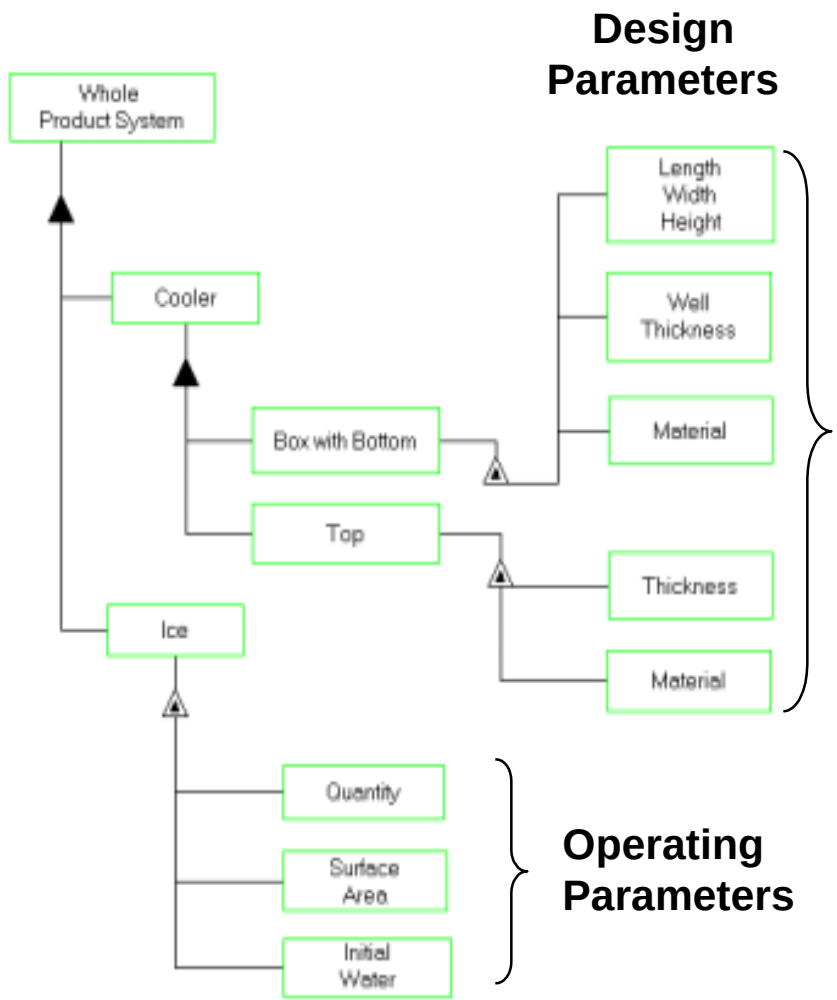
- **Examine the interactions implied by the decomposition of form**



Establishing the complexity of the object-object architecture

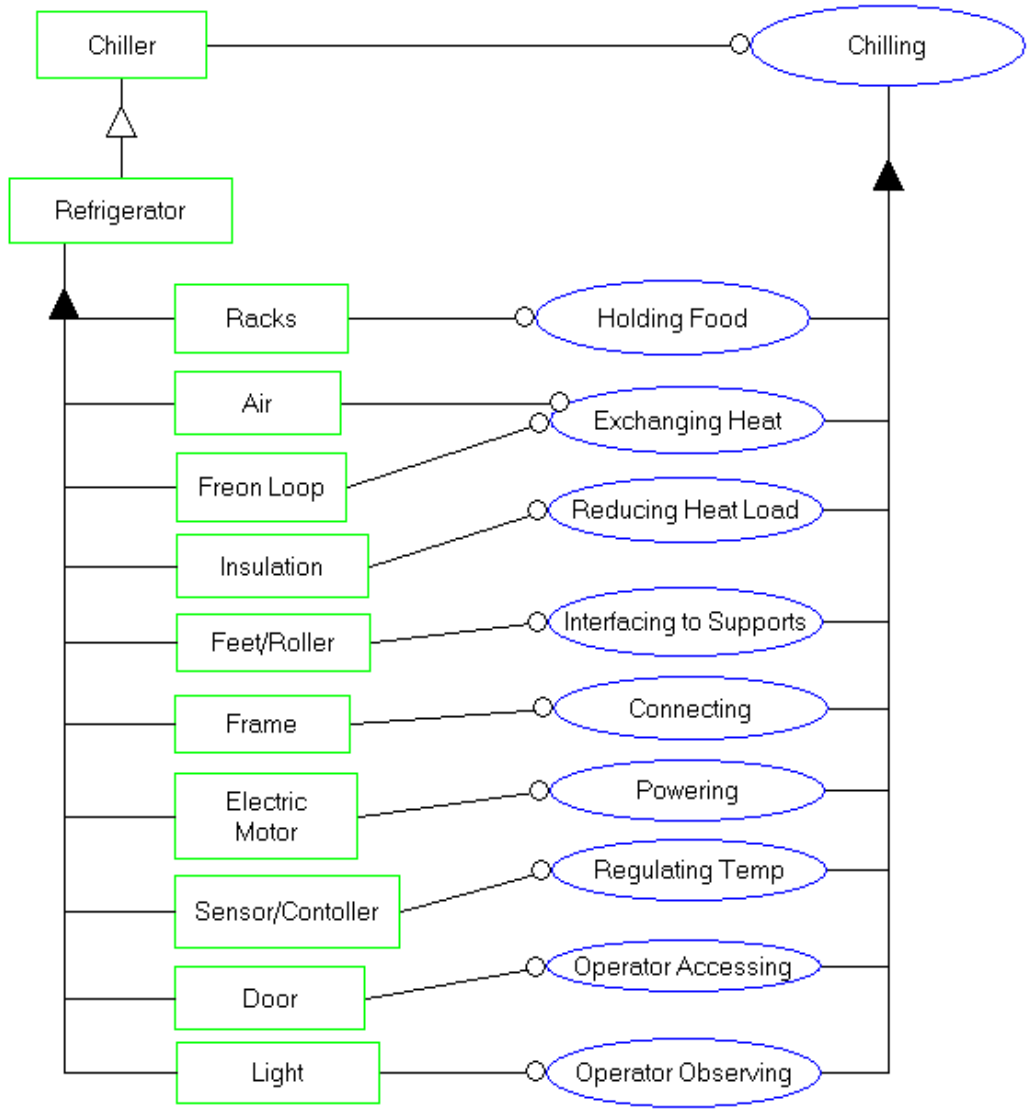
Design vs. Architecture

- **Architecture selects the concept, decomposition and mapping of form to function**
- **Architecture establishes the vector of design and operating parameters**
- **Design selects of the values of the vector of parameters**
- **This is what optimization is good for**
- **Some work in "architecture" is just an exhaustive search over the design of one architecture**

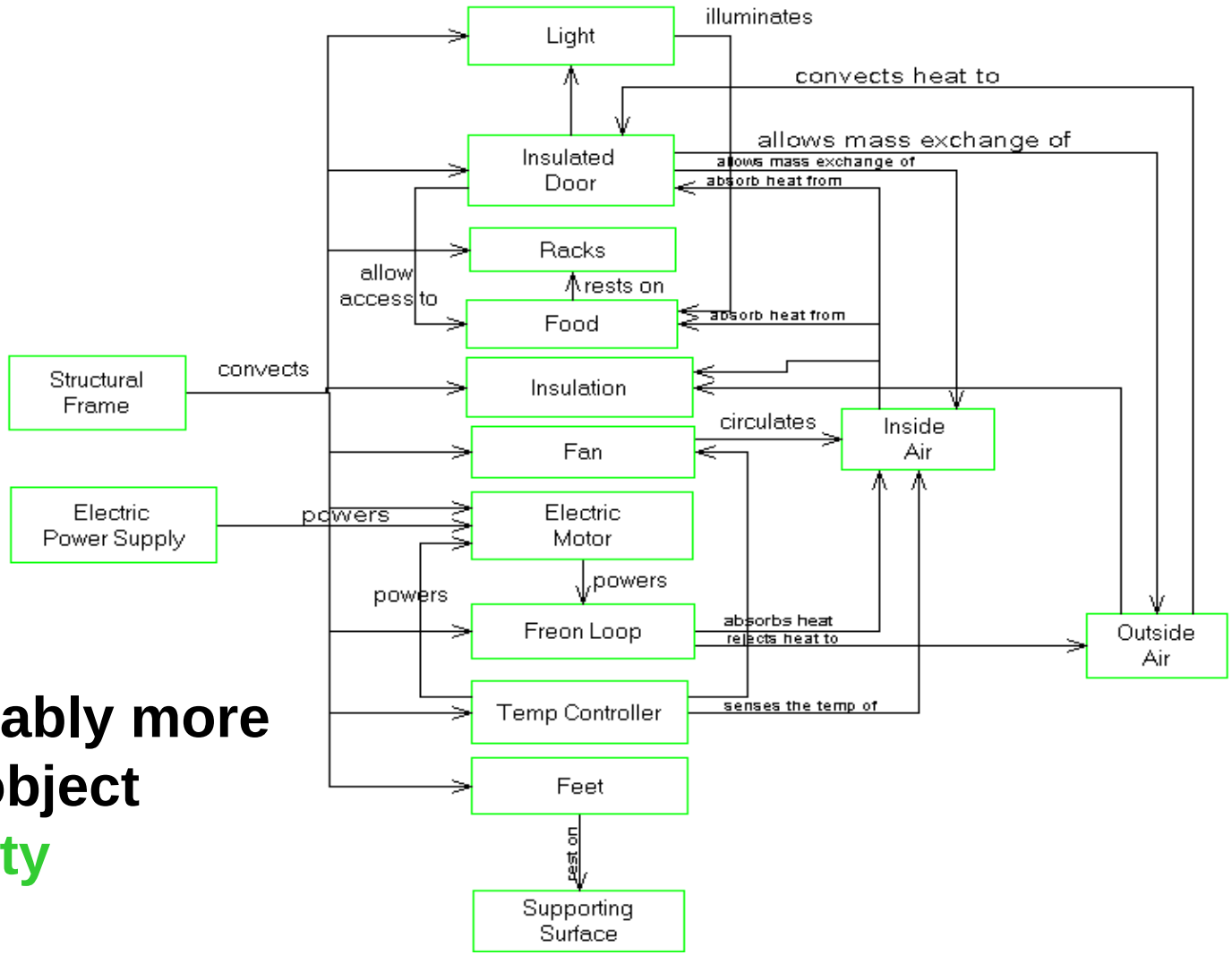


Decomposition of the Refrigerator

- More one to one correspondence of objects and processes
- Note the whole product elements suppressed:
  - Food
  - Support structure
  - Heat load
  - Operator



Structure of the Refrigerator



Considerably more object - object complexity

So Why Refrigerators and not Coolers?

- **Refrigerators have significantly more complexity than coolers**
- **Refrigerators have more functions, performance and robustness than coolers.**

Is a principle lurking here?

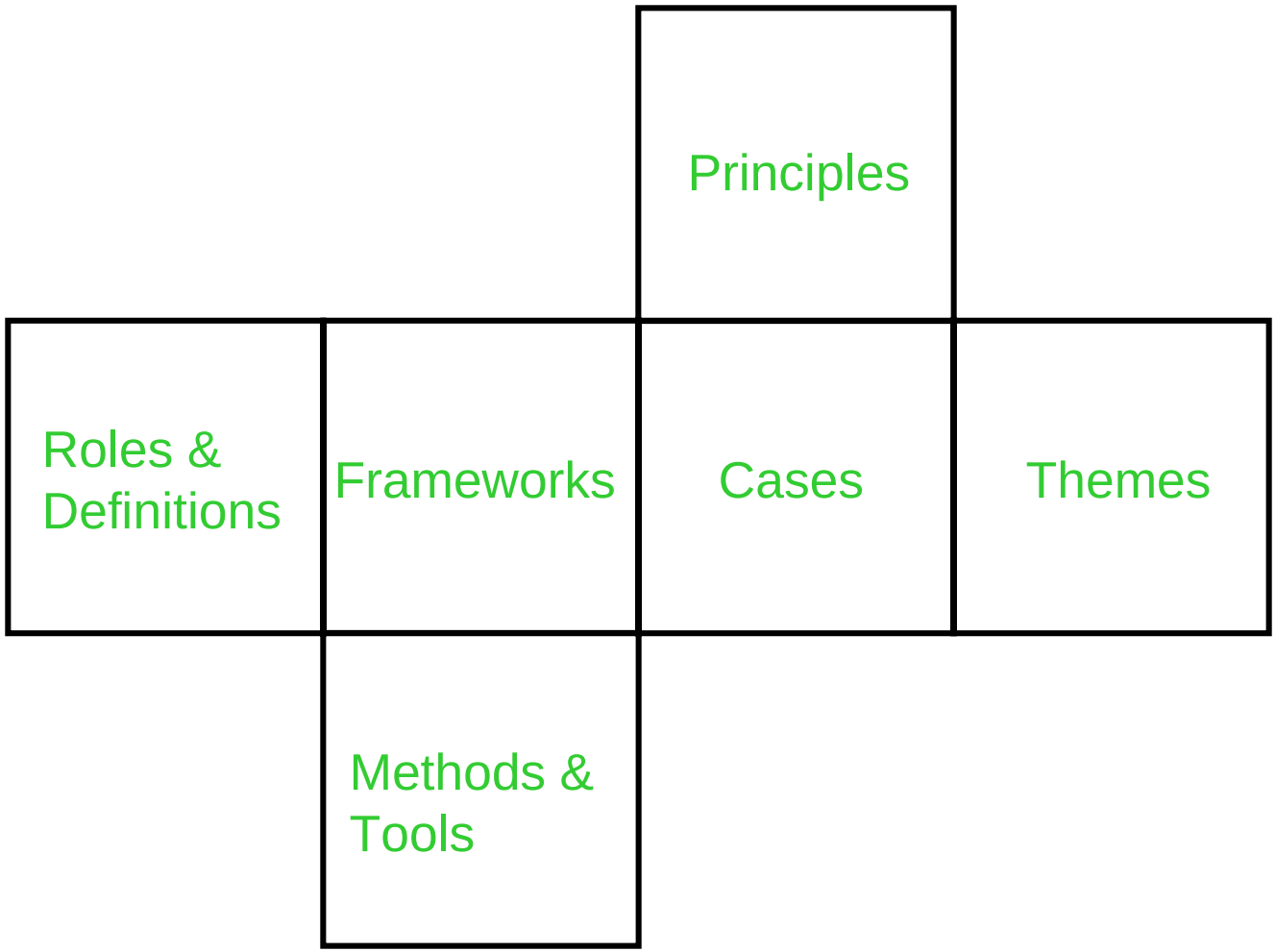
Principle: underlying and long enduring fundamentals that are always (or almost always) valid.

A Principle

Robust Functionality Drives Essential Complexity

- **Essential complexity is that which is essential to deliver functionality before gratuitous complexity slips in**
- **Functionality drives complexity in any given concept**
- **But "Functionality" is often defined as a surrogate for a much broader set of functions which the product will actually be use for.**
- **Therefore, it is the (often implicit) robust functionality which drives essential complexity**

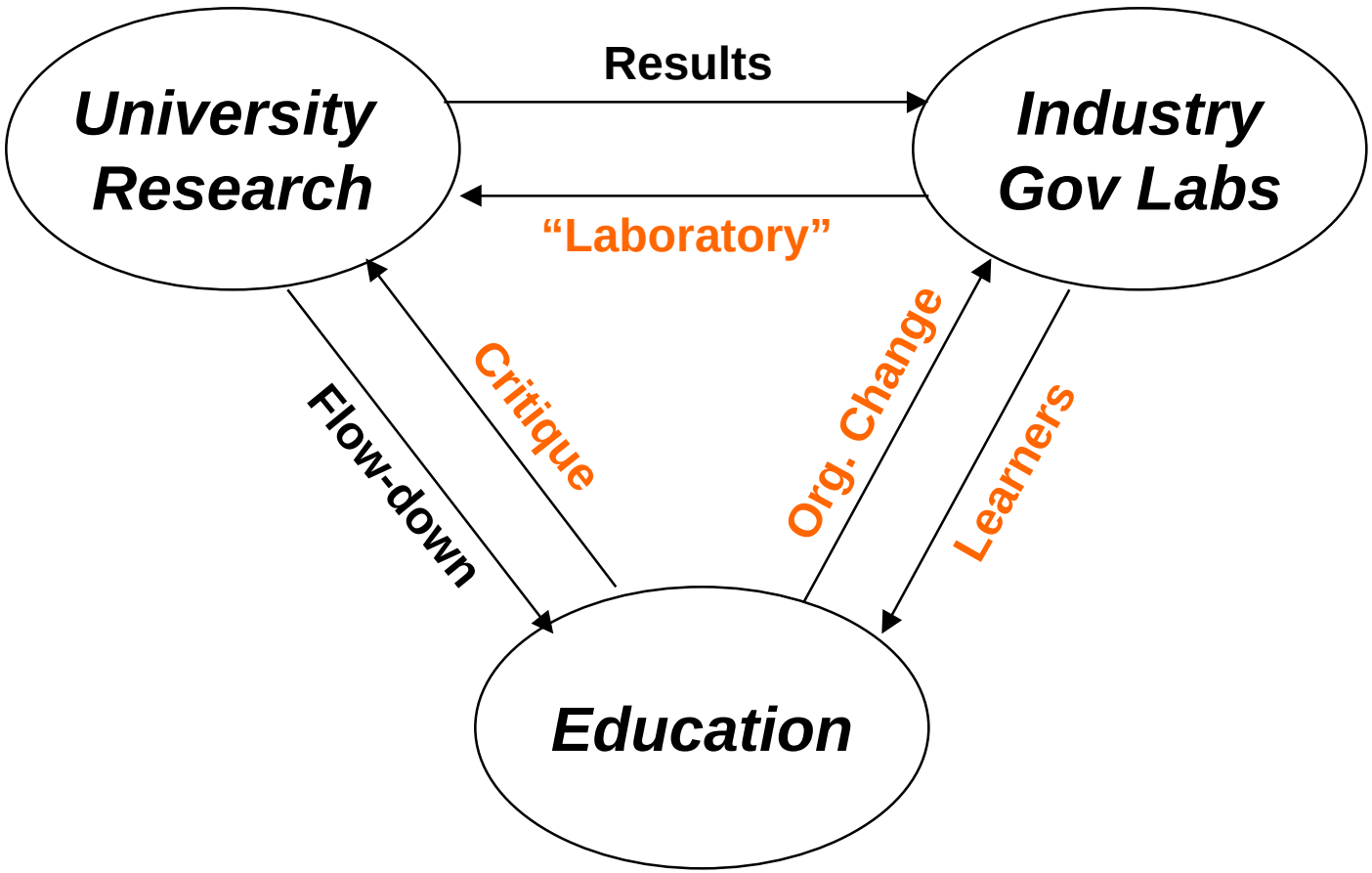
Architecture - 6 Views



Research Agenda

- We must identify, codify and build the principles, methods and tools of system architecture
- These must follow the deployment and delivery of value to the customer
- To do this we must trace the flow of information through the Product Development Process
- The tools we develop must work for systems of real complexity
- They must also have utility to the real potential users.

A New Research Partnership



Building Blocks

- **There are many disciplines upon which we can build**
  - **Mech Eng. - Formal Design Theory**
  - **Management - System Dynamics, Options Theory**
  - **Control - Robust Hybrid Systems Theory**
  - **AI - Computational Design Theory**
  - **Mathematics - Topology, Graph Theory**

- **We must build on (and build something more useful than) Generalized System Theory of the 60's**

We must build the intellectual foundation for the field of System Architecture