Creating Value Through System Thinking
System Thinking

- System Thinking is not: *thinking systematically*
- System Thinking is: *thinking of things as systems*

- A set of interrelated entities which perform a function, *whose functionality is greater than the sum of the parts*

**Emergence**
Information System and Emergence

Emergence: Function
Human System and Emergence

Emergence: Performance
Mechanical System and Emergence

Emergence: Safety, Reliability, ...ilities
Natural System and Emergence

Emergence: Emergency!
Link Between Emergence and Value

- Function
- Performance
- Safety, Reliability, ...
- EMERGENCIES

BENEFIT

VALUE = BENEFIT AT COST
Step 1) Identify System Form and Function

• **Form is:**
  – What the system *is*
  – The physical/ informational embodiment
  – The shape, configuration, arrangement, or layout
  – Is what is eventually implemented

• **Function is:**
  – What the system *does*
  – The *activities*, operations and transformations that cause, create or contribute to performance
  – The *actions* for which a thing exists or is employed
  – Is what eventually *happens*

Emergence occurs in Functional Domain
Form and Function - Factory

<table>
<thead>
<tr>
<th>Function</th>
<th>Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>????</td>
<td>Factory</td>
</tr>
<tr>
<td>Process</td>
<td>Operand</td>
</tr>
</tbody>
</table>

- Benefit
- Cost
Form and Function - Team

Function

- Team

Form

- Team

Process

Operand

Instrument

Benefit

Cost
Form and Function – Circulatory System

<table>
<thead>
<tr>
<th>Function</th>
<th>Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circulatory System</td>
<td>???????????</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process</th>
<th>Operand</th>
<th>Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit</td>
<td>Cost</td>
<td></td>
</tr>
</tbody>
</table>
Step 2) Identify the Entities of the System

- Think holistically
- Focus on the important
- Define abstractions for entities
- Define the boundaries of the system and the surrounding context
Step 3) Identify the Form and Function of the Entities – Factory

<table>
<thead>
<tr>
<th>System Function</th>
<th>Entity Function</th>
<th>Entity Form</th>
<th>System Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembling Cars</td>
<td>Integrate drive</td>
<td>Station 1</td>
<td>Factory</td>
</tr>
<tr>
<td></td>
<td>train</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Integrate body</td>
<td>Station 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Integrate interior</td>
<td>Station 3</td>
<td></td>
</tr>
</tbody>
</table>

Which One is “The System”??
## Circulatory: Entity Form and Function

<table>
<thead>
<tr>
<th>System Function</th>
<th>Entity Function</th>
<th>Entity Form</th>
<th>System Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplying Oxygen</td>
<td>Pumps Blood</td>
<td>Heart</td>
<td>Circulatory System</td>
</tr>
<tr>
<td></td>
<td>Exchange O2 and CO2 with Air</td>
<td>Lungs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exchange O2 and CO2 with Organs</td>
<td>Capillaries</td>
<td></td>
</tr>
</tbody>
</table>
# Team: Entity Form and Function

<table>
<thead>
<tr>
<th>System Function</th>
<th>Entity Function</th>
<th>Entity Form</th>
<th>System Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make a Decision</td>
<td>Collect Information</td>
<td>Marie</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Develop Values</td>
<td>John</td>
<td>Team X</td>
</tr>
<tr>
<td></td>
<td>Synthesize and Evaluate</td>
<td>Joseph</td>
<td></td>
</tr>
</tbody>
</table>
Step 4) Identify the Relationships Among Entities

- Relationships are fundamental to it being a system.
- Relationships can be formal - structure (they exist).
- Relationships can be functional – interaction (they do something).

Focus on Functional Relationships
Formal Structure
Functional Interaction
Formal Structure and Functional Interaction

- Station 1: Integrates Drive-train
- Station 2: Integrates Body
- Station 3: Integrates Interior
- Supplier: Supplies Parts
- Transport: Distributes Cars

Output is Car - Structure is Pipe or Flow Through

- Pipe or Flow Through
Formal Structure and Functional Interaction

Joseph Synthesizes Info and Applies Values

Marie Collects Info

Sources Provide Info

John Develops Values

Sources Explain Values

Output is decision - Structure is Bus or Tree

Interface
Lungs
Exchange Gasses

Hearth Pumps
Blood

Capillaries
Exchange Gasses

Organs

Air

Outcome, but no “output” - Structure is Loop or Feedback

Formal Structure and Functional Interaction

Interface
Step 5) Predict Emergence

- Emergence occurs when the *function* of the entities and their *functional interaction* combine to produce a new functionality, which is more than the “sum of the parts”
## Emergent Function

<table>
<thead>
<tr>
<th>System Function</th>
<th>Entity Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplying Oxygen</td>
<td>Pumps Blood</td>
</tr>
<tr>
<td></td>
<td>Exchange O2 and CO2 with Air</td>
</tr>
<tr>
<td></td>
<td>Exchange O2 and CO2 with Organs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>System Function</th>
<th>Entity Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make a Decision</td>
<td>Collect Data</td>
</tr>
<tr>
<td></td>
<td>Develop Values</td>
</tr>
<tr>
<td></td>
<td>Synthesize and Evaluate</td>
</tr>
</tbody>
</table>

Emergence
Predicting Emergence

Form

Function?

Emergent Function?

Structure enables, but emergence is from function and interaction
Predicting Emergence

Form

Function?

Emergent Function?

Structure enables, but emergence is from function and interaction
Predicting Emergence

Procedure bubblesort (List array, number length_of_array)
   for i=1 to length_of_array - 1;
      for j=1 to length_of_array - 1;
         if array[j] > array[j+1] then
            temporary = array[j+1]
            array[j+1] = array[j]
            array[j] = temporary
         end if
      end of j loop
   end of i loop
return array
End of procedure

Structure enables, but emergence is from function and interaction
Emergence

• Emergence can be predicted *a priori* by:
  – Precedent,
  – Experimentation or
  – Modeling

• For unprecedented systems for which experimentation and modeling are not easy, only human reasoning can be relied on to predict emergence

• This is the real *goal*, and the real *art* in System Thinking
Failures are often System Emergence

• What is the formal structure?
• What is the functional interaction?
• How did failure emerge?
Failures are often System Emergence

- What is the formal structure?
- What is the functional interaction?
- How did failure emerge?
Using System Thinking

• Understanding what is
• Predicting what might be
• Judgment and balance in decisions
• Synthesizing systems - Architecting
Architecture

• The embodiment of concept, and the allocation of physical/informational function to elements of form, and definition of relationships* among the elements and with the surrounding context.

• Consists of:
  – Function
  – Related by Concept
  – To Form

*sometimes, but not always, defined by interfaces
Practicing System Thinking

• Family/Relationships
• Commuting
• Team at work
• Your “job”
• News
• The things we build
System Thinking Helps us Make Complex Things Less Complicated

Function?
Form?
Entities?
Relationships?
Emergence?
Summary System Thinking

• Focus on entities and relationships
• Form and function
• Emergence and value

A good *way* to think!
China demands Japan release detained boat captain.

A Japan Coast Guard boat arrests the crew of a Chinese fishing boat near a chain of disputed islands in the East China Sea, Tuesday, Sept. 7, 2010. The event occurred near the islands claimed by both countries after the ship received repeated warnings from Japan's coast guard to move out of the waters, officials said.
China Boat Captain
Arrest in Disputed Seas Riles China and Japan

By MARTIN FACKLER and JAN JOHNSON

TOKYO — What started nearly two weeks ago with the Japanese Coast Guard’s arrest of a Chinese trawler captain in disputed waters has snowballed into a heated diplomatic standoff between China and Japan, highlighting anxieties in Asia about China’s rising power and assertiveness.

The standoff over the arrest, which took place in waters near uninhabited islands claimed by both countries, escalated Sunday as China announced that it had suspended high-level exchanges with Japan, and threatened additional “strong countermeasures,” after Tokyo said it would extend its detention of the captain.

The captain, Zhan Qixiong, 41, was arrested on Sept. 8 after his fishing boat collided with two Japanese Coast Guard vessels near the islands.

The arrest, for obstructing officers on duty, quickly grew from a seemingly minor incident into a highly emotional issue in both countries, where it has become a top news item and has begun to spill over into other aspects of the two nations’ extensive economic and political ties.

Since the arrest, there have been mass cancellations of trips to Japan by Chinese tourists and protests in front of Japanese diplomatic missions and schools in China, as well as tensions over the possibility of drilling for natural gas in contested waters in the East China Sea.

In a statement on Sunday, China’s Foreign Ministry said Japan had “seriously damaged Sino-Japan bilateral relations.” Beijing suspended all relations between provincial and central government officials and their Japanese counterparts, including talks aimed at expanding aviation routes and cooperation on coal.

“We demand the Japanese side immediately release the Chinese captain unconditionally,” said a Foreign Ministry spokesman, Ma Zhaoxu. “If the Japanese side clings obstinately to its course,
China Boat Captain

- China
- Captain
- Boat
- Island
- Resources
- Disputed Territory
- Coast Guard
- Japan
- US

- Tourists
- Public Protest
- Media
- Trading
- Command
- In
- Containing
- Containing
- Accesses
- Influences
- Shared
- Historical
- Political links

- Authorizes
- Arrest
- Near
- Influences
- Asian Nations
- Accesses
- Resources
- History
- Political links

- Authorizes
- Trading
System– Civil

Function?
Form?
Entities?
Relationships?
Context?

Florida

Beach

Source - www.coolhouseplans.com
System—Mechanical

Function?
Form?
Entities?
Relationships?
Context?

Cable-stayed bridge

Suspension Bridge

Source - www.bridgepro.com
Function?
Form?
Entities?
Relationships?
Context?

System-Information Network

PowerShot S10/S20 System Map

Supplied with Camera

PowerShot S10 / S20

Wrist Strap WS-100

Lithium Battery 2CR5

Power Supply Kit DK110

Compact Power Adapter CA-P5100

AC Power Cord

Battery Pack NB-5H

Soft Case SC-P5100

CF Card for S10 / PC 8MM

CF Card for S20 / PC 8MM

Adobe PhotoDeluxe CD-ROM

PowerShot Solution CD-ROM

USB Interface Cable IFC-200PCU for PC and Macintosh

Serial Interface Cable IFC-200MC for Macintosh

Video Cable VC-100

CF Card Reader

Digital Printer CD-300

PC Card Slot

Parallel Port

USB Port

IBM PC/AT Compatible Computer

Canon

© 2000 CANON INC. PRINTED IN JAPAN
System- Instructional

Function?
Form?
Entities?
Relationships?
Context?
System Thinking

• Holism - thinking as extensively as is reasonable about what might be considered the system
• Focus - identify what in the whole is important, and defining boundaries
• Define abstractions for the entities
• Define relationships among the entities, and interfaces
• Predict emergence
Form and Function

• All systems have form and function
• The Primary Function of a built system is usually clear from observation or historical knowledge, but systems can easily acquire secondary functions
• The Primary Function of evolved systems is subject to interpretation – there is no designer!
### Form and Function Examples

<table>
<thead>
<tr>
<th>Function</th>
<th>Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembling</td>
<td>Cars</td>
</tr>
<tr>
<td>Making</td>
<td>Decision</td>
</tr>
<tr>
<td>Supplying</td>
<td>Oxygen</td>
</tr>
<tr>
<td>Process</td>
<td>Operand</td>
</tr>
<tr>
<td></td>
<td>Instrument</td>
</tr>
</tbody>
</table>

- Benefit
- Cost
Form and Function of the Entities

• Each of the entities that make up the system will have form and function.
• Each element or entity that makes up the system will, in general, also be a system
• All system will form part of one or many larger systems
Relationships Among Entities

• Entities of a system will have both a functional and formal relationship:
  – Functional interactions are activities, and involve exchange of an operand, or the joint action by two entities on the same operand
  – Formal structure enable interaction, and are primarily geometric (where things are), connective (how things are connected)

• Some of the entities of a system will also have relationships with context entities outside of the system, which occur across external interfaces.
China demands Japan release detained boat captain

In this photo released by Japan Coast Guard, a Japan Coast Guard boat, foreground, goes by a Chinese fishing boat which Japan Coast Guard officers are on board for inspection after it collided with two Japanese patrol vessels near a chain of disputed islands known as Senkaku in Japanese or Diaoyu in Chinese in the East China Sea, Tuesday, Sept. 7, 2010. The collisions occurred near the islands claimed by both countries after the ship received repeated warnings from Japan's coast guard to move out of the waters, officials said. (AP Photo/Japan Coast Guard)
Systems and System Thinking

• System Thinking is thinking about things as a system
• A system has form and function
• A system is composed of entities
• Each entity has form and function
• The entities are related, in both form and function
• Collectively a function emerges which is greater than the sum of the individual entities
Practicing System Thinking

• News – there are individual news stories, but how do they connect and interrelate?
• Family – what roles do each play, what are the human relations, what is exchanged?
• Commuting – what are the elements of form, how do they connect, what are their function, how do things move among them?
• Team at work – who are the members, what do they share, what are power relationships among them?
• Your “job” – what are your functions, who do you need what from in order to do them, besides yourself, what form is needed to do the job?
System Thinking is One Way of Reasoning

- System Thinking
- Analytic Reasoning
- Creative Thinking
- Critical Reasoning
- Inquiry
- Decision Making
<table>
<thead>
<tr>
<th>Relationships:</th>
<th>Formal Relationship</th>
<th>Functional Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entities:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Form</td>
<td>Instrument</td>
<td>Instrument</td>
</tr>
<tr>
<td>Function</td>
<td>structure</td>
<td>Interaction</td>
</tr>
</tbody>
</table>