Design of Integrated Systems and Modeling

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System:

A set of interrelated components organized to achieve certain goals.

Examples -

Automobile:
- engine, body, wheels, transmission,
- brakes, alternator, battery, stereo, etc.

Advanced Life Support System:
- crew
- biomass production
- food processing
- waste processing & resource recovery
- etc.
Underlying Concept of Systems Informatics and Analysis for Decision Support

Requirements 
& Design Considerations 
Incl. Tasks and Functions 
(Criticality)

Mission Scenarios 
Incl. Initial & Boundary 
Conditions 
(Management and 
Operation Schemes)

Systems Analysis & Integration 
Reference design; 
Systems workability; 
Trade studies; 
Technology development; 
Systems performance indicators; 
Systems Anal. & Integr. Capability; 
Etc.

Configuration of Components, 
Subsystems, & System 
(System Architecture) 

Candidate Technologies 
Incl. Useable Information 
(Technology Readiness Level)
Challenges in Integration of Scientific Information

- Many scientists have been very successful within their well defined disciplinary boundaries.
- It is not clear, to individual scientists, why active participation in the effort of information integration is of any value. In fact, the effort is frequently viewed as an extra burden.
- The concept of systems analysis has not been made interesting and the mechanism of systems analysis is perceived as formidable.
- The tools used for systems analysis are mostly not user-friendly and incapable of dealing with dynamically changing information base in a real-time fashion.
- The integration of information from traditionally disparate fields, such as life science and engineering science, is likely to encounter new challenges.
Systems Thinking

What:
emphasizing the performance of the system as a **whole** by understanding all **components** in the system, as well as the **interrelationships** among the components

Why:
• individually functioning components do not necessarily make up a workable system;

• **piece-wise knowledge about individual components does not automatically provide a complete understanding of the overall system**;

• necessary yet missing components can be detected after observing/analyzing the system as a whole
Issues of Systems Analysis

- Systems to be analyzed
- Case-by-case vs. tool-building
- Essential aspects of systems analysis
- Methodology needed to carry out the analysis
- Implementation of methodology for easy access by users
Essential Aspects of Systems Analysis

(A) Source of Information

(B) Information

(C) Systems Analysis Procedures and Tools

(D) Results of Systems Analysis

(E) Uses of Systems Analysis Tools and Results
Systems Analysis

How:
• define the system and its objective
• identify descriptors of the system (including initial & boundary conditions)
• establish the relationships among the descriptors
• designate system performance indicators
• develop a model to represent a system and its operation
• verify and validate the model
• perform simulation using the model (investigate “what if?”)
• draw conclusions about the system:
  technical workability & reliability
  resource requirements
  environmental impact
  economic viability
  optimization
  etc.
Modeling

- Quantification of information and/or processes
- Mathematical and/or logical correlation of data
- Representation of real systems
- Creation of tools to enable description and/or application of concepts and ideas

In many cases, Modeling is to develop tools for Systems Analysis; but not systems analysis in itself
Modeling goals for each subsystem in the ALSS top-level model (Rodriguez, 2002; Rodriguez et al., 2003; Rodriguez and Ting, 2003; Ting et al., 2003; Fleisher et al., 2006)

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Simulation Goals</th>
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<tbody>
<tr>
<td>Biomass Production (Fleisher et al., 1999)</td>
<td>• Crop growth</td>
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<td></td>
<td>• Culture tasks</td>
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<td></td>
<td>• Facility maintenance</td>
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<tr>
<td>The Crew (Goudarzi and Ting, 1999; Goudarzi, 2003)</td>
<td>• Perform daily tasks</td>
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<td></td>
<td>• Generate system loads</td>
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<td>• Consume system resources</td>
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<tr>
<td>Food Processing and Nutrition (Hsiang et al., 2001; Hsiang, 2002)</td>
<td>• Cooking</td>
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<tr>
<td></td>
<td>• Determine ingredient requirements</td>
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<tr>
<td></td>
<td>• Determine food processing loads</td>
</tr>
<tr>
<td></td>
<td>• Determine nutritional requirements of the crew</td>
</tr>
<tr>
<td></td>
<td>• Determine nutritional value of daily diet</td>
</tr>
<tr>
<td>Waste Processing and Resource Recovery (Rodriguez et al., 1999; Rodriguez, 2002)</td>
<td>• Solid waste handling</td>
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<td></td>
<td>• Waste water processing</td>
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<td></td>
<td>• Air revitalization</td>
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</tbody>
</table>
Cook Meals
- Ingredient requirements
- Food processing load
- Nutritional value

Perform Tasks
- BP
- WPRR

New Day

Disposal of Crew Wastes

WPRR
- Handle solid wastes
- Revitalize atmosphere
- Provide water – maintain quality

Crop Growth

Det. Personal daily nutrient requirement
Challenges in Integrated Systems Design and Modeling

• Top-Level vs. Process Level
• Breadth vs. Depth
• Information/Data Exchange Protocol
• Expandability, Compatibility, and Adaptability
• System Abstraction
• Computational platforms
• Targeted participants and audiences
• Validation
• Handling of heuristic, uncertain, and incomplete information
• Deliverables – case-by-case vs. computational tools
• Coordination of activities (i.e. concurrent science and engineering)
Concurrent Science and Engineering (CS&E)

The concept

(1) Integrate information and knowledge related to the base camp system from various sources in a real-time fashion

(2) Perform systems analysis (including optimization)

(3) Evaluate systems level performance

(4) Deliver the results of analysis based on the most current information, also in a real-time fashion
Opportunities

- Systems Approach to Sustainability Analysis of Base Camp Systems

Definition of Sustainability: Continuing to do “well”

- Identify critical system needs to form basis of study
- Identify candidate technologies
- Explore feasibility of dissimilar redundancy
- Prepare for stochastic simulation
- Assign probability distributions; perform simulation; and determine failure modes
- Utilize simulation results to determine model-based sustainability
- Develop integrated actions for sustainability improvement
- Conduct concurrent sustainability assessment
Questions/Answers and Discussion

emPower Human Capacity with knowledge and Wisdom (kW)

Integrate Life and Engineering for Enhancement of Complex Living Systems

......Thank you!