Development of Simulation Tool for Life Support System Design Based on the Interaction Model

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Motivation

- I have long used and developed several simulation tools for the design and operation of Life Support Systems (LSS).
- Through my experience in the work, I discovered the following two points.
  - The use of a conventional tool enables the development of a simulation model in a short time as compared with one's own development, but no product can be obtained which is more than what is given by a model building support environment and an analysis tool established on the basis of a conventional tool.
  - Alternatively, when independently developing one's own tool, the degree of freedom in modeling is large, but both sophisticated programming technology and a considerable amount of time are required. As a secondary effect, while debugging software, a programmer gains significant understanding of the target system and in the process of the debugging work, a programmer occasionally comes up with a new idea for the design.
- That is, while building a simulation model on a computer, the designer develops and confirms his/her own idea. This outcome yields a great effect on the conceptual design.
- However, conventional simulation tools are not designed so that the interaction between the designer and a model building support environment is dynamically used to bring out a designer's idea.

Objection

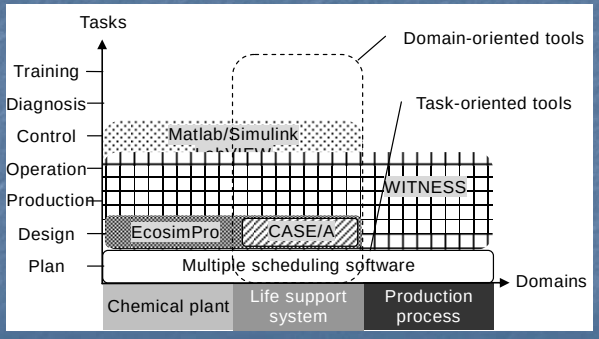
- Therefore, I consider the development of a conceptual design support tool in the design of the LSS, while focusing attention on the interaction between the simulation tool and the designer.

History of LSS simulation

Purpose	ECLSS	ALSS (Ground Facilities)
Actual systems / Experimental Facilities	Soyuz, Space shuttle, and International Space Station (ISS)	BIOS3, Lunar-Mars Life Support Test Project (LMLSTP), BIO-Plex, and Closed Ecology Experiment Facilities (CEEF)
Trade Studies	ECLSS's Assessment Program (ESAP) for S. S. Freedom.	Tools using Equivalent System Mass (ESM) like the Advanced Life Support Sizing Analysis Tool (ALSSAT)
System model Steady state analysis	Mass balance analysis for O_2 and CO_2.	Element modeling by Averner. Biochemical stoichiometry by Tyler Volk and John D. Rummel.
System model Transient analysis	Thermal and fluid analysis. SINDA'85/FLUINT, G189A, CASE/A, and Aspen.	Mass flow analysis. OCAM, OCAM2, BioSim, EcosimPro, LabVIEW, Matlab/Simlink, and WITNESS.

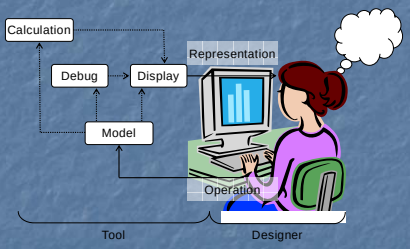
The CASE/A developed in the 1980s includes a graphical user interface for model construction and data management.

Classification of simulation tools using task and domain



I focus attention on the analysis function of a simulation tool and the use of an emergence function thereof by interaction made with the designer.

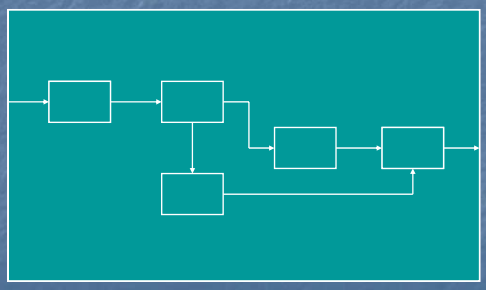
Interaction between tool and designer in conceptual design support



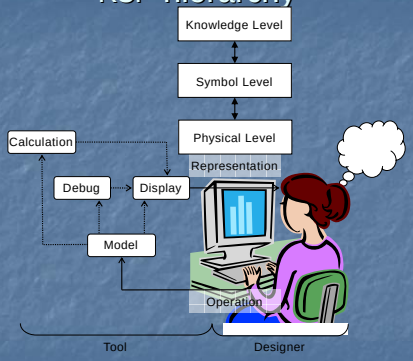
Interaction design

- The interaction design determines the representation and operation systems of the tool from the perspective of the thought and action processes that the user experiences with the application tool. At this time, a model of thought and action is referred to as an interaction model.
- To develop an application tool enabling the designer to think without difficulty in support of a creative activity, Dr. Nakakouji cites the following four prerequisites for externalizing the interaction design:
  1. Representation system enabling representation of ambiguity;
  2. Representation system enabling representation of solution and problem;
  3. Representation system enabling simultaneous overview of the halfway finished part and the whole coming to successful completion; and
  4. Operation system enabling intuitive operation for these three prerequisites.

Four prerequisites for externalizing

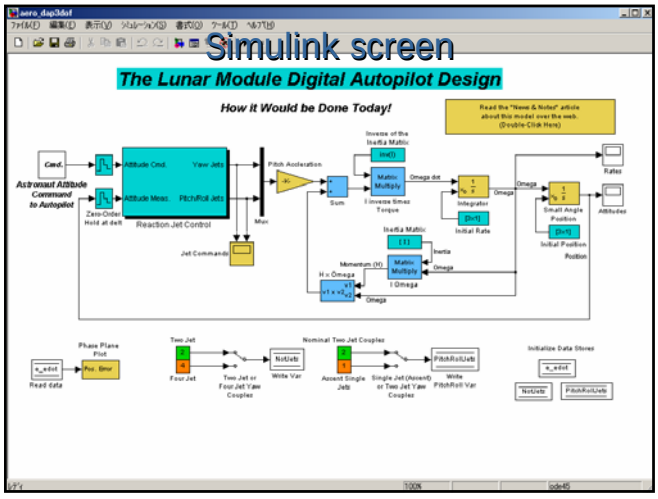


KSP hierarchy

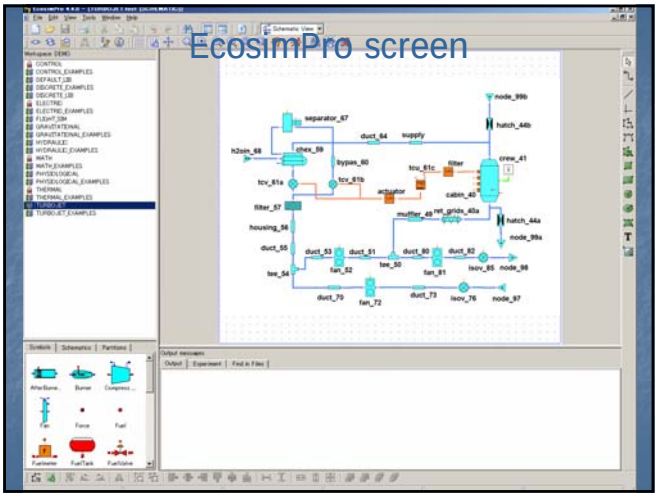


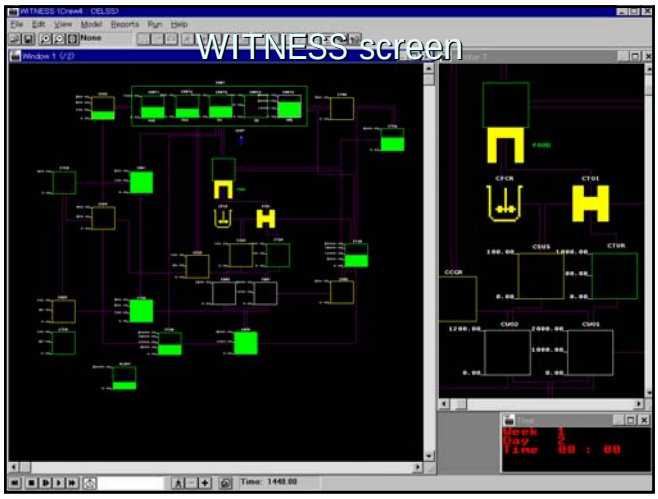
In this study, the KSP hierarchy is used for the definition of interactions from the designer to a software application (externalized operation), and from a software application to the designer (externalized representation).

Simulink screen



EcosimPro screen

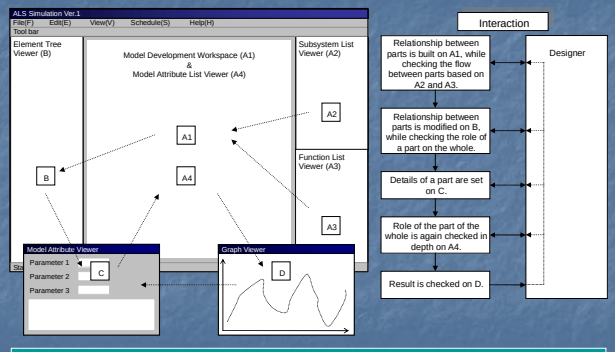




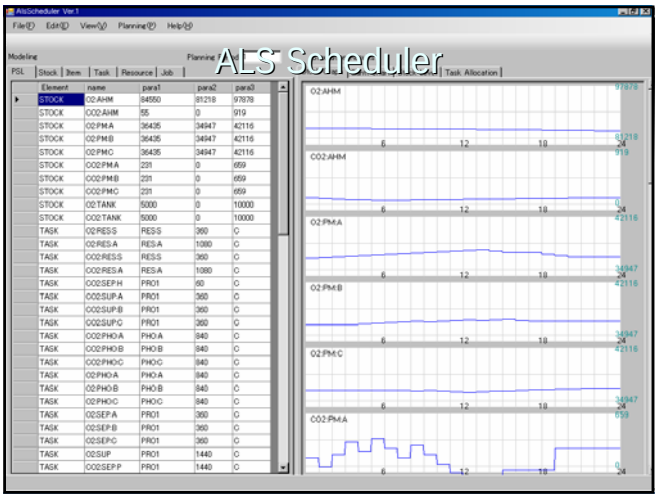
Comparison with respect to operation system and representation system

Externalization	Evaluation Items	Simulink	EcosimPro	WITNESS
Operation system	**Knowledge Level**			
	Conceptual creation support	✓ Logic circuit knowledge	✓ Model element attributes	✓ Model element attributes
	Symbol Level			
	GUI base modeling	✓ Logic circuit icon	✓ Device icon	✓ Device icon
	CUI base programming	✓	✓	✓
	LSS library		✓	
	Calculation solver	✓	✓	
	Physical Level			
	User-intuitive	✓ Mouse and key board	✓ Mouse and key board	✓ Mouse and key board
Representation system	**Knowledge Level**			
	Display using a table or graph	✓	✓	✓
	Symbol Level			
	Display of whole-part hierarchy			✓
	Display of relationship between parts	✓	✓	✓
	Display of part attributes	✓	✓	✓
	Physical Level			
	Animation			✓

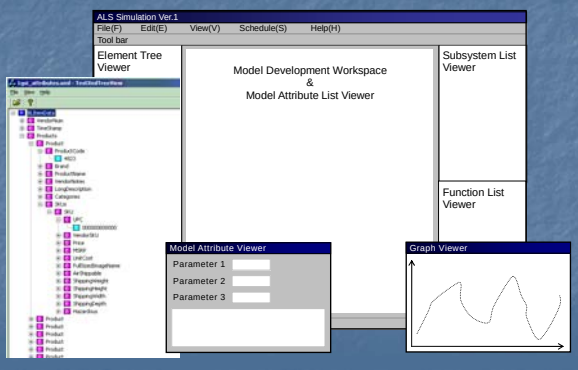
Overview of conceptual design support tool



The concept is formed while the simulation tool and the designer repeat such interactions.



ALS simulation based on interaction model



Conclusion

- In this presentation, the role of the simulation tool of the LSS was outlined. Also pointed out was that the simulation tools are lacking in concept formation function.
- To install this function, the goal is that development be conducted in light of the interaction between the designer and the simulation tool.
- Next, comparison was made with the operation and representation systems of the three simulation tools in terms of the interaction design so as to analyze the functions of the simulation tool necessary for the support of a conceptual design.
- Based on the analysis, the interaction model was created, and the development outline was shown, in which the ALS scheduler is modified to a tool placing importance on the extraction of the designer's mental model by interactions.

In the future, I will discuss the effects and use of this tool in the conceptual design through design experiments that a designer conducts.