xFFBD: towards a formal yet functional modeling language for system designers

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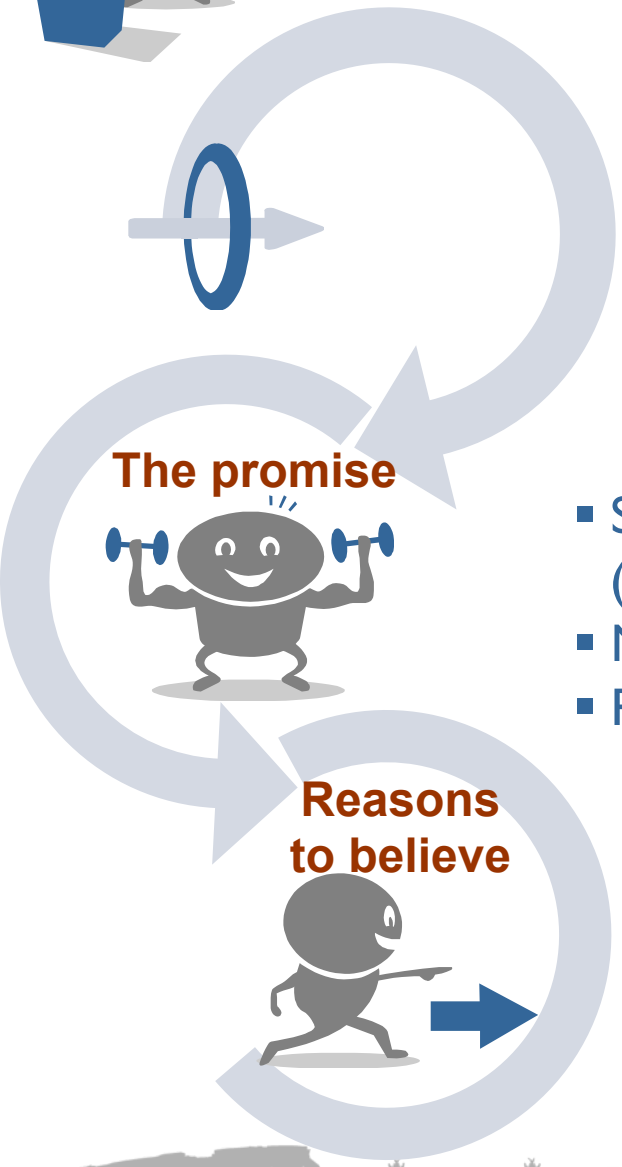
What *xFFBD* is the name of …

A (definitive?) comprehensive, design-oriented functional modelling language for system designers (and maybe more …)



- Support to design, thus creation process (quick V&V, what-if, composition …)
- No paradigm breakthrough, respect legacy
- Respect the plurality of actors/disciplines/aspects

- Strong foundation for eFFBD and functional modelling (block diagram, system dynamics …)
- Modelica, Altarica become "ready"
- Model transformation and interoperability are "quite" ready
- New paradigm and new modality in HMI

Who we are and why are we found of eFFBD?

- We are all professors, or associate professors or lecturer in system engineering, and more particularly related to Architectural Design.

- eFFBD has "good" educational properties and is a "good" teaching aid for functional **design**.

  - Clear separation between control and flows,
  - Formal enough ("closed to" – even isomorphic - to Temporal Petri Nets)
  - "on the fly" execution/simulation capabilities to support quick V&V loops.
  - Functional Architecture relying on Functional Architectural patterns

This is not a Function …

René MAGRITTE, *La Trahison des images*
(1929, oil painting, 62 x 81 cm)

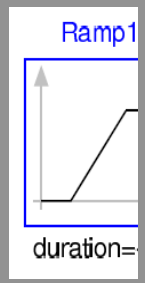
We heard so many definition and interpretation of ***"what is a function …"***

What is a function, a functional model … a galaxy of legitimate answers

System Dynamics: a concrete example of usage

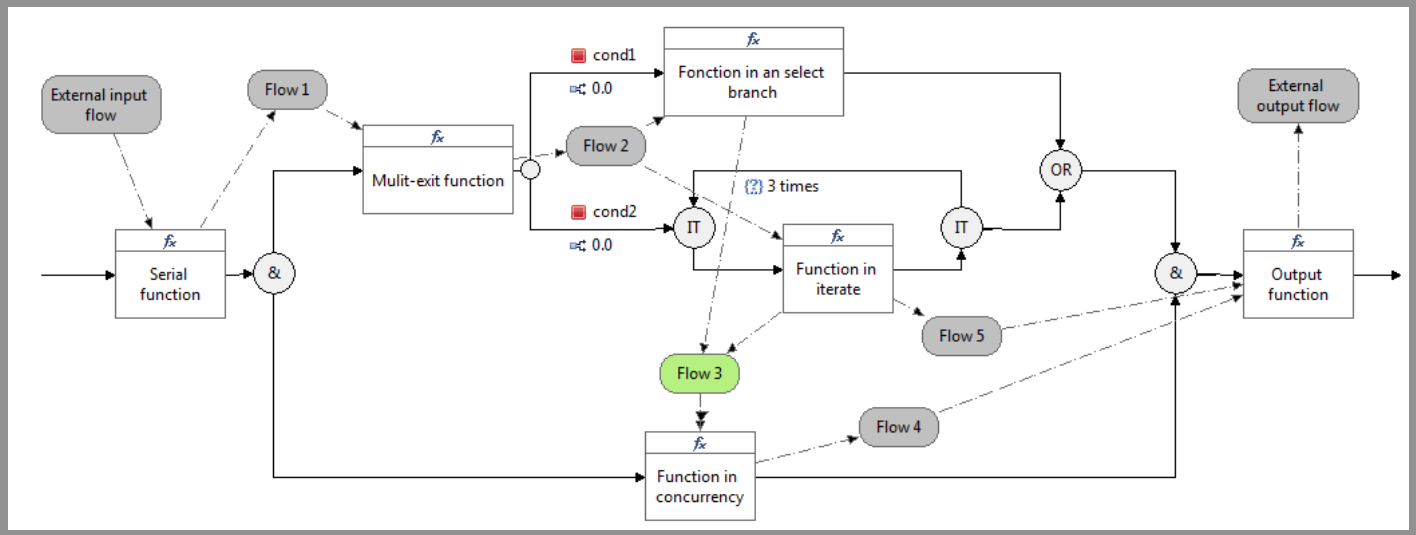
Modelica (multi-physics)

the Salafist



EFFBD

Inspired from "Relationships between Common Graphical Representations in System Engineering", Jim Long, President Vitech Corporation



(e)FFBD in short…

1921
Process Flow Chart
Frank Gilbreth, "*Process Charts—First Steps in Finding the One Best Way*"

1947
Multi-Flow Process Chart
ASME Standard for Operation and Flow Process Charts

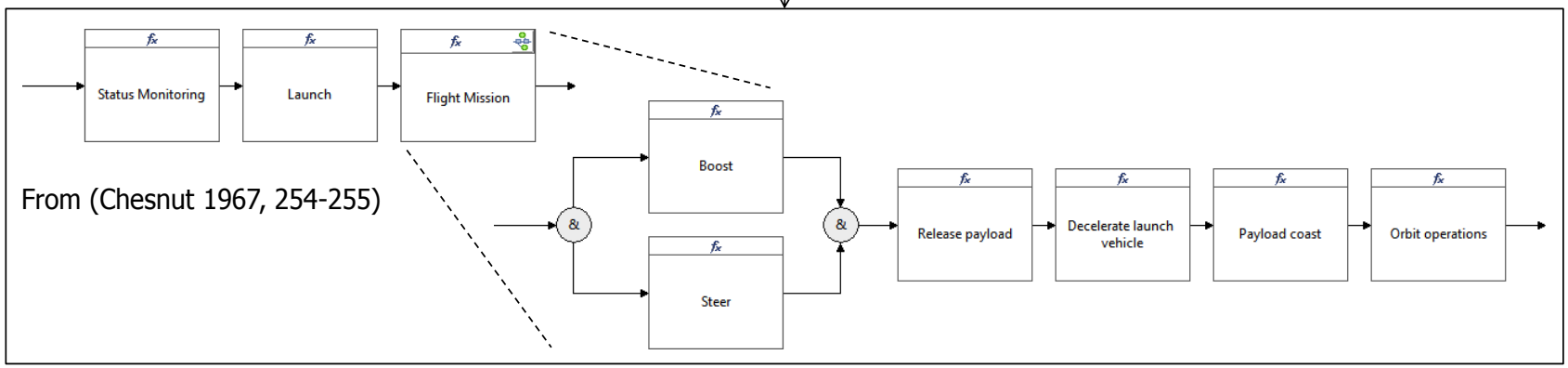
2009
eFFBD semantics formalisation for eFFBD model checking
Charlotte SEIDNER, PhD Thesis

30's | 40's | 50's | 60's | 70's | 80's | 90's | 2000's

FFBD (by TRW)

widely used by NASA for space mission

eFFBD

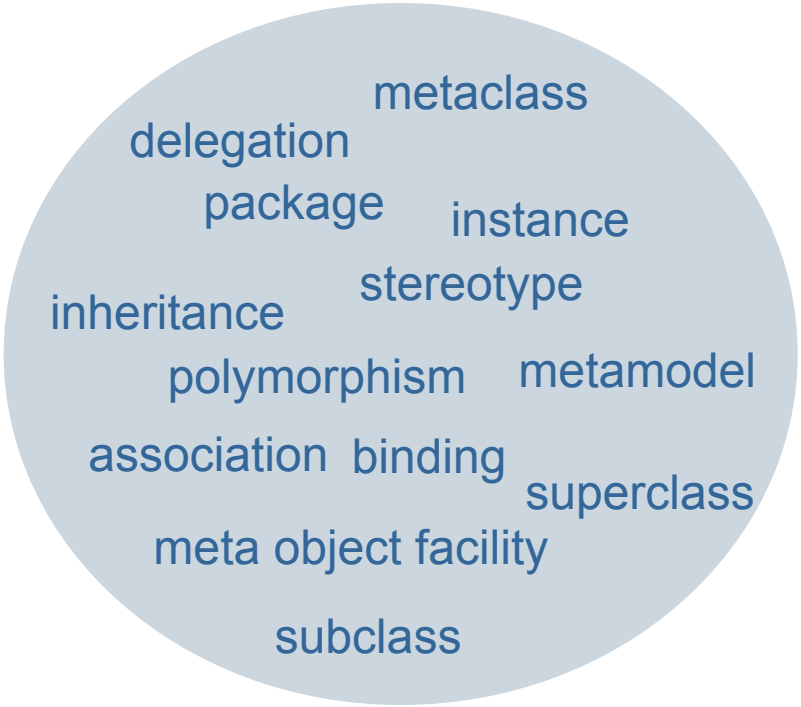


From (Chesnut 1967, 254-255)

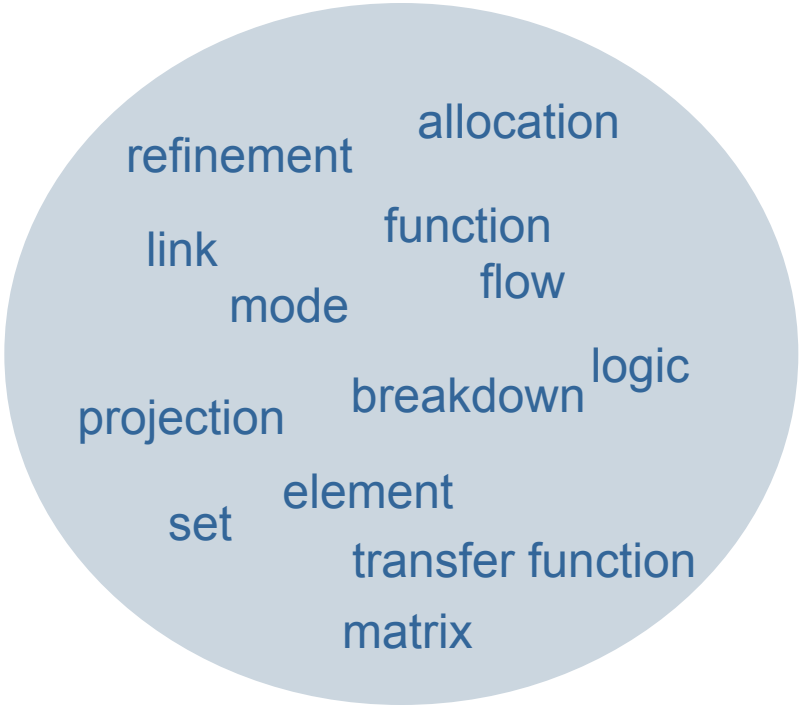
According to INCOSE SE HDBK …

… Two tracks for MBSE

Object-Oriented SEM



Functions-Based SEM



What kind of Improvement can be expected …

Towards a formal semantics for xFFBD

Flows:

- kind: information (not only!), matter, energy
- discrete vs. continuous
- streaming vs. event vs. …
- computational model for flows (queuing …)

***Function* itself:**

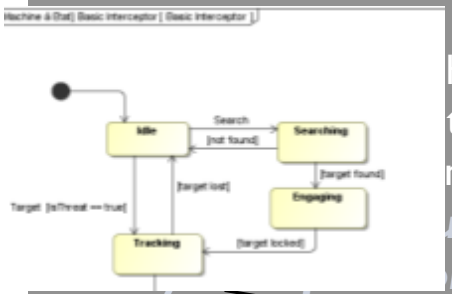
- transformation?
- transfer function?
- processes?
- dysfunctional behaviour

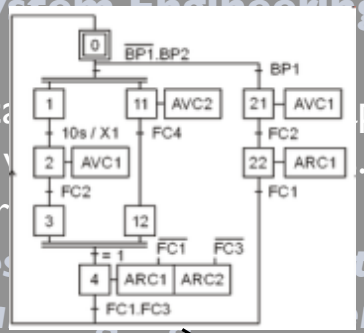
(enhancement of) Operational semantics of a functional architecture

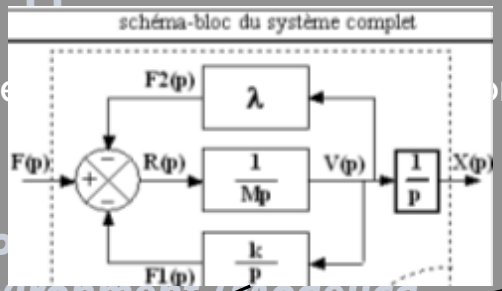
- Capability to validate an architecture against formalised expected behaviour or properties.
- Capability to map the functional architecture on the physical one.

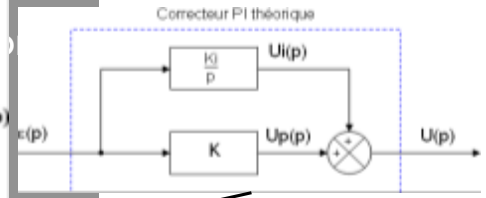
Towards "self contained" models

xFFBD to support System Engineering approach









Altarica, Matlab/Simulink …)

- ***Hybrid and co-simulation capabilities***
- Transformation rules to a mathematical counterpart model in order to "on the fly" properties analysis, verification and validation

xFFBD ::= {eFFBD with modeling enhancements and formal operational semantics}

Hybrid (co)simulation

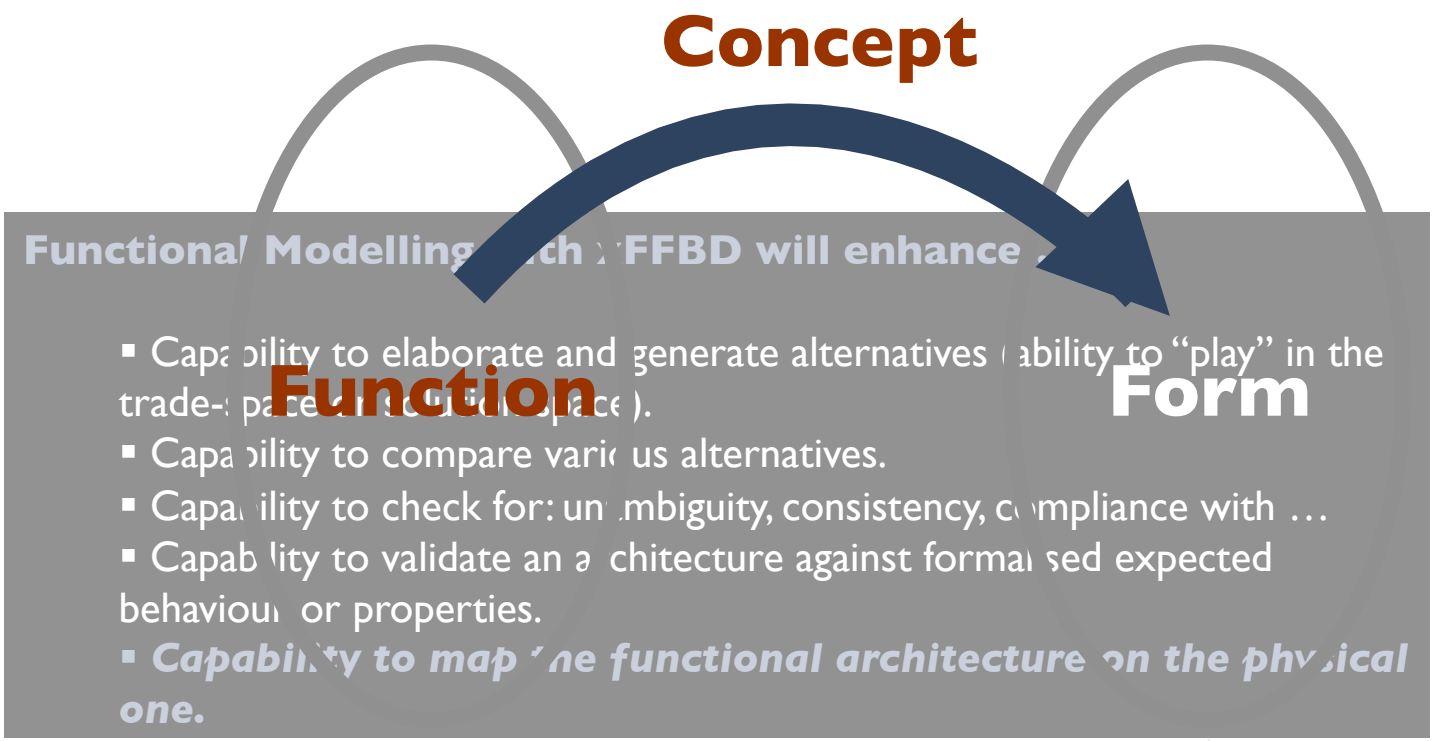
properties checking and assessment

Dependability analysis

- **An xFFBD model does not "throw away" other functional models; it just provides the "cement"**
- **Aspect-oriented modelling**

Functions and Forms

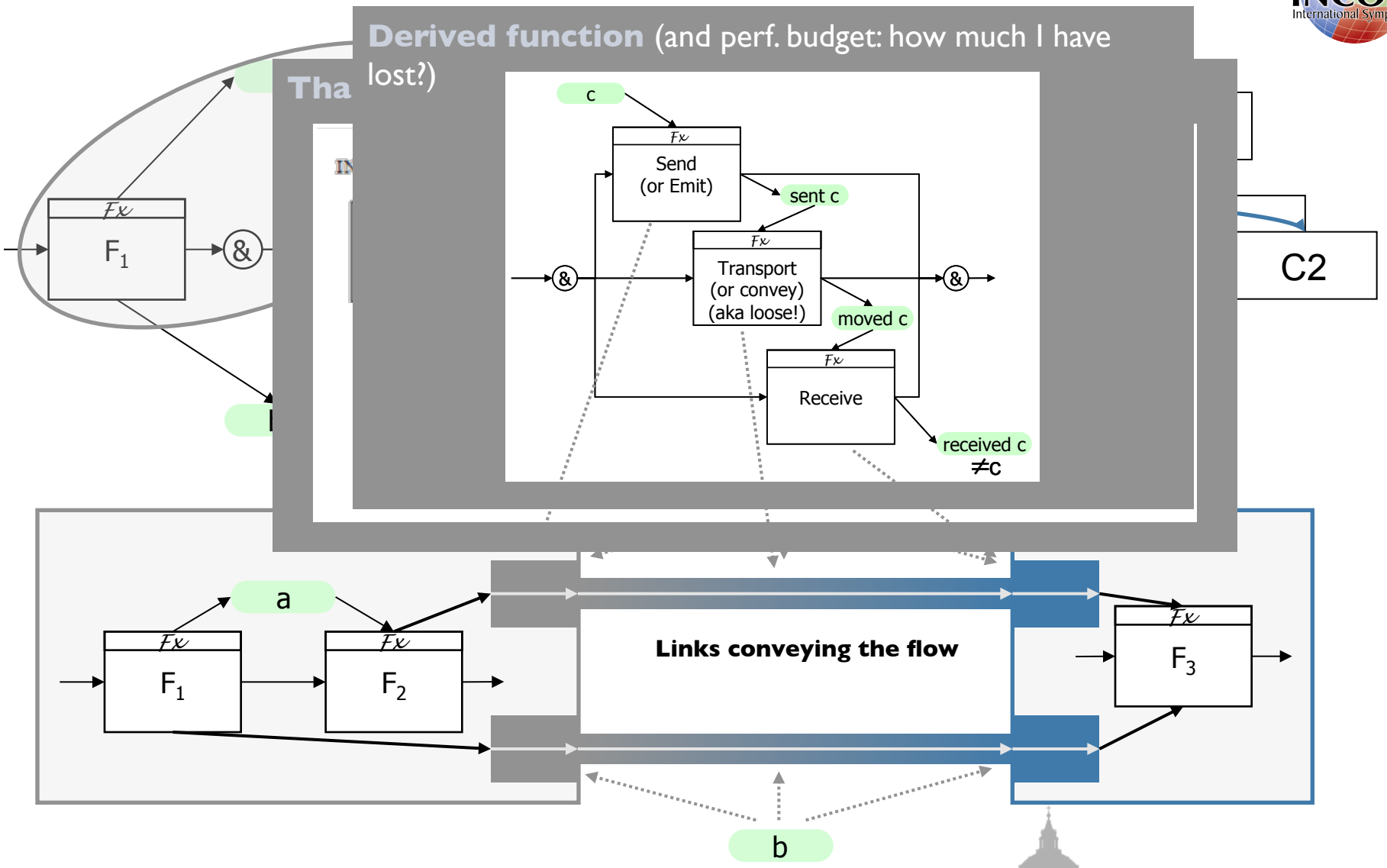
Architecture: the embodiment of **concept**, and the allocation of physical/ informational **function** to elements of **form**, and definition of **interfaces** among the elements and with the surrounding **context**. (Ed. Crawley, MIT)



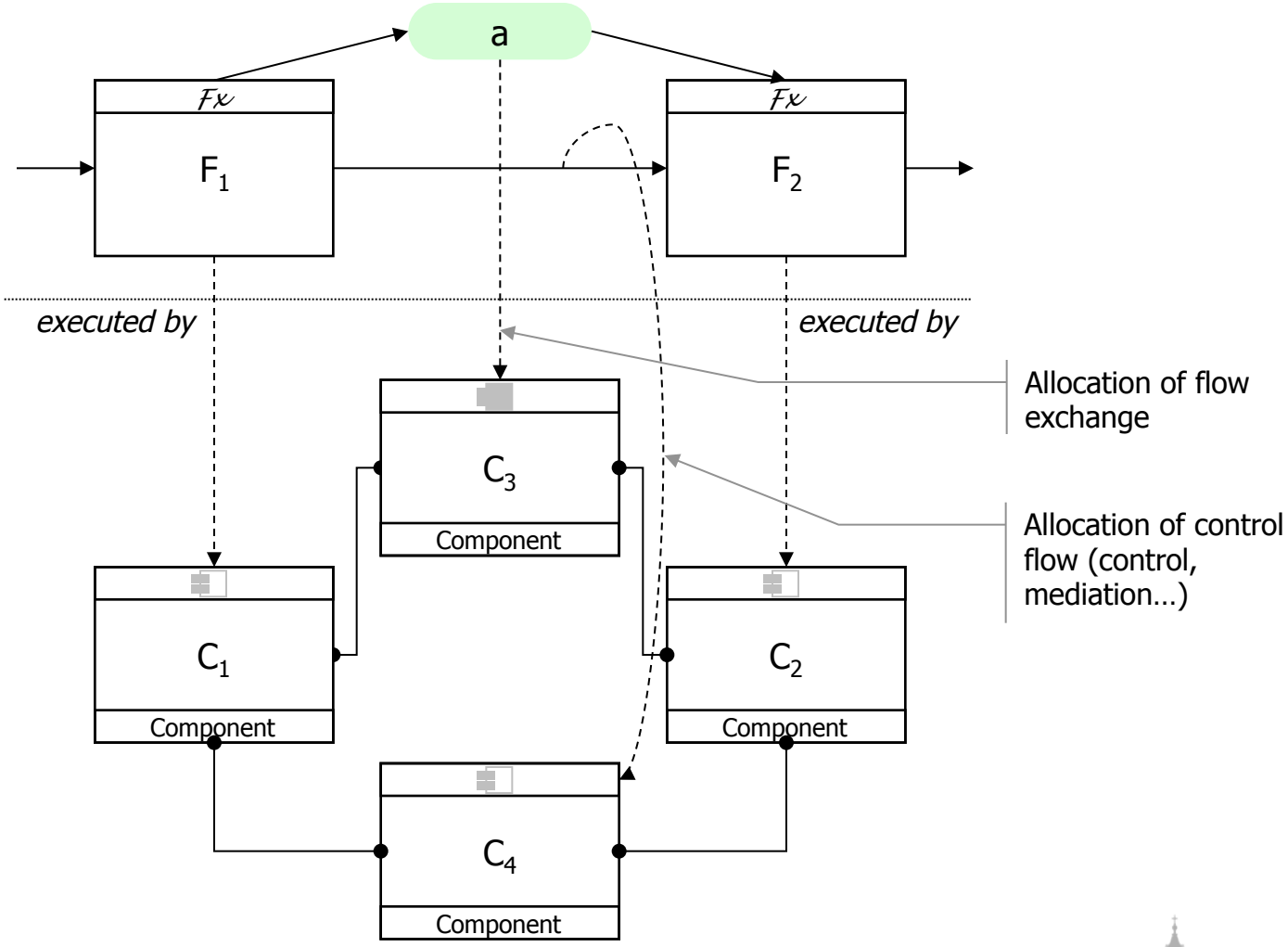
What the system **does**

What the system **is**

Mapping: Not a simple "drag&drop"!



Interface Engineering: NOT a "simple" drag&drop of functions into components!



extracted from "Complex Systems and Systems of Systems Engineering", Wippler & ali

Architecting is the **deliberate manipulation** of **structure** to **achieve** desired system **behaviour** and **properties** (OCW, MIT)

Functional Modelling with xFFBD will enhance …

- ***Capability to elaborate and generate alternatives (ability to "play" in the trade-space or solution space).***
- ***Capability to compare various alternatives.***
- Capability to check for: unambiguity, consistency, compliance with …
- Capability to validate an architecture against formalised expected behaviour or properties.
- Capability to map the functional architecture on the physical one.

We should look on "How to?" from …

TRIZ: 40 Principles for Innovative Problem Solving

- Another dimension
- Mechanical vibration
- Periodic action
- Continuity of useful action
- Phase transitions
- Thermal expansion
- Strong oxidants
- Inert atmosphere
- Composite materials

ASIT (Advanced Systematic Inventive Thinking)

- **Unification**: Solve a problem by assigning a new use to an existing component (the pipe and metal balls problem is solved by Unification - the balls are put to a news use, i.e. protecting the pipe).
- **Multiplication**: Solve a problem by
copy of an existing object into the curre
- **Division**: Solve a problem by dividing
parts.
- **Breaking Symmetry**: Solve a prob
situation into an asymmetrical one.
- **Object Removal**: Solve a problem
system and assigning its action to anoth

The six modular operators (Design Rules, The power of modularity, Baldwin & Clark)

- **Splitting**
- **Substituting**
- **Augmenting**
- **Excluding**
- **Inverting**
- **Porting**

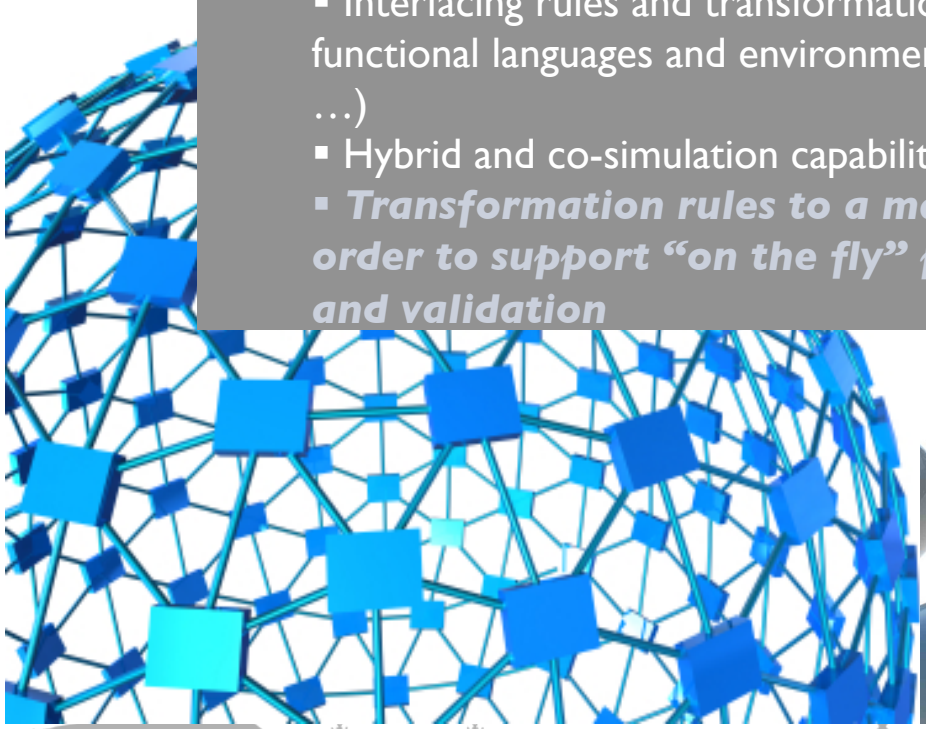
"The fact that many complex systems have a... hierarchic structure is a major facilitating factor in enabling us to understand those systems." Herbert Simon, *The science of the artificial*, (1969), MIT Press

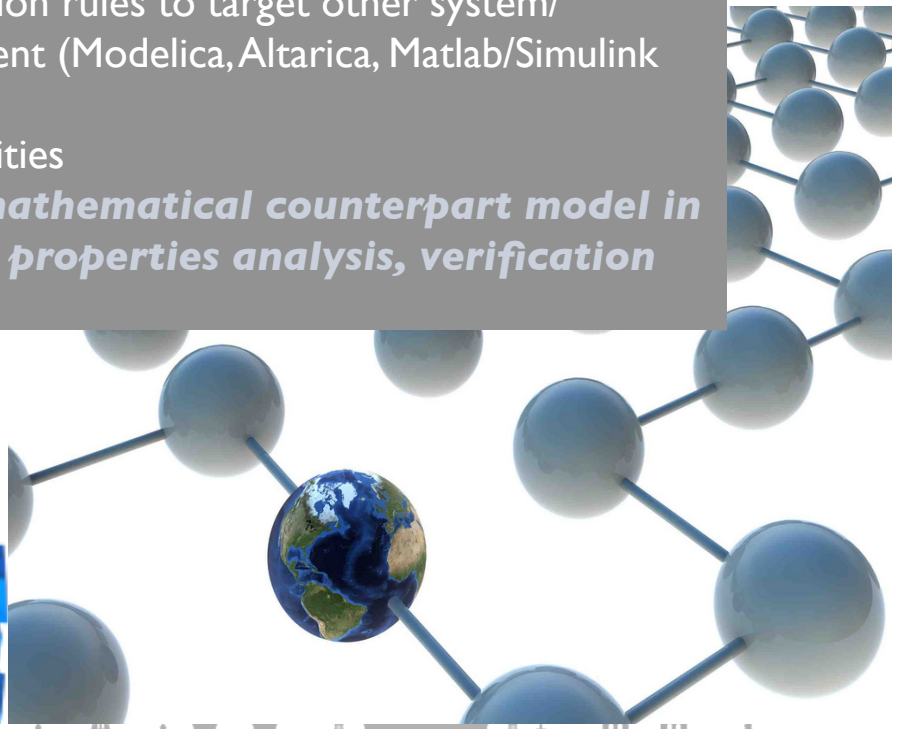
However, reducing the architecture of such system to a hierarchic breakdown is not a way to fully comprehend its structure, its characteristics, its behaviour
"**A city is not a tree**", Christopher Alexander, 1965

A step in graph theory …

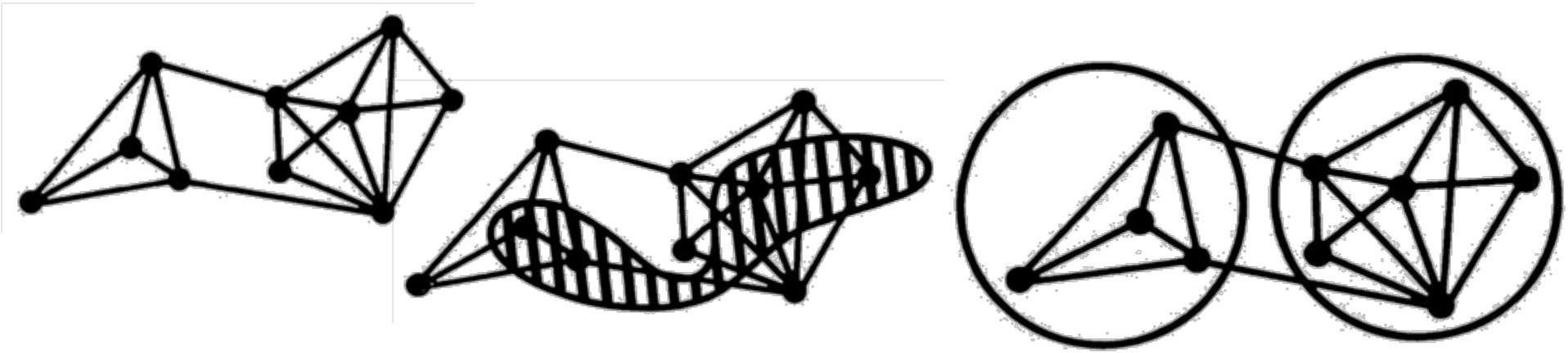
xFFBD to support System Engineering approach

- Executable graphical model with an adapted rendering of the simulation results according to various stakeholders.
- Capability to generate test scenario
- Interfacing rules and transformation rules to target other system/ functional languages and environment (Modelica, Altarica, Matlab/Simulink …)
- Hybrid and co-simulation capabilities
- ***Transformation rules to a mathematical counterpart model in order to support "on the fly" properties analysis, verification and validation***





Address (truly and objectively!) modularity



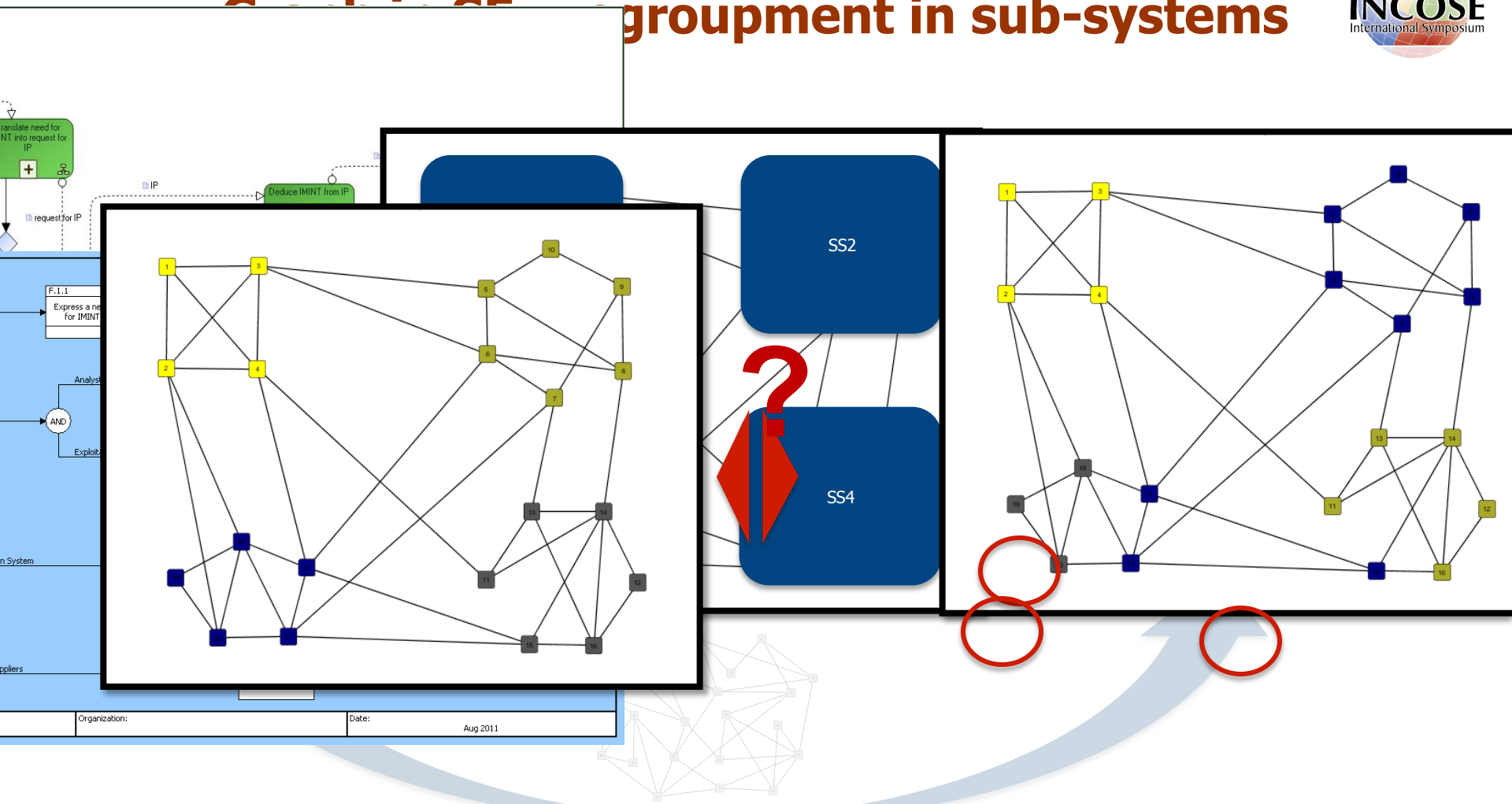
Simon: **modularity related to evolution, survival, and complexity (1962)**

- Can't survive (due to propagating failures) unless there is some independence between modules
- The modules form into (nested/closed) hierarchies
- Evolution can proceed in separate activities
- Also: decomposable systems are less complex

Alexander: **modularity related to efficient design procedures (1964)**

- Can't make design decisions (due to interactions) unless they are clustered meaningfully and dealt with in bulk
- Design can proceed as independent steps
- The right clusters may not be the obvious visible ones

groupment in sub-systems



Automated

clustering

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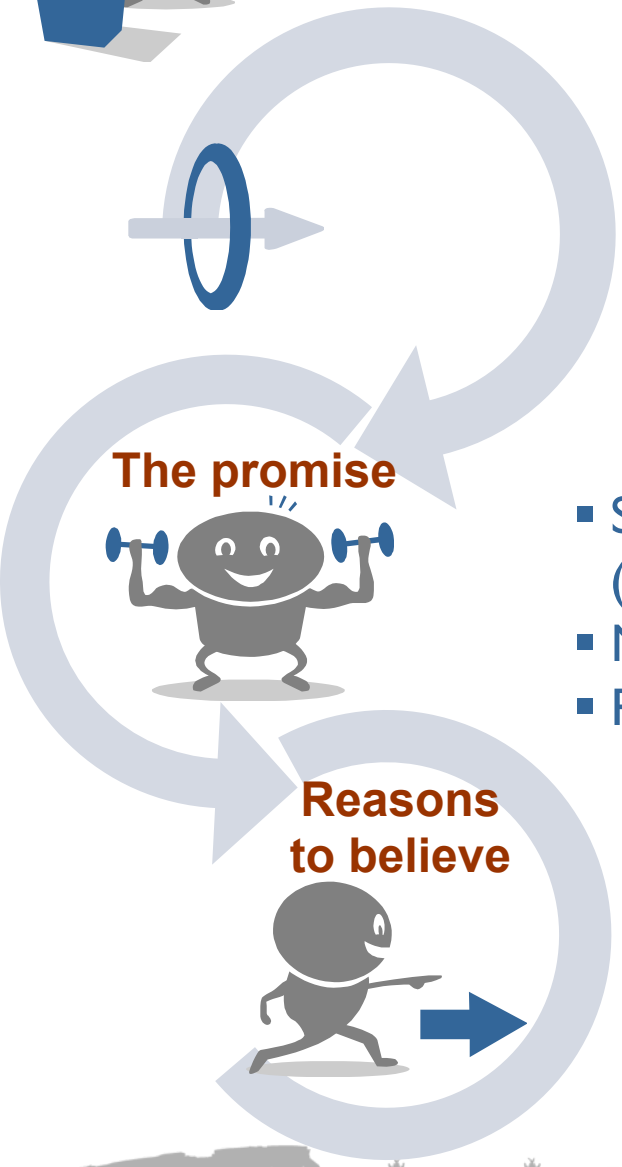

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Thank you for your attention.

Hope to see you on the road to xFFBD