A Swarm Ontology for Complex Systems Modeling

Overview Slides

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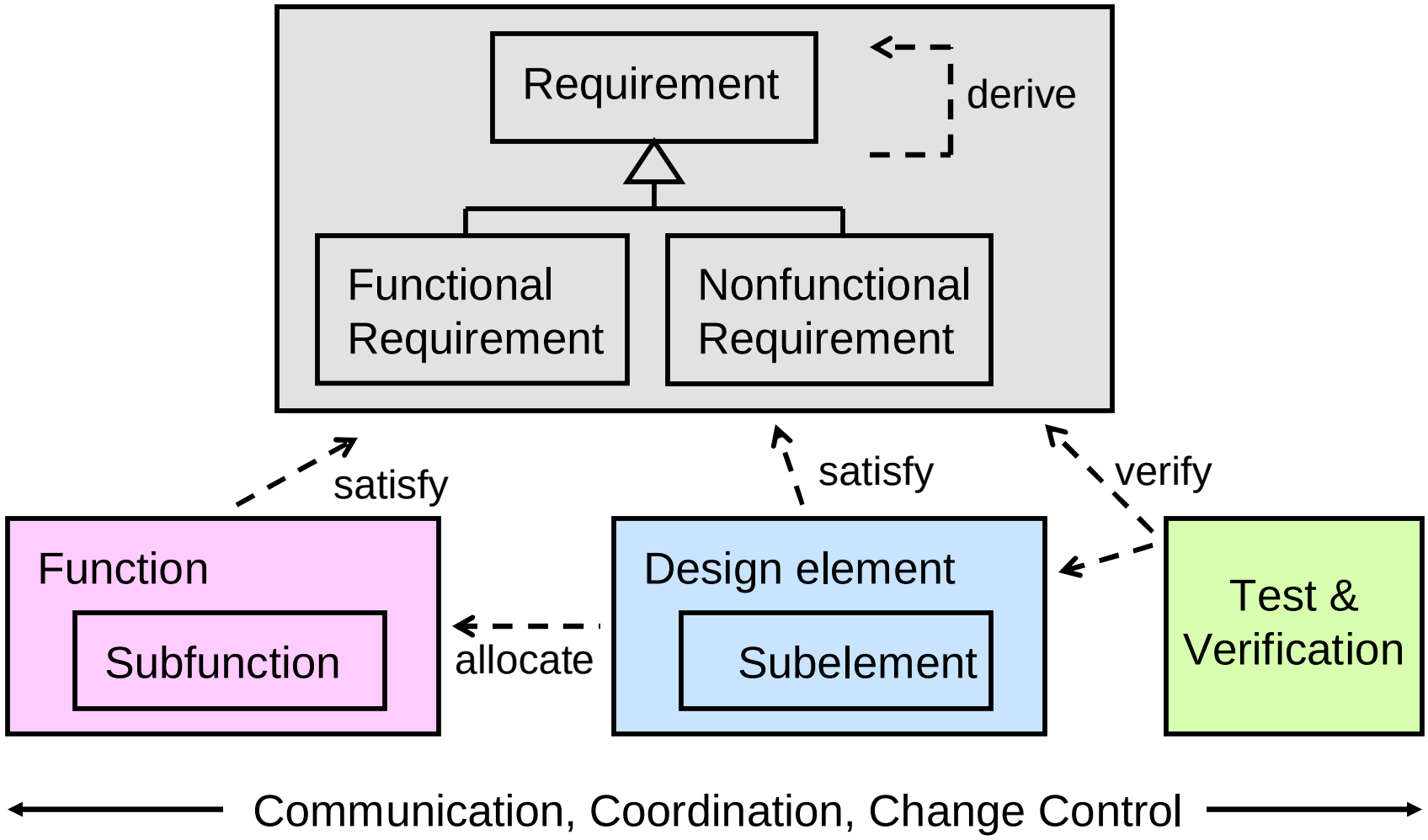
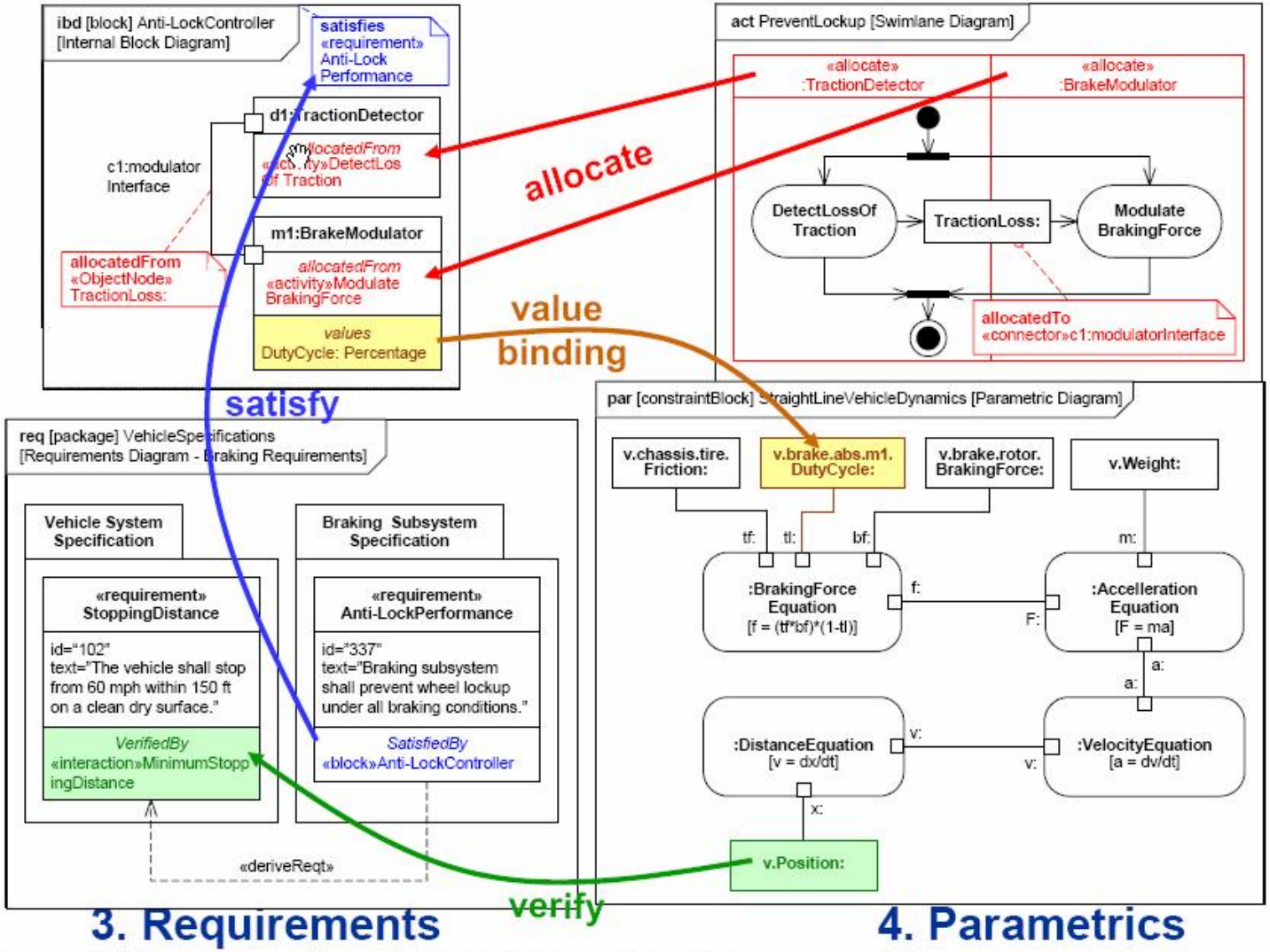
OMG System Modeling Language (OMG SysML™)

- SysML is a profile and extension of the Unified Modeling Language, developed by an industry team in response to a request issued by the Object Management Group (OMG)
- Supports the specification, analysis, and verification of complex systems
- Improves the ability to exchange systems engineering information across tools
- Supports systems engineering processes

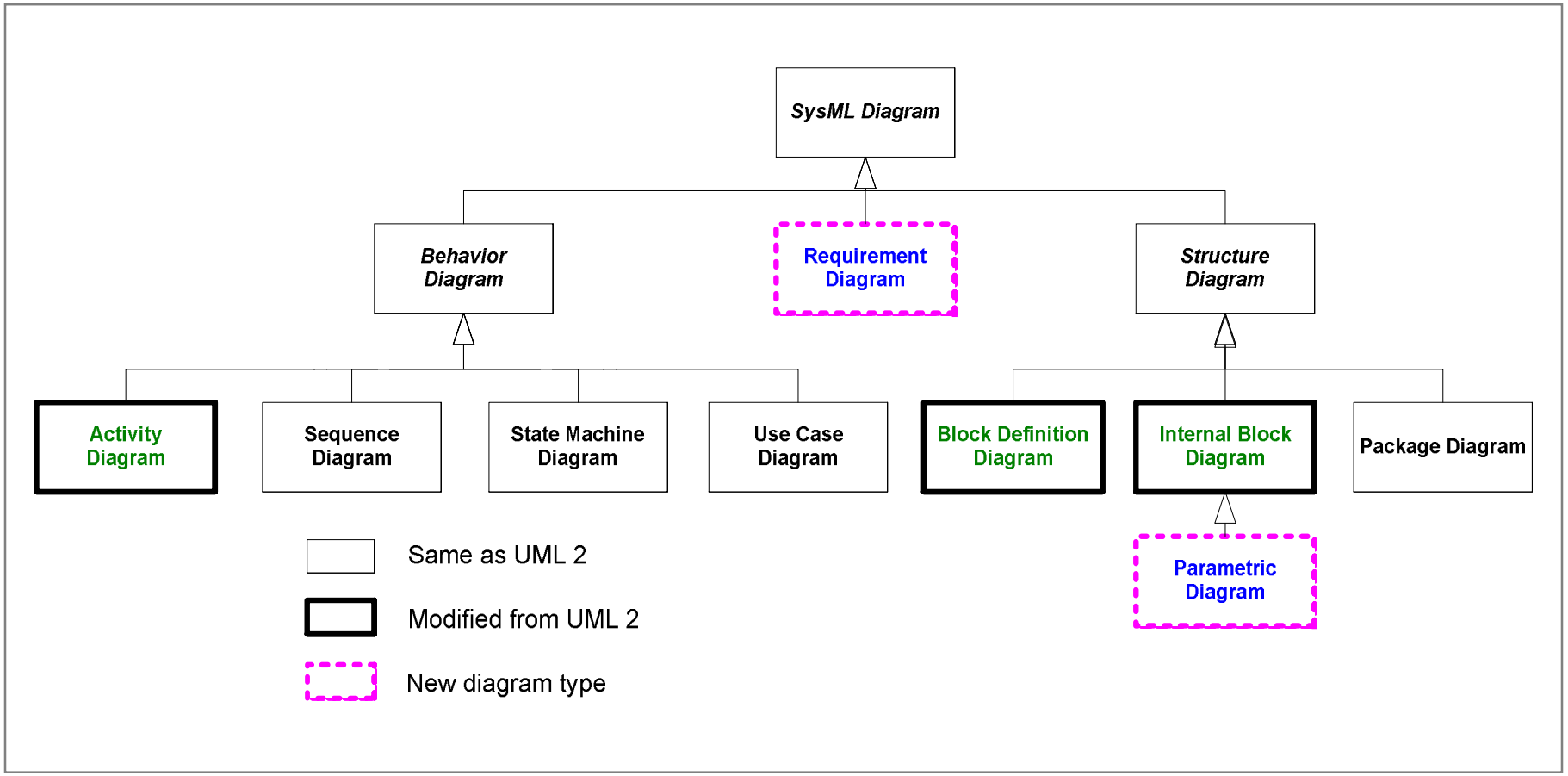
Systems Engineering Lifecycle



Cross Connecting Model Elements



SysML Diagram Taxonomy



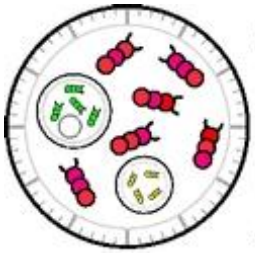
System structure models for agents

- **“Systems thinking” is a hallmark of both complex adaptive systems research and applied systems engineering**
- **Properties and functions at emergent levels is a persistent, common theme**
  - **Many engineering applications are increasingly recognized as complex adaptive systems, in which decentralized policies and rules generate desired outcomes**
- **Multi-level systems and multi-level agents can share modeling foundations**
  - **Basic description of state and behavior**
  - **Connection of working elements in local system context**
  - **Custom description at any level with optional linkage across levels**

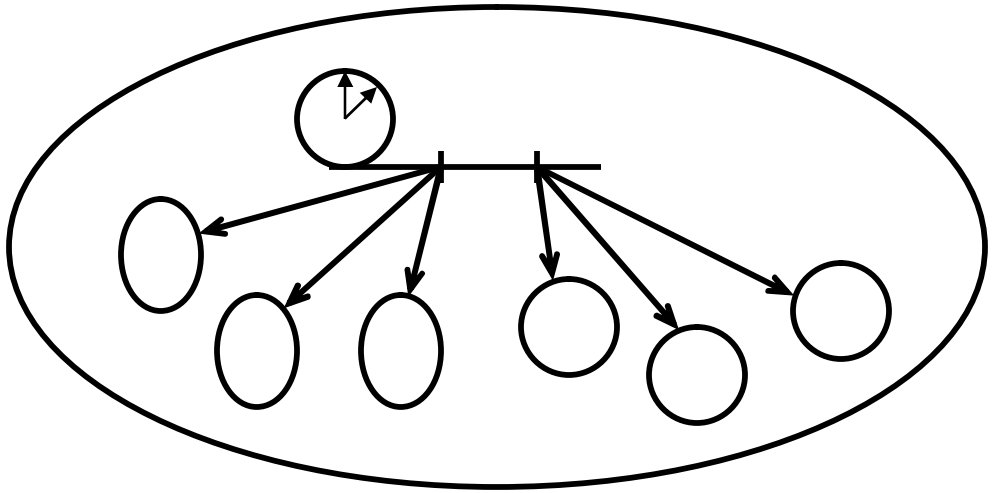
Swarm design goals

- Conceptual framework for agent models
- Programming support for building agent simulations
- Experimenter support for running simulations
- Nucleus for a community of agent modelers

Santa Fe Institute



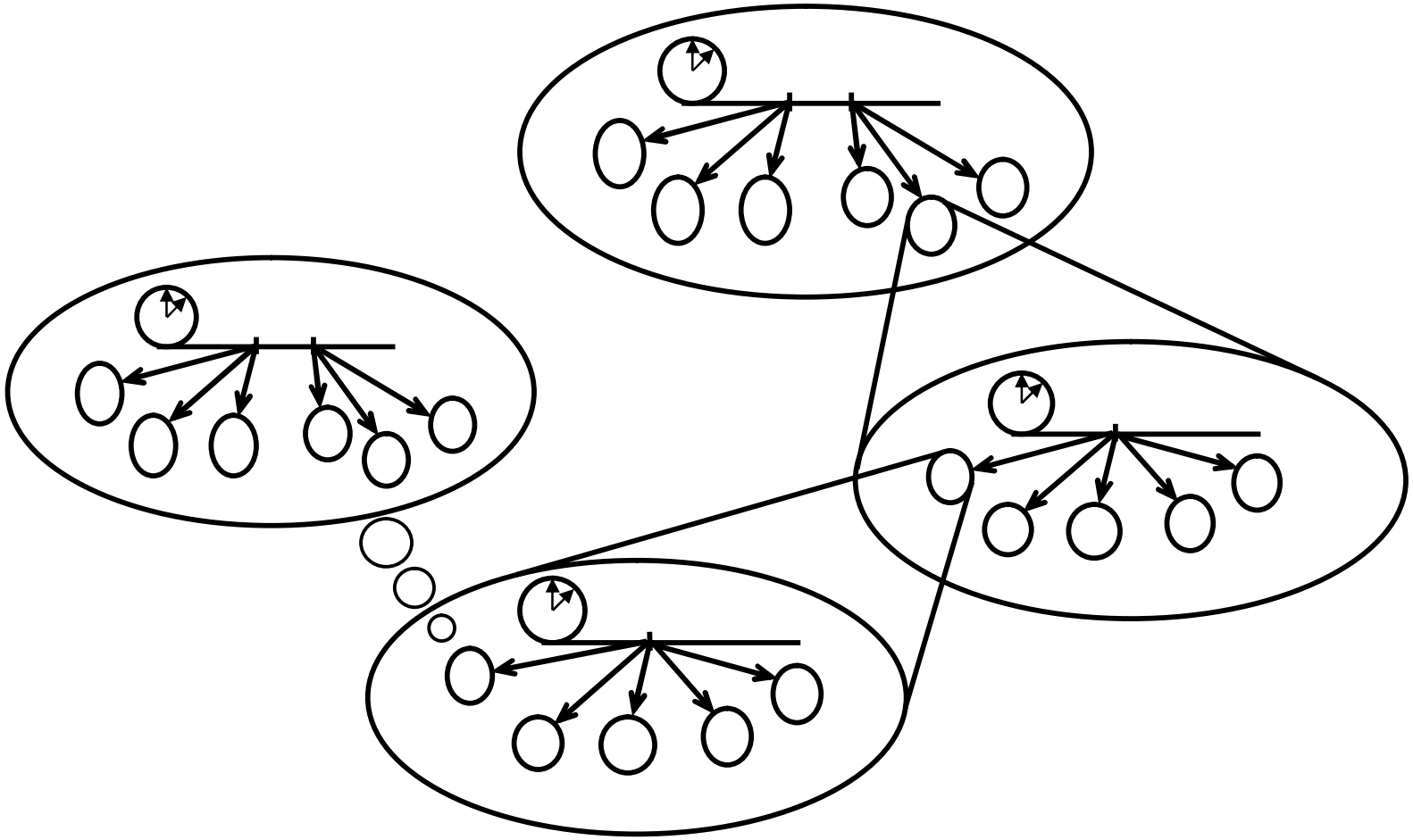
Original Swarm Structure



A swarm is:

- **A collection of objects**
- **A schedule of actions over those agents**

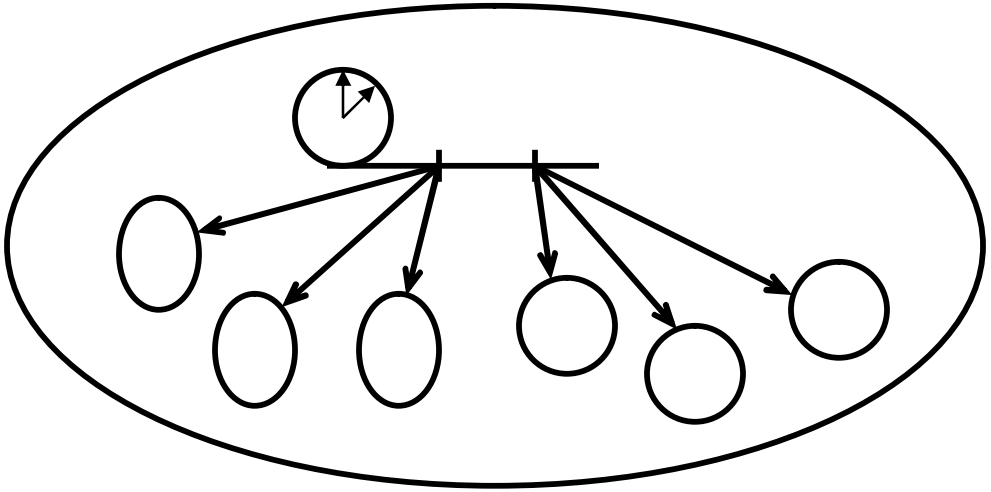
Hierarchical and Reflective Swarms



Self-constructing swarms

- Starting from an initial, minimal structure and internal schema, let the swarm itself control the creation of all internal structure and the behavior it enables
- Similar to a process of biological development
- Initial schema serves as an internal “genetic code” that enables agents to share blueprints for component construction and binding, including transfers across independent lifetimes
- Behavior model to express cognition, learning, organization, growth and evolution

Extension for agent life cycles



A swarm is:

- **A collection of objects**
- **A schedule of actions over those agents**
- ⇨ **A schema that controls the development and behavior of the swarm over its entire lifetime**

Problem statements from the Workshop on Biological Framings of Problems in Computing held April 17-19, 2002 at the Santa Fe Institute:

"Living Language" Problem Statement

Define a formal language that can be used to describe trajectories of development through a state space that expands as a system runs. The expanding state space must be able to include the products of innovation produced during evolution of a system and the individuals within it. This means that the formal language must be able to add new elements to whatever vocabulary it starts with [...]

"Back to Development" Problem Statement

Create a program that can control its own future growth and form. Find an encoding/specification that can control the elaboration of computer system functions/features throughout a lifetime of ever increasing requirements and corresponding complexity.

Summary

- There are both practical and theoretical challenges to apply Modeling & Simulation to the needs of complex systems engineering
- Building on existing modeling frameworks (Systems Engineering models, logic-based knowledge representation, agent-based modeling) can provide useful cross-fertilization and multiple bridges to existing practice
- Because Modeling & Simulation will be fundamental to the practice of complex systems engineering, new modeling frameworks could be an important enabler