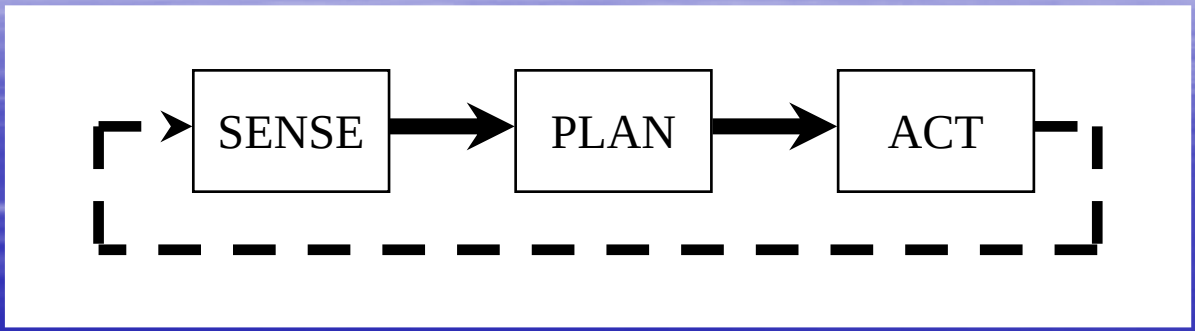
Hybrid Intelligent Systems

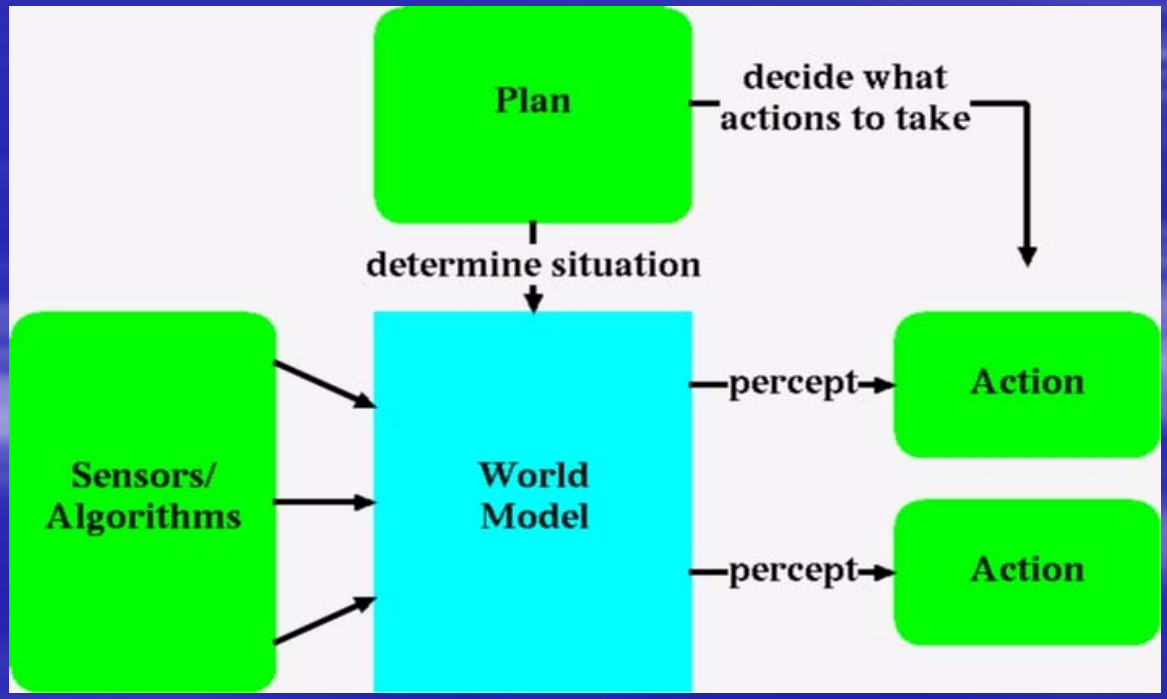
Lecture 16

Hybrid Information Systems for Robots

Organization of hierarchical paradigm for control of robot

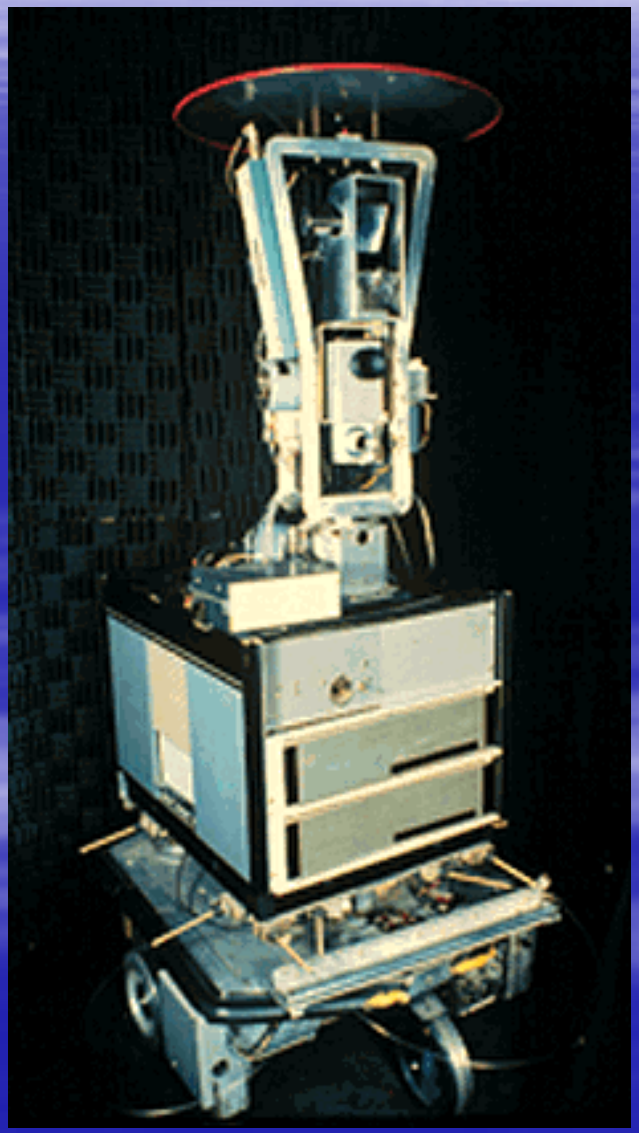


World model:
1. A priori rep
2. Sensed info
3. Cognitive



Shakey

- First AI robot
- Built by SRI (Stanford Research Institute) for DARPA 1967-9
- Used ***Strips*** as main algorithm for controlling what to do

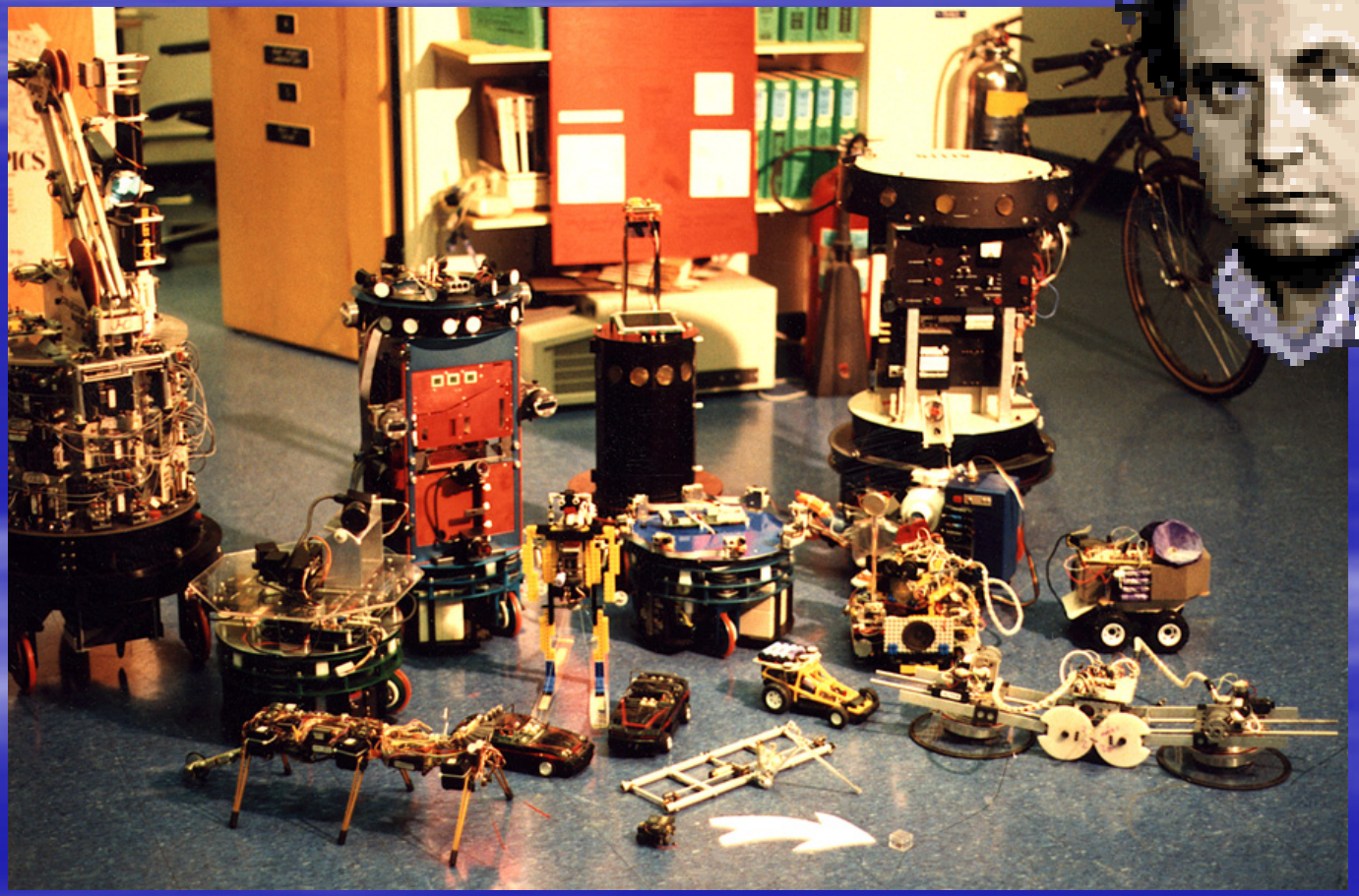


Strips Summary

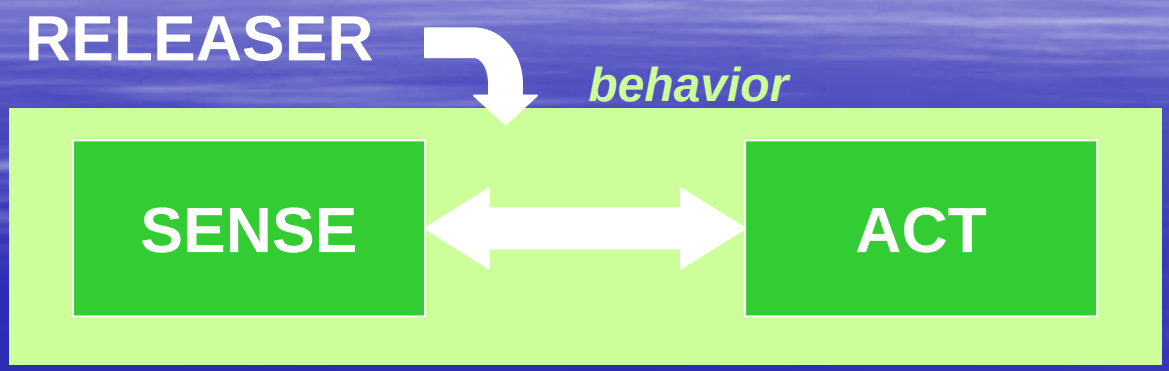
- Designer must set up
  - World model representation
  - Difference table with operators, preconditions, add & delete lists
  - Difference evaluator
- Strips assumes ***closed world***
  - Closed world: world model contains everything needed for robot (implication is that it doesn't change)
  - Open world: world is dynamic and world model may not be complete
- Strips suffers from ***frame problem***
  - Frame problem: representation grows too large to reasonably operate over

Rodney Brooks:
Behavior-based robots

or reactive robots

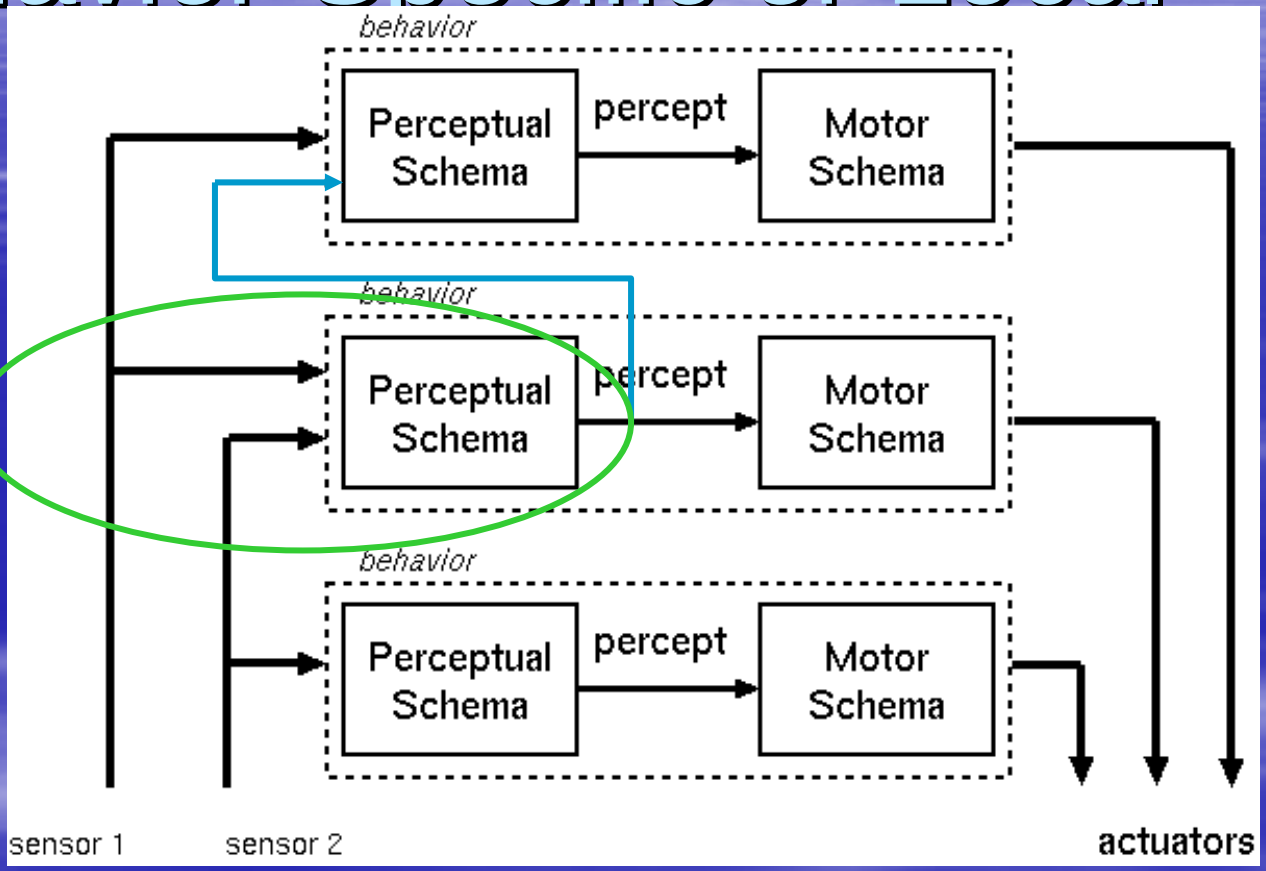


Reactive Robots



- Most apps are programmed with this paradigm
- Biologically based:
  - Behaviors (independent processes), released by perceptual or internal events (state)
  - No world models or long term memory
  - Highly modular, generic
  - Overall behavior *emerges*

Sensing is Behavior-Specific or Local



Behaviors can "share" perception without knowing it

This is behavioral sensor fusion

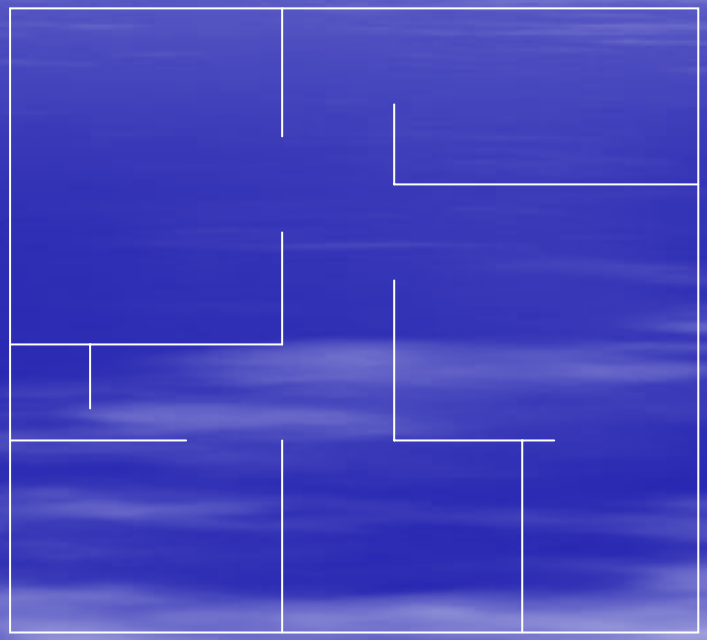
Example 1: Robomow

- Behaviors?
- Random
- Avoid
  - Avoid(bump=obstacle)
  - Avoid(wire=boundary)
- Stop
  - Stop(tilt=ON)
- All active

www.friendlymachines.com

Motivating Example for Deliberation: USAR

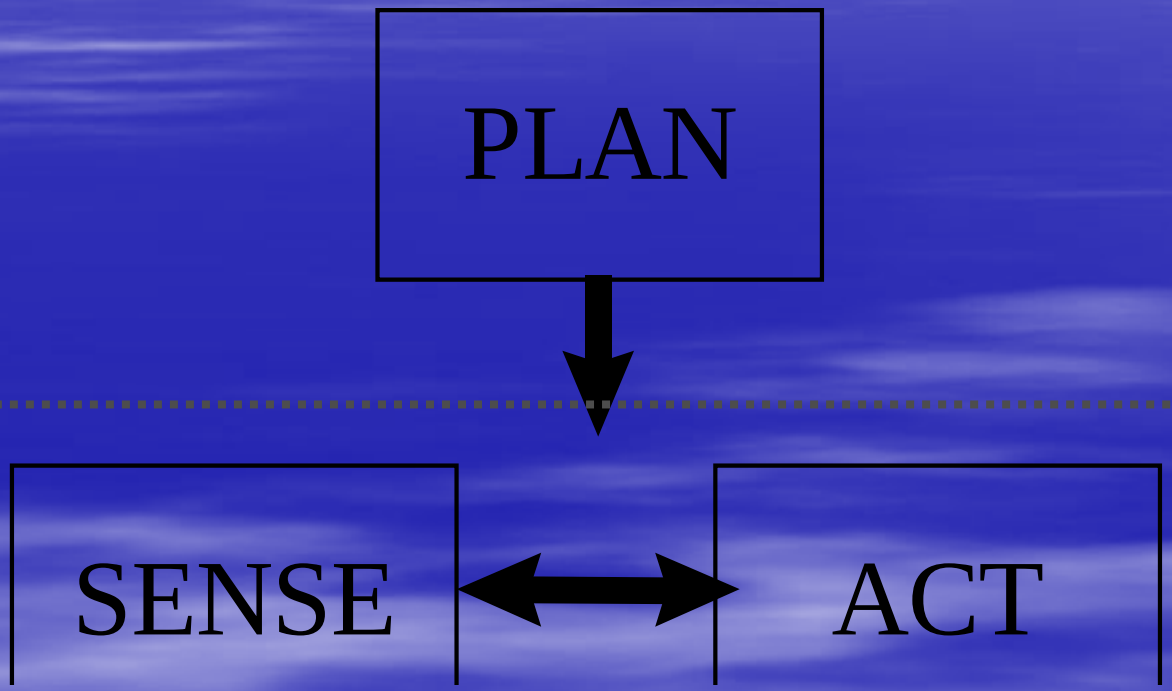
- Worker places robot at entrance to unstable building, loads in the floor plan, contextual knowledge and tells robot to look for survivors efficiently and map out safe routes for workers to pass through
- contextual knowledge includes probability of where people are more likely to be



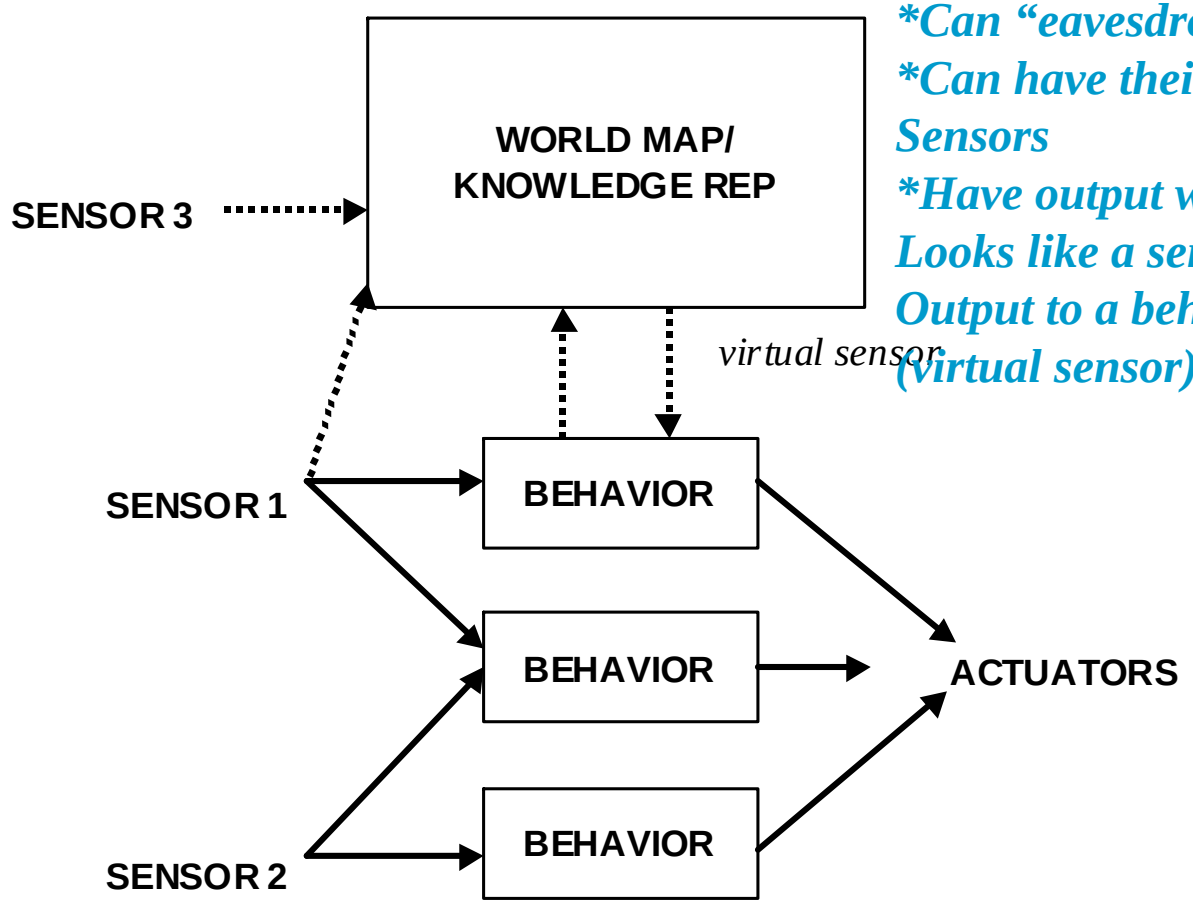
What can a reactive architecture do? What can't it do?

Path planning, handling detours due to blockage, map making, learn from past rescues

Organization: Plan, Sense-Act



Sensing Organization



Deliberative functions
****Can "eavesdrop"***
****Can have their own Sensors***
****Have output which Looks like a sensor***
Output to a behavior (virtual sensor)

Deliberation v. Reaction as a function of TIME

- Past, Present, Future
- Reactive
  - –exists in the PRESENT (will a bit of duration)
- Deliberative
  - –can reason about the PAST
  - –can project into the FUTURE

Architectures: Key Questions

- How does the architecture distinguish between reaction and deliberation?
- How does it organize responsibilities in the deliberative portion?
- How does overall behavior emerge?

Architectures: Common Functionality

- Mission planner
- Cartographer
- Sequencer agent
- Behavioral manager
- *Performance monitor/problem solving agent (fairly rare)*

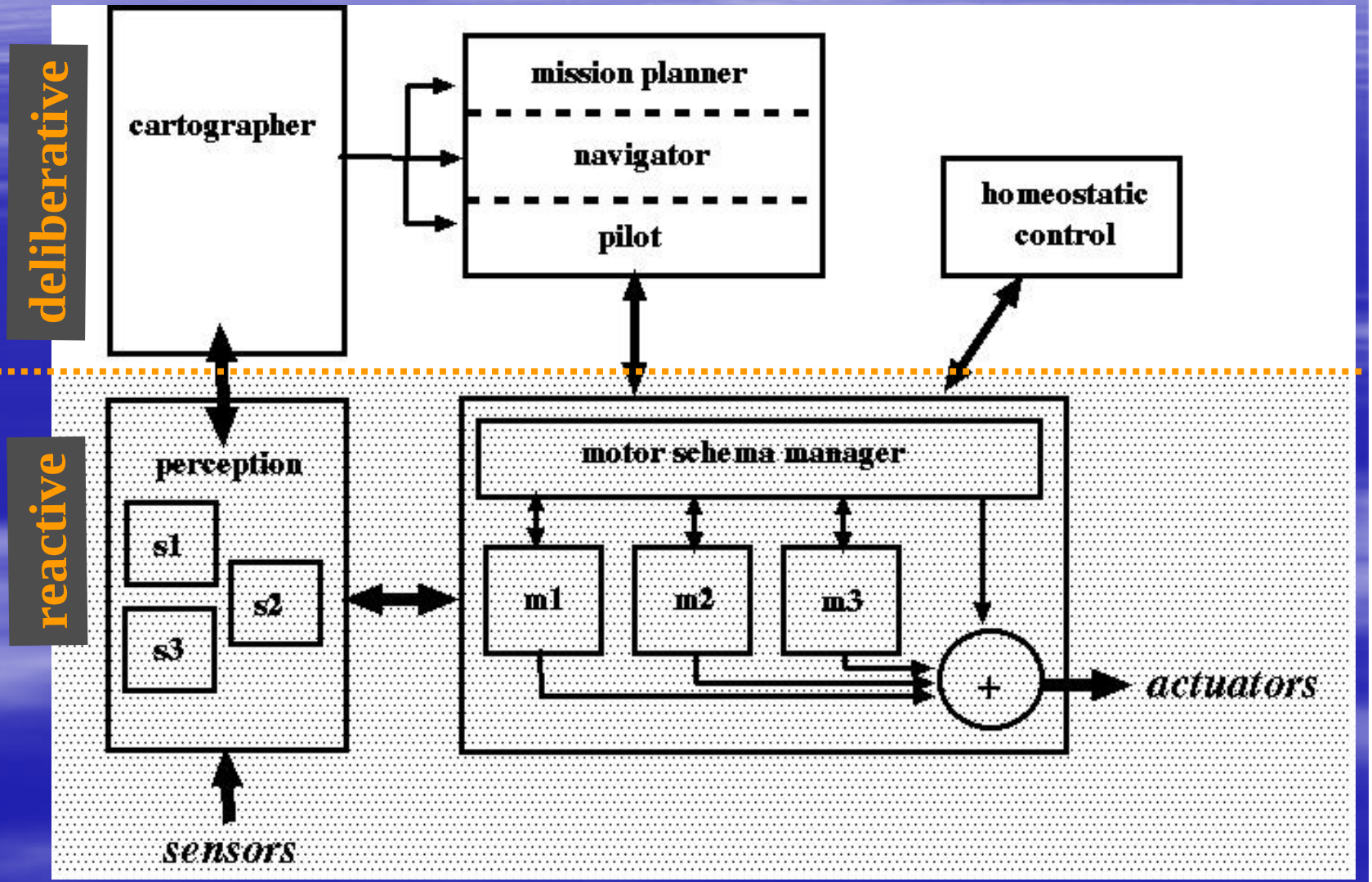
Architectures: 3 Styles

- Managerial (division of responsibilities looks like in business)
  - *AuRA, SFX*
- State Hierarchies (strictly by time scope)
  - *3T*
- Model-Oriented (models serve as virtual sensors)
  - *Saphira, TCA*

Mgr Architecture 1:
AuRA (Autonomous Robot Architecture)

Ron Arkin, Georgia Institute of Technology

AuRA Architectural Layout



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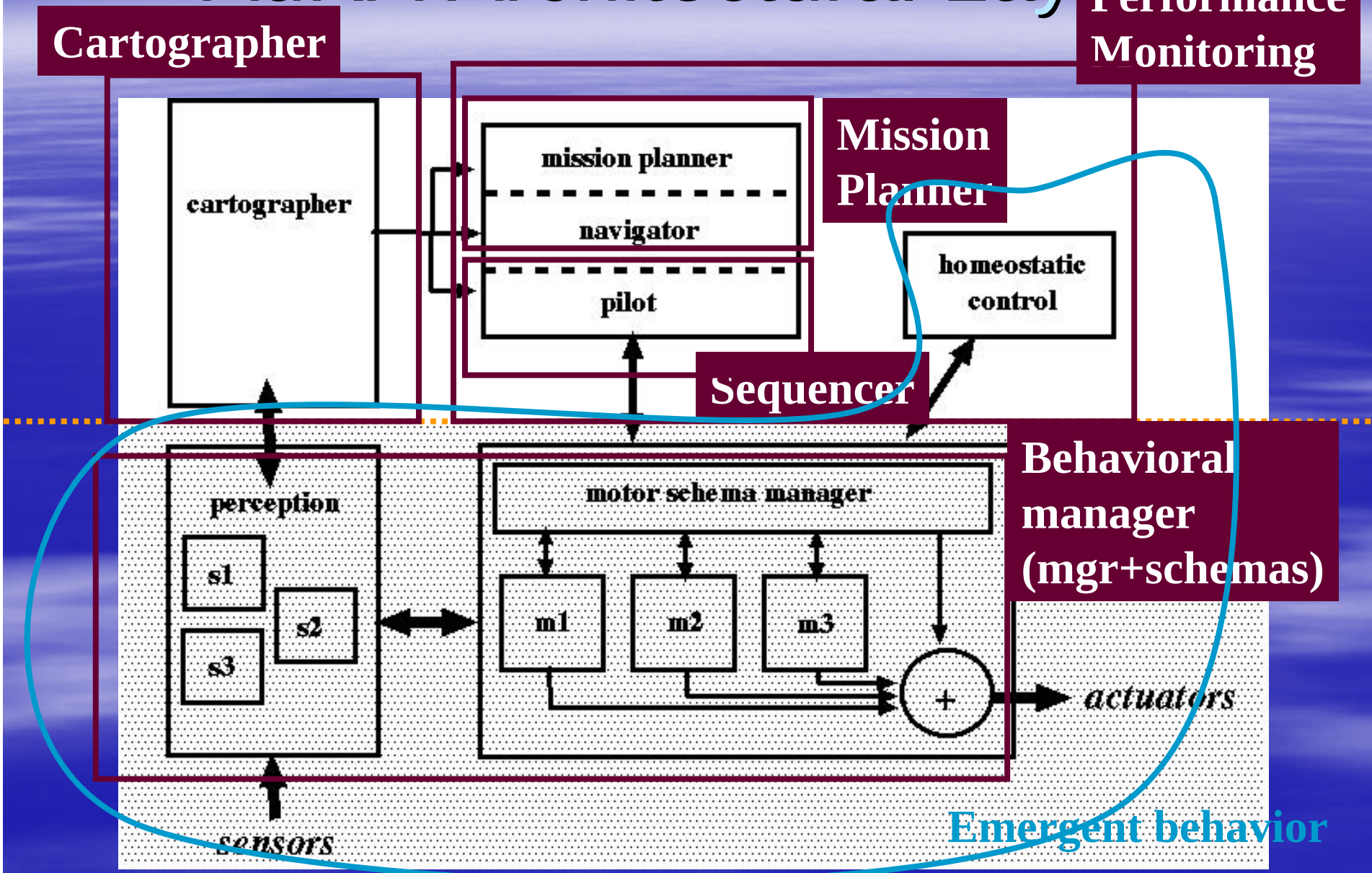
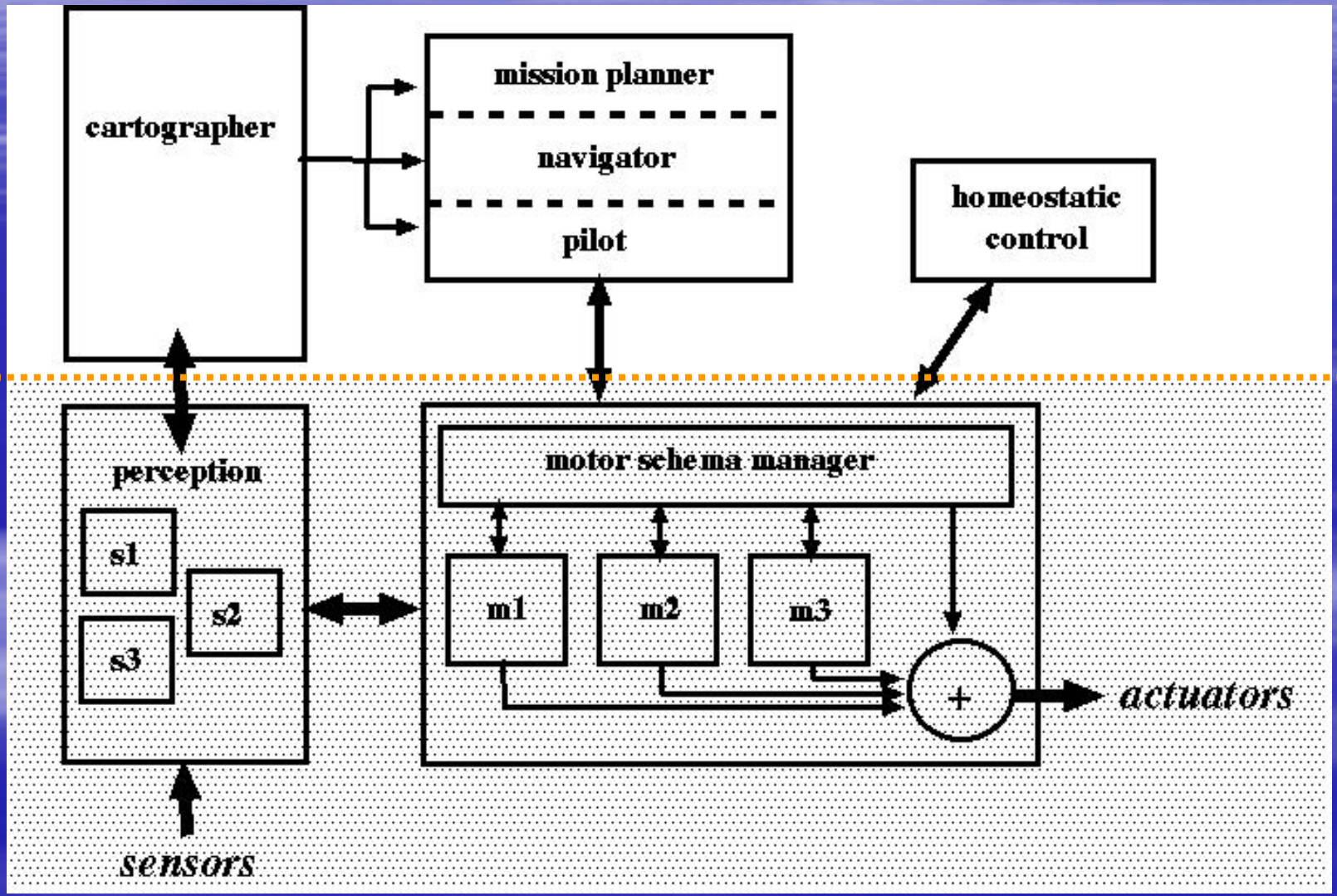


HOW WOULD THIS DO USAR TASK?



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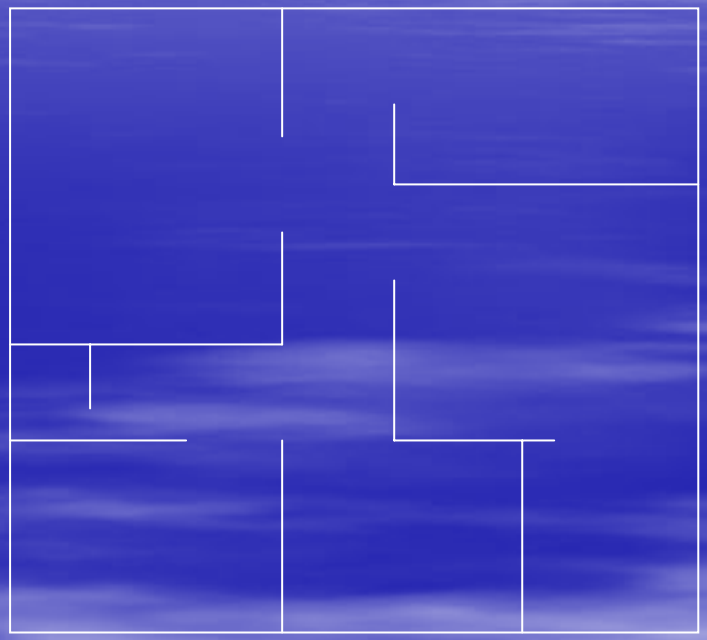

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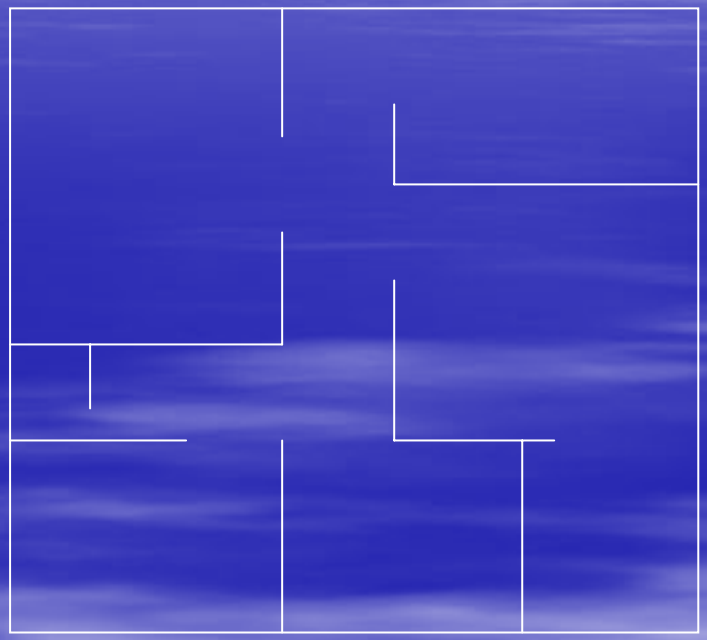

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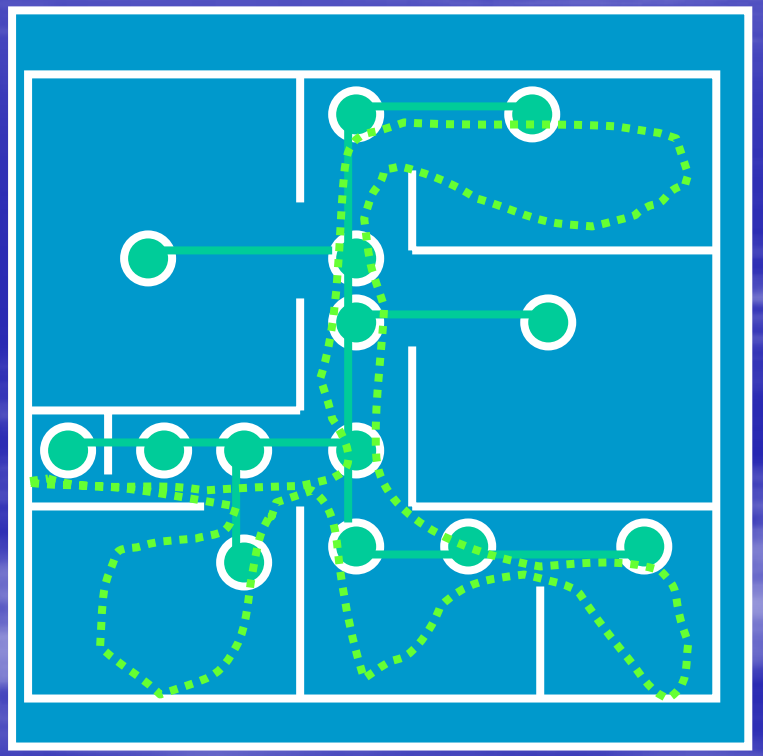
Example USAR (overlay)

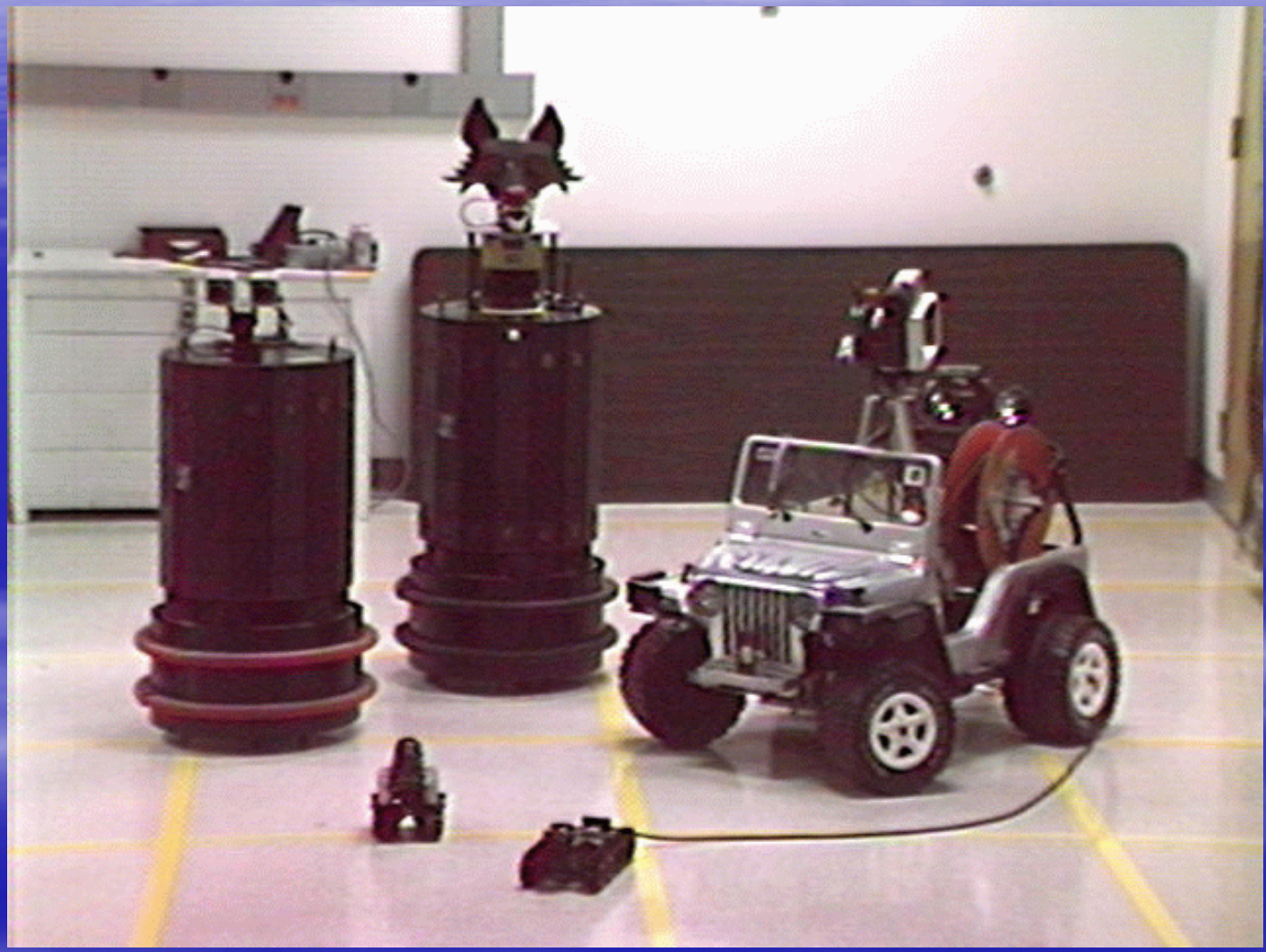
- **Cartographer** accepts the map
- Navigator uses path planning algorithm to visit nodes in order of likelihood of survivors
- Pilot determines the list of behaviors, **Motor Schema Manager** instantiates them (MS & PS) and waits for termination
- **Homeostatic** might notice that robot is running out of power, so opportunistically picks up low probability room on way back to home



Mgr. Architecture 2: SFX (Sensor Fusion Effects)

- Focus on sensing
- Biomimetic organization
- deliberative layer consists of managerial agents
- reactive layer has *tactical behaviors*

SFX (Sensor Fusion Effects)



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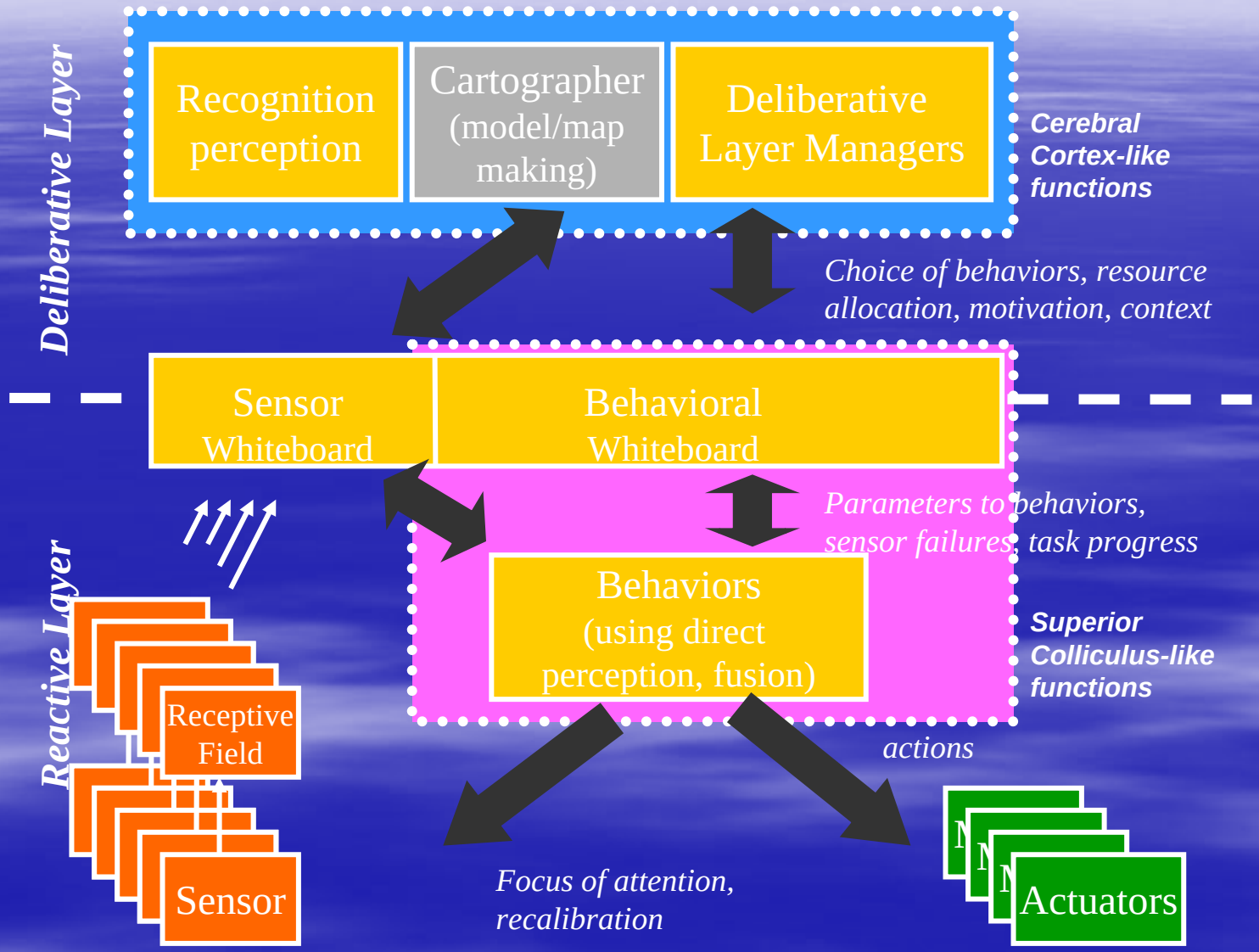
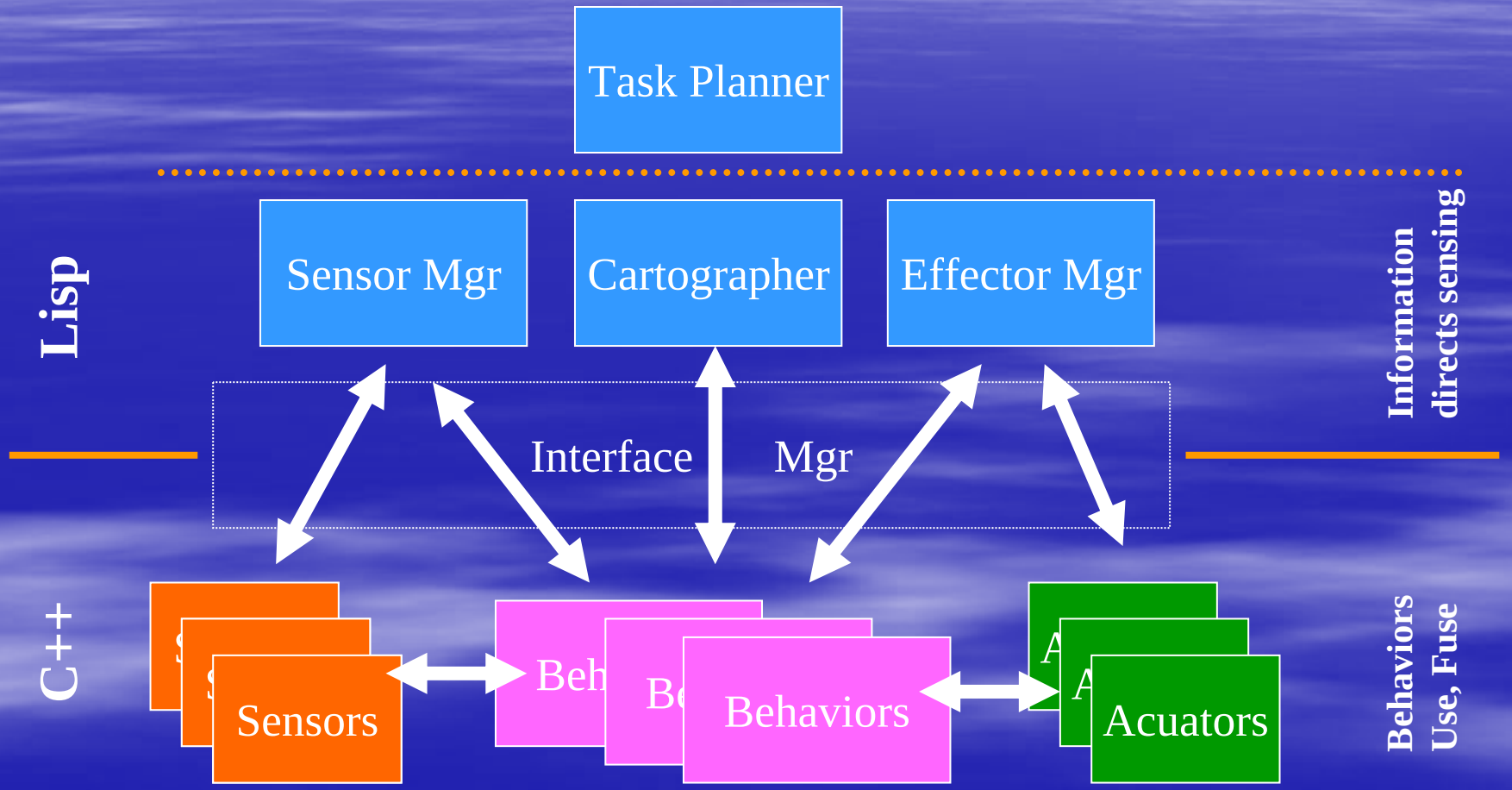


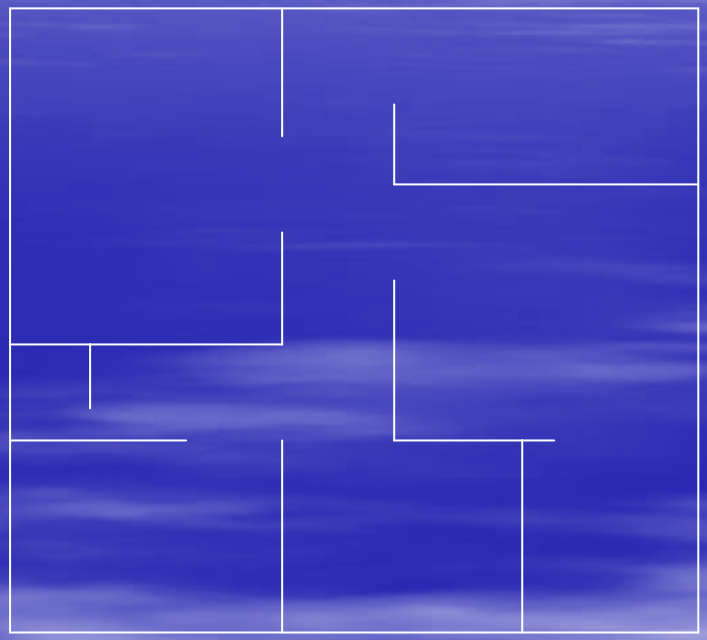
SFX Implementation

HOW WOULD THIS DO USAR?



Ability to Substitute Components

Motivating Example for Deliberation: USAR



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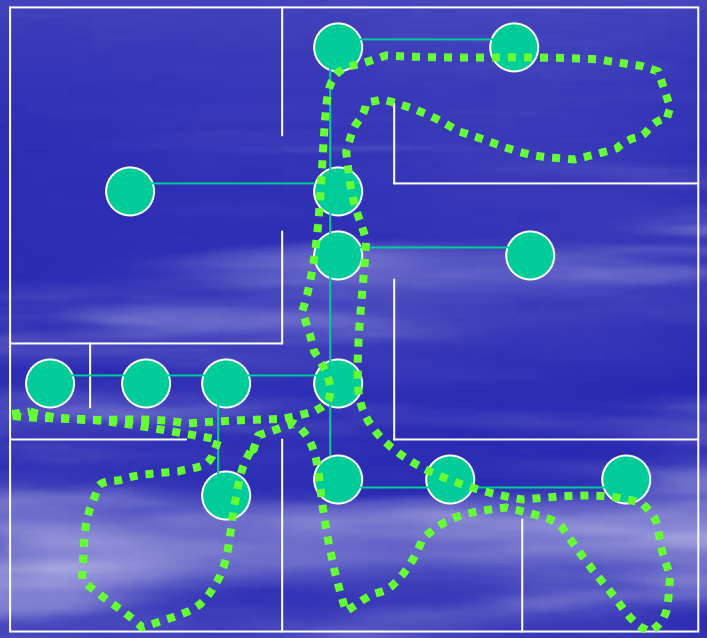
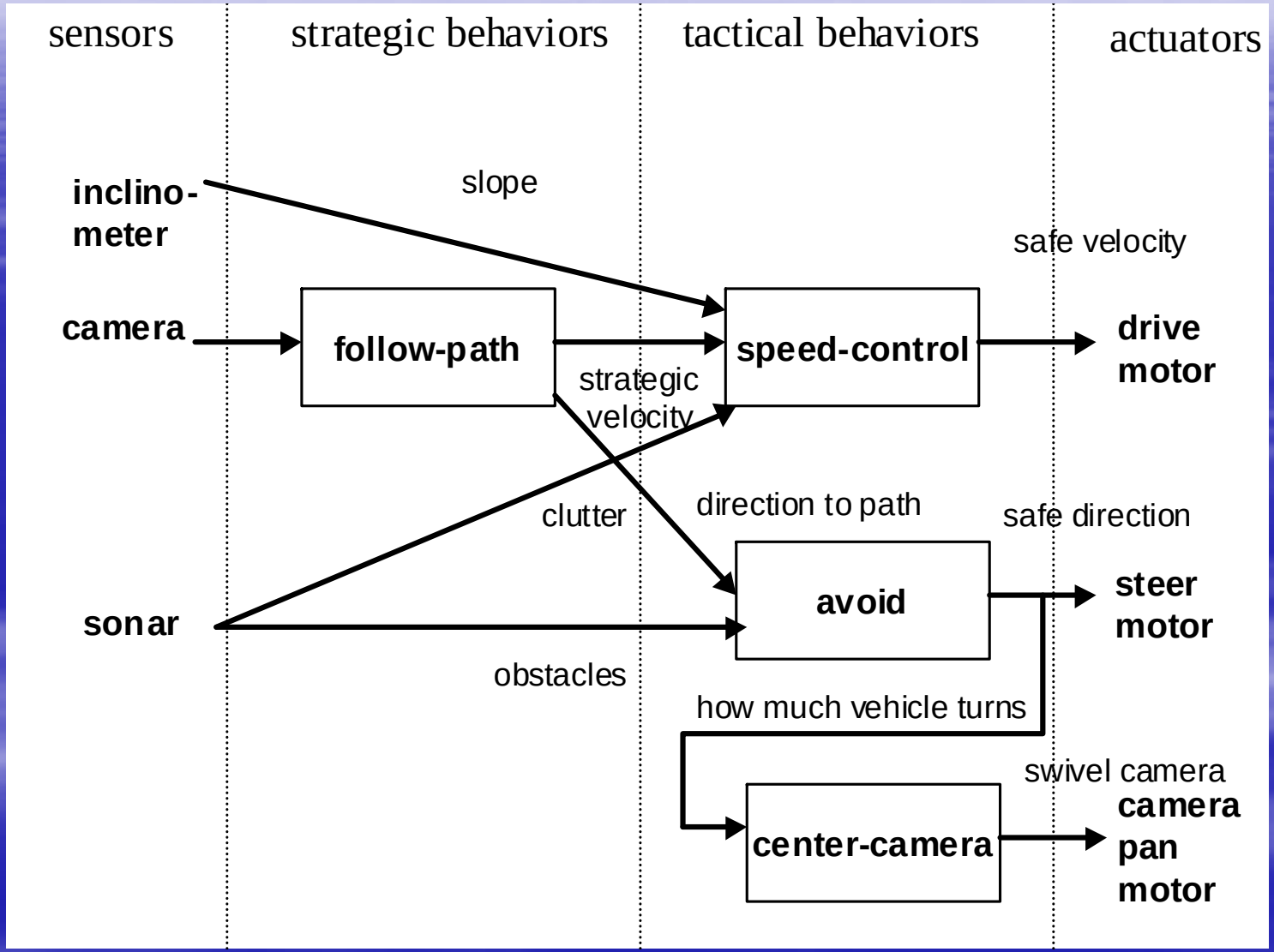
Example USAR (overlay)

- **Cartographer** accepts the map
- **Task Planner** agent asks for path, requests behaviors, passes to managerial layer
- **Sensing and Effector Mgrs** negotiate allocation
- **Behaviors** run until terminate or encounter exception (either preset condition by mgrs or through monitoring)
- Mgrs can see “below” but not above--cannot relax constraint of Planner/Boss



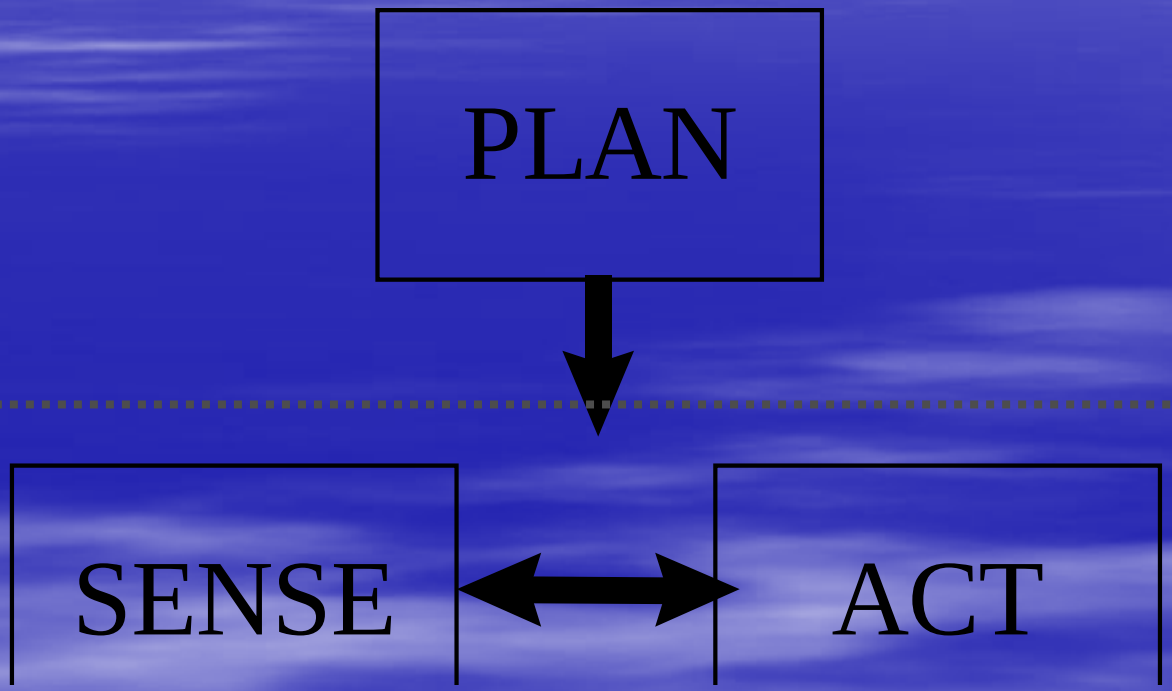
Tactical Behaviors



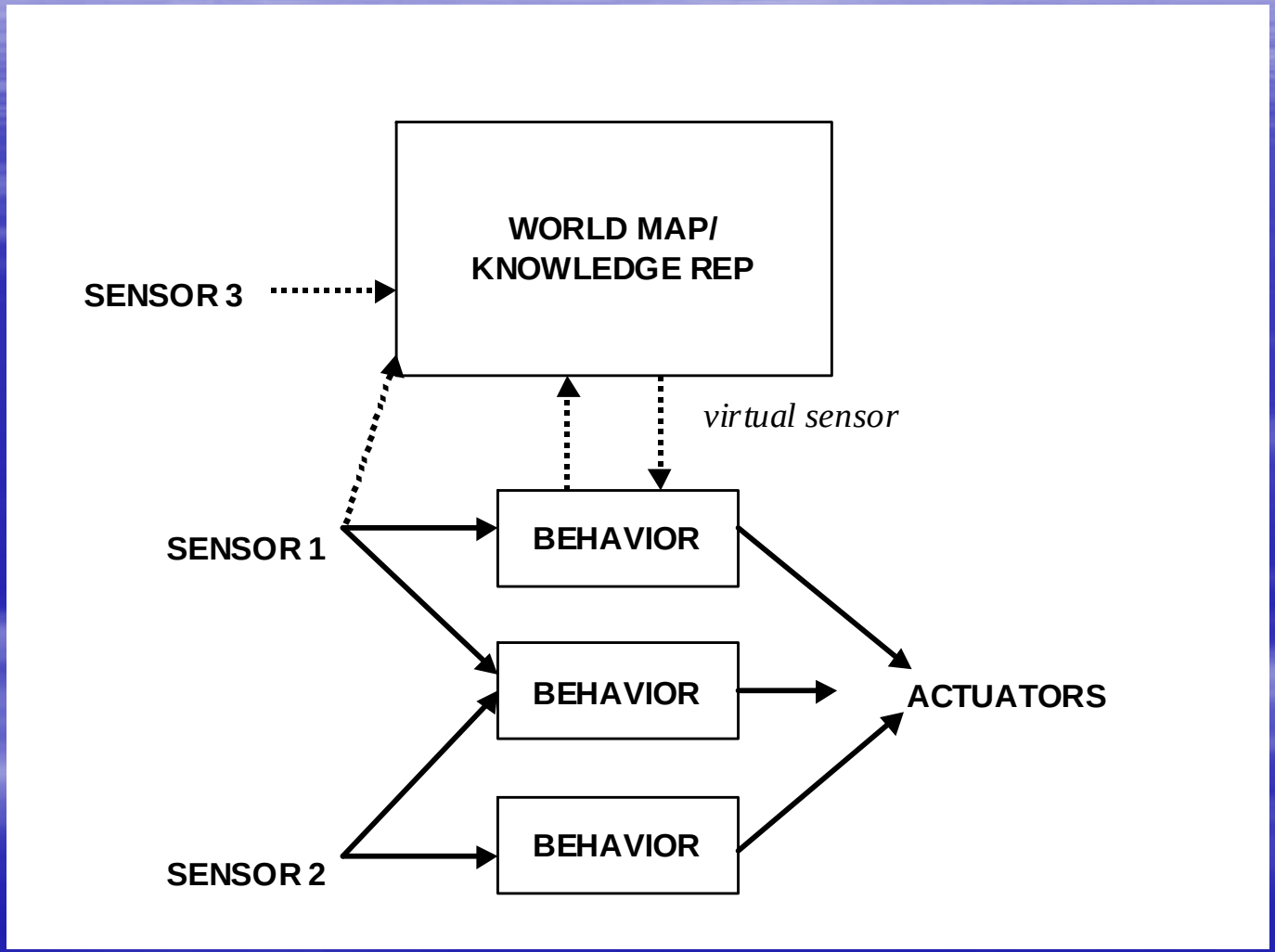
Summary: Managerial Architectures

- How does the architecture distinguish between reaction and deliberation?
  - **Deliberation: global knowledge or world models, projection forward or backward in time**
  - **Reaction: behaviors which have some past/persistence of perception and external state**
- How does it organize responsibilities in the deliberative portion?
  - **hierarchy of managerial responsibility, managers may be peer software agents**
- How does overall behavior emerge?
  - **From interactions of a set of behaviors dynamically instantiated and modified by the deliberative layer**
  - **assemblages of behaviors**

Plan, Sense-Act



Sensing Organization



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- Managerial (division of responsibilities looks like in business)
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- State Hierarchies (strictly by time scope or "state")
  - 3T
- Model-Oriented (models serve as virtual sensors)
  - Saphira, TCA

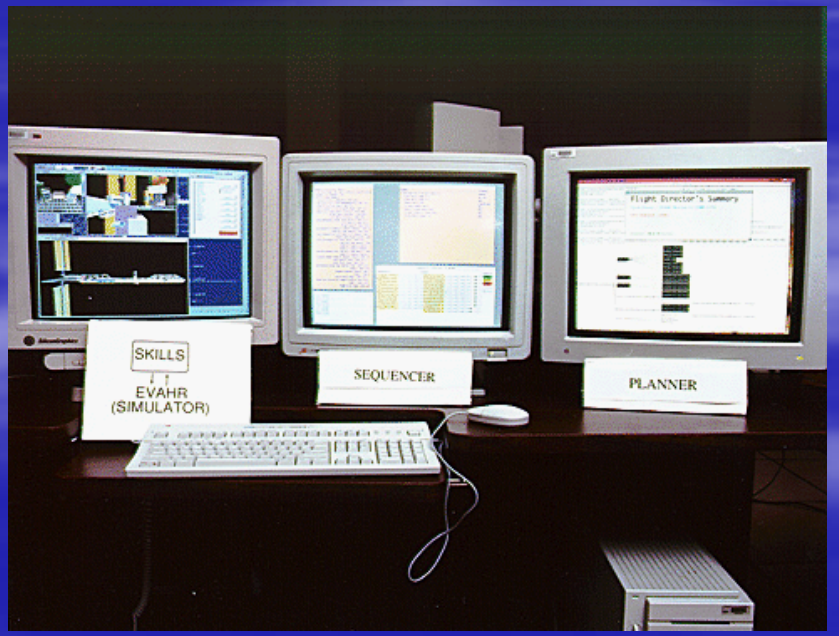
State Hierarchy Architectures

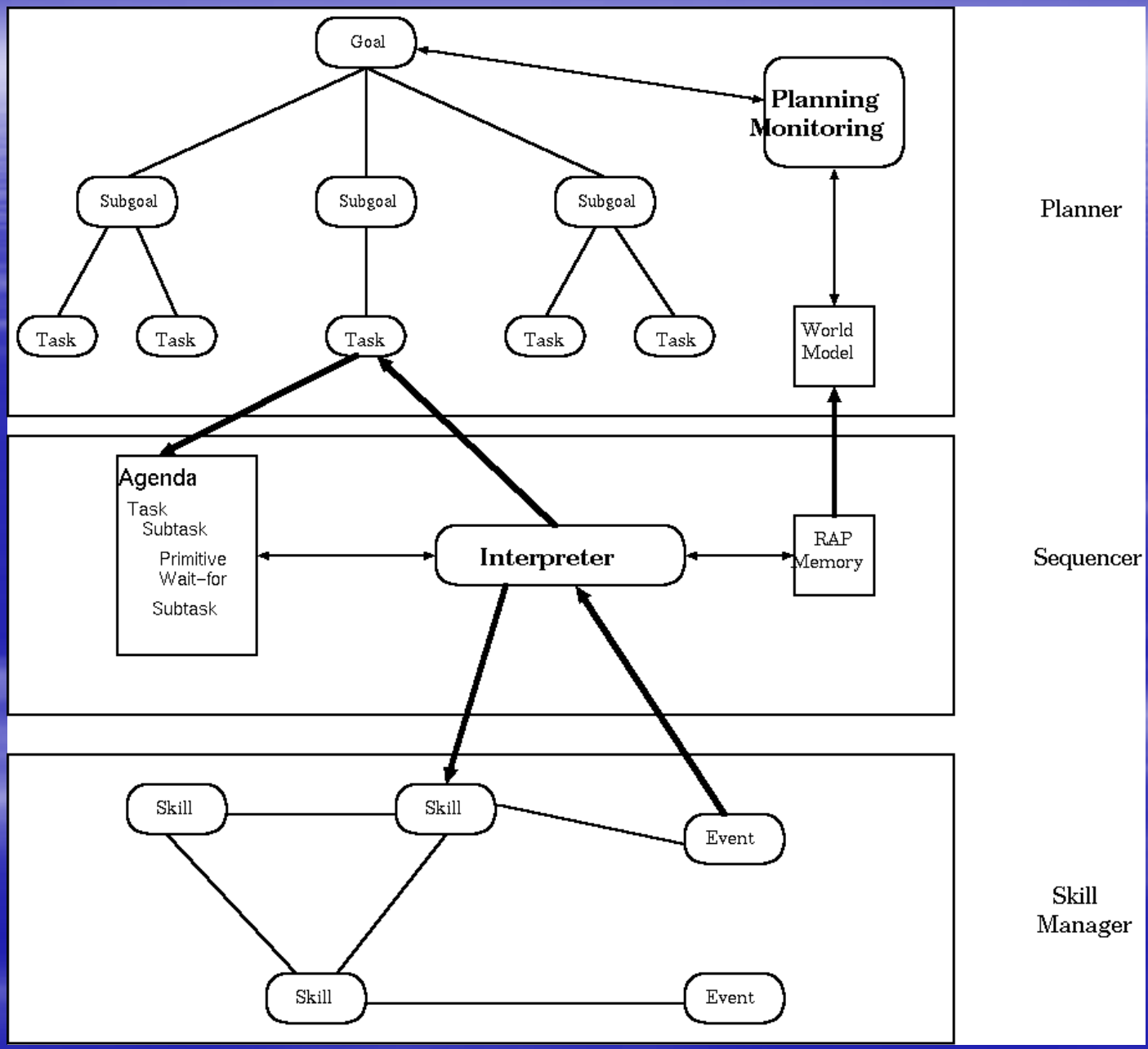
- How does the architecture distinguish between reaction and deliberation?
  - **Deliberation: requires PAST or FUTURE knowledge**
  - **Reaction: behaviors are purely reflexive and have only local, behavior specific; require only PRESENT**
- How does it organize responsibilities in the deliberative portion?
  - **By internal temporal state**
    - **PRESENT (controller)**
    - **PAST (sequencer)**
    - **FUTURE (planner)**
  - *By speed of execution*
- How does overall behavior emerge?
  - **From generation and monitoring of a sequence of behaviors**
  - **assemblages of behaviors called skills**
  - **subsumption**

3T Architecture

- Used extensively at NASA
- Merging of subsumption variation (Gat, Bonasso), RAPs (Firby), and vision (Kortenkamp)
- Has 3 layers
  - reactive
  - deliberative
  - in-between (reactive planning)
- **Arranges by time**
- Arranges by execution rate
  - ex. vision in deliberation

Dave Kortenkamp, TRAC Labs (NASA JSC)




Goal
Planning
Monitoring
Subgoal
Subgoal
Subgoal
Task
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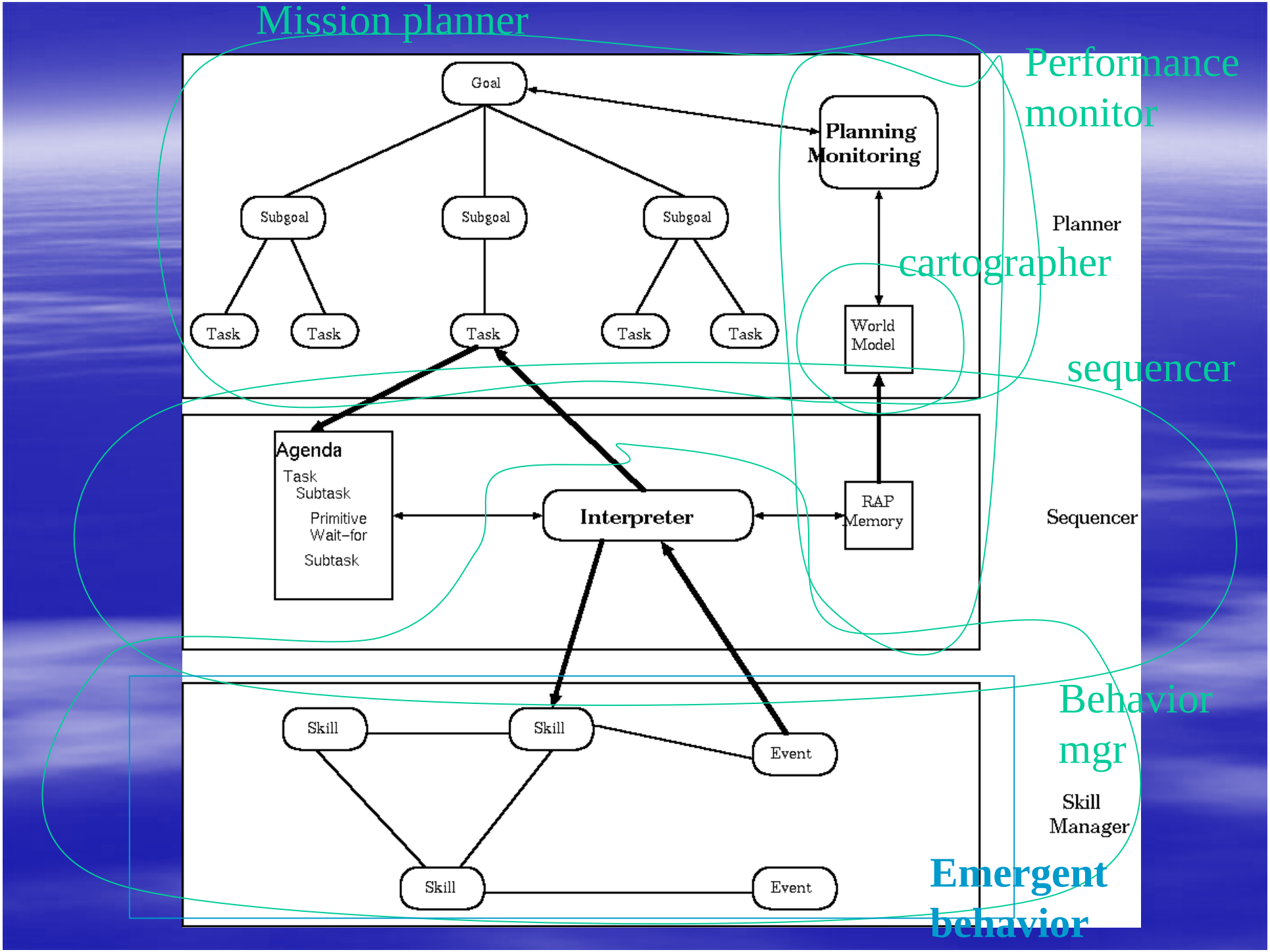
Task
Task
World
Model
Planner
Agenda
Task
Subtask
Primitive
Wait-for
Subtask
Interpreter
RAP
Memory
Sequencer
Skill
Skill
Event
Skill
Event
Skill
Manager


Mission planner
Performance monitor
Goal
Planning Monitoring
Subgoal
Subgoal
Subgoal
Task
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Task
Planner
cartographer
World Model
sequencer
Agenda
Task
Subtask
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Skill
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Behavior mgr
Skill Manager
Emergent behavior

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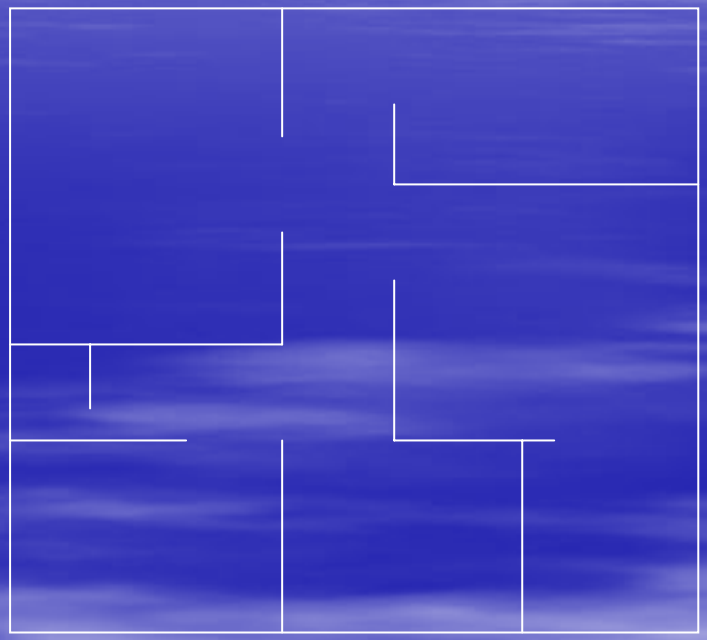


What can a reactive architecture do? What can't it do?

Path planning, handling detours due to blockage, map making, learn from past rescues

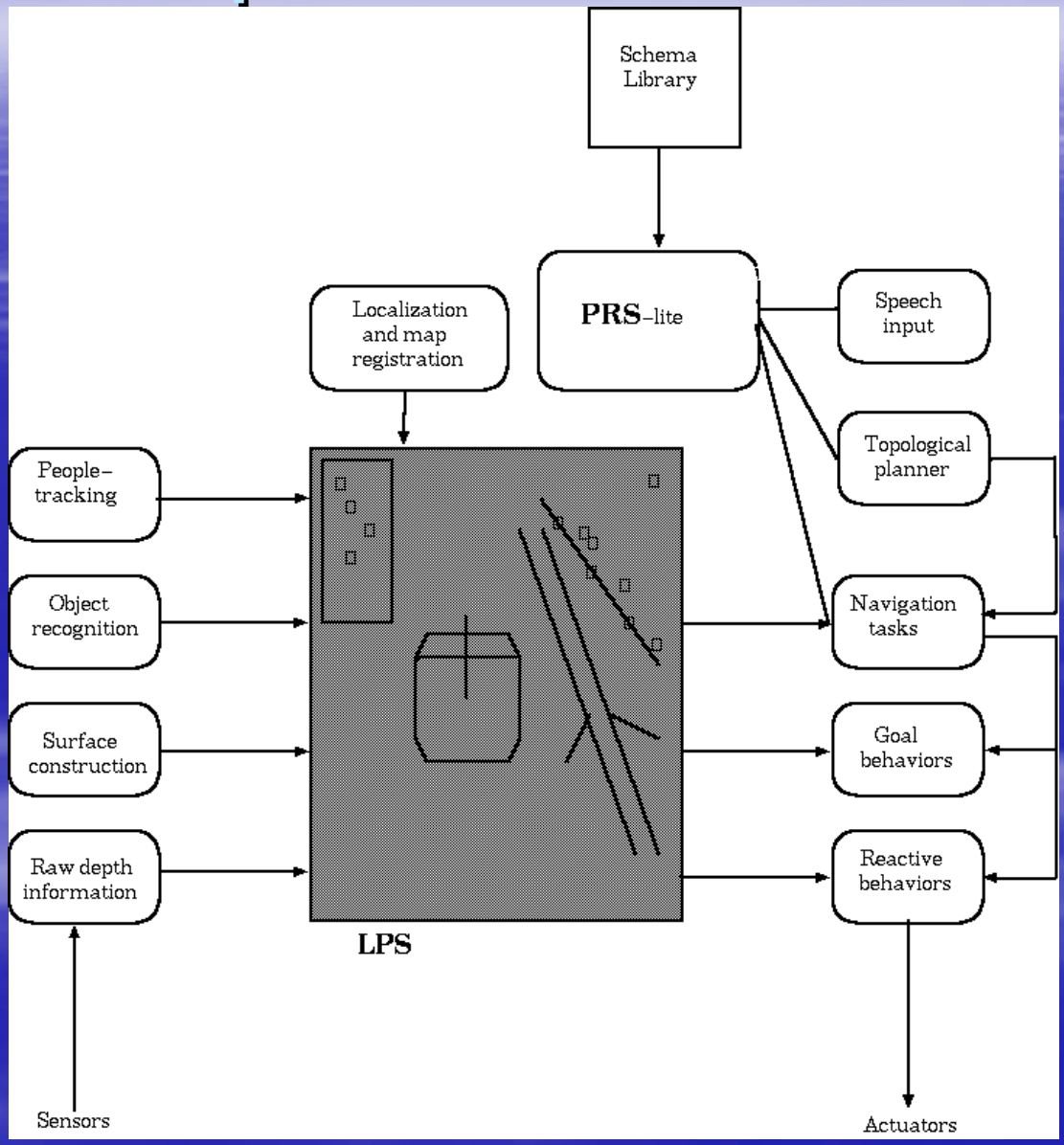
Model-Oriented Architectures

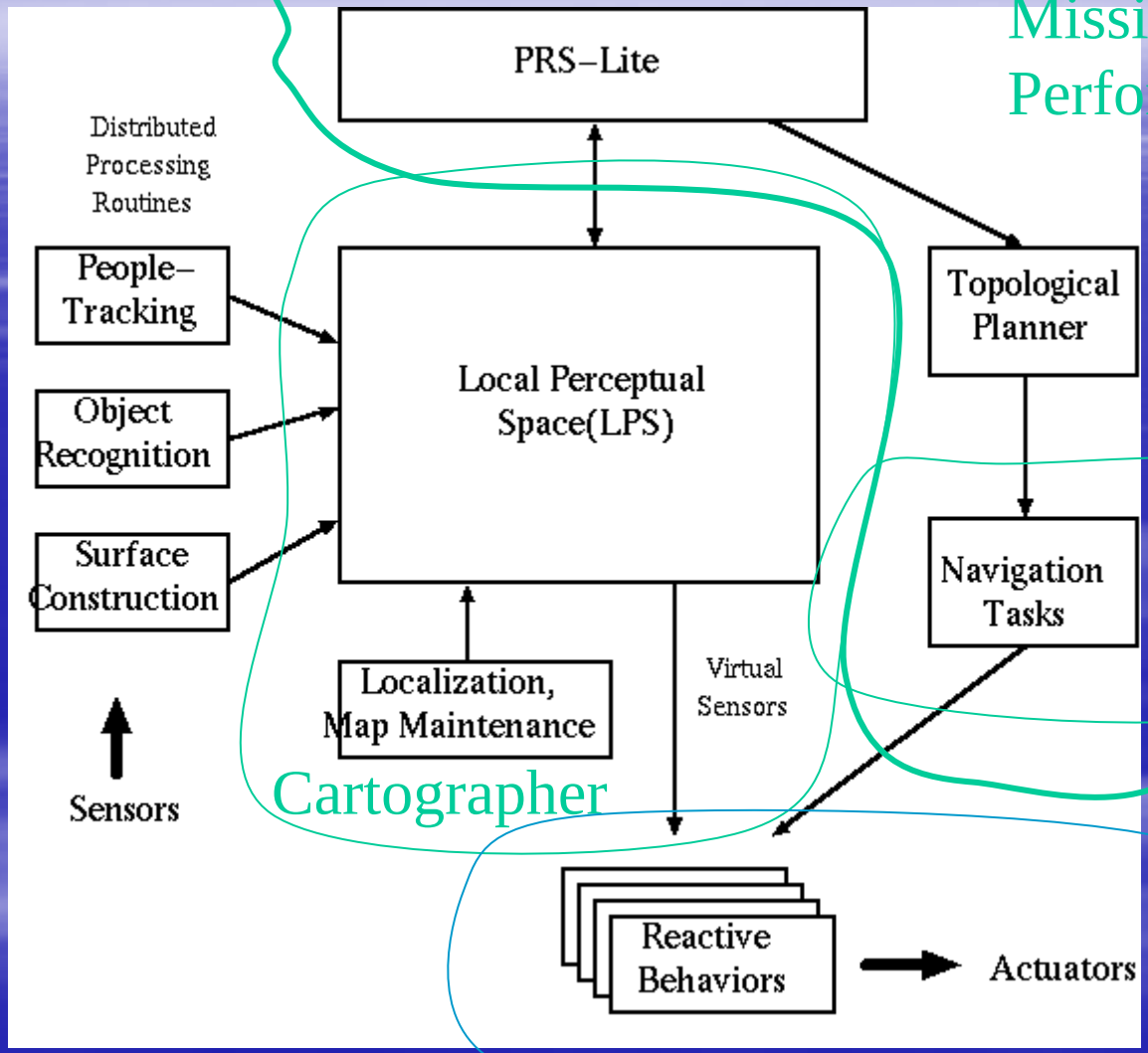
- How does the architecture distinguish between reaction and deliberation?
  - **Deliberation: anything relating a behavior to a goal or objective**
  - **Reaction: behaviors are "small control units" operating in present, but may use global knowledge as if it were a sensor (*virtual sensor)***
- How does it organize responsibilities in the deliberative portion?
  - **Behavioral component**
  - **Model of the world and state of the robot**
  - **throwback to Hierarchical Paradigm with global world model but virtual sensors**
  - **Deliberative functions**
- How does overall behavior emerge?
  - **From generation and monitoring of a sequence of behaviors**
  - **voting or fuzzy logic for combination**

Saphira Architecture

- Developed at SRI by Konolige, Myers, Saffioti
- Comes with Pioneer robots
- Behaviors produce fuzzy outputs, fuzzy logic combines them
- Has a global rep called a **Local Perceptual Structure** to filter noise
- Instead of RAPs, uses PRS-Lite

Saphira and LPS





Sequencer agent,
Mission Planning,
Performance mon.

Behavior mgr

Cartographer

Emergent behavior

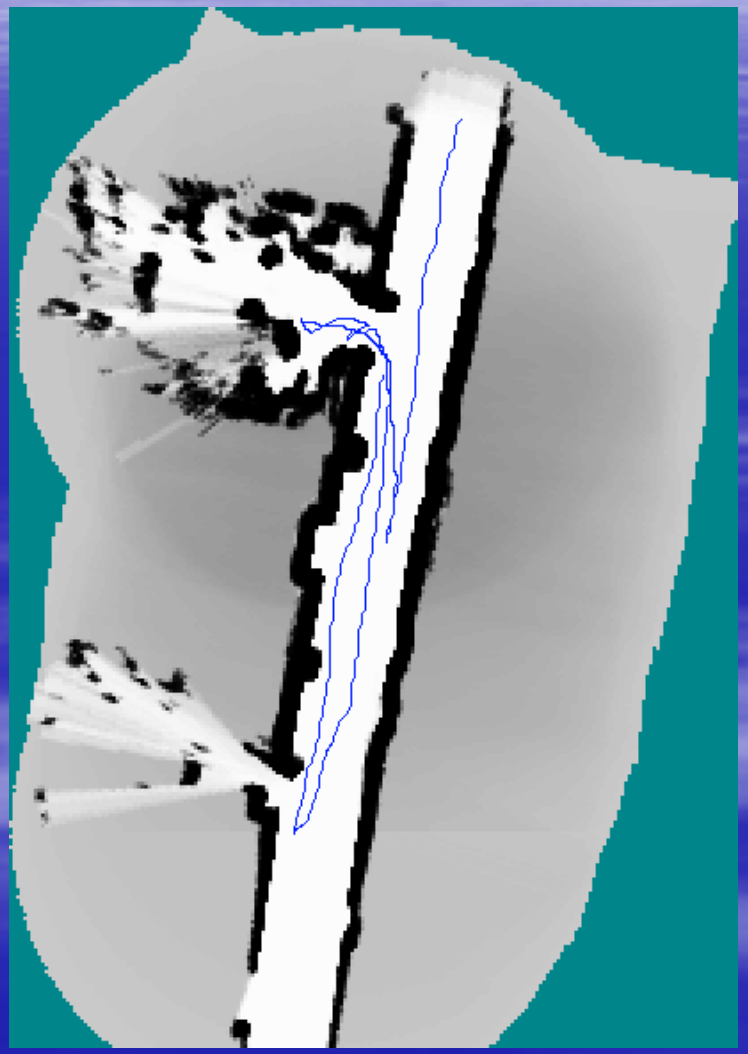
Symbol-Grounding Problem

- Computers (and AI) reasons using symbols
  - Ex. “room”, “box,” “corner,” “door”
- Robots perceive raw data

- *How to convert sensor readings to these labels?*

Spatial World Knowledge

- What do you see?
- How could a robot reliably extract the same labels?



Types of Knowledge (Arkin)

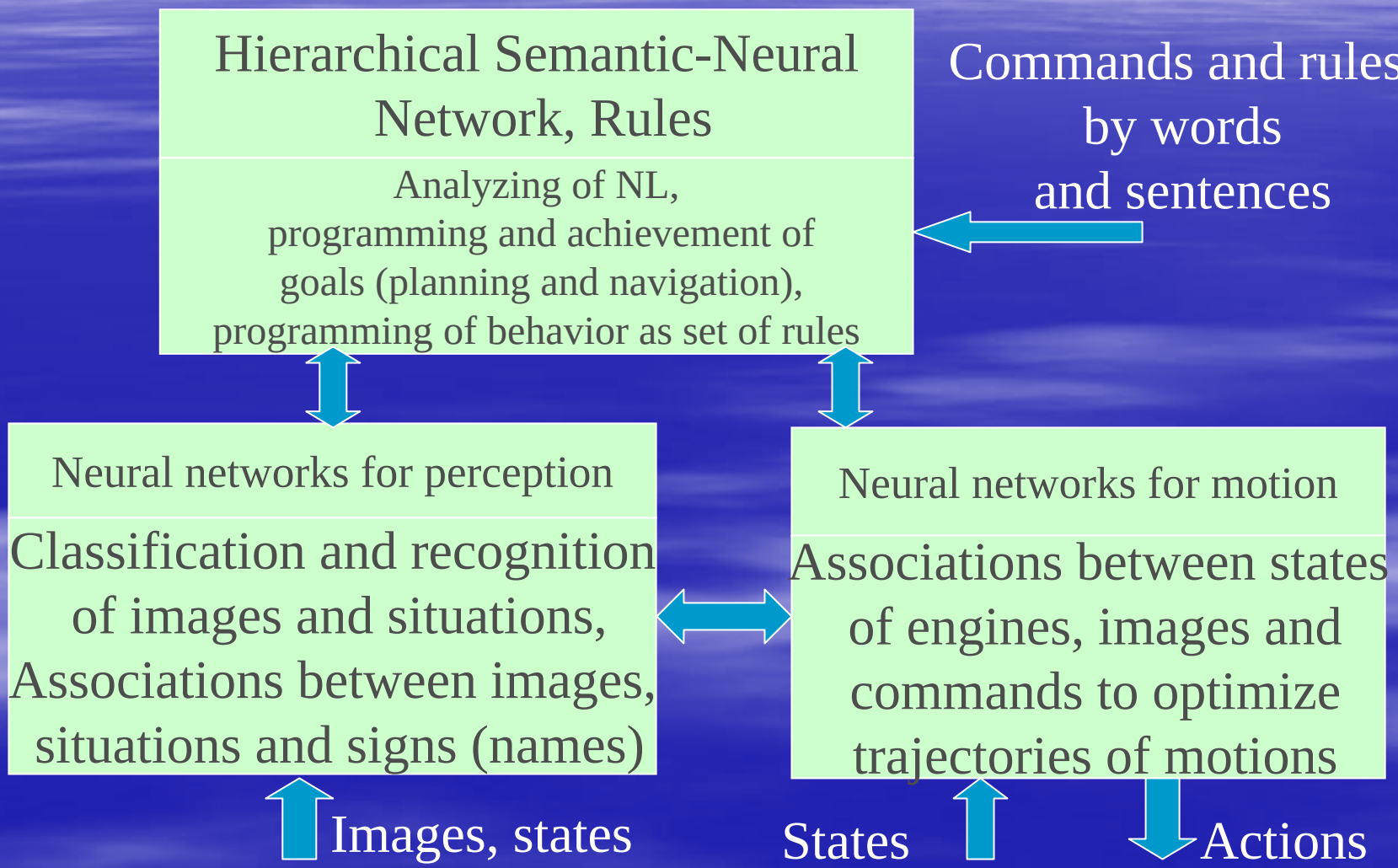
- Spatial World knowledge
- Object knowledge
- Perceptual knowledge
- Behavioral knowledge
- Ego knowledge
- Intentional knowledge

Main scientific tasks in hybrid approach

- To provide producing of meaning during action/learning as result of fusion of multimodal information from sensors and actuators
- Simulation of logical reasoning in neural networks
- Usage of meaning as feedback for recognition
- Usage of meaning for collaboration between robots – simulation of birth and evolution of language

Proposed Architecture of Control System for Mobile Robot (A.Gavrilov, 2003).

Main idea – usage of associations between visual image and word (phrase) in NL for commands to move



Used own technologies

- Fuzzy semantic nets technology for processing of words and sentences from technology in learned system for search of documents by query in Natural Language [Gavrilov, 2001]
- Hybrid neural network based on ART-2 and MLP for recognition of visual images (since 2004)
- Engine of fuzzy rule-based expert shell ESWin for programming of behavior (since 2001)

Hybrid Summary

- P,S-A, deliberation uses global world models, reactive uses behavior-specific or virtual sensors
- Architectures generally have modules for mission planner, sequencer, behavioral mgr, cartographer, and performance monitoring
- Deliberative component is often divided into sub-layers (sequencer/mission planner or managers/mission planner)
- Reactive component tends to use assemblages of behaviors
- Hybrids think in closed world, act in open world

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