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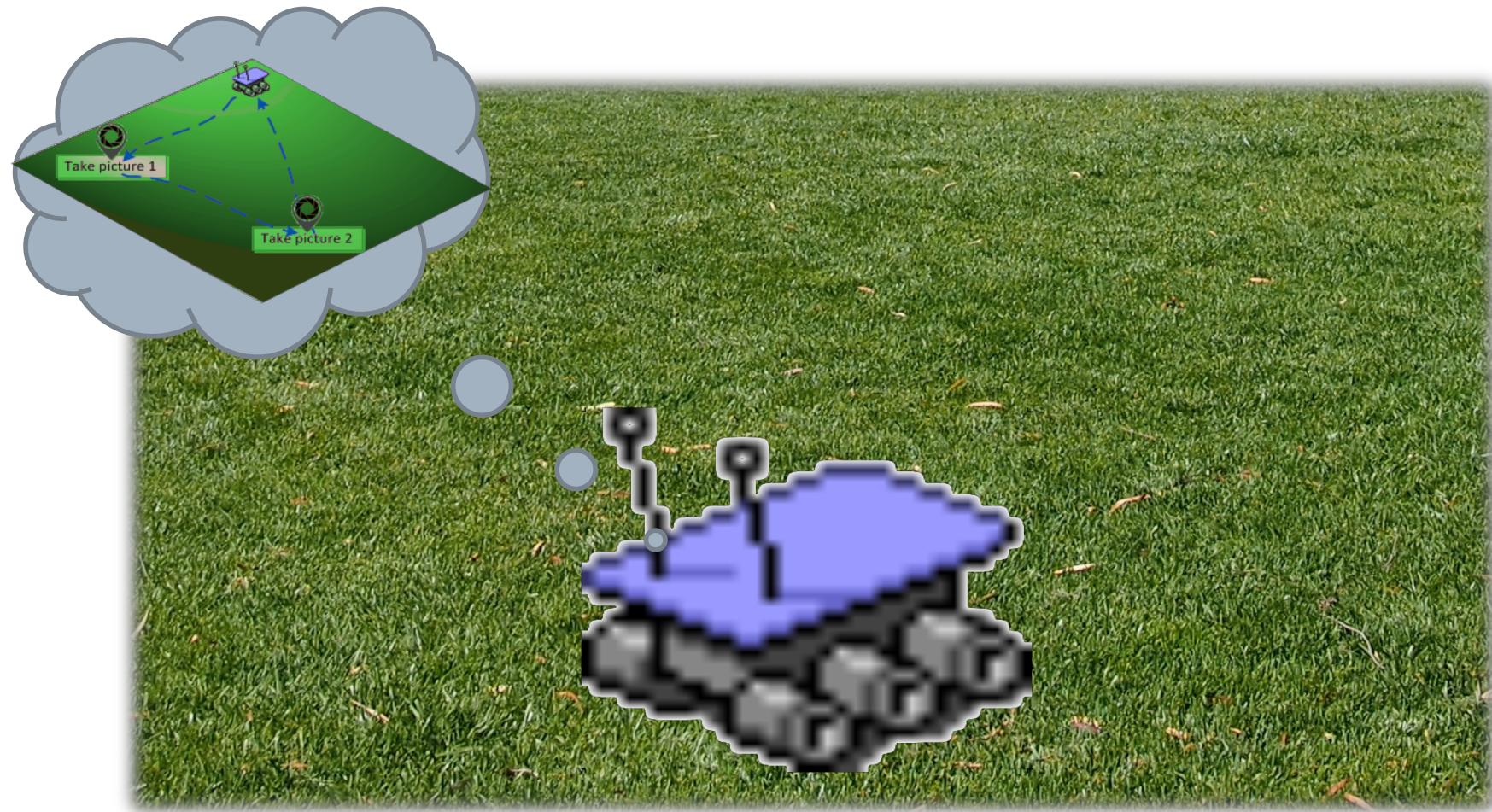
Autonomous Control Architectures



Outline

- **Introduction**
- Autonomous Control Architecture
- Conclusions

Introduction



Introduction

- Autonomous control architectures use models:
 - To reason about the system that control
 - The environment where they act
- They achieve a set of extended goals over a period of time, and are able to reason about faults with little or no human
- Given the initial state and external goals: they generate a set of actions
- If an action is not executed as expected: “recover”

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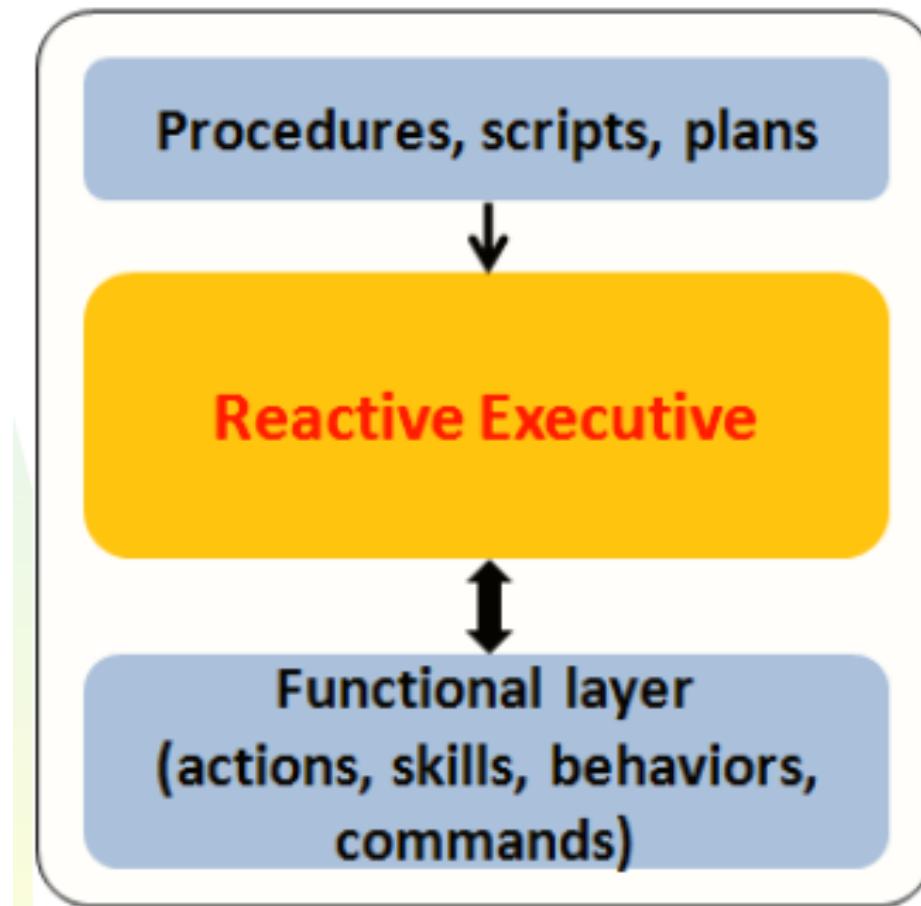
Classification

- Attending to the “**reactivity/deliberativeness**” of the system, the main architectural approaches are:
 - Reactive, procedural approach (non-deliberative)
 - Purely reactive controllers
 - Symbolic reactive controllers
 - Hybrid approach
 - Three-tiered controllers
 - Model-based, planning centric methods

Reactive (non-deliberative)

- **Purely reactive controllers**: motor action as response to the collected data by sensors without reasoning about them (no internal state is contained)
- **Symbolic reactive controllers**: an intermediate “decision-making” step that infers an action output from the sensor input and a symbolic representation is introduced (based on behaviours)
- Suitable when:
 - Real world cannot be accurately modeled
 - Uncertainty is quite delimited
 - Real-time warranty is a safety-critical concern

Reactive (non-deliberative)

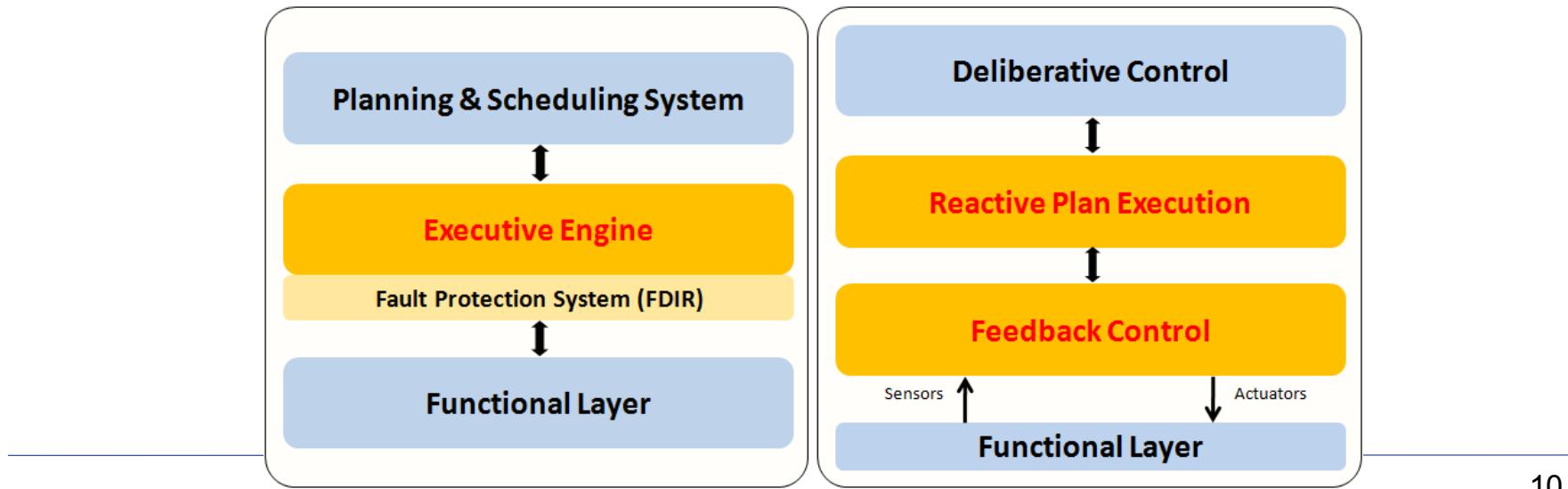


Reactive (non-deliberative)

- Examples:
 - **Subsumption architecture** [Brooks, R.A., 1986]
 - System decomposed into concurrent (hierarchically arranged) behaviors: higher layers represent more abstract behaviors, and have lower priorities than the lowers
 - Behavior: sense-act function which maps perceptual inputs to actions
 - **Agent Network Architecture (ANA)** [Maes, P., 1991]
 - Similar system decomposition
 - Behaviors modules defined by their pre-conditions and post-conditions (interfaces), and by a (dynamic-valued) activation level

Three layer architectures (hybrid)

- Interleave a planning step using a model of the world (implements Sense-Plan-Act cycle)
- Limitations:
 - Monolithic planning cycle
 - Slow reactivity when deliberation is needed
 - Hard scalability and robustness decreasing

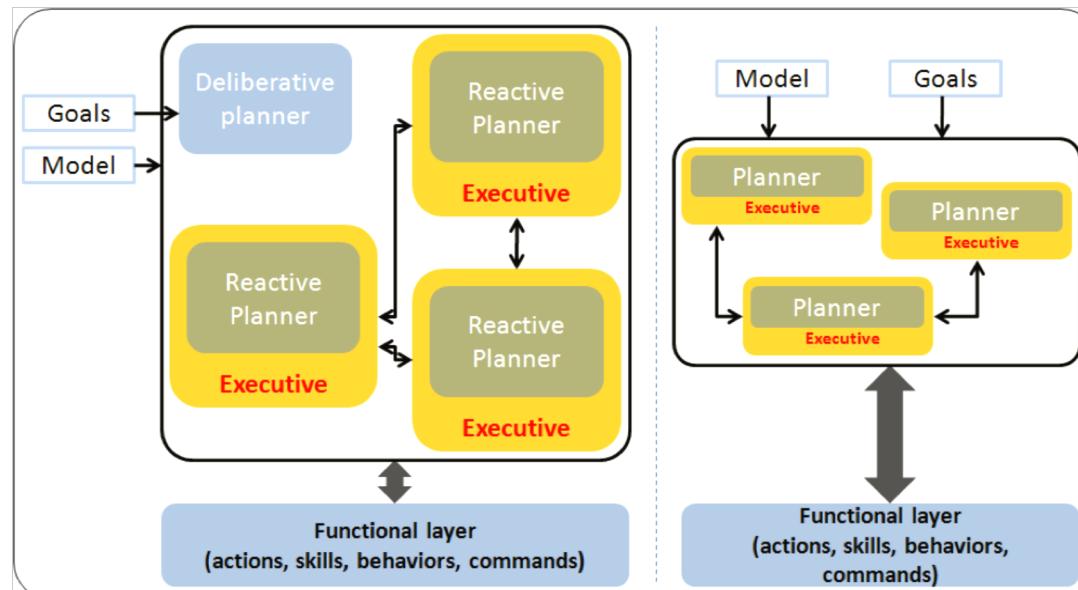


Three layer architectures (hybrid)

- Examples:
 - **3T** [Bonasso et al., 1997]
 - 3 layers
 - **Tripodal Control Architecture** [Kim, G. and Chung, W., 2006]
 - Consist of a deliberative, a sequencing and a reactive layer.
 - The deliberative layer is the interface with the user and with the planning process execution
 - **ATLANTIS** [Gat, E., 1992]
 - Consists of a reactive controller, a sequencer and a deliberator
 - Includes monitor capabilities to re-planning/plan-repairing

Model-based, planning centric methods (hybrid)

- Exploits automated planning and model-based reasoning at the core
- Divide-and-conquer scheme: system functionality is distributed
- Theoretically meets:
 - The efficiency/robustness of the reactive controllers
 - The high-level reasoning capabilities of the (purely) model-based approach

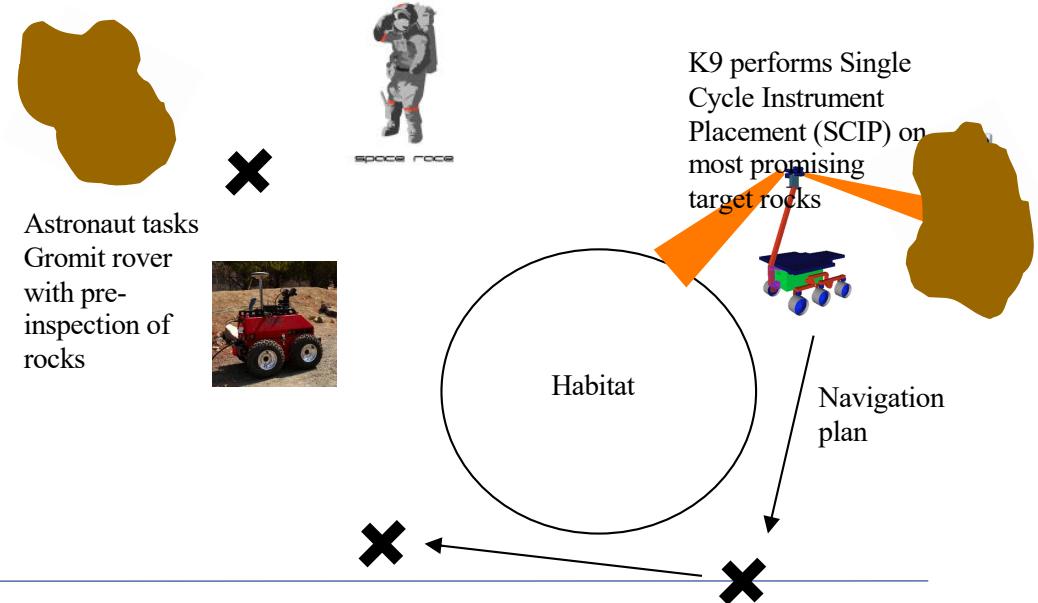


An example: IDEA

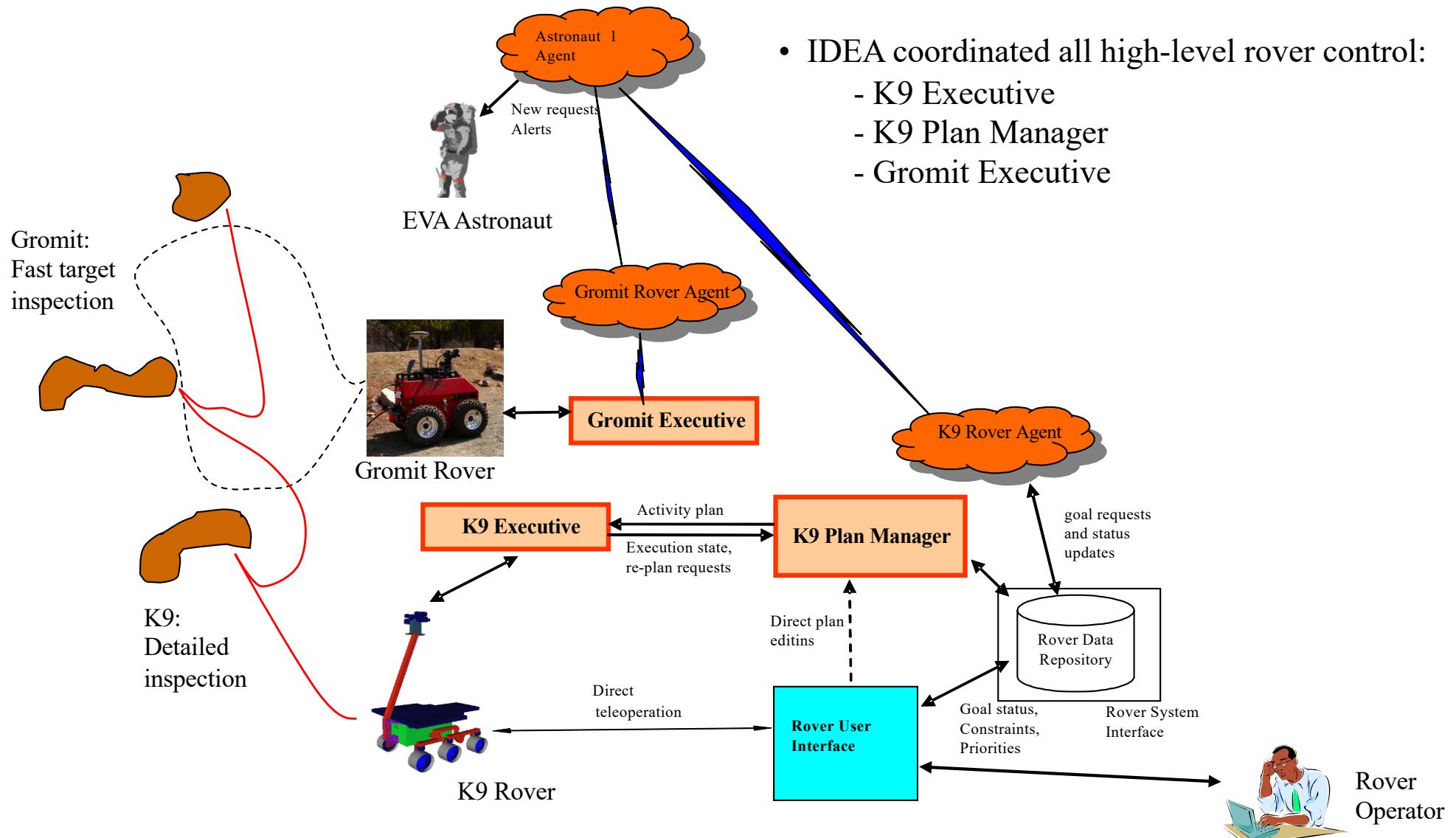
- IDEA is an architecture that enables high-level control by tightly integrating planning and execution
- Interleaved planning and execution
 - AI planning and scheduling is the core reasoning approach for execution
 - Planning over different horizons enables deliberation and reaction in a single framework
- Model-based control
 - Declarative models define system behavior and interactions with other systems
 - Models restrict plan search to legal behavior

An example: IDEA

- Collaborative Decision Systems (CDS)
- Human-robot collaboration for planetary surface operations
 - Gromit rover (rock pre-inspection)
 - K9 Rover (detailed science sampling)
 - EVA astronaut (directing geology)
 - RoverOperator (oversees rover ops)
- Project Goals:
 - Demonstrate coordinated human-robot surface operations near human habitat
 - Coordinated field geology
 - Tightly integrate and test existing technologies
- IDEA K9 Exec and PlanManager
 - PlanManager: turns goal requests from RoverOperator into plans for K9
 - K9 Exec: using plans, oversees mobility, target tracking, instrument placement and measurements
- IDEA Gromit Exec
 - Coordinated mobility and panoramic image taking
- Results Synopsis
 - Successful demonstration of coordinated operations
 - IDEA greatly eased system integration



CDS System Architecture

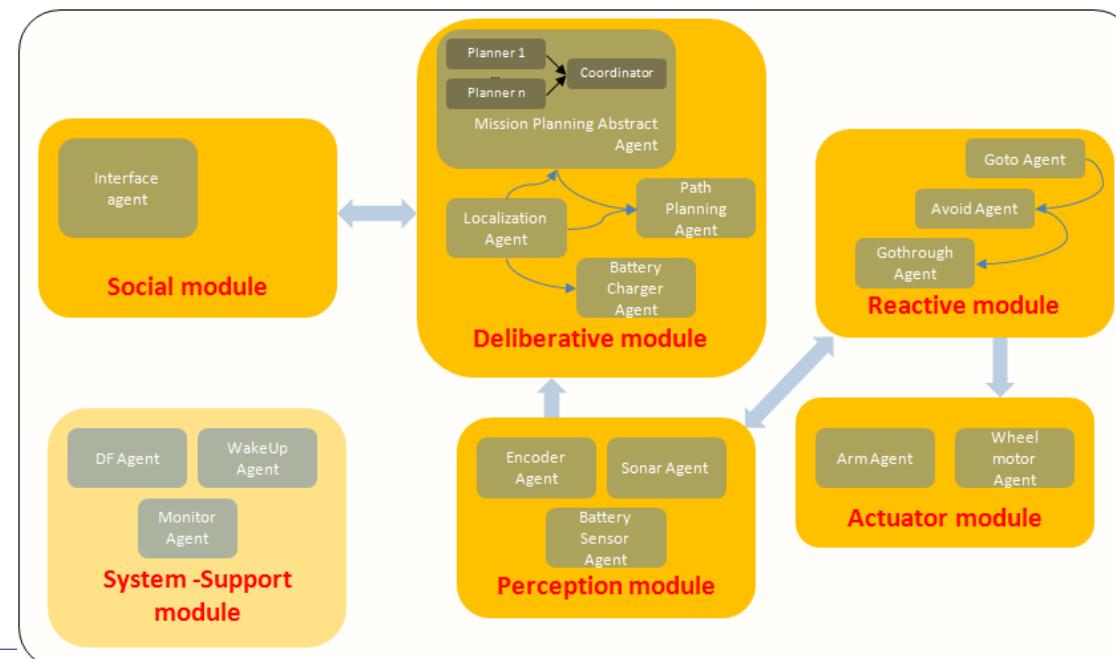


Model-based, planning centric methods (hybrid)

□ Examples

■ ARMADiCo [Innocenti, B., 2008]

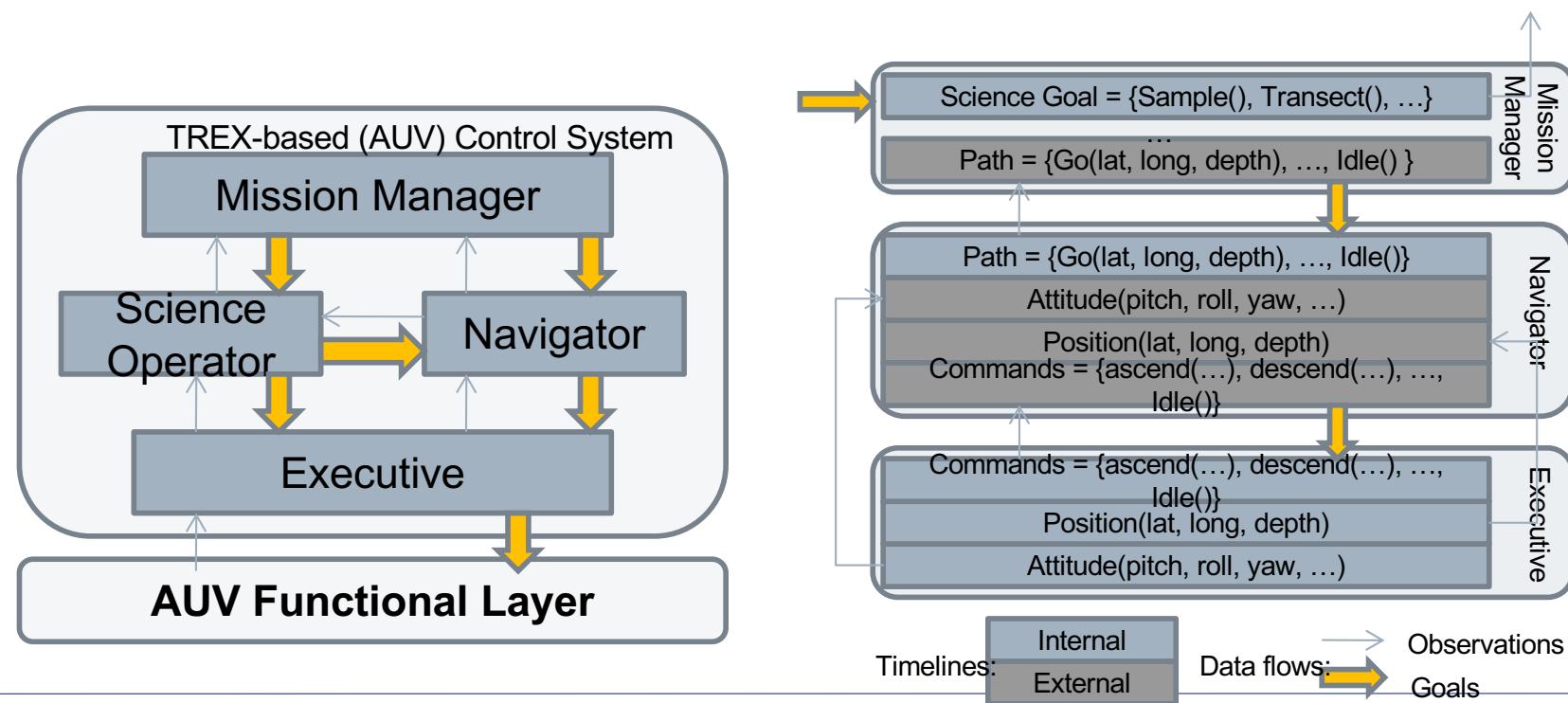
- Multi-agent and general purpose architecture for mobile robots
- Distributed communication scheme which allows agents compete for the available resources



Model-based, planning centric methods (hybrid)

□ Examples

- **TREX** [McGann, C. et al., 2008]
 - Combines goal- and event-driven behavior in a framework based on temporal reasoning & planning
 - Developed for Autonomous Underwater Vehicles



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Conclusions

□ Where can we apply AI in robotic systems?

- ◆ Diagnosis and reconfiguration
- ◆ Navigation and Path Planning (depends on the mission)
- ◆ Planning/Scheduling and Intelligent Execution
- ◆ Command sequence generation
- ◆ Data processing and validation
- ◆ Vision

Conclusions

- A system is autonomous if it is able to achieve their goals with little or no human supervision
- Traditional systems are based on 3T-arquitectures
- New approaches distribute the systems between different controller



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