

A Framework for Problem Solving Activities in Multi-Agent Systems

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Agent Oriented Design

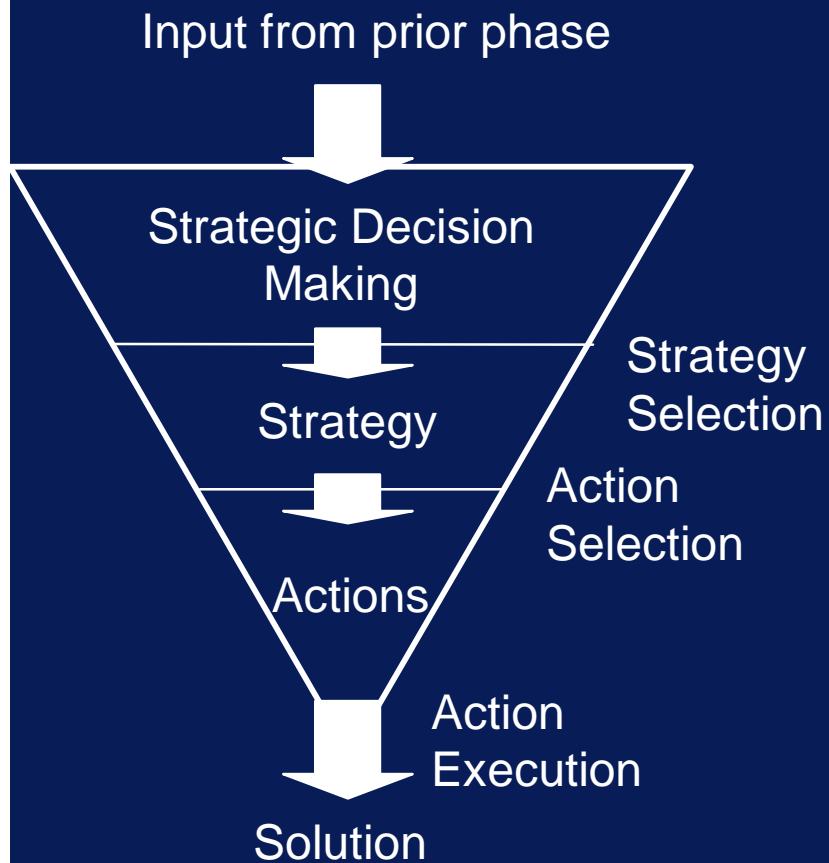
Agent-oriented design involves the **selection and integration of “strategies”** tied to core agent problem solving functionality.

Strategy Selection: the strategy for use during each phase (what is the best or most appropriate strategy to use), and

Strategy Integration: recognizing dependencies among strategies across problem solving phases. (are the chosen strategies for each phase compatible?)



Strategic Decision Making

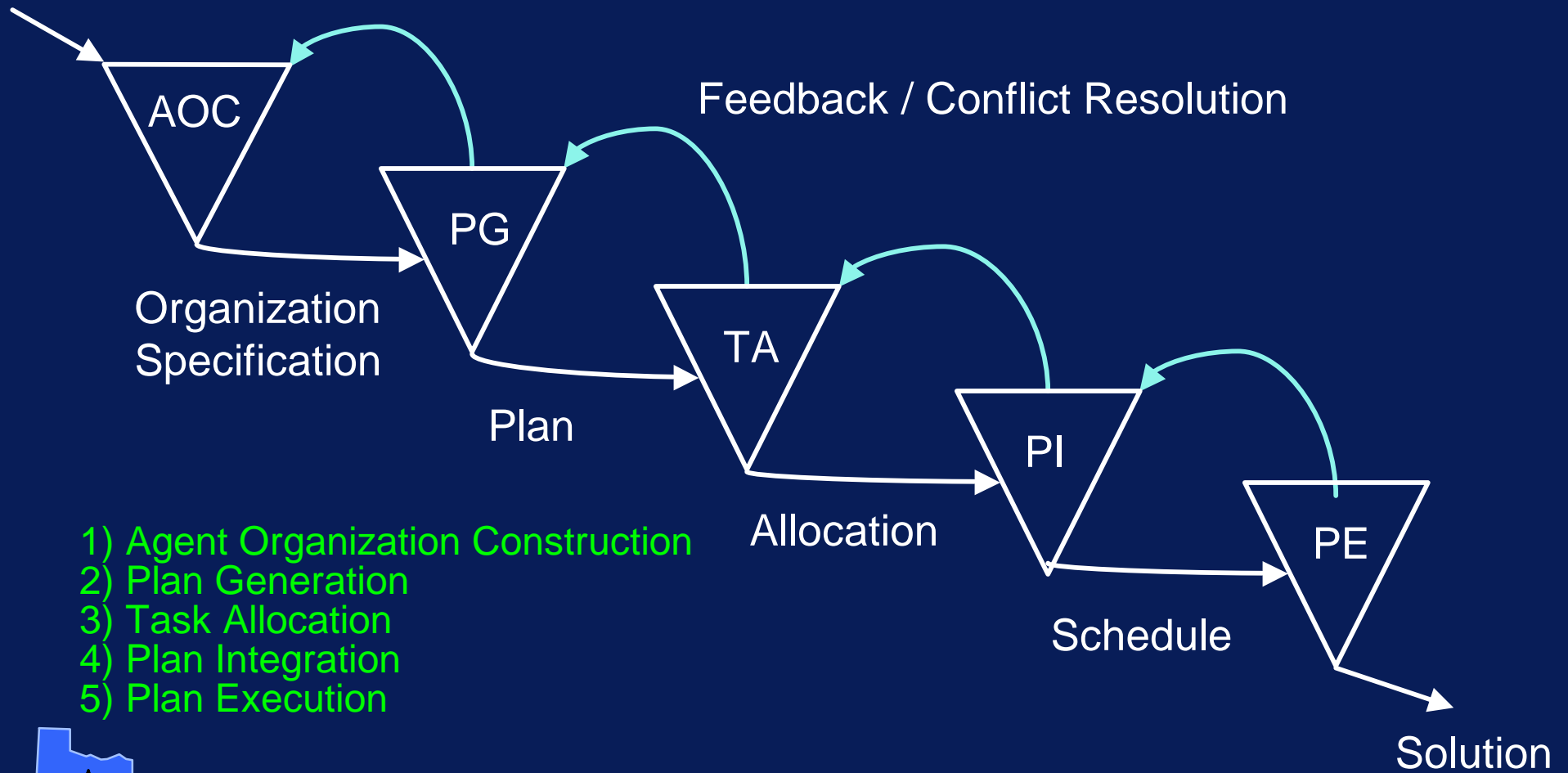


- **Strategic Decision Making:** selecting the appropriate strategy.
 - On-Line
 - Off-Line, a priori
- **Strategy:** A decision making mechanism which provides long-term consideration for selecting actions toward specific goals.
- **Action:** actions or sequences of actions trigger events and change certain states.



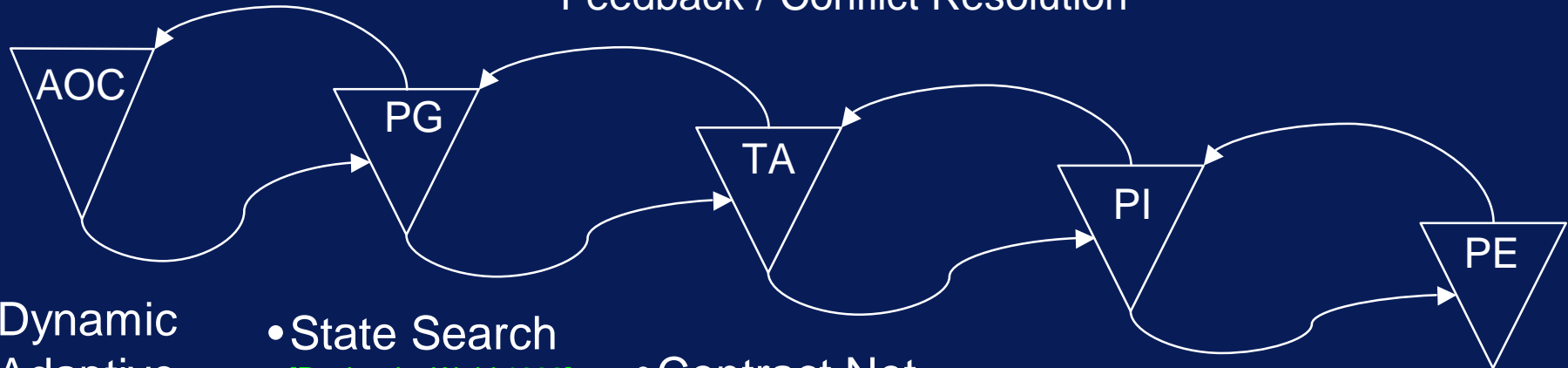
An Agent's Core Problem Solving Functionality

Domain
Specific Goal



Example Associated Strategies

Feedback / Conflict Resolution



- Dynamic Adaptive Autonomy [Barber 1998]

- State Search [Penberthy, Weld 1992]
- Hierarchical [Corkill 1979]

- Contract Net [Smith 1980]
- Negotiation

- “un-clobbering” techniques

- Commitment [Jennings 1993]
- Convention

- Organization Self-Design [Ishida et al. 1992]

- Partial Global Planning [Durfee, Lesser 1987]
- Multi-Agent Planning [Corkill 1979]

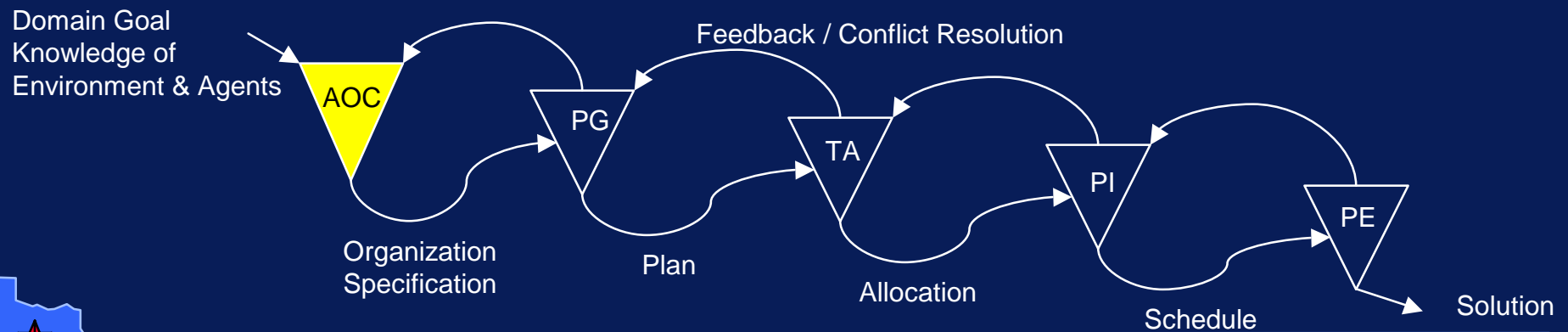


Agent Organization Construction Phase (AOC)

Inputs: 1) Knowledge of Environment & Agents
2) Domain Specific Goal

Function: Decide and Implement “Best” Organization under which to solve the Domain Specific Goal

Outputs: Organization Specification =
Agents Involved
Agent’s Role in a problem solving organization



Agent Organizations

For each Domain Specific Goal:

Agent performs AOC online

Human designer performs AOC offline, a priori

AUTONOMY SPECTRUM = Agent's Role

Command-Driven

Agent does not plan but responds to external commands from a Master agent

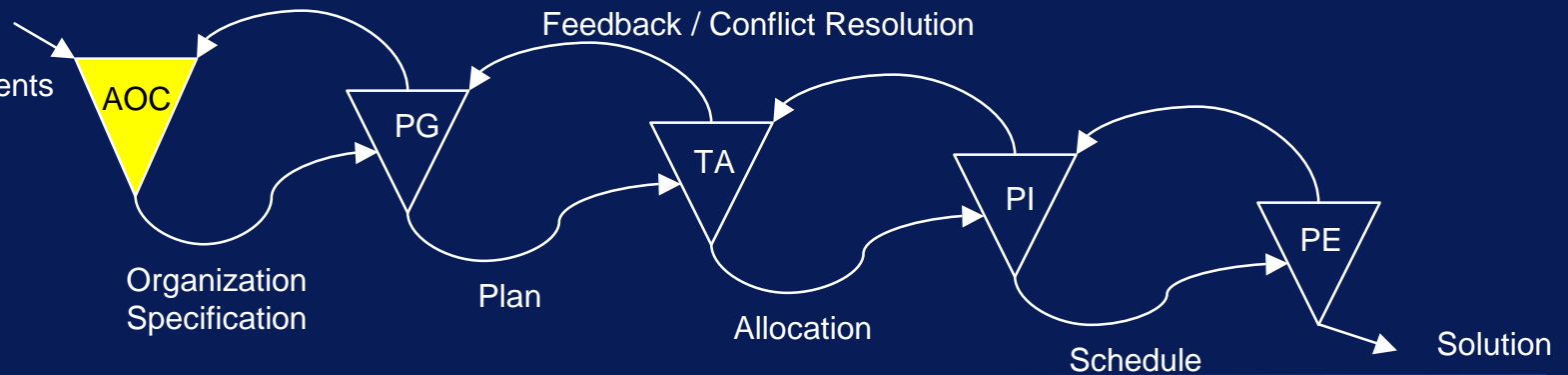
Consensus

Agents work together as a team, sharing planning tasks with other agents, to devise plans

Locally Autonomous / Master

Agents plans alone. May or may not give orders to other agents

Domain Goal
Knowledge of
Environment & Agents

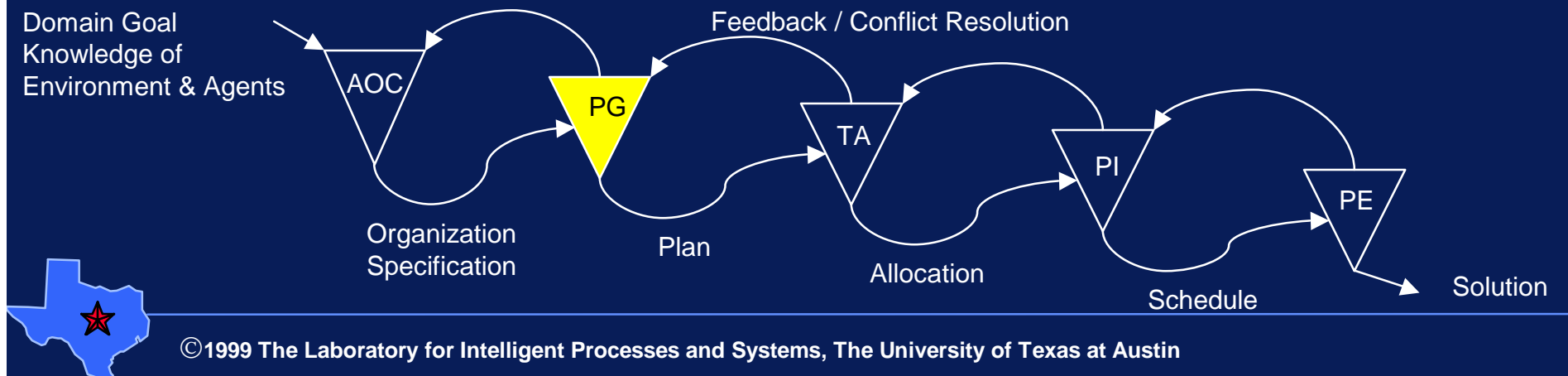


Plan Generation Phase (PG)

Inputs: 1) Knowledge of Environment & Agents
2) Domain Specific Goal
3) Organization Specification

Function: Select Actions/Goals to Achieve

Outputs: Available task decompositions and plans
e.g. a goal is decomposed to a set of sub goals with several sub-plans



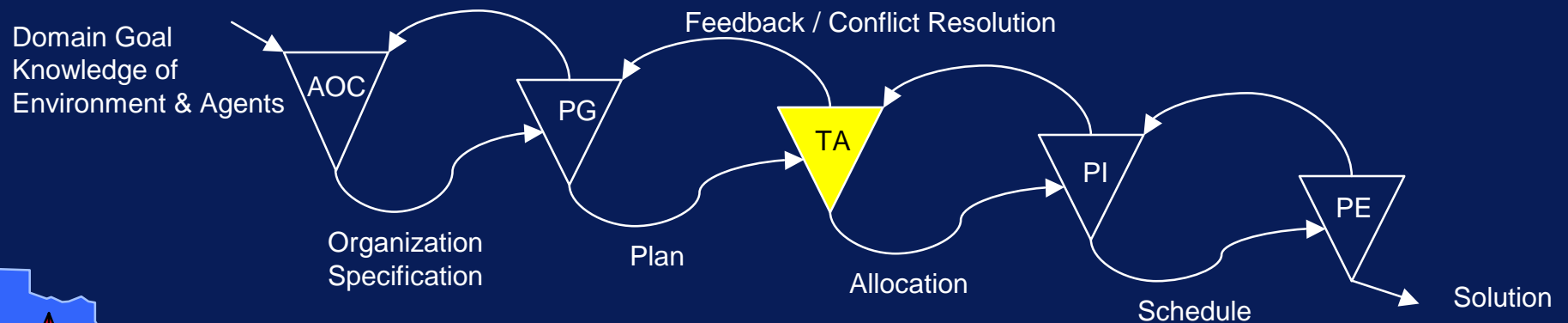
Task Allocation Phase (TA)

- Inputs:**
- 1) Knowledge of Environment & Agents
 - 2) Organization Specification
 - 3) Set of Actions/Goals and plans
 - 4) Task decompositions & plans

Function: Assign Goals/Plans to Specific Agents

Outputs: Task Allocation

e.g. Goal X is assigned to Agent Y to generate detailed plans

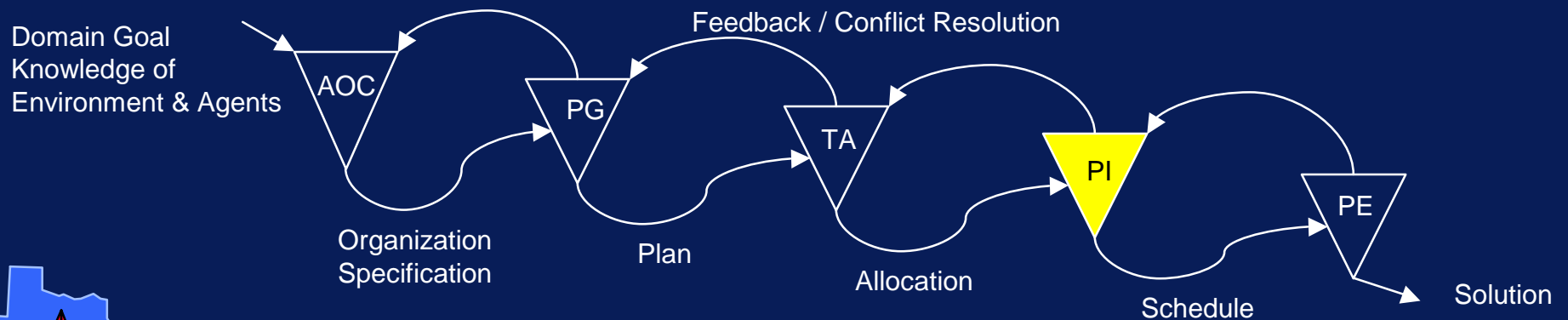


Plan Integration Phase (PI)

- Inputs:**
- 1) Knowledge of Environment & Agents
 - 2) Organization Specification
 - 3) Set of Actions/Goals and plans
 - 4) Task decompositions & plans
 - 5) Task Allocations

Function: Coordinate and schedule Agent's Plans

Outputs: Agent's Schedule

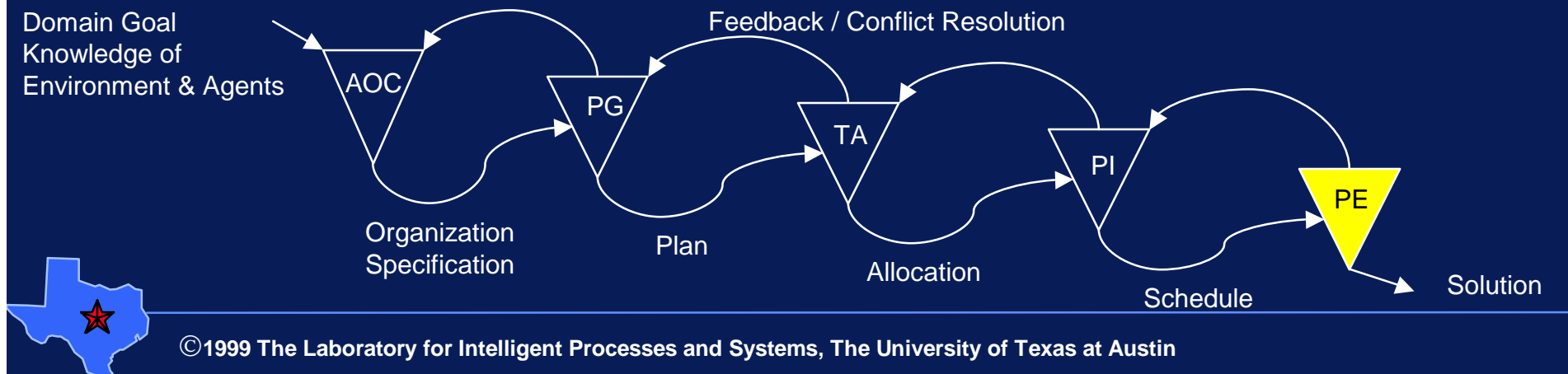


Plan Execution Phase (PE)

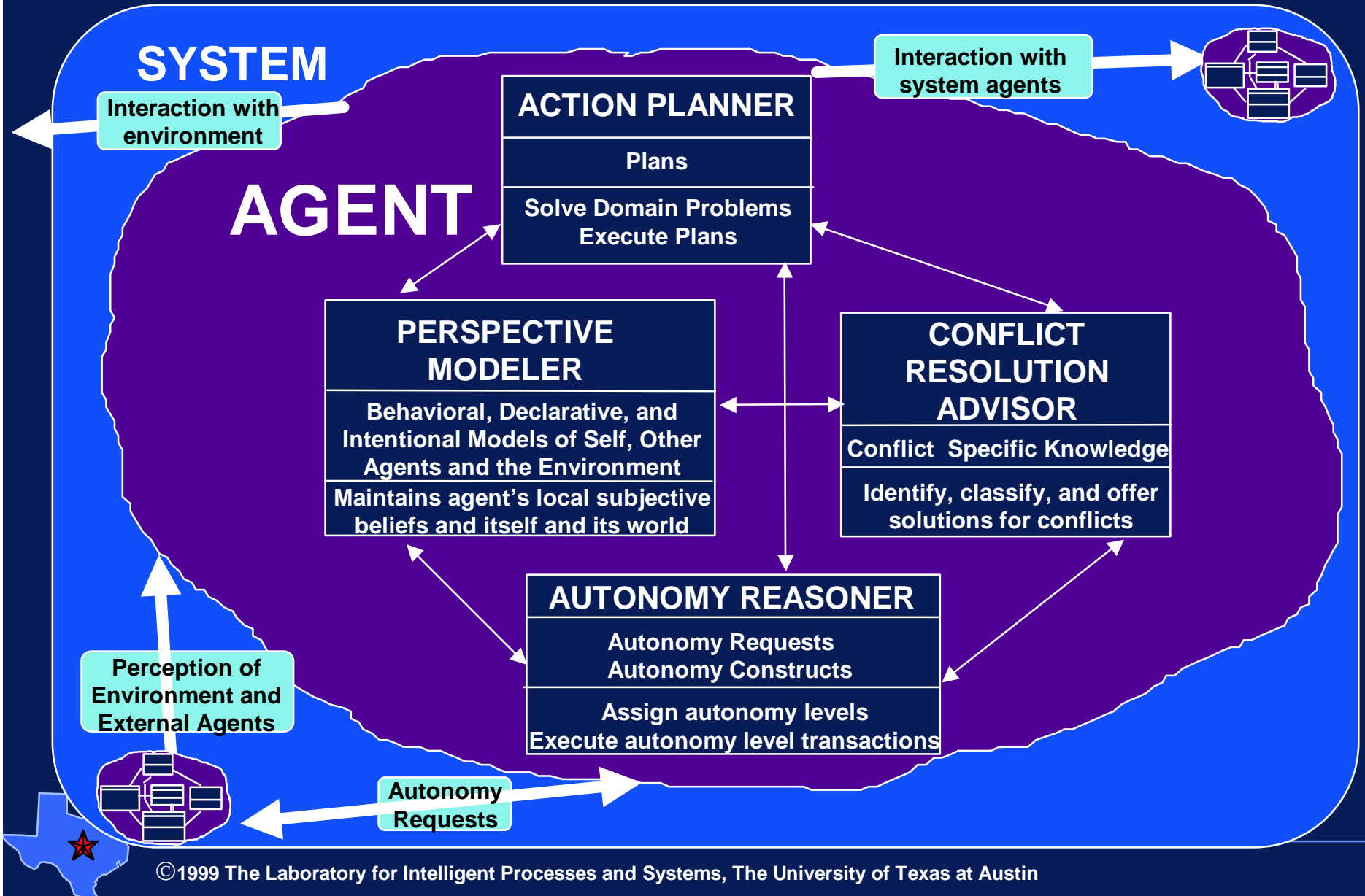
- Inputs:**
- 1) Knowledge of Environment & Agents
 - 2) Organization Specification
 - 3) Set of Actions/Goals and plans
 - 4) Task decompositions & plans
 - 5) Task Allocations
 - 6) Schedule

Function: Monitor Execution of Actions

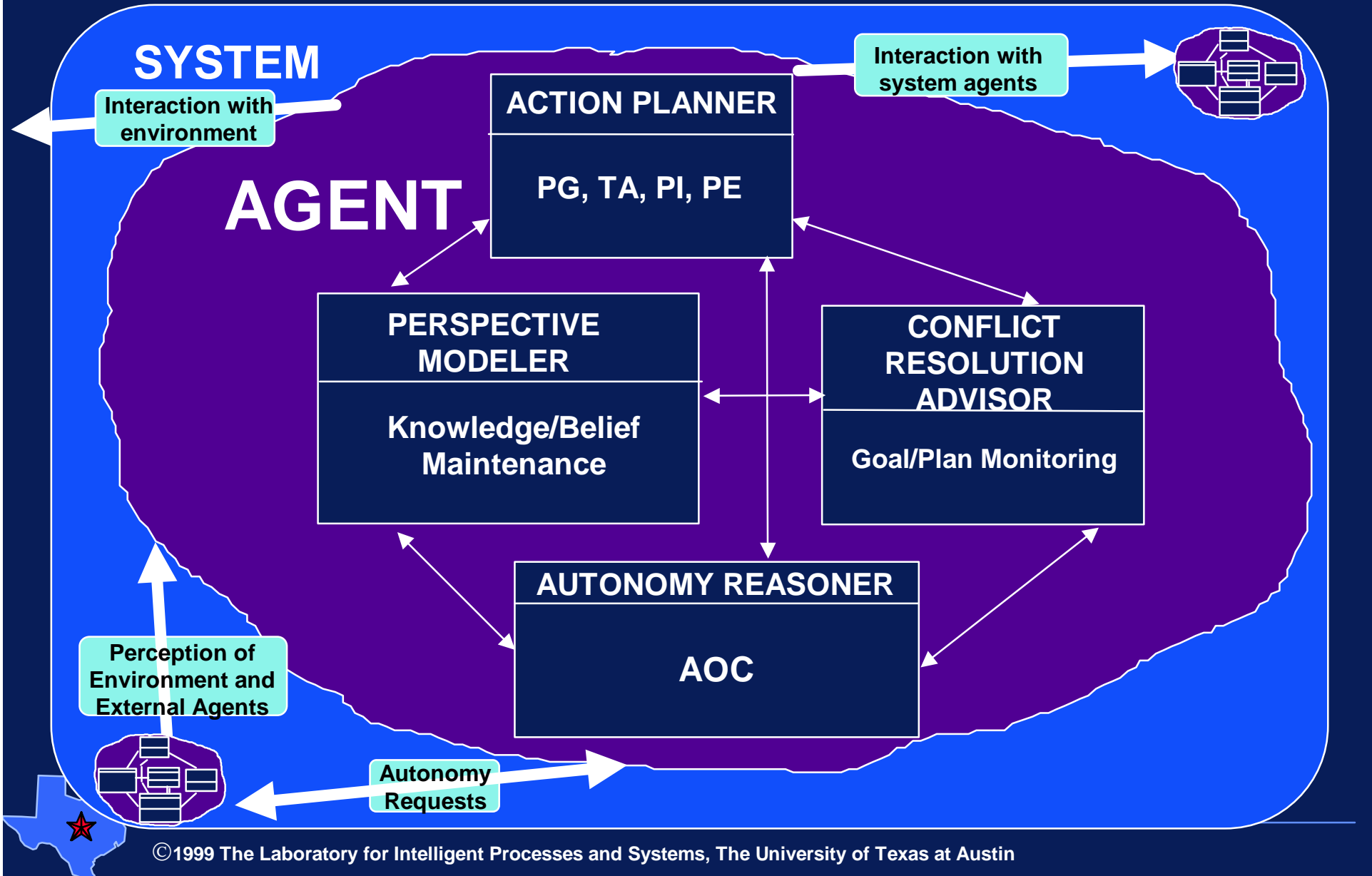
Outputs: Solution to Domain Problem



Sensible Agent Model

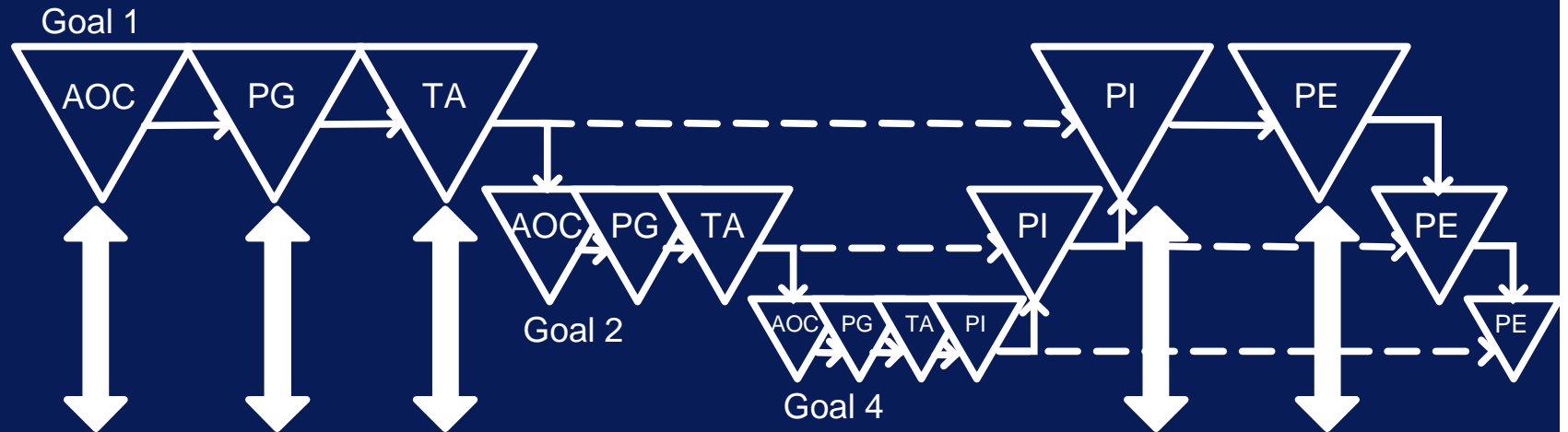


Sensible Agent Model

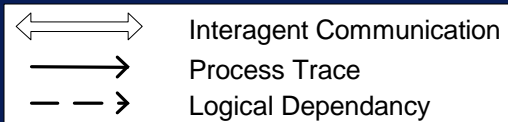
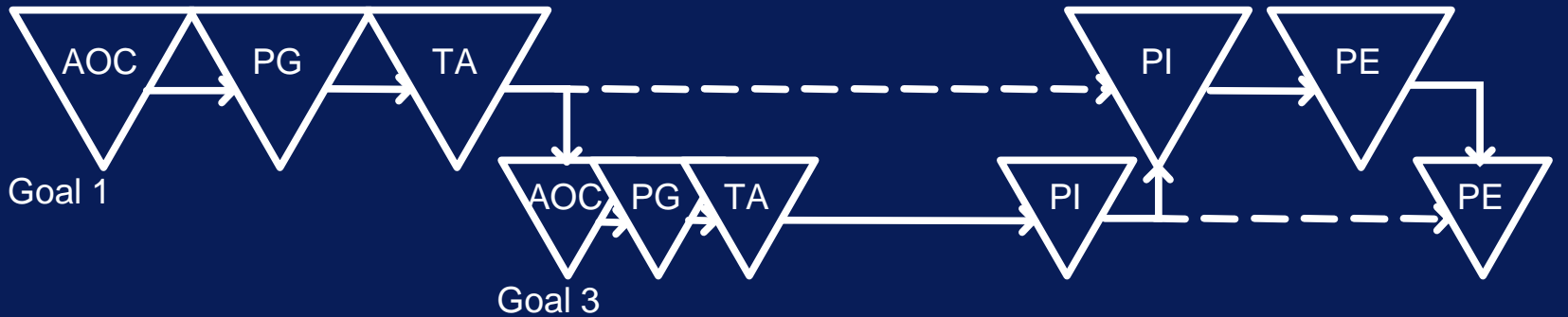


Interactions Among Sensible Agents

Agent 1



Agent 2



Summary

- **Core Problem Solving Functionality:**
 - Agent Organization Construction
 - Plan Generation
 - Task Allocation
 - Plan Integration
 - Plan Execution
- **Need for strategic design of multi-agent systems.**
 - Selection of strategies to deliver core agent functionality
 - Integration of strategies accommodating dependencies



Contributions

- **Flexible design for problem solving framework**
 - Applicable to different domains
 - Considers various strategy implementation techniques.
 - Facilitates infusion of new strategies.
 - Promotes cross-fertilization of research efforts and re-use of agent functionality-specific techniques.
- **Formal Specification of Strategies promotes Meta-level Strategic Decision Making to:**
 - **Select and Integrate strategies**
 - On-Line or Off-Line
 - By Humans or by Agents
 - **Facilitate design rationale and trade-offs**



Future Work

- A domain analysis methodology guiding the decomposition and assignment of domain-specific functionality across a system of agents
- A representation specifying techniques for problem solving phases and agent architecture designs to support automation assistance
- Verification mechanisms for the evaluation of design completeness.

