# Modeling Command and Control in Multi-Agent Systems*

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# C2 in Agent-Based Systems

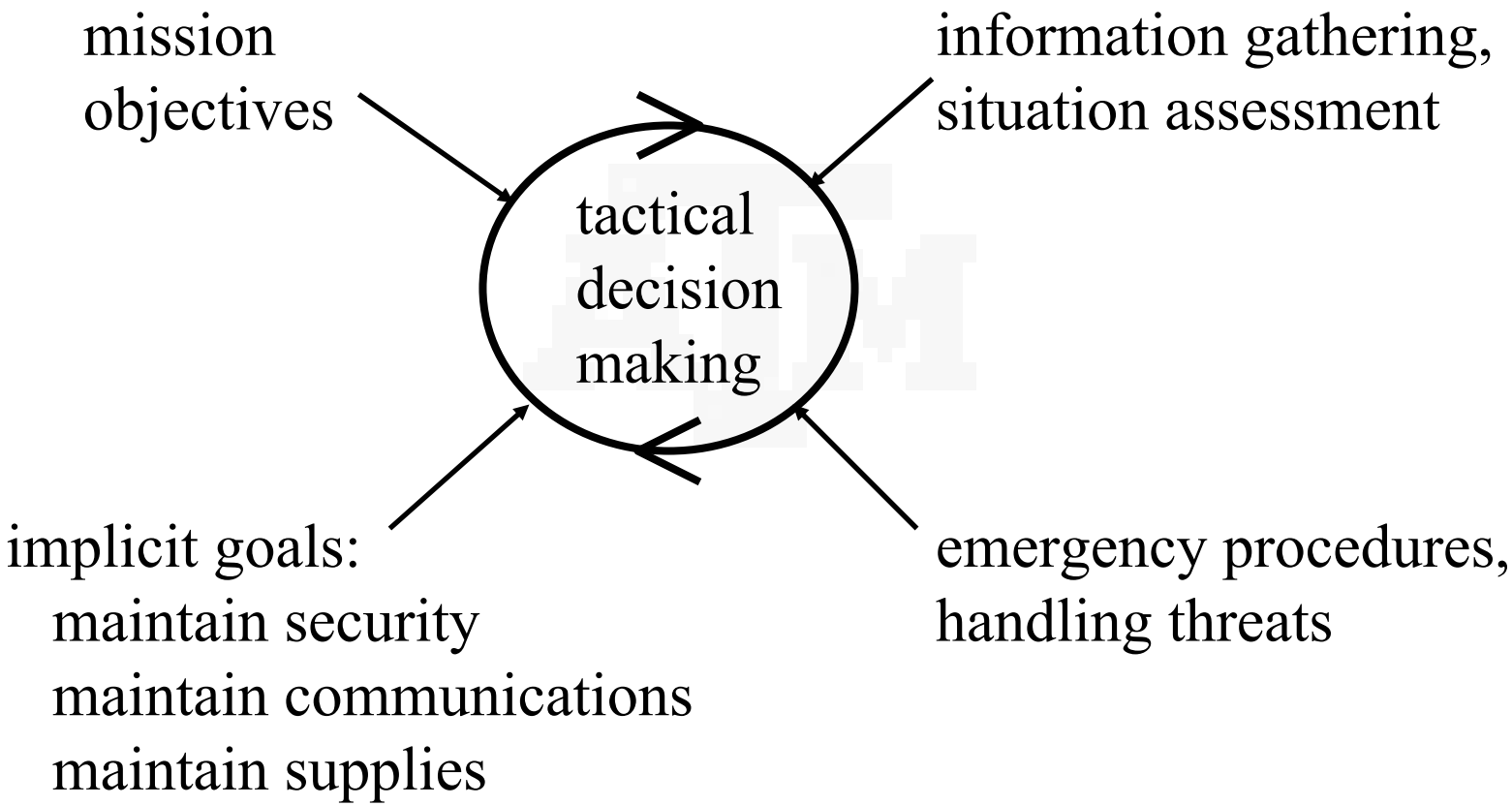
- What is C2?
  - accomplishing goals/mission in a *competitive* environment with *distributed* resources (sensors, effectors)
- Applications:
  - combat simulations, fire fighting, ATC, urban disaster rescue operations, training systems
- Existing multi-agent systems
  - SOAR/STEAM, RETSINA, PRS/dMARS
  - good for distributed problem-solving, e.g. coordinating maneuver of entities on battlefield

- Tactical behavior is more than just coordinating maneuver of entities
  - it involves a decision making process, collaborative information gathering and fusion
- Example: staff operations in a battalion TOC
  - an S2 agent can be told to automatically forward a situation report, but shouldn't it already know?
- Importance of emulating human tactical decision-making
  - human behavior representation
  - information gathering activities, assessing relevance
  - understanding & interacting with humans

# Cognitive Aspects of C2

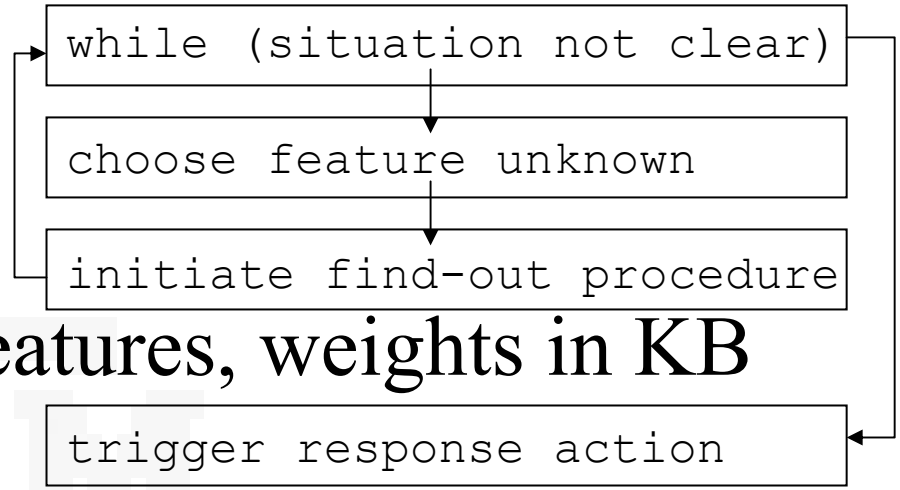
- Naturalistic Decision Making
- Situation Awareness
- Recognition-Primed Decision Making (RPD)
- Strategies for Dealing with Uncertainty
- Meta-cognition
- Teamwork

# Basic Activities to Integrate



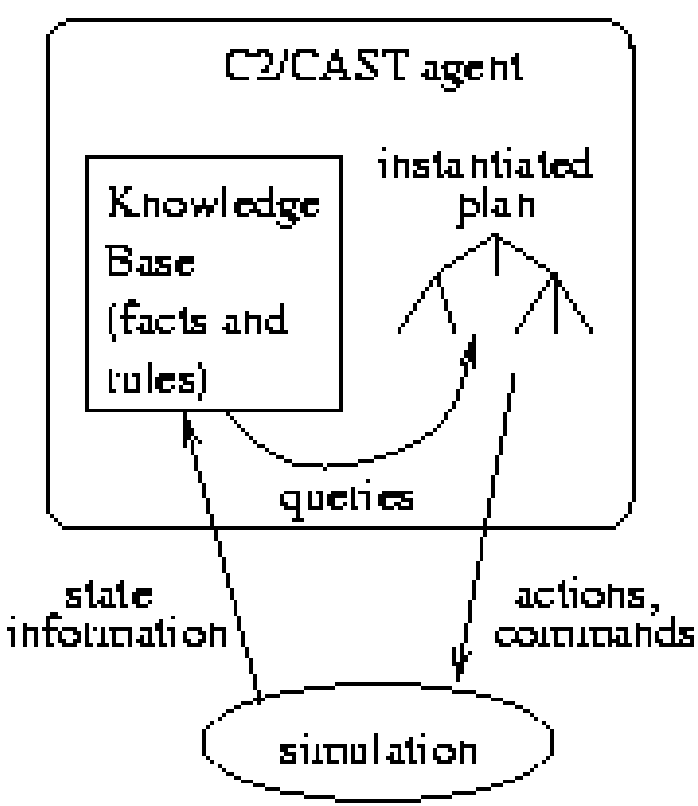
# Overview of Approach

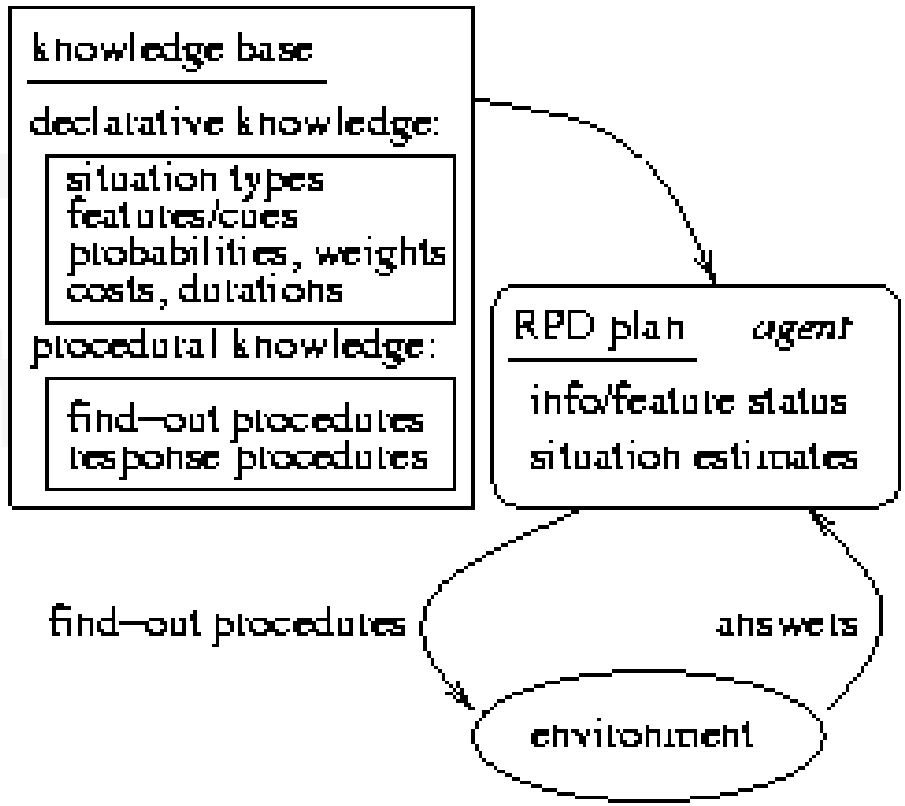
- Implement RPD loop:




- represent situations, features, weights in KB
- find-out procedures
  - e.g. use radar, UAV, scouts, RFI to Bde, phone, email, web site, lab test...
- challenges:
  - information management (selection, tracking, uncertainty, timeouts)
  - priority management among activities

- C2/CAST: declarative and procedural KB's (rules and plans)



# Model of Situation Assessment

- situations: $S_1 \ldots S_n$

  e.g. being flanked, ambushed, bypassed, diverted, enveloped, suppressed, directly assaulted

- features associated with each sit.: $F_{i1} \ldots F_{im}$
- RPD predicts DM looks for these features
- weights: based on relevance of feature (+/-)
- $evidence(S_i) = \Sigma_{j=1..m}\, w_{ij} \cdot F_{ij} > \theta_i$
- unknowns: assume most probable value:

  $F_i = true$ if $P[F_i = true] > 0.5$, else $F_i = false$

# Situation Awareness Algorithm

- (see paper for details)
- basic loop:

```
while situation is not determined (i.e. no
   situation has evidence>threshold),
     pick a relevant feature whose value is unknown
     select a find-out procedure, initiate it
```

- information management issues
  - ask most informative question first (cost? time?)
  - asynchronous, remember answers pending
  - some information may go stale over time (revert to unknown, re-invoke find-out)

# RPD "wrapper" task

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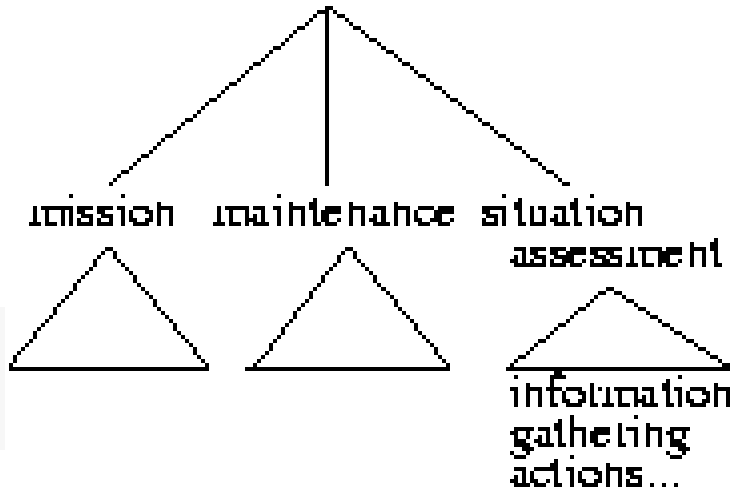
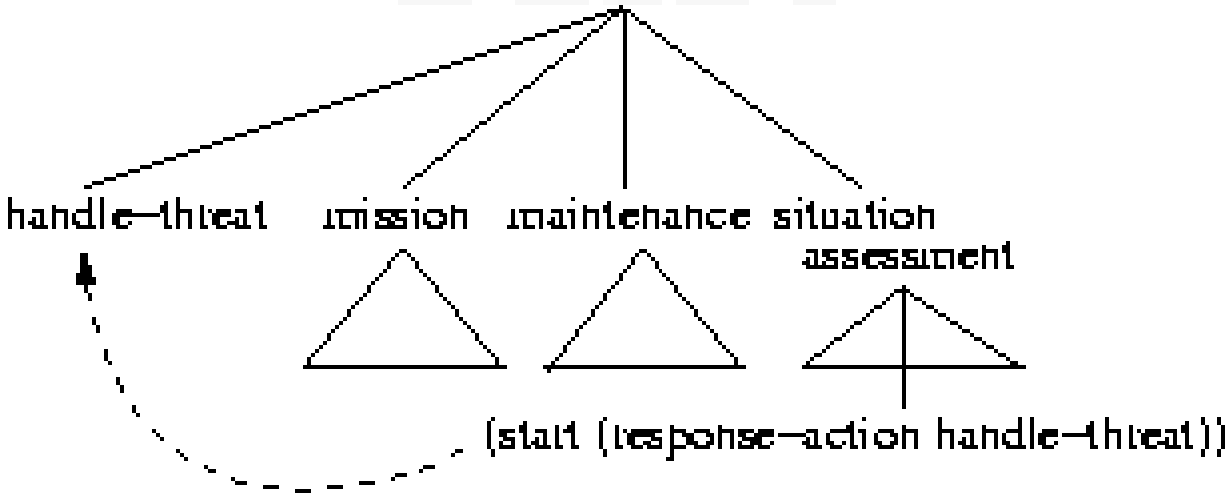
(task RPD ()
   (method (parallel
      (do (mission))
      (do (maintenance_tasks))
      (do (situation_awareness)))))
```



# Priorities

Model: current "alert" level suspends lower-level activities

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5 - handling high-level threats
4 - situation awareness
3 - handling low-level threats
2 - maintenance tasks for implicit goals
1 - pursuing targets of opportunity
0 - executing the mission
```

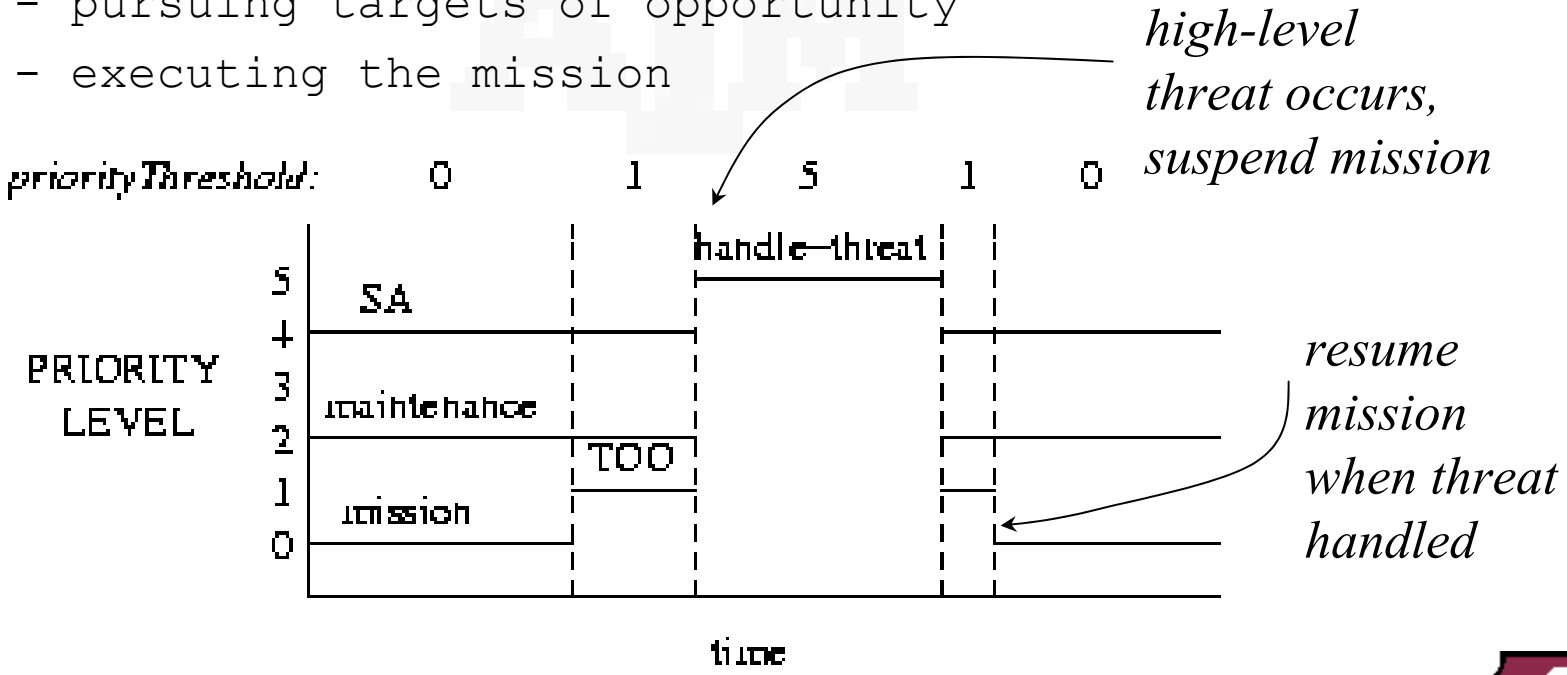

# Directions for Future Work

- on-going situation assessment (monitoring)
  - change thresholds? confirmation bias, etc.?
- mental simulation, response adaptation, dynamic re-planning
- team-based C2
  - write RPD as *team plan* in multi-agent language
  - joint commitment to goal (SA) drives collaboration and information flow
  - shared mental model of goal, plan, facts