

Netherlands Defence Academy

# Agent Coordination Mechanisms for Multi-National NEC

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# Outline

- Introduction
- Agent coordination:
  - Multi-Agent Systems
  - Relationship NEC  $\leftrightarrow$  multi-agent systems
  - What is coordination?
  - Taxonomy of agent coordination strategies
- Coordination in NEC:
  - Requirements
  - Evaluation
  - Proposed coordination architecture
- Conclusions



# Introduction (1)

- **Netherlands Defence Academy (NLDA):**

Academic education of officer cadets:

- Army, Navy, Air Force, & Military Police

Ambition to become accredited university:

- Importance of research
- Importance of partnerships

- **Research project:**

Intelligent Logistics Concepts

- **Authors:**

Patrick Storms:

Guest researcher, 2005

Specialist in Multi-Agent Systems: Y/all b.v.

Tim Grant:

NLDA Professor

Operational ICT & Communications



# Introduction (2)

- **Military context:**

- Conflicts with many global & regional actors

- Joint, combined, multi-department, civil-military missions

- New threats pose new operational requirements

- Need for agility & flexible deployment of assets

- ICT enables information sharing

- **NEC brings together in grid:**

- Sensors: gather information

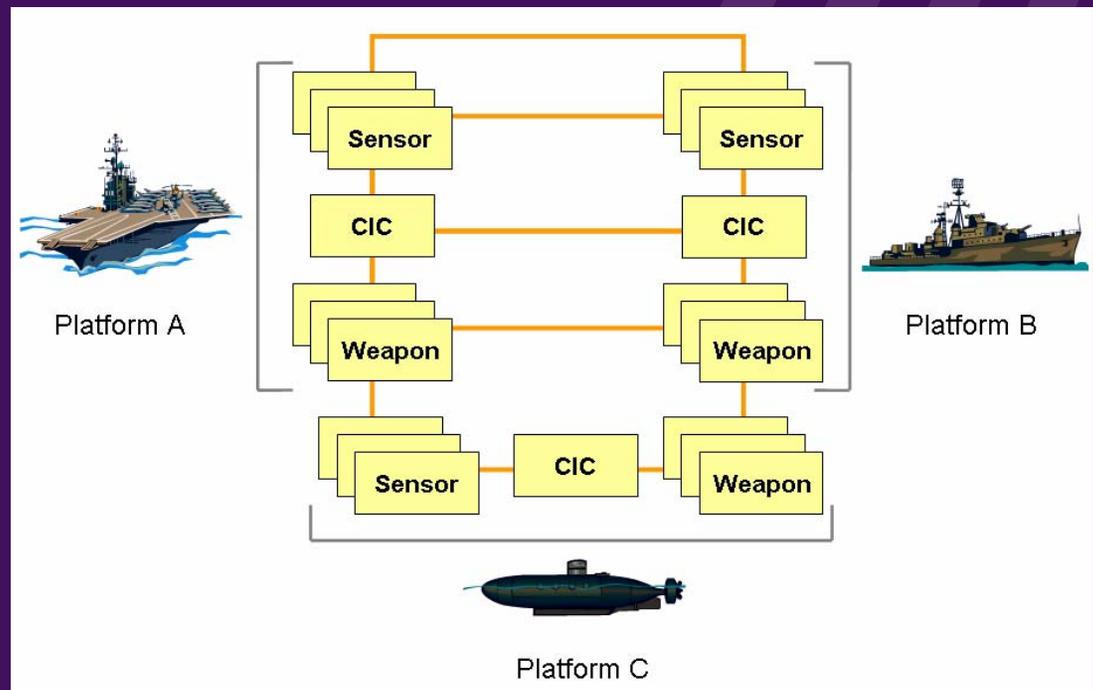
- C2 nodes: fuse, communicate & exploit information

- Weapons: agile action, effect-based



# Introduction (3)

- NEC fully exploits assets by:
  - High degree of decomposition & logical decoupling
  - Organizing assets in information grid
- NEC challenges:
  - Interoperability
  - Security
  - Coordinating tasks
  - .... and more



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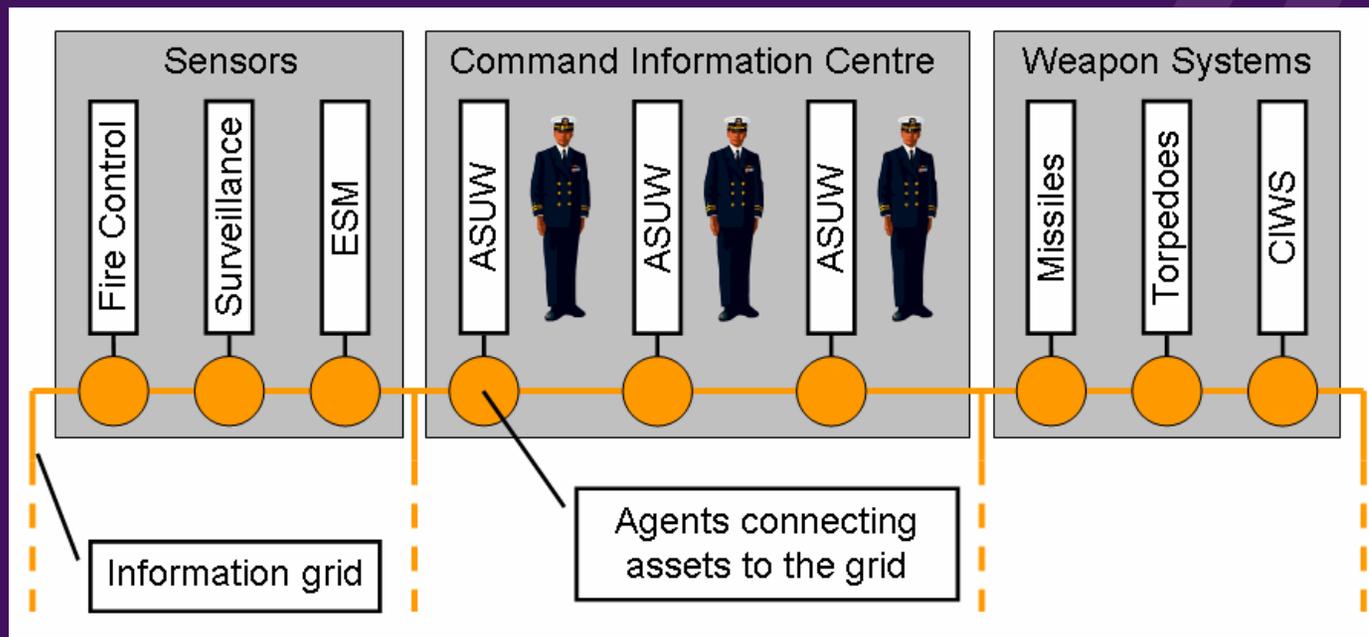
# Agent Coordination: multi-agent systems

- **Intelligent agents:**
  - Small, specialized software components
  - Autonomously pursue set of goals
  - Sense & act
  - Proactive & reactive
  - Take actions on behalf of other entities (*agency*)
- **Multi-agent system (MAS):**
  - Agents interconnected in network
  - Agents interact with agents, humans & non-agent entities
  - Agents combine their capabilities to perform composite tasks
  - Agents may engage in several tasks



# Agent Coordination: NEC & MASs

- View NEC as multi-agent systems:
  - Agents represent assets
  - Agents connect assets to information grid
  - Agent monitor asset availability & control access
  - Agent platform takes care of message transport
  - Agents shield assets from technical & behavioral differences



# Agent Coordination: coordination

- **Coordination (in MAS):**  
*“the act of working together harmoniously”, or  
“managing interdependencies between activities”*
- **Harmoniously:**  
No conflicts, or  
Conflicts are resolved
- **Activities:**  
Consuming, transforming and distributing objects  
Objects:
  - Data, information, knowledge
  - Physical entities
- **Interdependencies:**  
Producer-consumer  
Shared resources  
Simultaneity  
Task execution (= organising groups of activities)



# Agent Coordination: taxonomy (1)

- Dimensions:

Implicit vs. explicit communication

Cooperation vs. competition

Centralised vs. decentralised organisation

Dynamic vs. static

# Agent Coordination: taxonomy (2)

- Dimension (1):

- Implicit:

- No (explicit) inter-agent communication

- Agents operate:

- Using shared agreements / rules, or
      - Under local sensing and control

- Agents may communicate indirectly via environment:

- Example: stigmergy

- Explicit:

- Explicitly communicate

- Use coordination strategy:

- Decision making pattern
      - Communication pattern

- Examples: market-, organisation-, negotiation-based systems



# Agent Coordination: taxonomy (3)

- Dimension (2):

- Cooperation:

- Agents join together to carry out activities of mutual benefit

- Agents willing to share information

- Activities orchestrated such that group benefits

- Individual goals & preferences of secondary priority

- Honest & benevolent* agents

- Example: Contract Net (task allocation / assignment)

- Competition:

- Agents primarily pursue individual goals

- Coordination strategy must “persuade” agents to cooperate:

- By satisfying individual goals

- By rewarding agents

- Example: market mechanisms, negotiation



# Agent Coordination: taxonomy (4)

- Dimension (3):
  - Centralised:
    - Specific agent takes care of coordination
    - Other agents have no coordination capabilities
    - N.B. Central coordination can be distributed, e.g. hierarchy
  - Decentralised:
    - All agents have coordination capabilities
- Dimension (4):
  - Dynamic:
    - Agents can alter their coordination strategy at run-time
  - Static:
    - Coordination strategy fixed *a-priori*

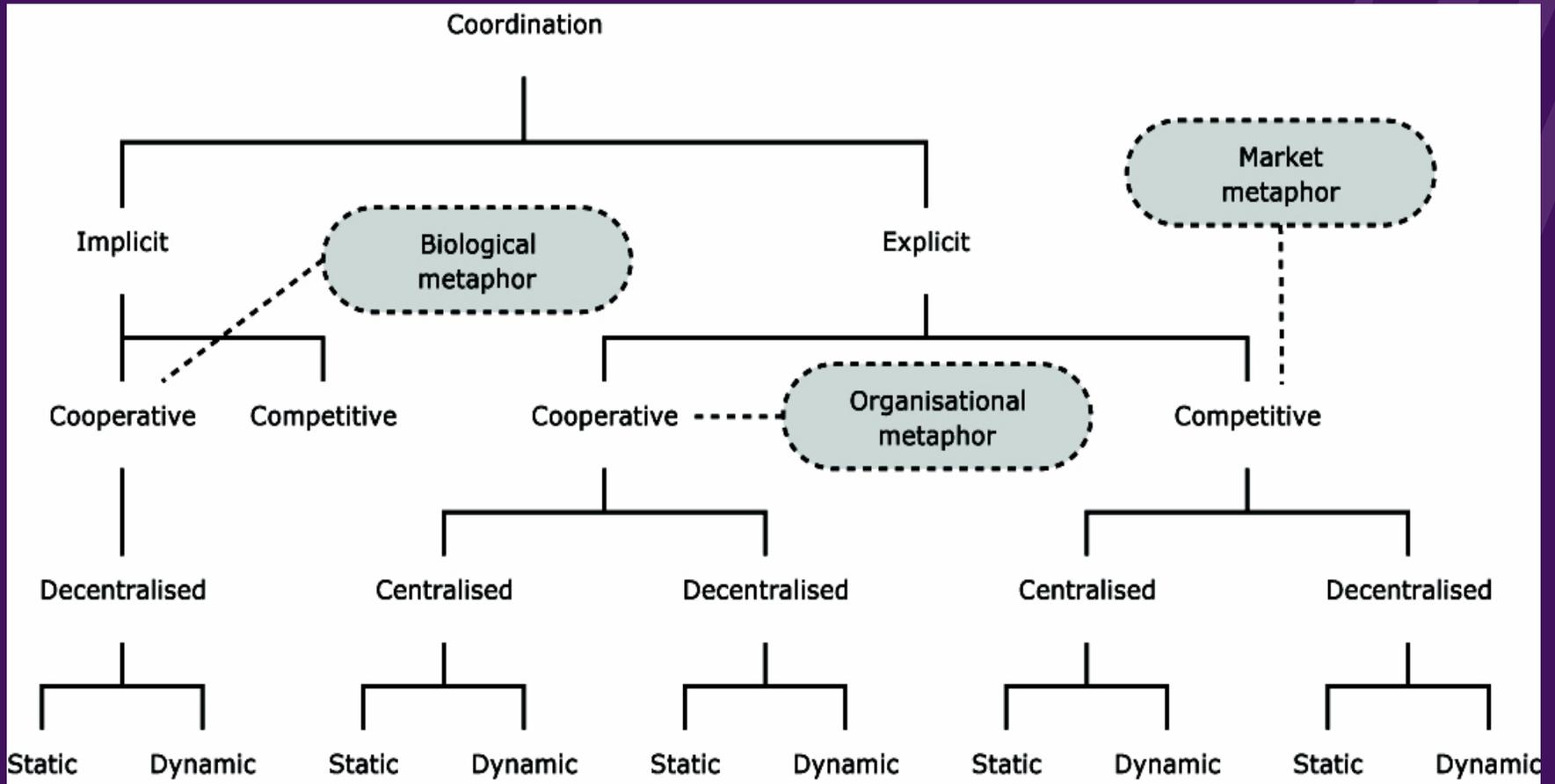


# Agent Coordination: taxonomy (5)

- Metaphors:
  - Organisational metaphor:
    - MAS modelled as human organisations
    - Organisation = authority structure + (social) rules
    - Agents are free to operate within organisational structure
  - Market metaphor:
    - Exploits competitive behaviour by treating MAS as a market
    - Agents engage in auctions, make deals, side-payments, etc.
    - Suitable for non-benevolent, selfish agents
  - Biological metaphor:
    - Coordination inspired by communities of living entities
    - Often employ stigmergy (= pheromones of social insects)
    - Swarming & mobbing



# Agent Coordination: taxonomy (6)



# Coordination in NEC: requirements

- **Flexibility:**
  - Ability to quickly (re)organise & (re)configure assets
  - Responsive to changing mission needs
- **Heterogeneity:**
  - Handle heterogeneous assets
  - Different technology, QoS, behavioural & physical constraints
  - Due to multi-national, joint & combined operations
- **Security:**
  - Resilience to malicious agents
- **Communication infrastructure:**
  - Differences in availability, latency, bandwidth, etc.
- **Robustness**
- **No negative influence on tempo**
- **Scalability**



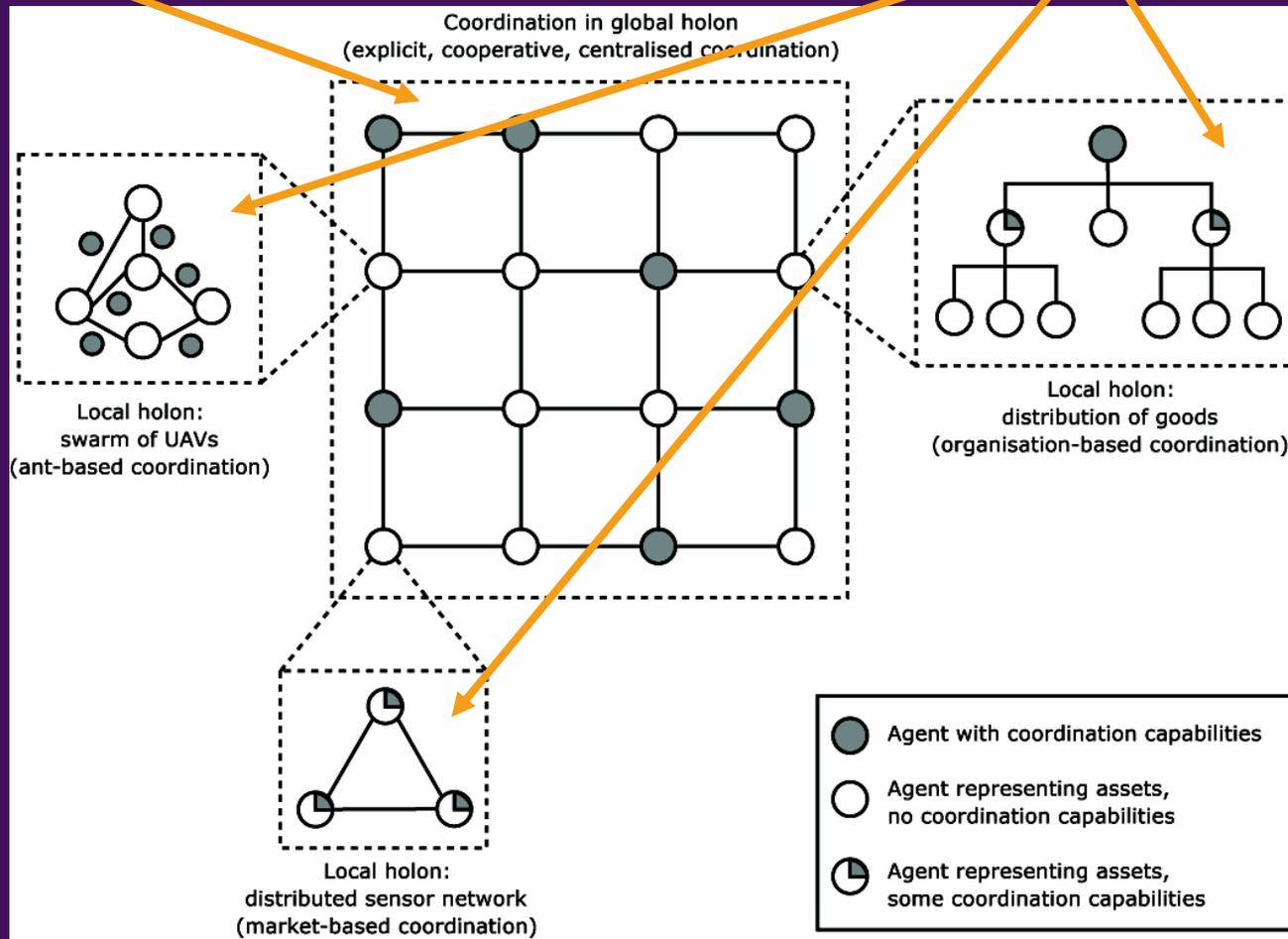
# Coordination in NEC: evaluation

- Main strategy:
  - Explicit coordination
  - Centralised coordination
  - Strategy with low-communication overhead
  - Design NEC system as a cooperative MAS
- Allow subordinate strategies:
  - For subsystems
  - For specific local tasks

# Coordination in NEC: holonic architecture

## Main strategy

## Specialised local strategies



# Conclusions

- Results:

Recognised need for tackling coordination

NEC seen as kind of MAS:

- Borrow MAS concepts

- Apply MAS coordination strategies

Taxonomy for MAS coordination strategies

Identified most promising type of coordination for NEC

Proposed holonic coordination architecture

- Future work:

- Validate theoretical results by prototyping

- Select suitable technology for realizing architecture

- Look at related domains, e.g. crisis management



# Any questions?

The NLDA logo consists of the text "NLDA" in a white, sans-serif font, positioned to the left of a stylized graphic. The graphic is composed of several parallel, diagonal lines that fan out from the bottom left towards the top right, transitioning in color from orange at the base to light blue at the tip.

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