

# **Adaptive and Resilient Behaviors**

RA3 Lead: George Pappas Govt. Lead: Jonathan Fink

The Nation's Premier Laboratory for Land Forces

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# **RA3: Adaptive and Resilient Behaviors**



## **Adaptive and Resilient Behaviors**

Develop theory and methods for heterogeneous teams to carry out tasks under dynamic and varying conditions in the physical world.

#### Adaptive

Dynamic environments

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- Changing teams
- Unpredictable communications
- Increased operational tempo

#### Resilient

- Agent failures
- Adversaries
- Uncertainties in localization, mapping, and sensing

#### **Tactical Behaviors**

- Coordinated rapid multi-agent maneuver in complex environments
- Swarm release and control for threat identification and engagement
- Response to electronic attack
- Persistent surveillance for extended time periods
- Mobile soldier services, e.g., network healing, threat sensing, and decision making

# **Army Relevance**



The Army challenge: complex unknown environments, little or no infrastructure, and high operational tempo.

#### Goal:

Systems must quickly **adapt** to new and rapidly changing missions while being **resilient** to adversarial actions and uncertainty.

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Megacities and Mixed Civilian/Adversary Population



Jungle





Subterranean



**Technical Challenges** 



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# Off-line learning is fragile in dynamic environments

Learning that adapts quickly in non-stationary environments Robust and resilient to unexpected or adversarial data

Agents adapting to uncertainty measures across distributed heterogeneous information types

Semantic, metric, model, environment, mission, communication, topological, knowledge base uncertainty

System-wide resilience for large number of failures or attacks

Resilience approaches are off-line, centralized, or non-scalable Resilience/performance tradeoffs are not quantitative

# **Technical Innovations**



# Thrust RA3.A Robust Perception, Action, and Learning

Fast learning adaptation using meta-learning Estimating probabilistic confidence of learning models Adversarial learning (including reinforcement learning) Robust, self-improving inference for long missions

### **Thrust RA3.B Information and Adaptation for Resilience**

Tensor decomposition model for scalable heterogeneous uncertainty Learning-based MPC for information-theoretic optimal control Distributed information-theoretic stochastic optimal control

#### **Thrust RA3.C Macro-scale resilience**

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Quantitative tradeoffs of resilience/performance/computation Online, distributed resilience mechanisms exploiting discrete convexity

Resilient communications and networking (topological, QoS)



**Research Plan** 



# Thrust RA3.A Robust Perception, Action, and Learning

Task RA3.A1 Robust Adaptive Machine Learning *Levine*, Pappas, Sukhatme Task RA3.A2 Robust Self-Improving Inference, Perception, and Action *Carlone*, Christensen, Daniilidis

### **Thrust RA3.B Information and Adaptation for Resilience**

Task RA3.B1 Adaptive Swarm Behaviors for Uncertainty Mitigation *Atanasov*, Karaman, Tsiotras

# **Thrust RA3.C Macro-scale resilience**

Task RA3.C1 Resilient Situational Awareness *Pappas*, Atanasov, Hsieh Task RA3.C2 Resilience to Failures of Subsets of Networks *Sukhatme*, Karaman, Kumar

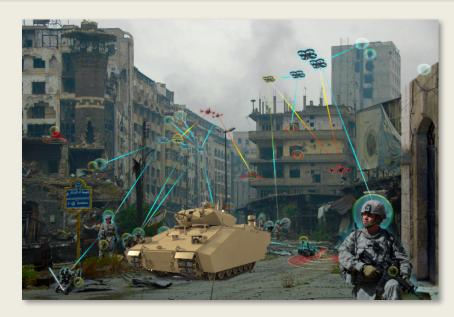
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# **RA3: Expected Outcomes & Impact**

 Dynamic online learning that responds to rapid changes in the environment and is resilient to unexpected and adversarial information

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- Adaptive agent-based behaviors that reason over rich representations of uncertainty to trade off performance and risk
- Techniques to ensure macro-scale resilience as a function of mobility, swarm size, heterogeneity, sensing, and communication.



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#### Impact

Distributed systems that are able to **engage in complex, time-varying, and contested environments** to accomplish Army missions by leveraging a mix of online adaptation and system-wide resilience.