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Integrated Fusion, Performance Prediction, and Sensor Management for Automatic Target Exploitation

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EXECUTVE SUMMARY

Summary of the Research Problem: Despite significant recent progress in automatic target exploitation (ATE) and recognition (ATR), current ATE systems do not meet the requirements of modern battlefield environments. Next generation ATE systems must actively manage sensor resources, aggregate sensed information across multiple platforms and diverse signaling modalities, and adapt to increasingly agile adversaries and operating conditions.

> **Thus, the fundamental research challenge is to develop an integrated systems theory that jointly treats information fusion, control, and adaptation using multiple, dynamic multi-modal sensor platforms in resource constrained environments.**

Research Team: To address this research challenge, we have created a team of recognized world leaders in the constituent disciplines, all of whom have both extensive experience in ATR and ATE applications—including strong ties to both AFRL and to leading ATR industries—and a proven track record of collaboration. The team comprises five universities and 10 senior researchers: Moses, Potter, Ertin from Ohio State, Willsky, Fisher, and Çetin from MIT, Castañón and Karl from Boston U., Hero from U. Michigan, and Srivastava from Florida State.

Technical Approach: We propose a system-theoretic approach that focuses on quantifying and optimizing ATE inference performance. We will develop techniques for optimal, **robust information fusion in uncertain environments**. We will use graphical models to aggregate information at multiple levels and scales in architectures that incorporate both top-down (context and behavior) and bottom-up (feature and shape parameter) information flows. Graphical models also exploit statistical structure to manage computational complexity and facilitate on-line learning. Information-theoretic performance metrics will be used to evaluate overall ATE performance and to inform both sensor management and front-end processing. These metrics provide for consistent fusion of disparate sources, enabling multi-sensor, multi-modal solutions. Optimal fusion is achieved by coupling with both inference-directed **innovative front-end processing** and **dynamic sensor resource management** that supports ATE inference. Front-end signal processing algorithms will extract optimal feature sets from sparse aperture data. We will develop robust, decision-directed imaging and reconstruction methods that can adapt to context and to changing inference objectives. We will also develop non-myopic sensor management and control strategies for sensor platform trajectories that optimally achieve sensing and exploitation objectives.

Collectively, the research program provides an end-to-end solution from processing of raw sensor data to fusion from multiple sensors and modalities to sensor management and control, all focused on a common ATE inference objective. At all levels we seek to provide provably good algorithms which follow directly from theoretical developments and to provide quantitative actionable performance prediction measures. Prior information and sensor physics, coupled with learning and adaptation to accommodate a wide range of operating conditions, provide a flexible, robust methodology for information fusion and sensor management.

Research Outcomes: The proposed research will:

- Provide an integrated theoretical framework and provably optimal algorithms for analyzing and designing optimal ATE systems, and provide a foundational "systems theory" for information exploitation systems in general.
- Develop the theoretical foundations for adaptive and learning-based ATE systems that will significantly enhance the performance, robustness, and applicable range of operating conditions of next-generation ATE systems.
- Develop new algorithms and performance assessment for coupled sensor signal processing, information fusion, and sensor platform control, enabling active ATE systems.

Impact: The proposed research will provide the systematic theory, analysis, and design tools to develop end-to-end ATE systems employing multiple sensing platforms and modalities. The research will enable inference-driven ATE systems in which sensor management and front-end processing are directed in order to optimally achieve ATE inference objectives.

Student Training and Technology Transfer: We will train future researchers through support for **12 graduate students per year** on this project. Close interactions with government research laboratories and leading ATE industries will ensure relevance and facilitate technology transfer. Our team has a distinguished record of training future leaders in topics related to ATR and ATE, and of tangible impact on DoD programs through our close interactions with government and industry partners.