Dr. Karen Zita Haigh
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Hands-on Cognitive EW (Agenda)

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3 Day Course Agenda

This agenda aims to provide a comprehensive introduction to Cognitive Electronic Warfare for the Association of Old Crows, hosted at the Southwest Research Institute in San Antonio, TX. It blends theoretical understanding with practical considerations and a hands-on component. The course is split into three 8-hour sessions across three days.

Day 1	Day 2	Day 3
Intro to Cognitive EW Cognitive EW System Loop Brief System Walkthrough Speed of AI	***TS/SCI:*** Speed of AI ***Alternate:*** Smart deinterleaving (SwRI) Decision Making Designing a Testable System	Test & Evaluation Detailed System Walkthrough Getting Started and Lessons Learned
Hybrid Learning Defining a Task Electronic Support	Data Management	
Python: Clustering and Feature Processing ***Alternate:*** CogEW @ SwRI	***Python:*** Classification for Specific Emitter Identification ***Alternate:*** Adaptive Sampling (SwRI)	***Python:*** Scenario Control Decision Making and Incremental Learning ***Alternate:*** Neuromorphics, quantum, photonics, and PINN (SwRI)
		TS/SCI (if needed): Speed of AI

Lectures will be held at collateral SECRET, except for the ones marked TS/SCI. Programming will be unclassified and require access to the internet.

For the programming session, students should bring their personal laptops. Government laptops are acceptable as long as students can access their Google accounts. All exercises will be completed in Google Colab. One week before class, students will receive instructions on copying the datasets and initial code.

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Day 1 (AM): Foundations of Cognitive Electronic Warfare (08:00-12:00)

- **What is Cognitive Electronic Warfare?** CogEW definition and its importance in modern EW. The limitations of traditional approaches in the face of dynamic and complex RF environments. Connecting AI concepts to EW challenges. What is unique about ML-enabled EW compared to cognitive EW.
- **The Cognitive EW System Loop:** Iterative process of perceiving the environment, reasoning, acting, and learning. How AI techniques enable situation assessment, decision making, and learning in real time.
- **Brief System Walkthrough:** A short discussion of a fielded system, its operating constraints, the technical approach, and results highlighting the improvement of in-mission learning over an adaptive approach.
- **Speed of AI (part 1):** The global landscape of AI research, development, and deployment.
- **Hybrid Learning in Cognitive EW**
    - **Overview of Machine Learning:** Basic concepts and techniques, and their limitations in the CogEW ecosystem.
    - **Combining Traditional EW Features with ML:** Leveraging existing signal processing techniques and domain expertise with the ML for enhanced performance. Models that combine contextual knowledge with empirical data.
    - **Benefits of Hybrid Approaches:** Improved accuracy, robustness, interpretability, and handling of limited data. The success of hybrid approaches.

Day 1 (PM): System Design (Part I) (13:00-14:30)

- **Defining a Task:** The mathematical framework for describing objectives, including observables that capture the current RF environment, the controllables that the system can change, and the metrics that evaluate system performance.
- **Situation Assessment for Electronic Support:** Example AI algorithms presented in the context of electronic support challenges.

Day 1 (PM): Python Programming (14:30-16:00)

- **Python Programming:** Clustering, with feature selection and regularization.
- **Alternate (SwRI):** Cognitive EW efforts at SwRI

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Day 2 (AM): Decision Making and Software Architecture (08:00-12:00)

- **Speed of AI (TS/SCI session):** Specific examples
  Alternate (SwRI): Smart Deinterleaving demo
- **Decision Making in a Real-time Physical System**
  - **Deliberative Decision Making:** Methods for deliberative decision making, including planning, optimization, and scheduling. Hierarchical task networks, multiple objectives, and randomized search. Advanced concepts including reward hacking, deliberate sensing (probing), anytime decision making, and game theory.
  - **Real-time Operations:** Updating existing plans based on mission progression. Learning from experience during a mission. Computing feedback about action effectiveness, including battle damage assessment (BDA).
- **Designing a Testable Cognitive EW System**
  - **Architecting for Testability:** Software architecture concepts that instrument the system for test.
  - **Engineering Resilient Systems:** Systems engineering, iterative development, and risk management. Defining bite-sized tasks. When is AI not necessary. Levels of cognition. Scoping a task, taking small steps along the cognition spectrum. Design recommendations.

Day 2 (PM 1): Data (13:00-14:30)

- **Data Management for Cognitive EW**
  - **Data Quality and Data Curation:** The critical role of high-quality, diverse data for training and evaluation. Data modeling techniques, including ontologies, metadata, and schemas. The need for comprehensive metadata and a federated data fabric.
  - **Overcoming Data Scarcity in EW:** Addressing data heterogeneity, missing data, and managing bias. Strategies for dealing with limited labeled data, including data augmentation, synthetic data generation, and transfer learning. The need for good, comprehensive RF-specific datasets.
  - **Pragmatic Data Considerations:** Managing dataset size on embedded systems, ensuring data diversity, augmenting data, forgetting data, and data security.

Day 2 (PM 2): Python Programming (14:30-16:00)

- **Python Programming:** Classification for Specific Emitter Identification, with data augmentation techniques.
- **Alternate (SwRI):** Adaptive Sampling

Day 3 (AM): Test & Evaluation; Getting Started (08:00-12:30)

- **Test and Evaluation of Cognitive EW Systems**
    - **Trust as a Function of Risk:** Risk Tolerance drives the assurance process. Concepts of measures of performance, effectiveness, and suitability.
    - **Unique Challenges of Testing AI/ML Systems:** How to evaluate systems that learn and adapt after deployment. The difference between evaluating an AI-enabled system vs evaluating a cognitive system. Paradigm shifts compared to traditional testing approaches.
    - **Methods for Evaluating Cognitive EW System Performance:** Evaluating the learning process, including formal and empirical verification methods. Evaluating learning goals, as a discussion of how the system learns to determine deployability. The importance of closed-loop testing and associated models. Smart experimental design to manage the combinatorial explosion of test axes. Using ablation tests to understand how much a priori data is required. Evaluating performance for novel settings and in open-set conditions.
- **Detailed System Walkthrough:** A discussion of a fielded system, its operating constraints, the technical approach, and results highlighting the improvement of in-mission learning over an adaptive approach.
- **Getting Started with Cognitive EW Development:** Choose a bite-sized task, develop an initial pipeline, evaluate with representative data, implementing on representative hardware. Overview of available tools including ML libraries, datasets, and simulation/emulation tools relevant to RF and EW development. Small-scale projects to get started. SwRI lessons learned. Wrapping up.

Day 3 (PM): Python Programming (13:30-16:00)

- **Python Programming:** Python programs for (1) basic decision selection and incremental learning, and (2) scenario control and evaluation of the decisions
- **Alternate (SwRI):**
  Neuromorphics, quantum, and photonics.
  For advanced students: Physics inspired neural networks (PINN)

Day 3 (PM as needed): Speed of AI (TS/SCI) (16:00-17:00)

- **Speed of AI (second session):** If more students register for the first TS/SCI session than the room can handle, then we will schedule a second session