

# Synergistic Signal Processing Methods for Sensor Fields

Dr. Garry M. Jacyna

703-883-6972 • [gjacyna@mitre.org](mailto:gjacyna@mitre.org)

MITRE Sponsored Research

The logo consists of a cluster of 3D cubes in yellow, orange, and blue, arranged in a stepped pattern. To the right of the cubes, the text "MITRE Technology Program" is written in a bold, sans-serif font.

MITRE  
Technology  
Program

# Problem

- There has been a lot of DoD and commercial interest in the use of distributed low-cost unattended sensors for remote sensing.
- The primary focus of these efforts has been in areas such as:
  - Network protocols
  - Adaptive network topologies.
- However, very little thought has been given to the signal processing issues associated with netted sensors.

# Background

- **Netted sensors will play an increasingly important role in commercial and military operations as evidenced by:**
  - **Military shift from platform centric to network centric operations**
  - **Added emphasis on early warning capabilities for homeland security**
  - **Utility of distributed netted sensors in the Afghanistan campaign**
  - **Increased interest in proximal in-situ environmental monitoring**

# Objective

- Develop robust signal processing algorithms for distributed sensor detection, classification, localization, and tracking applicable for Navy littoral and Army battlefield environments as well as homeland defense/security
- Particular emphasis on **unique** localization and tracking techniques constrained by sensor power and bandwidth limitations:
  - Leverage existing work in blind beam-forming and numerically efficient classification techniques
  - Develop robust sensor-selective multi-target tracking algorithms

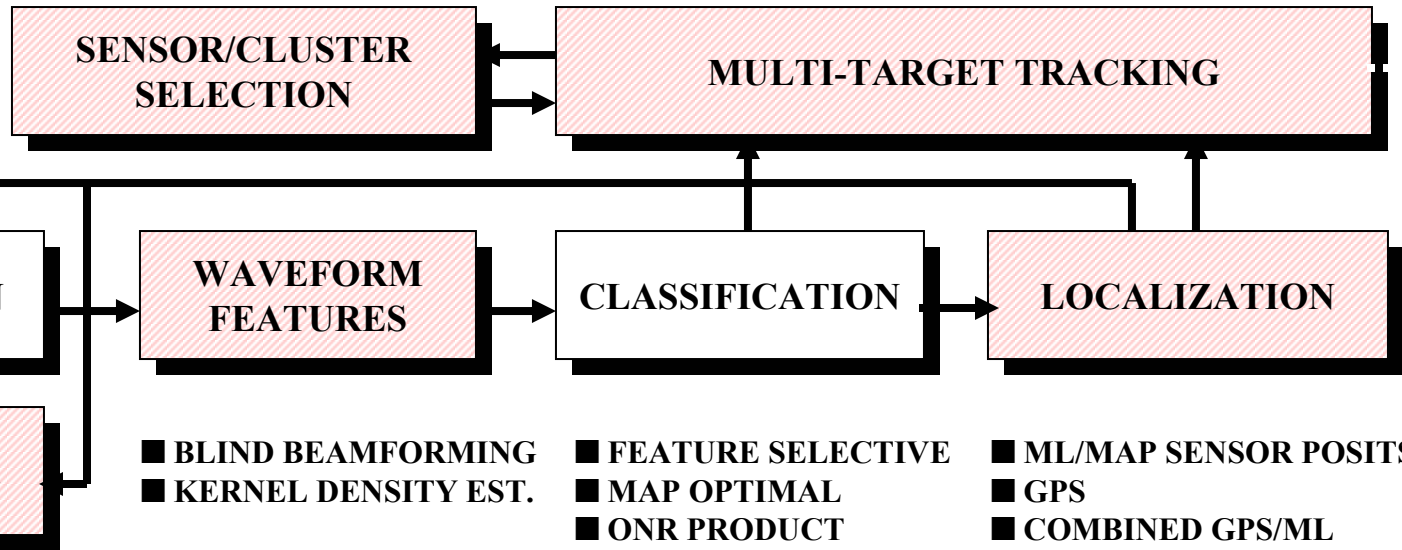
# Activities

## Cluster-Level Signal Processing (FY03)

Develop a logical approach for addressing key signal processing components in a locally optimal manner given numerous resource constraints

- PARTICLE FILTER-BASED
- ML SENSOR SELECTION
- NONLINEAR TARGET MODEL
- NONLINEAR MEAS. MODEL

- COVARIANCE-BASED
- WOLCIN
- PAGE
- LOCALLY OPTIMAL

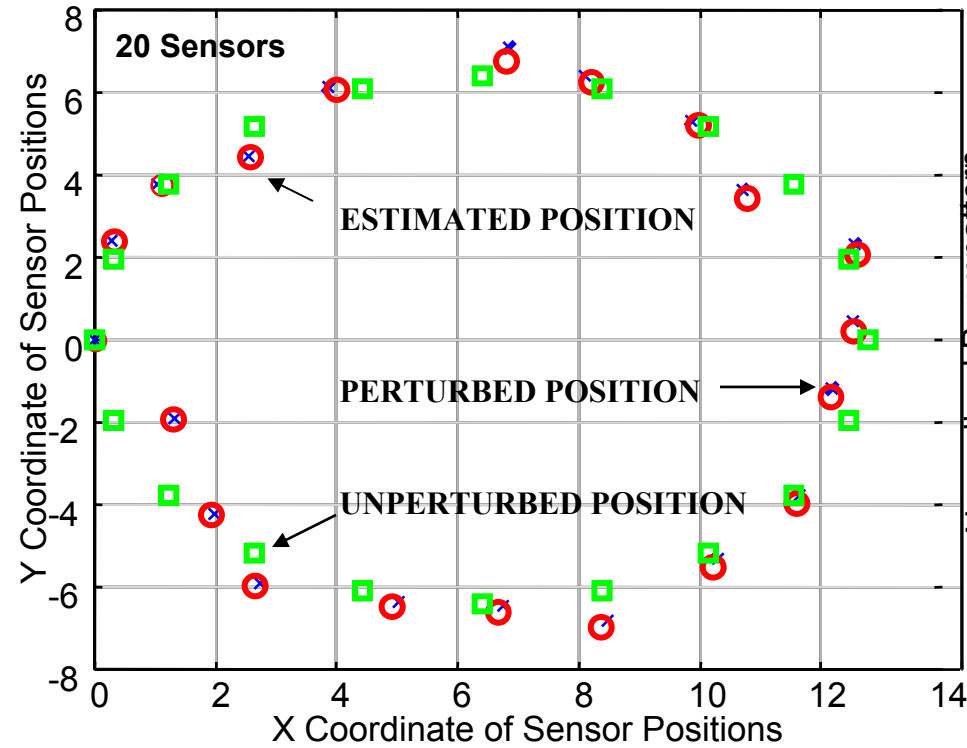


- TEMPORAL MODEL-BASED ML
- SPATIAL ADAPTIVE NULLING

# Highlight

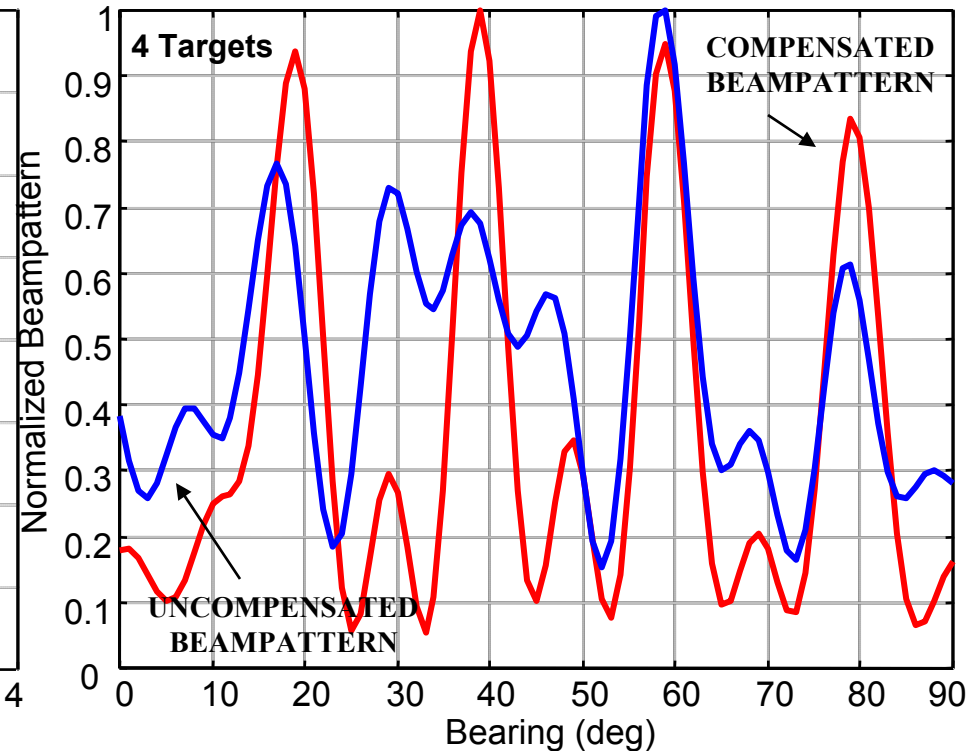
- I. We developed a robust nonlinear estimation algorithm to correct for sensor position uncertainties that does **not** require a separate GPS receiver for each sensor.

Actual (X) Versus Estimated (O) Sensor Locations Relative to Unperturbed



**SENSOR POSITION ESTIMATION**

Estimated Beampattern Before (Blue) and After (Red) Compensation

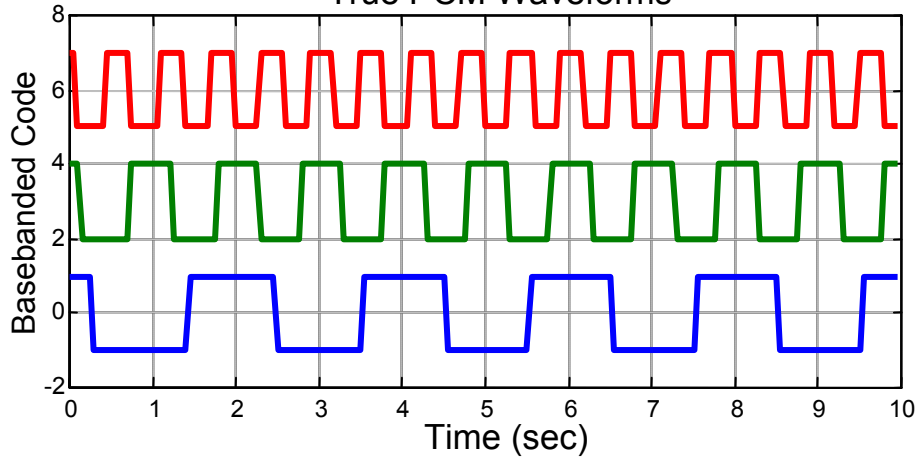


**COMPENSATED BEAMPATTERNS**

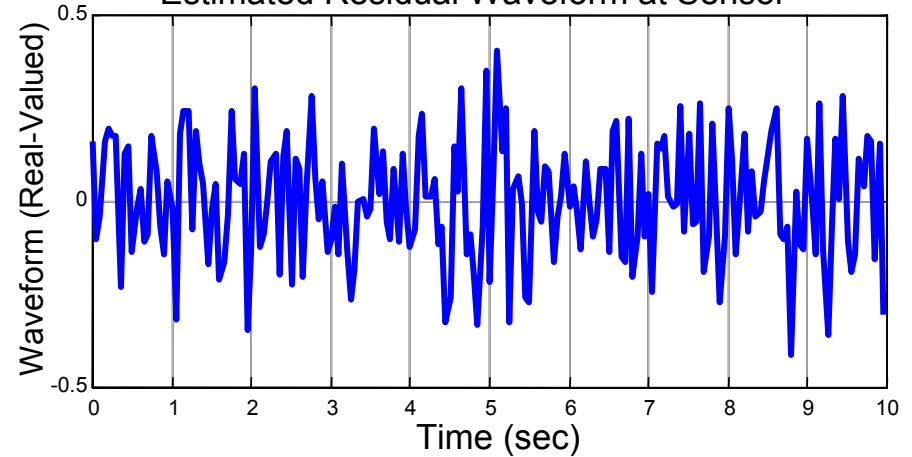
# Highlight

II. We developed four ICA-based methods for extracting signal information from a linear mixture of signals in noise

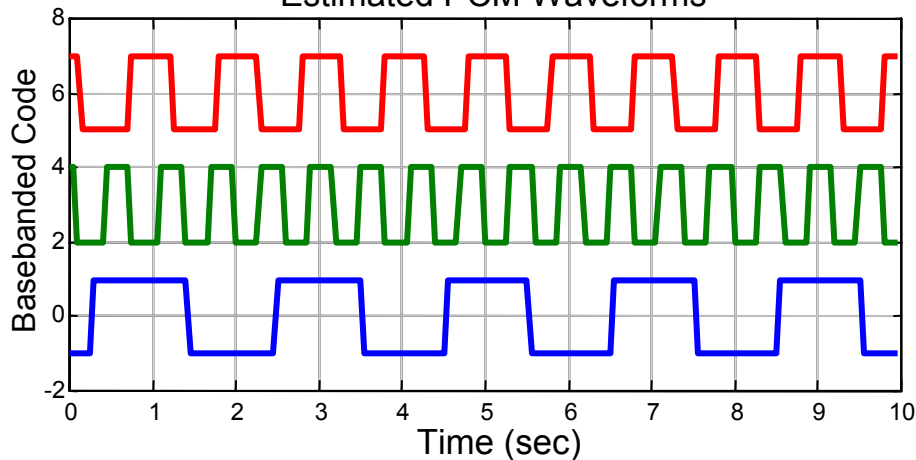
True PCM Waveforms



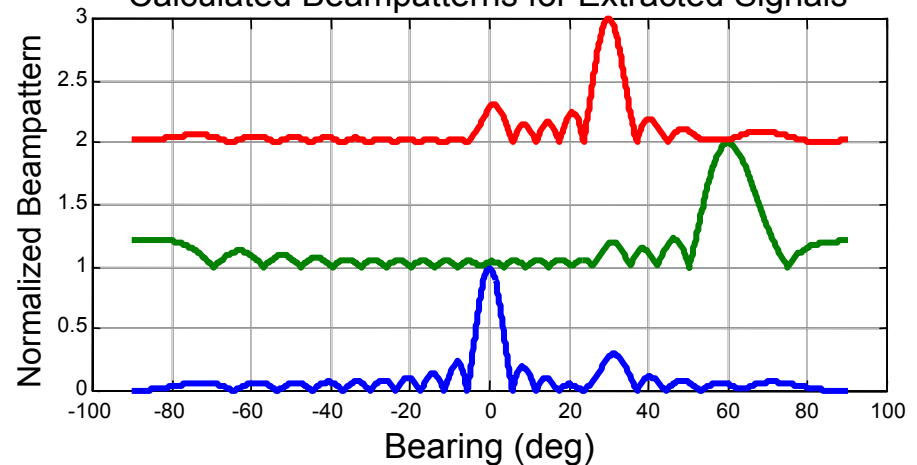
Estimated Residual Waveform at Sensor



Estimated PCM Waveforms



Calculated Beampatterns for Extracted Signals



# Impacts

- **Developed proof-of-concept algorithms for:**
  - Clutter mitigation
  - Beamforming with non-stationary arbitrarily-arranged sensor elements
  - Blind beamforming for signal feature extraction
  - Distributed sensor-selective tracking
- **Ideas applicable across the spectrum of netted sensors problems within MITRE and the community at large**

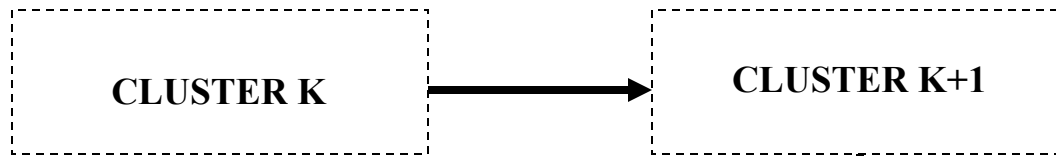
# Future Plans

## ■ Sensor Field Signal Processing (FY04)

Develop methods for combining track fragments from disparate sensor clusters given limited cluster detection ranges/resources

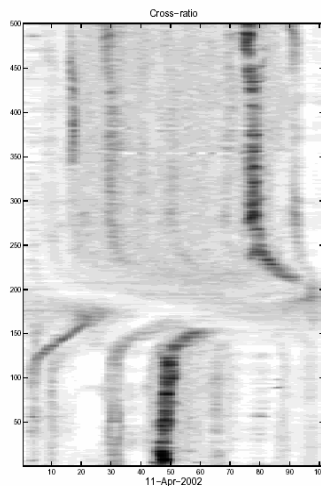
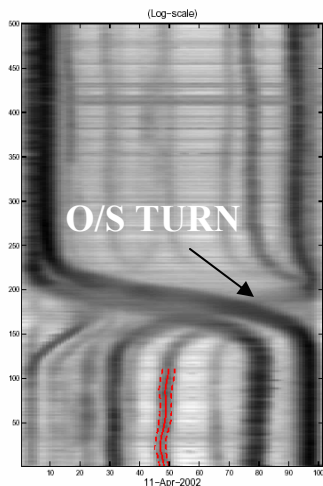
ENCODED FEATURES  
TIME/SPATIAL TAGS

ML SENSOR SELECTION ALGORITHM  
CHOOSES CLUSTER K+1 FOR HANDOFF



BTR

CROSS RATIO



DETERMINE IF  
CLUSTER IS ACTIVE

YES

TRACK  
ASSOCIATION

NO

KEEP SEPARATE  
TRACKS

YES

KEEP ONE TRACK

- USE CROSS RATIO TEST
- RATIO OF ECKART FILTERS
- USES SPECTRAL/KINEMATIC FEATURES
- OPTIMAL IN GLR SENSE