Understanding And Managing Chaotic Test And Evaluation Results

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Outline

- A Brief History Focused On ECM System Effectiveness Test and Evaluation Results
- Primary ECM/Radar System Interactions
- Testing ECM Effectiveness Though Simulation
- Comparison of HWIL and Software Simulation
- Test and Evaluation Steps To Improve The Future History of ECM Effectiveness T&E
1999 ECM Test Results*

• Open Air Range and Hardware In The Loop results exhibited very weak statistical correlation

• Data collected were not sufficient for verifying and validating the Advance Distributed Simulation based test architecture

• Statistical correlation between the ADS and baseline tests was also very weak and could not support V&V

• The operators were a significant source of variation … however, … found evidence … that the samples may not fully capture the real variation possible

* Joint Advanced Distributed Simulation Electronic Warfare Tests
Earlier ECM Test Results

• ALQ-131 Jammer (1995)
  – “Band 3, is ineffective against some threats”
  – “Testing … indicates significant problems persist”

• ALQ-165 Jammer (1996)
  – “Key performance criteria for effectiveness were not met”
  – “Can not certify ALQ-165 (ASPJ) is effective against original requirement”
  – “The ASPJ was not operationally effective because it did not meet the requirement threshold value for increasing the survivability of an ASPJ equipped F/A-18 strike force”
  – DOT&E 1996 Annual Report

• Such Results Indicate Problems in Testing Jammers to Demonstrate That Their Effectiveness Meets Requirements
JADS ECM Test Example

• Phase 1
  - Open Air Range (OAR) Tests: ALQ-131 h/w on F-16 vs SADS VIII h/w (WTR, Edwards AFB)
  - Hardware In The Loop Tests: ALQ-131 h/w vs SADS VIII h/w (AFEWS, Fort Worth)

• Phase 2
  - Distributed Simulation Tests: Digital ALQ-131 s/w Model (Patuxent NAS) vs SADS VIII (AFEWS, Fort Worth)

• Phase 3
  - Distributed Simulation Tests: ALQ-131 h/w on F-16 (ACETEF, Patuxent NAS) vs SADS VIII h/w (AFEWS, Fort Worth)
SADS VIII Characteristics

- Target Acquisition Radar With Operator In The Loop
- Target Tracking Radar With Operator In The Loop
- Simulated Command Guided Surface To Air Missile

TTI’s SAM (CG) ECM Engagements

\[ P_{\text{ECM}} = 22 \text{ dBW}, \text{ Servo BW } = 1.0 \text{ Hz} \]

\[ P_{\text{ECM}} = 23 \text{ dBW}, \text{ Servo BW } = 1.2 \text{ Hz} \]
TTI’s Tests of RGPO vs SAM (CG) Miss Distance Results (40 Runs Each)

Small Changes in Input Parameters (20%)

Result In Large Changes In Output Miss Distance (20 Times)
Probability Distributions

Percent of Runs vs Miss Distance For Four Different Trial Configurations

Multiple Maxima For Each Distribution

Not Single Maxima Normal Distribution

Needs New Statistical Analysis Tools?
JADS and TTI Comparison

- JADS HWIL and TTI Software Simulation Trials Produce Similar Results, Including:
  - Statistical Correlation Is Poor To Non-Existent From Data Set To Data Set
  - For Similar Input Conditions, Output Results May Differ Substantially From Run To Run
  - Consistent With Chaotic Behavior
What Is Chaotic Behaviour?

- Noticed By Lorenz In Weather Prediction Studies
- Plot Trajectory Depends On Initial Conditions
- May Possess “Quasi-Stable Regions
- Plot Trajectory Is Not Repetitive
- May Possess Multiple “Strange Attractors”
- Final Result Depends On Duration Of Interaction
- Caused By *Non-Linearities In Extended Dynamic Interactions*
Missile Miss Distance And Chaos

- Missile Miss Distance Occurs After *Extended Dynamic Interactions* Between ECM And Weapon Systems
- Weapon Systems Contain Many *Non-Linear Functions* and Components, Such as Radar Mode Switching and Tracking Discriminators
- ECM Signals Inherently Cause Radars To Operate In Non-Linear Regions And With Non-Linear Logic And Functions
- Extended Dynamic Interactions Between Non-Linear Systems Inherently Gives Rise to *Chaotic Behavior*
- Chaotic Behavior Means a *Small Change in an Input* Condition or Parameter Can Lead To a *Large Change in Miss Distance*
Chaotic Miss Distance Results: A Function Of Missile Launch Direction

Miss Distance Scatter vs Missile Launch Angle
(Command Guided Surface To Air Missile)

Monte Carlo Missile Launch Selection
Launch Time: 0 to 2 sec
Velocity: 800 to 1100 m/ s
A Different Scatter Plot: Three Miss Distance Thresholds

Monte Carlo Missile Launch Selection
Launch Time: 0 to 2 sec
Velocity: 800 to 1100 m/s

- > 10 m miss
- > 20 m miss
- > 30 m miss
T And E Steps

• System Performance Test Specifications Based On:
  – Analysis Models that Include Weapon System Non-linearities, Like Mode Switching and Tracking Discriminator Characteristics
  – Weapon System With Tightly Defined Parameter Values, Particularly In Tracking and Guidance
  – Probability Of Successful Performance Based On Multi-Peaked Probability Distributions

• Evaluations Based On:
  – Chaotic Behavior Expectations
  – Non-Linear Probabilistic Analysis Approaches And Tools
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The Beginning