Understanding And Managing Chaotic T and E 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

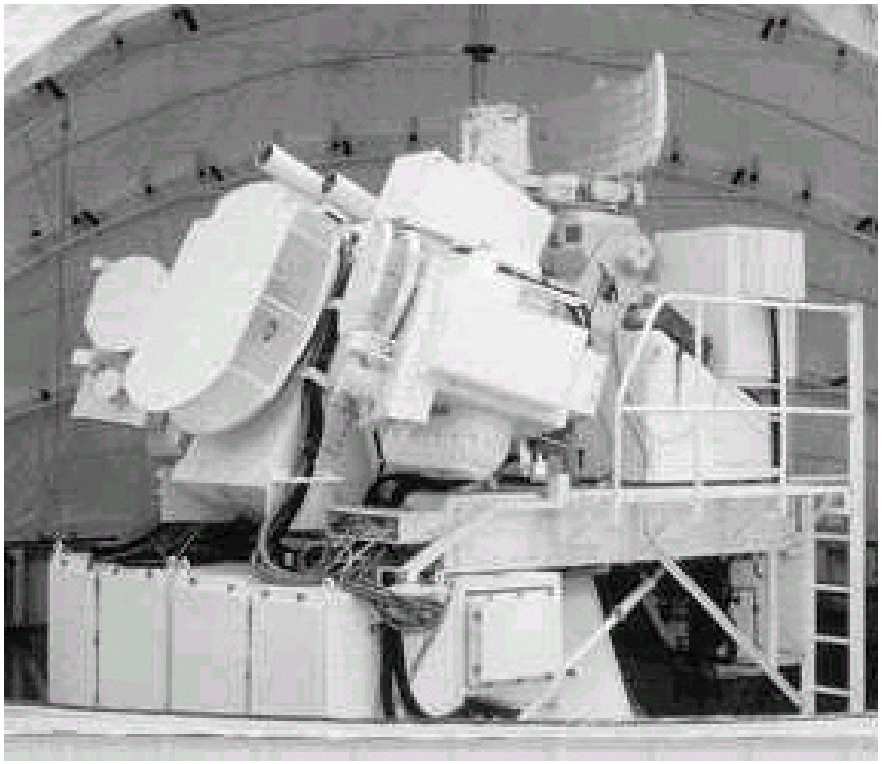
- ALQ-131 Jammer (1995)
  - "Band 3, is ineffective against some threats"
  - "Testing … indicates significant problems persist"
  - GAO Report NSIAD-1995-47
- ALQ-165 Jammer (1996)
  - "Key performance criteria for effectiveness were not met"
  - "Can not certify ALQ-165 (ASPJ) is effective against 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

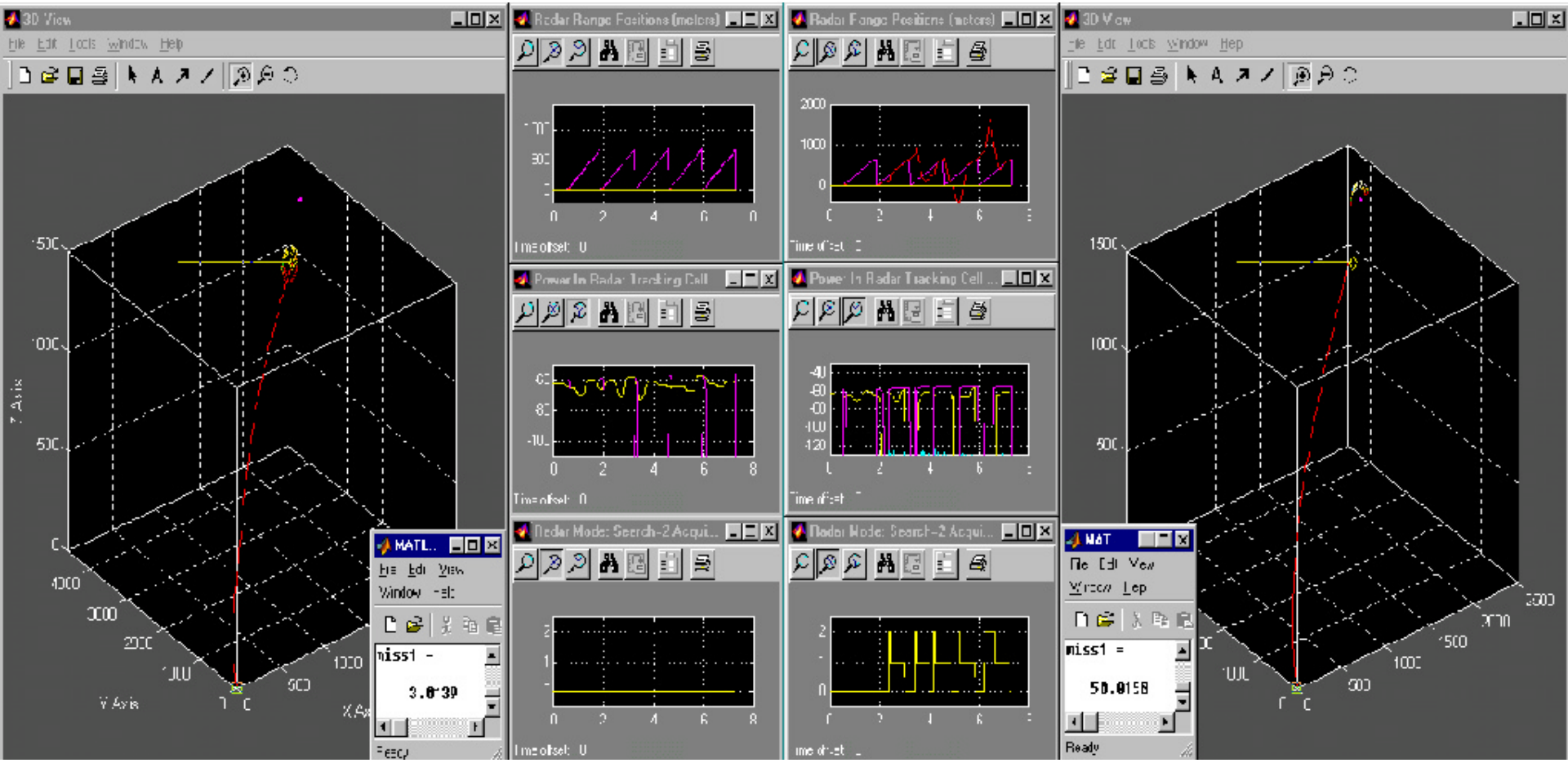


From “JADS Electronic Warfare Baseline Testing”, a Paper Presented to Military Operations Research, June 1999, and “A Multiprocessor Architecture for a Threat Radar Simulation System”, Australasia Workshop on Parallel and Real Time Systems” July 1994.

TTI's SAM(CG) ECM Engagements

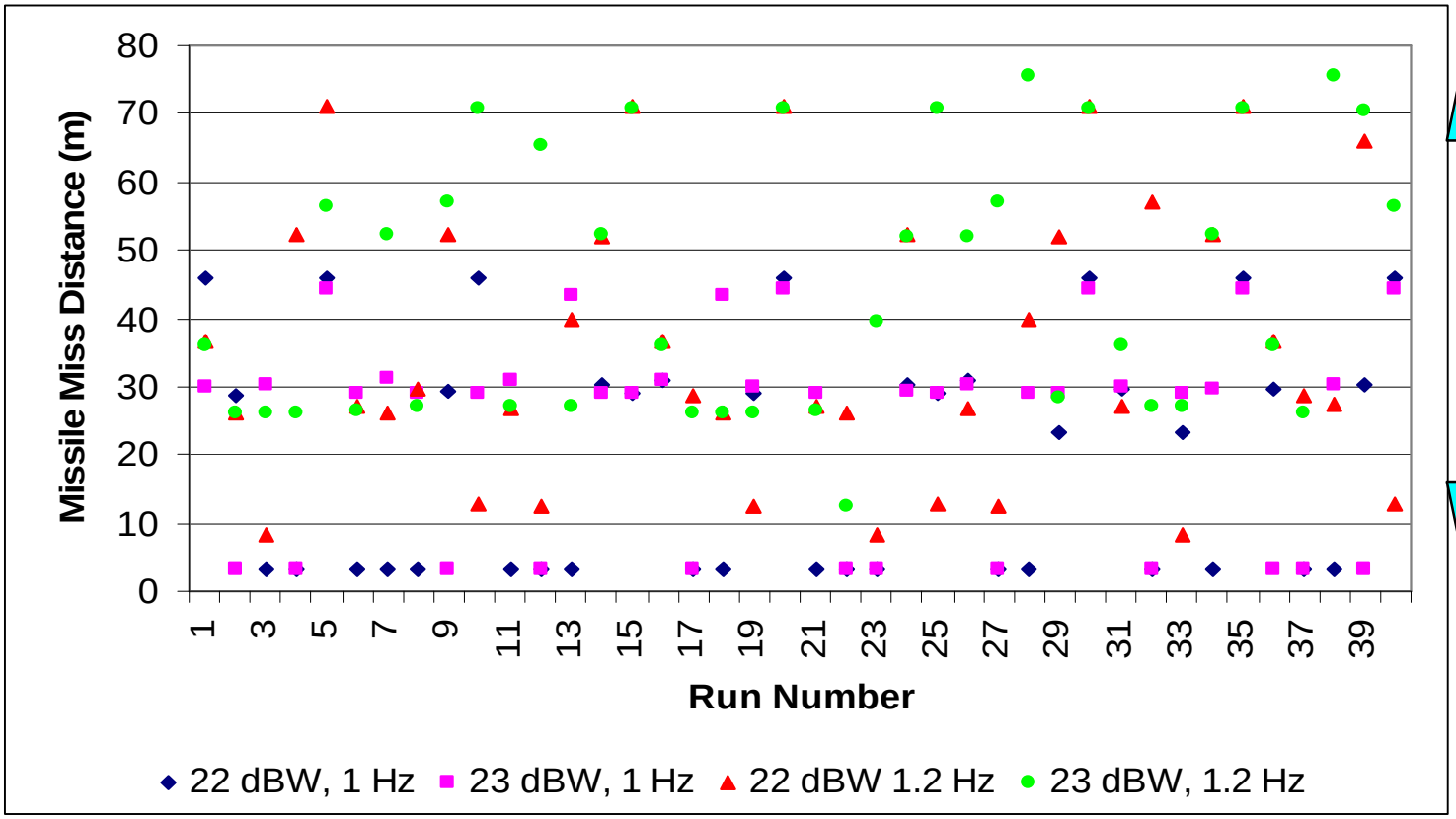
P_{ECM} = 22 dBW, Servo BW = 1.0 Hz

P_{ECM} = 23 dBW, Servo BW = 1.2 Hz



TTI's Tests of RGPO vs SAM(CG)

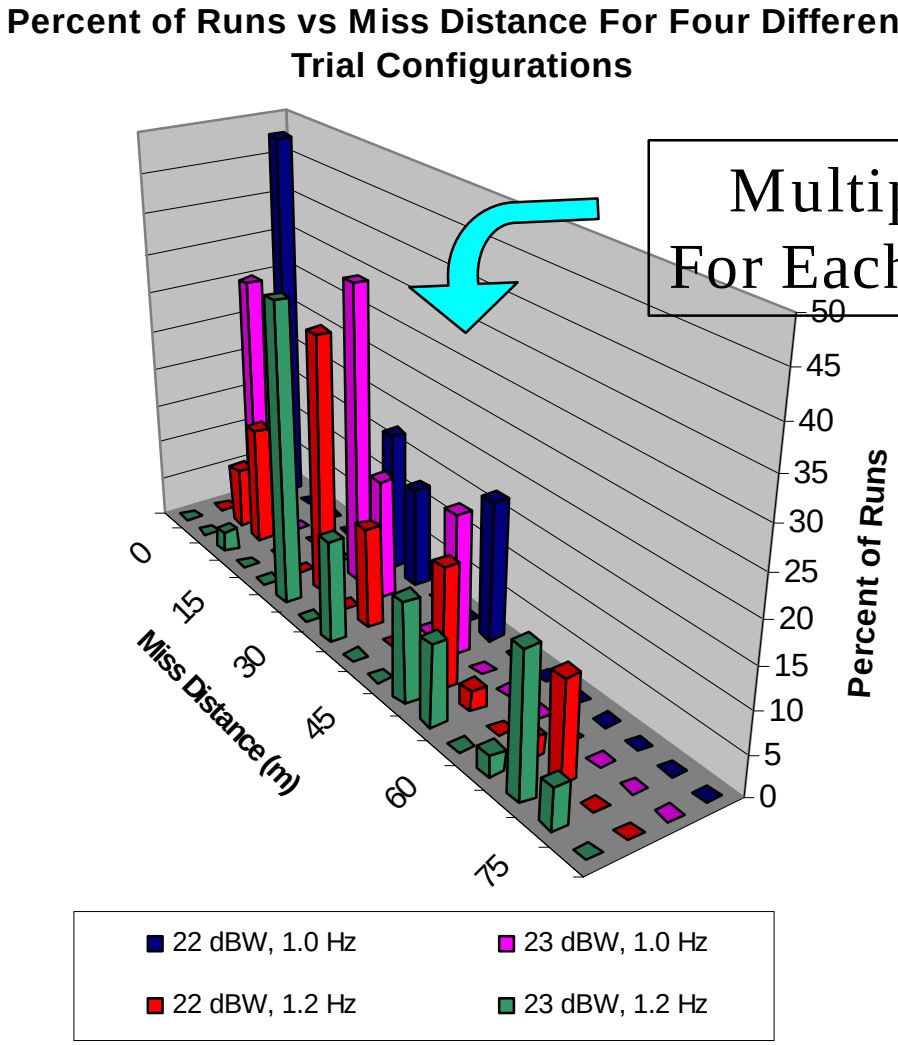
Miss Distance Results (40 Runs Each)

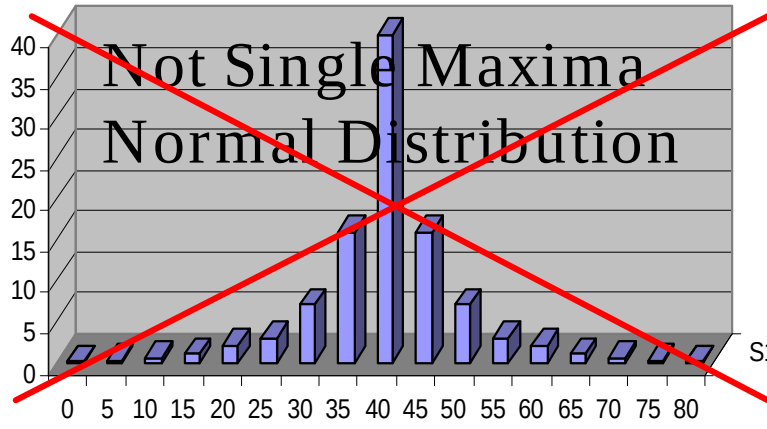


Result In Large Changes In Output Miss Distance (20 Times)

Small Changes in Input Parameters (20 %)

Probability Distributions





Needs New Statistical Analysis Tools?

JADS and TTI Comparison

- JADS HWIL and TTI Software Simulation Trials Produce Similar Results, Including:

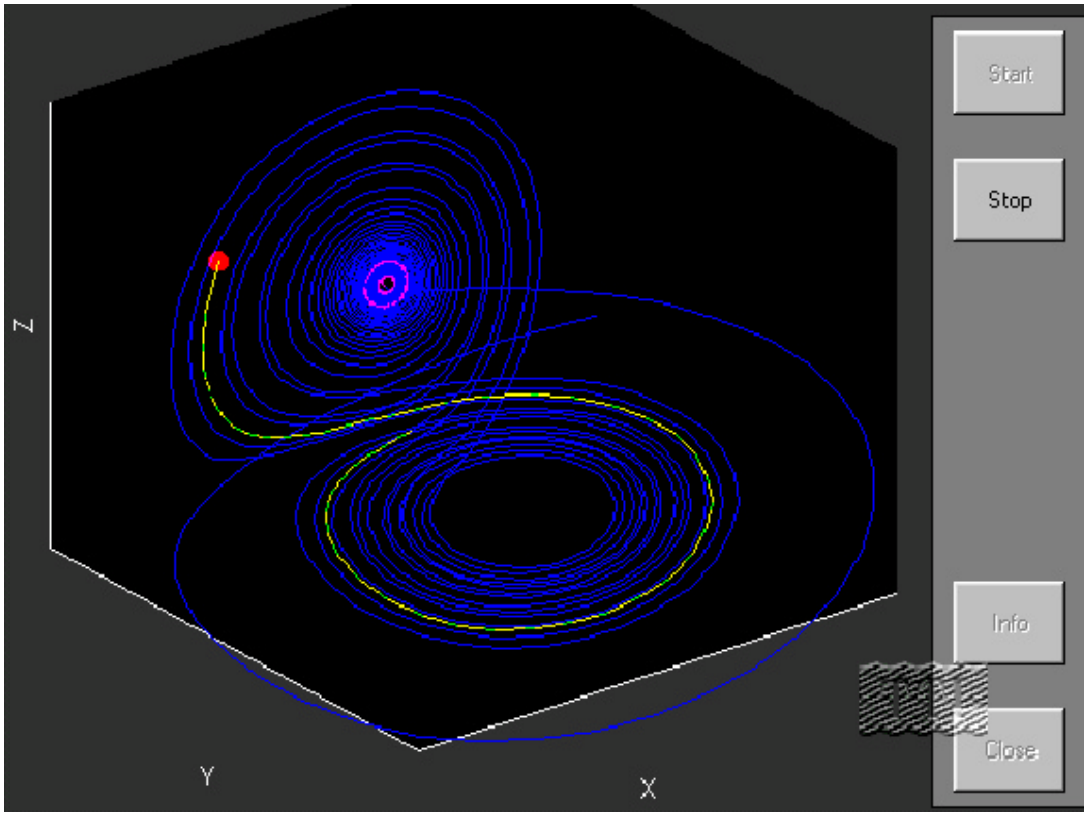
  - Statistical Correlation Is Poor To Non-Existent From Data Set To Data Set

  - 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

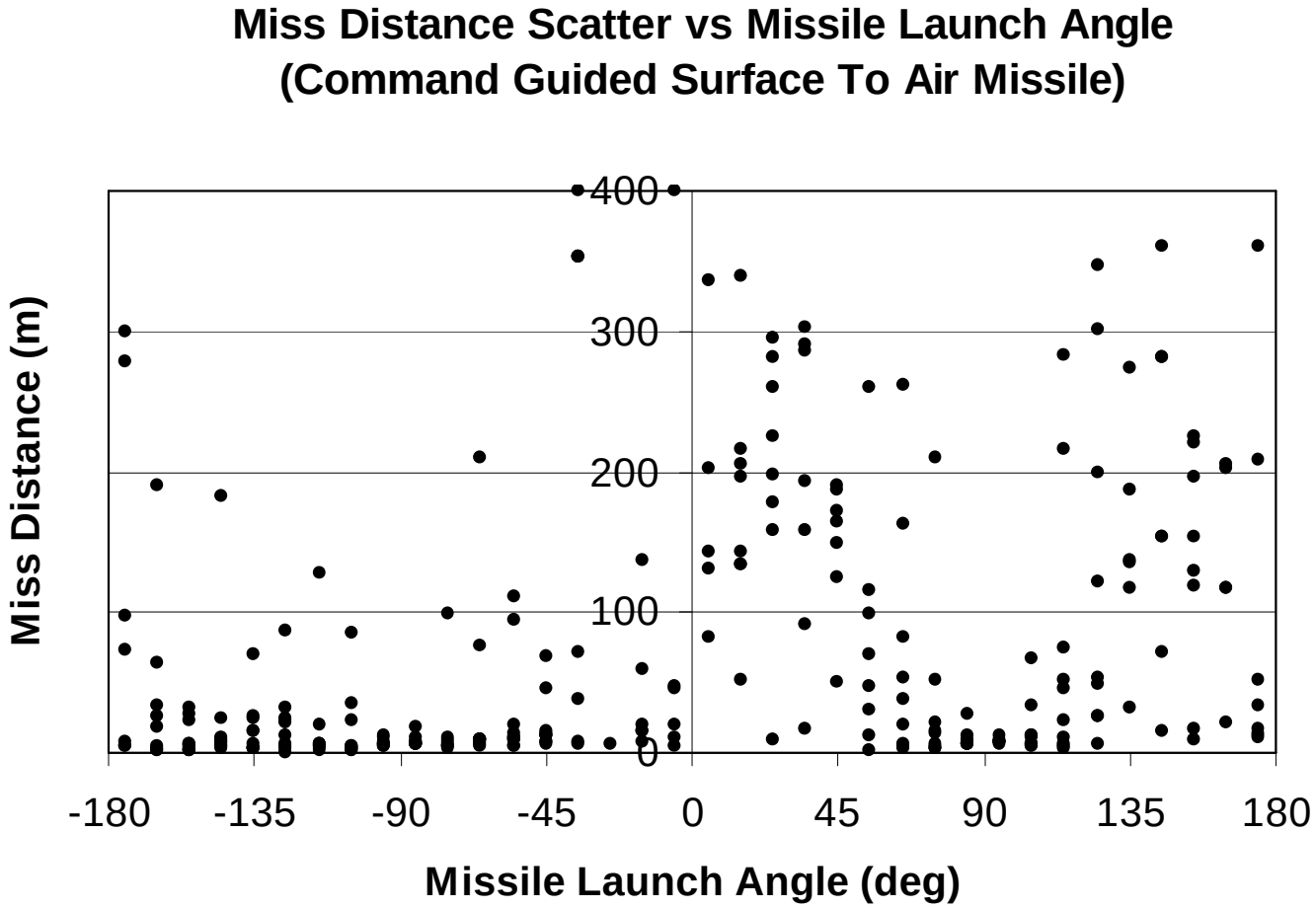


- Caused By ***Non-Linearities In Extended Dynamic Interactions***

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***

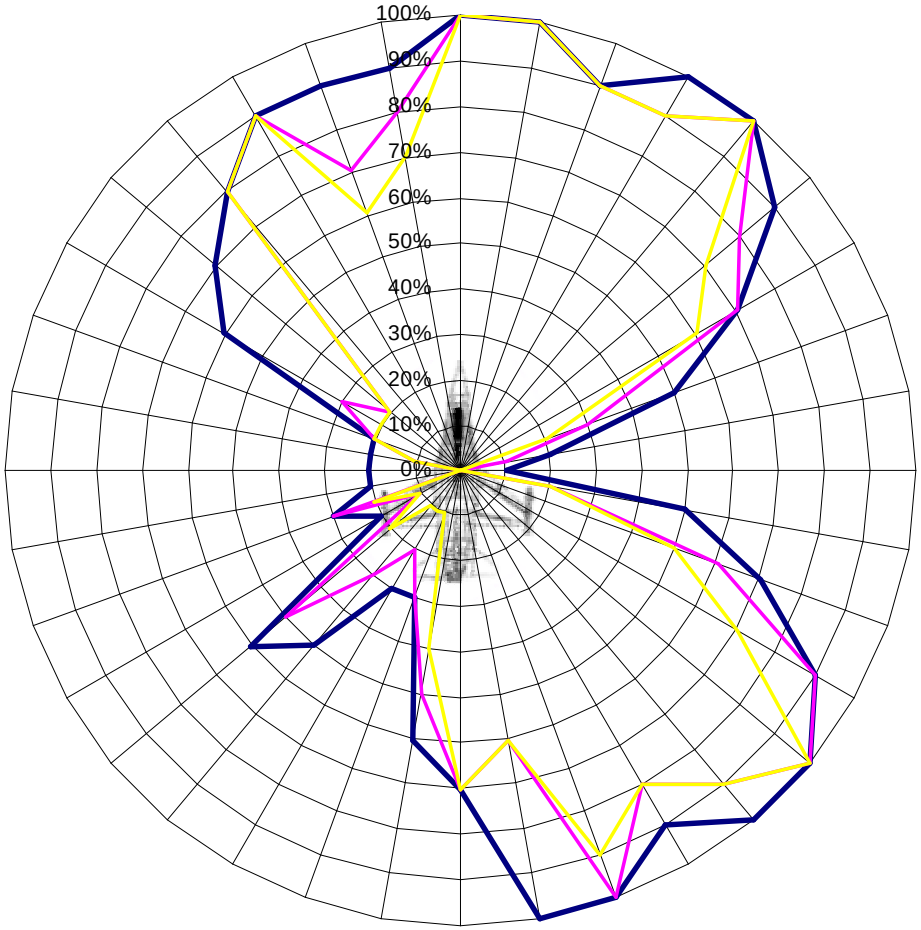
Chaotic Miss Distance Results:
A Function Of Missile Launch Direction



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