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Near-field RCS and Fuze Modeling: Assessment and Strategy

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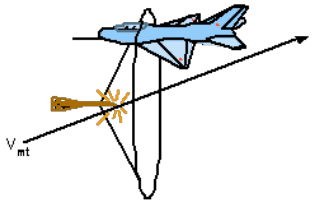
Objectives

- In an encounter between an aircraft and a missile, fuze function is one of the most important endgame elements in determining the probability of kill (Pk)
- In recent years, proximity fuze modeling and the required near-field RCS modeling do not appear to have received adequate attention
- This effort is investigating the state-of-the-art of proximity fuze modeling
  - Our goal is to help determine the need for resurrecting and improving this capability
  - We are actively seeking information on who's doing what with which kinds of models
  - We're interested in all kinds of fuzes:
    - RF
    - Active Optical
    - IR
    - Guidance Integrated



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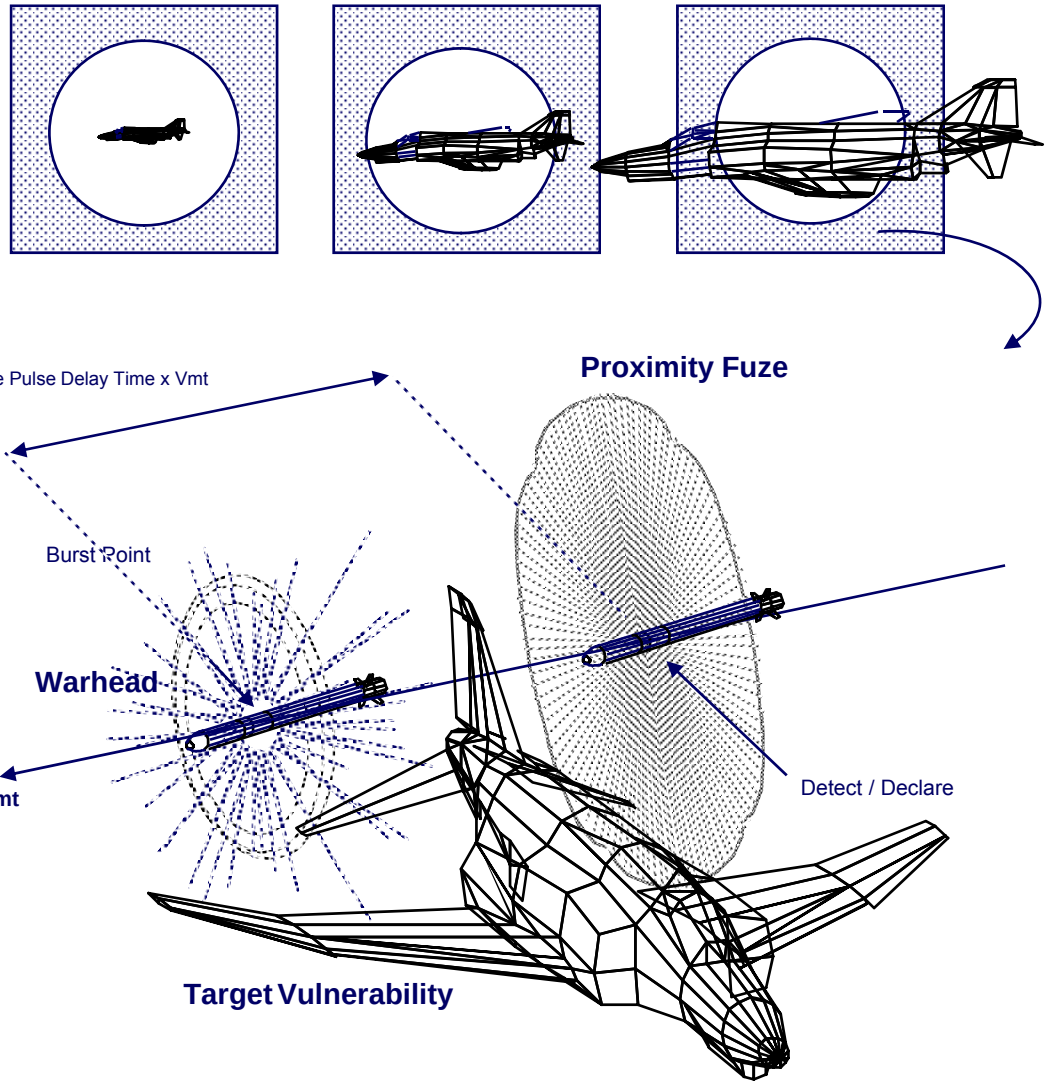
Applications

- **SYSTEM LETHALITY**
  - **U.S. Missile Systems**
- **SURVIVABILITY**
  - **Threat Missile Systems**



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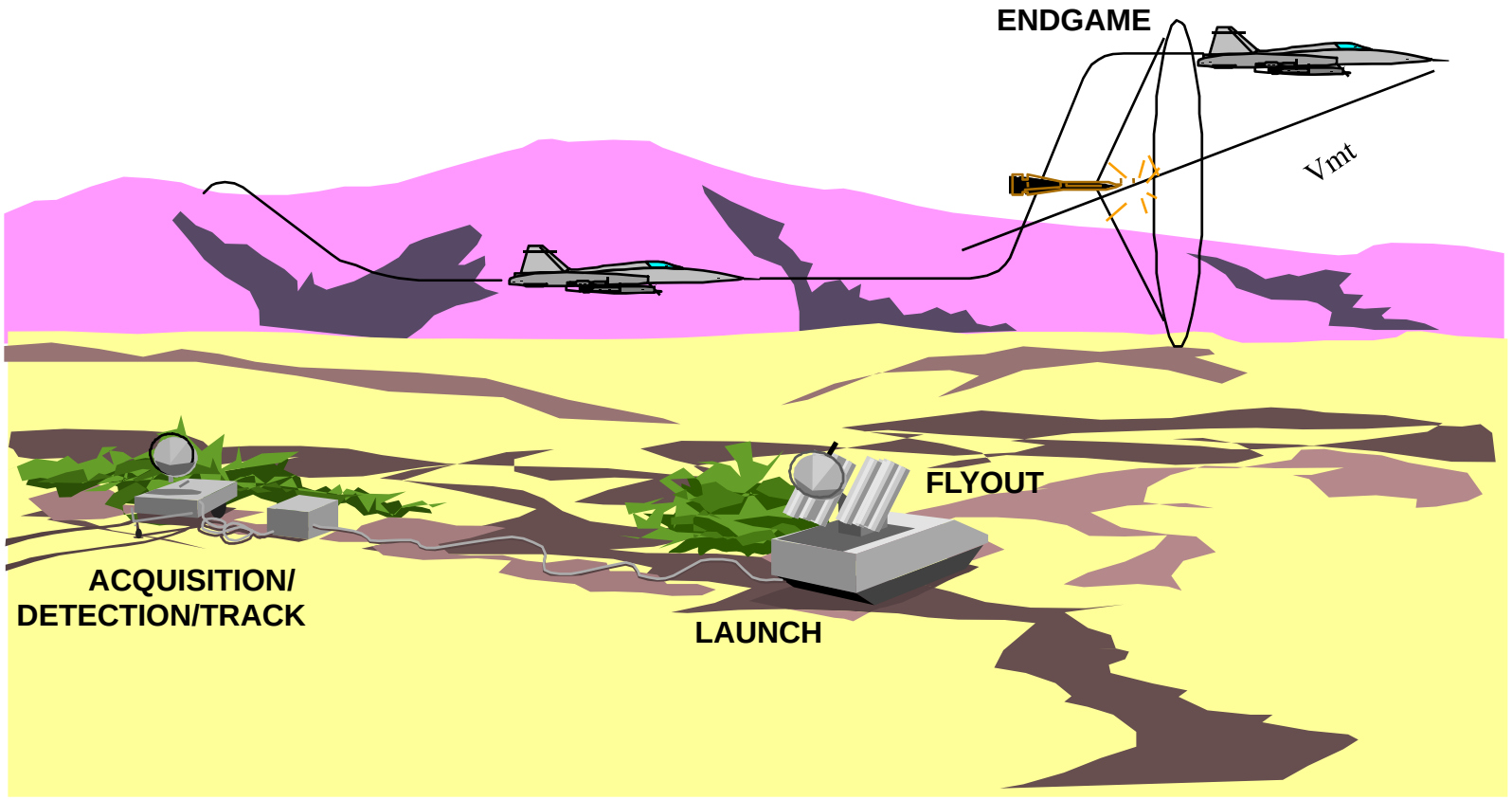
Typical Surface-to-Air Missile Engagement



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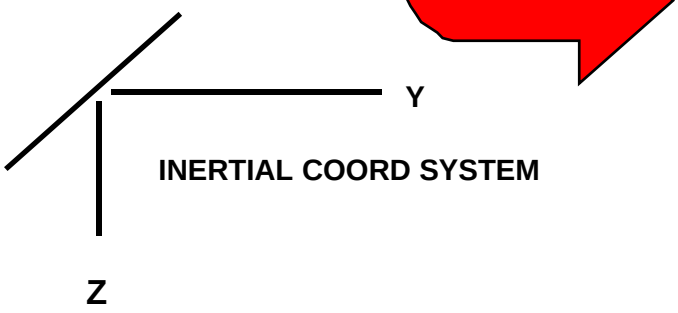
Endgame Models

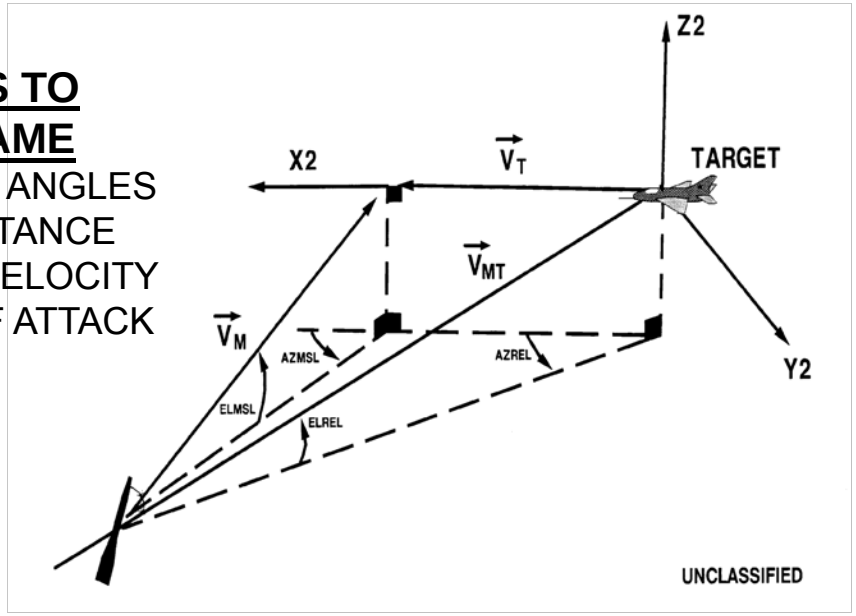
OUTPUT FROM FLYOUT

- MISSILE VEL COMPONENTS
- TARGET VEL COMPONENTS
- MISSILE POSITION
- TARGET POSITION
- ANGLES OF ATTACK



INPUTS TO ENDGAME

- APPROACH ANGLES
- MISS DISTANCE
- RELATIVE VELOCITY
- ANGLES OF ATTACK



- What happens after the last missile guidance time-constant before intercept
  - Everything is assumed to be a straight line
  - Acceleration is assumed to have little or no effect during endgame
- Calculate events along the relative missile-target velocity vector (Vmt)
  - Fuze Declaration Position
  - Warhead Burst Point
  - Impact with Target (if direct hit)

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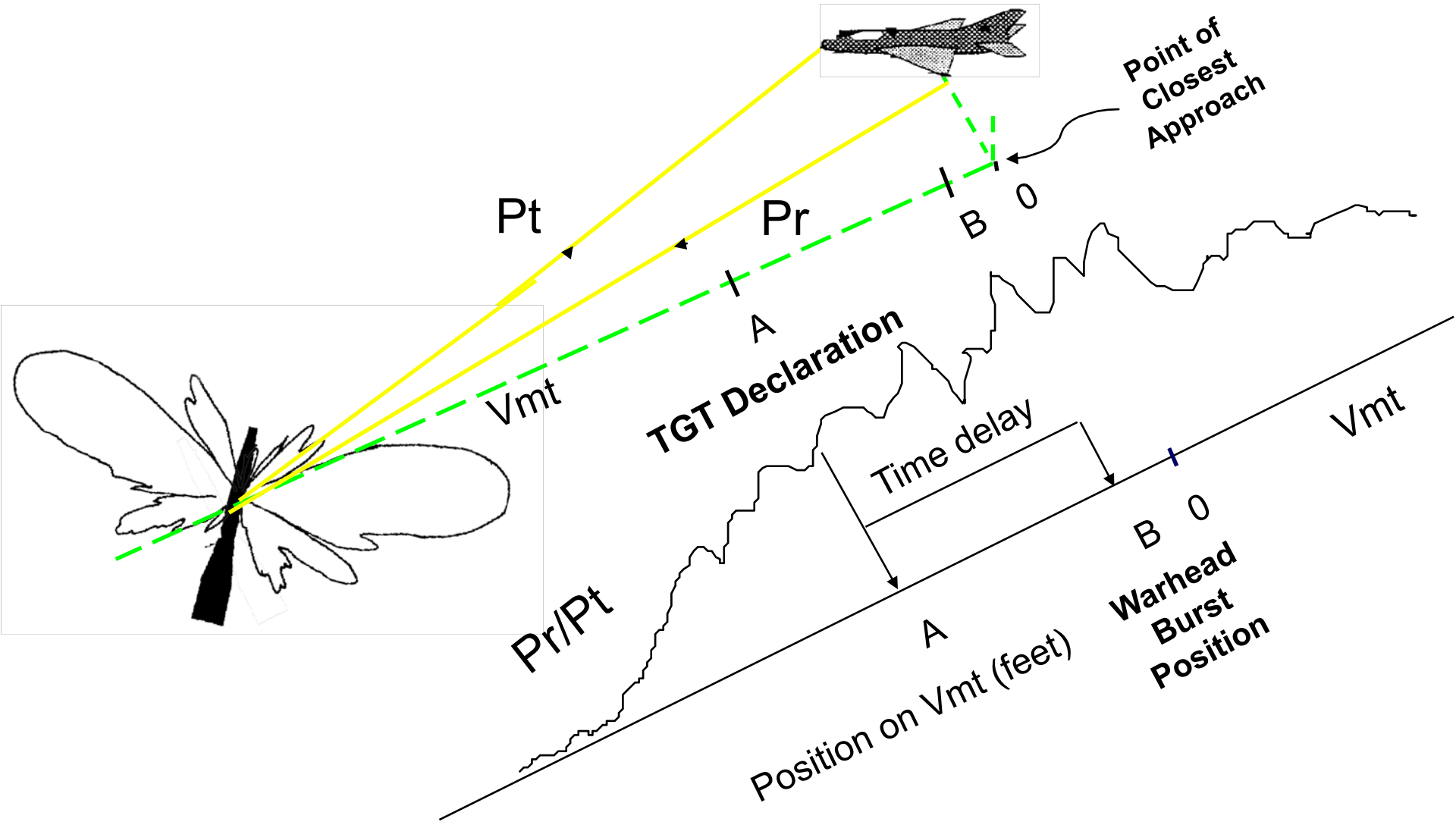
Fuze Determines Burst Point



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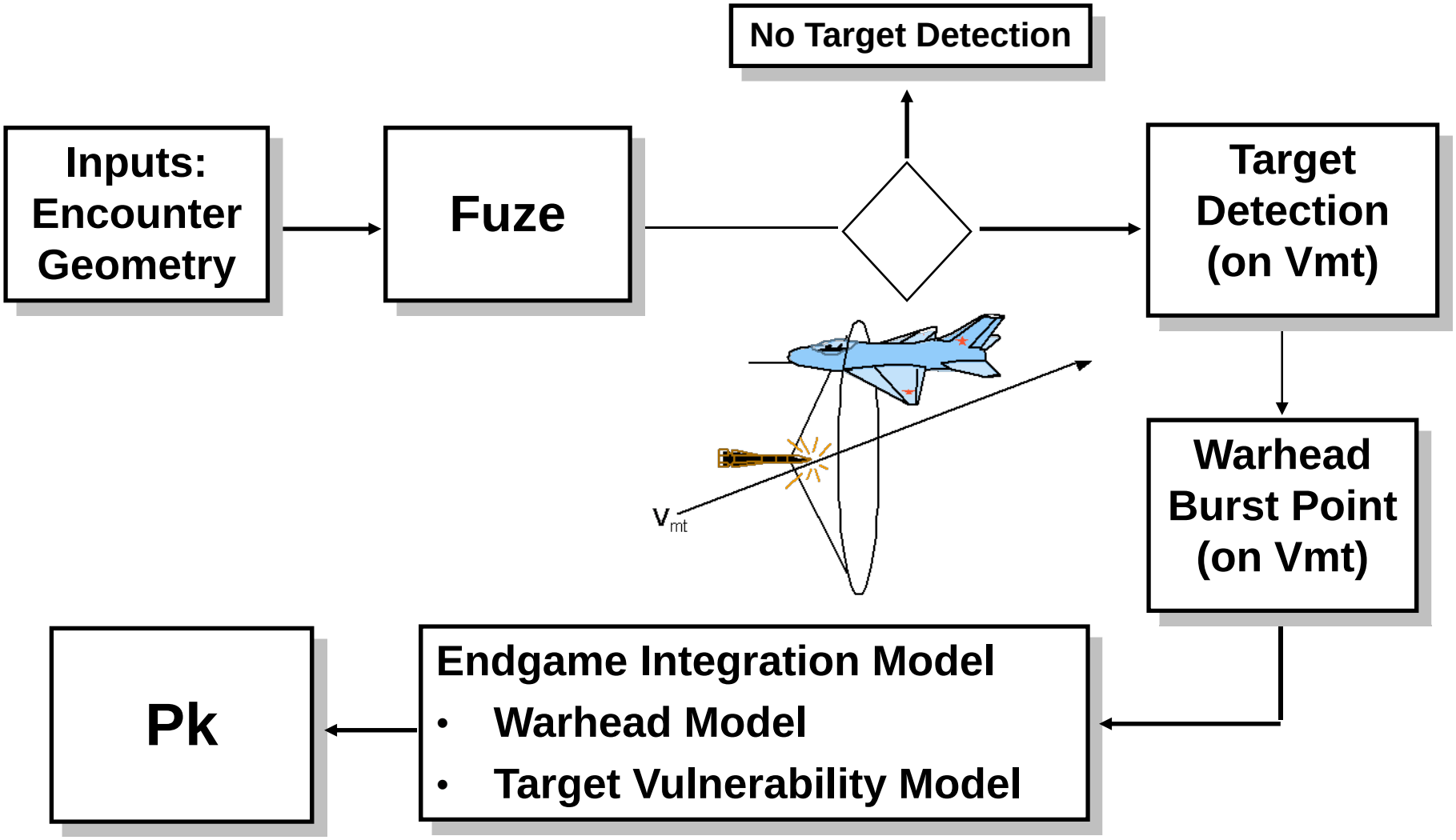
Fuze Model Within the Endgame



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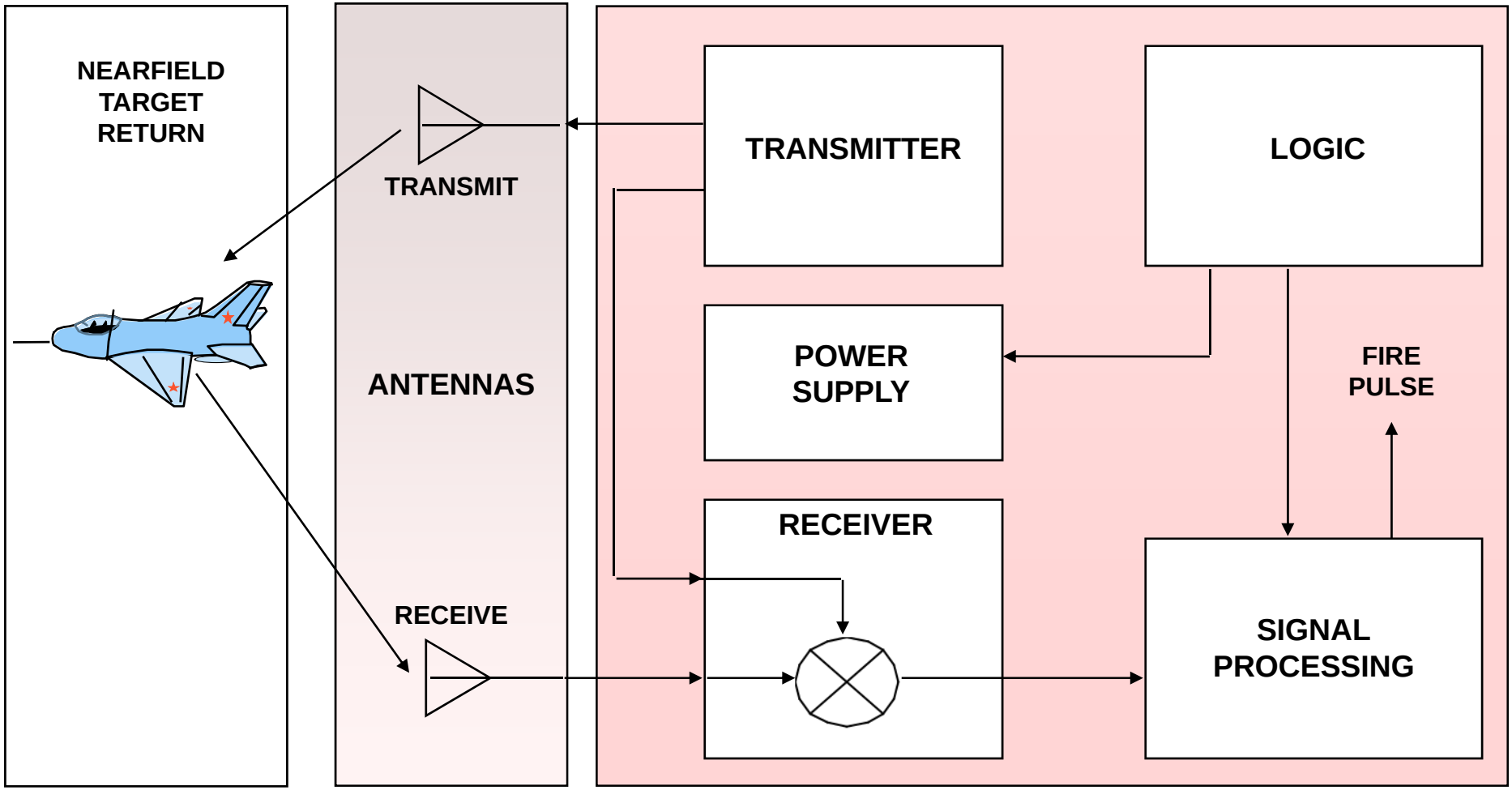
Fuze Model Elements



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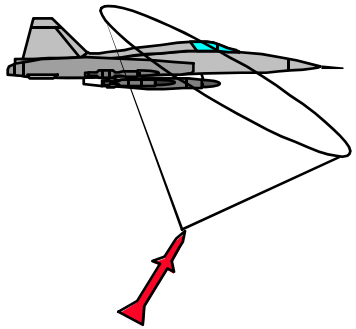
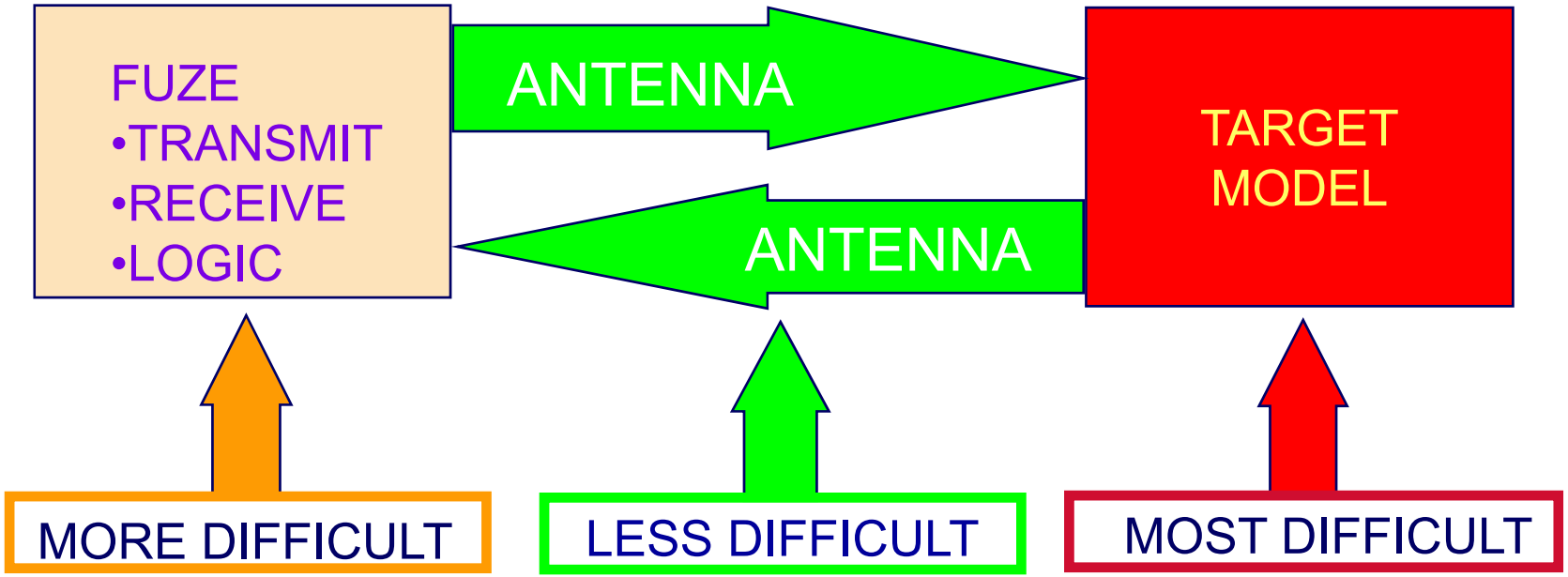
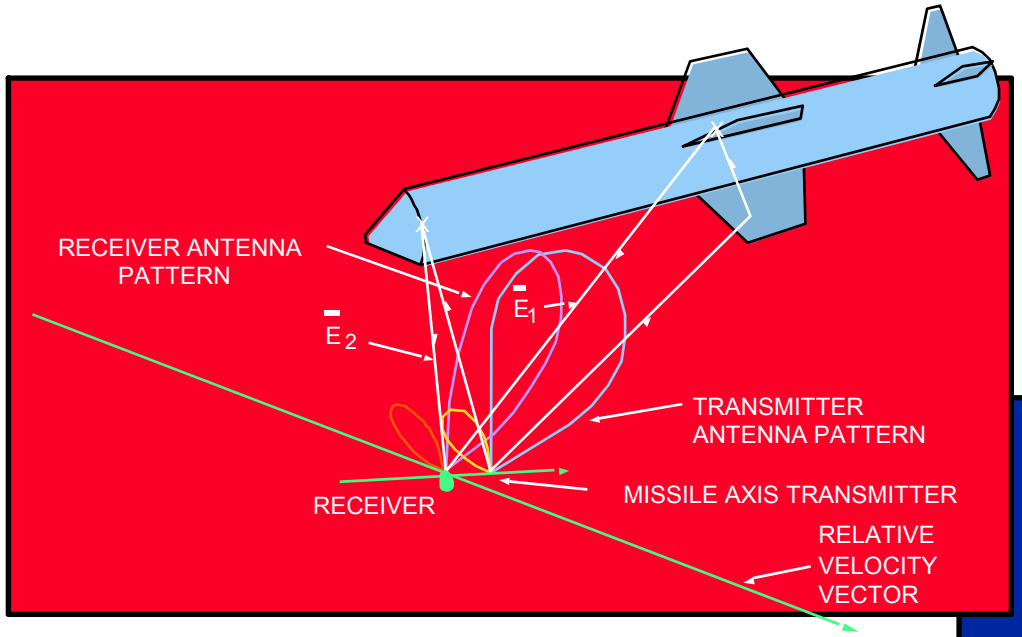
Modeling a Proximity Fuze

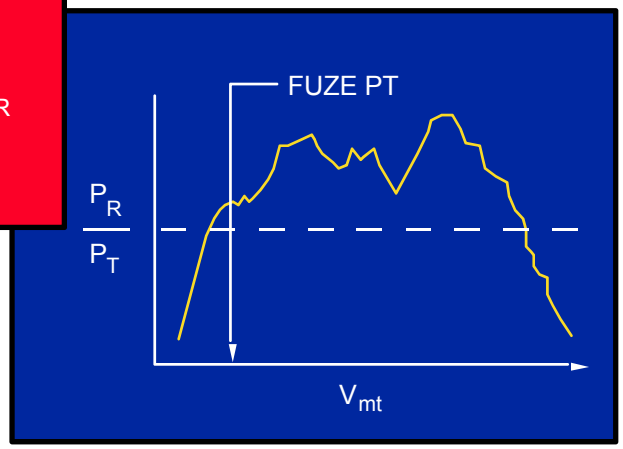




RELATIVE MODELING DIFFICULTY

Example Near Field Signature Methodology: Geometrical Theory of Diffraction (GTD)





TOTAL FIELD AT RECEIVER LOCATION $E_T = E_1 + E_2$

- CONVERTED TO P_R/P_T
- P_R/P_T COMPARED TO THRESHOLD LEVEL

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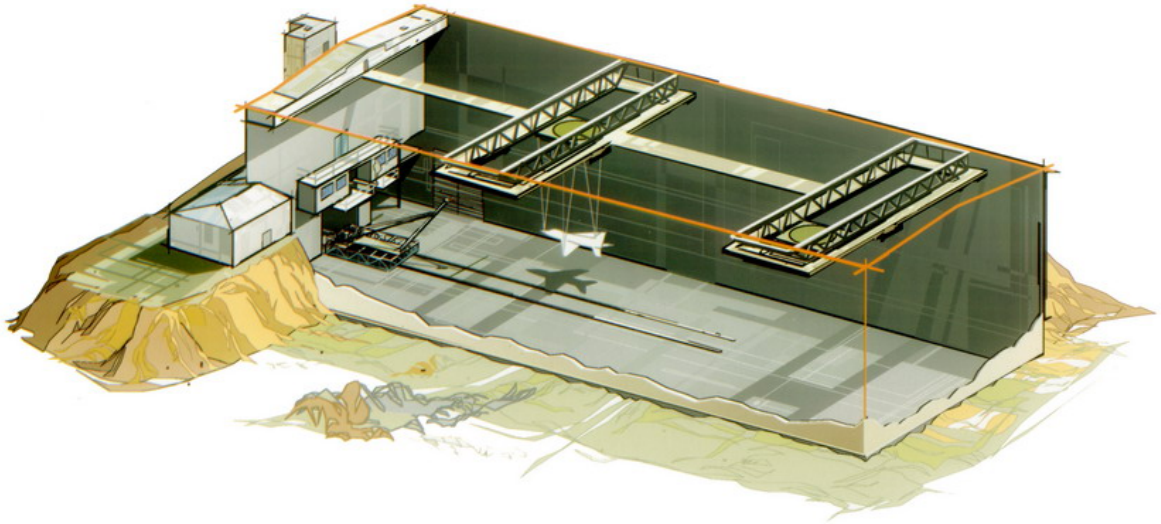
Missile Engagement Simulation Arena (MESA)

- Unique China Lake Facility for Evaluation of Missile Proximity Fuzes Against Full Scale Targets
- Effects of Near Field Signatures (Aircraft or Missile) on Threat Missile Fuze Performance



- Realistic Encounter Simulations Provide:
  - **Fuze Performance (Pd)**
  - **Warhead Burst Point**
  - **Countermeasures Effects**
  - **Overall Missile Performance**
  - **Effectiveness Analysis Support**
  - **M&S Validation Data**

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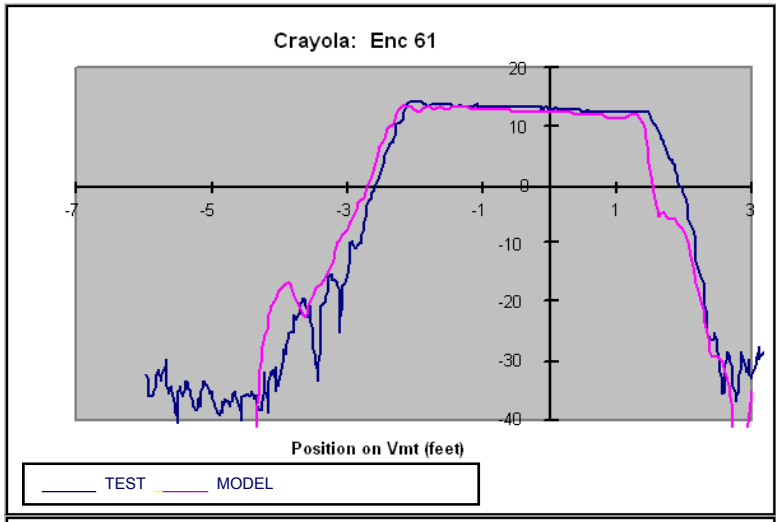
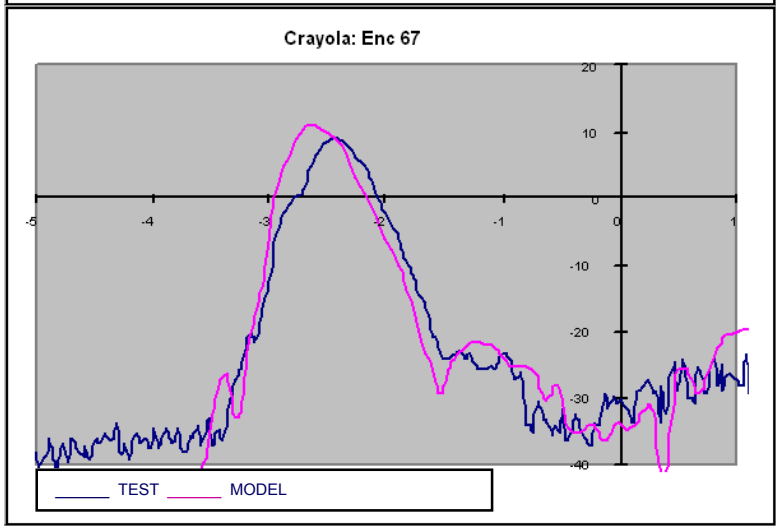
Example Measurements vs. GTD Model "Crayola" Target





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What Drives Pk the Most?
How Good Does the Fuze Model Need to Be?

- **Sensitivity Analysis Can Support the answers:**
  - **Determine Effect on Pk Caused by Errors in Inputs to the Endgame**
  - **Compare results to Pk accuracy requirements for specific applications**
  - **Example: Net Reduction in Lethality (NRL) for ECM**

$$NRL = 1 - \frac{Pk(wet)}{Pk(dry)}$$

Endgame Parameters Affecting Pk

- **Primary parameters**
  - **Intercept geometry parameters**
    - » **Miss distance, direction**
    - » **Vm, Vt**
    - » **Approach angles**
    - » **Angles of attack**
  - **Fuze declaration position [on Vmt]**
  - **Target Vulnerability**
- **Secondary parameters**
  - **Fuze parameters: detection thresholds, etc.**
  - **Warhead parameters: ejection angle, etc.**
  - **Fault trees: redundancies, etc.**

Example P(K) Sensitivity to Fuze Detection Position

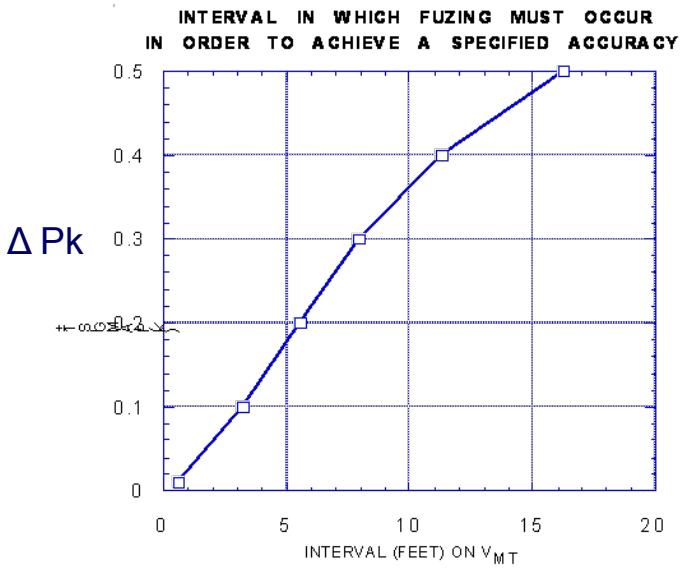

Figure I-3. Interval in Which Fuzing Must Occur To Achieve A specified P(K) Accuracy

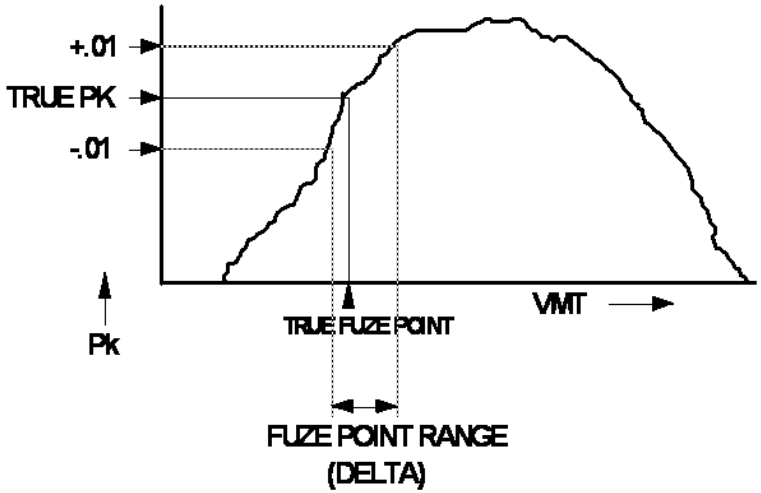

Figure I-2. P(K) Profile Along Vmt

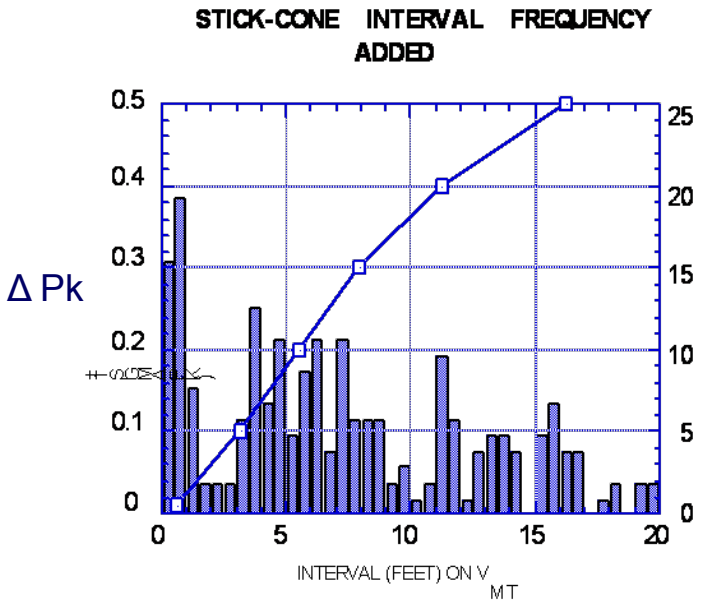

Figure I-3A. Interval in Which Fuzing Must Occur (on Vmt) To Achieve a Specified P(K/F) Accuracy

Sensitivity Analysis Results

Primary Drivers of Pk (in order):

1. **Fuzing (Burst Position)**
2. **Miss Distance**
3. **Az**
4. **El**
5. **Yaw**
6. **Pitch**

Relative importance depends on specific intercept conditions, type of missile and type of target

It Is Impossible to Know the Validity of Simulated Pk Without Knowing the Validity of the Fuze Model

- **Errors in fuzing prediction can change the predicted Pk from zero to one or vice versa**

Modeling Fuze Performance

- Models of proximity fuzes require simulation of near field signatures as well as fuze system (sensors, processing)
  - Some options include:
    - » Simple geometric model (stick-cone model)
    - » “Advanced Fuze Model” in models like ESAMS, SHAZAM
    - » Near field signature models (GTD, PTD)
- Risk Areas:
  - Some elements of threat fuzes not well understood
    - » Burst Control Logic
    - » Detection algorithms
  - Stick-cone model does not well represent threat fuze characteristics
  - Models like ESAMS advanced fuze model have little or no usage history nor any documented V&V
  - GTD, PTD signature models require development for use with fuze models

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Project Objectives

- ID current approaches to Proximity Fuze modeling
  - Government and Industry
  - Document the “State-of-the-Art”
- Determine/Examine needs for improvement
  - Methodology
  - Data
  - Verification and/or Validation
- Develop a strategy for improvement
  - Develop a plan for filling methodology, data & V&V gaps
  - ID potential funding sources

We are actively seeking information on the current status of fuze modeling in Government and Industry (and in other countries)
Please let us know if you have any information!