Gun Weapon System Safe Separation: A Standardized Approach

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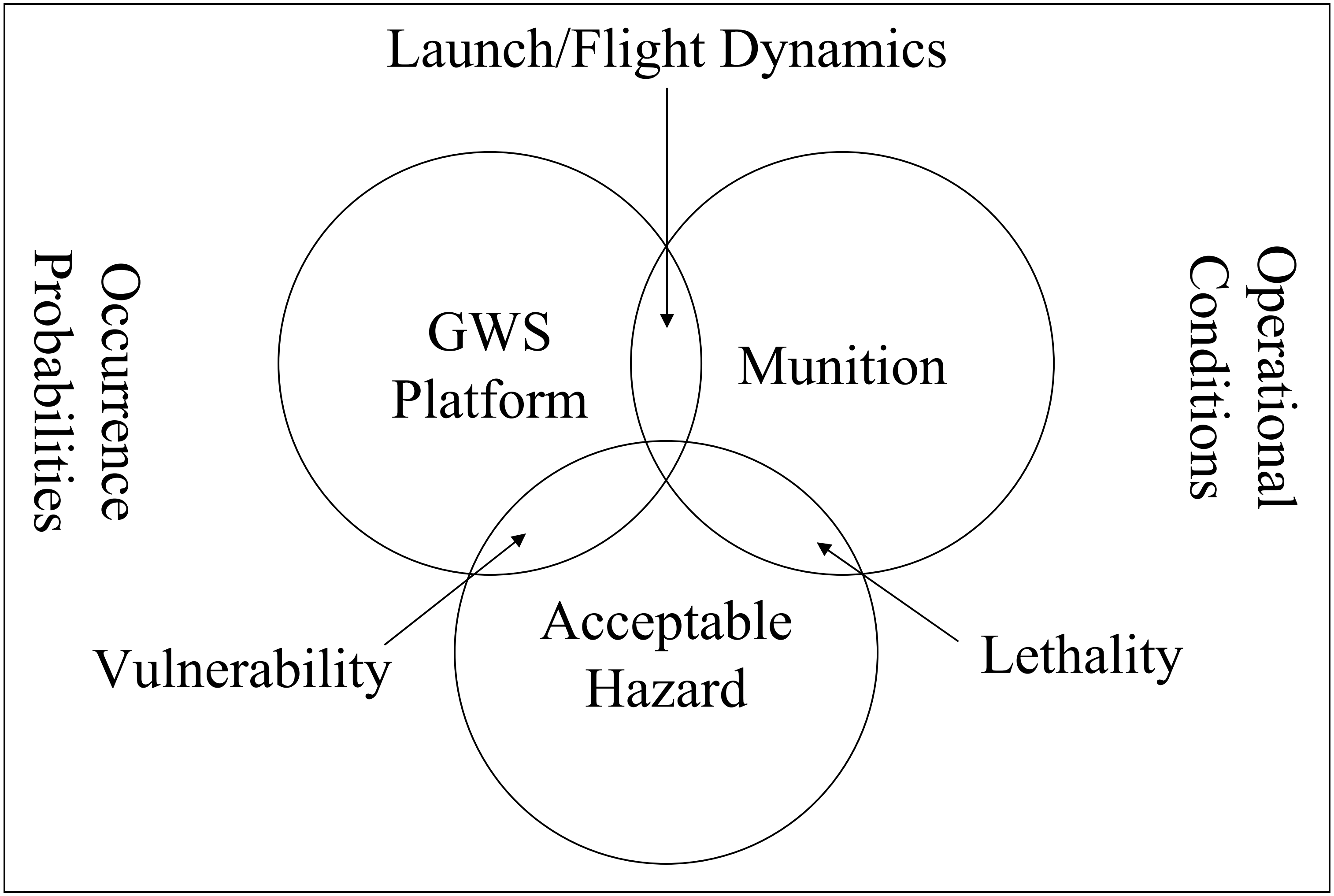
What is Safe Separation?

- MIL-STD-1316
  - Paragraph 3.29 - “The minimum distance between the delivery system (or launcher) and the launched munition beyond which the hazards to the delivery system and its personnel resulting from the functioning of the munition are acceptable.”
  - Paragraph 4.2.2 – “A safety feature of the fuze shall provide an arming delay which assures that a safe separation distance can be achieved for all defined operational conditions.”

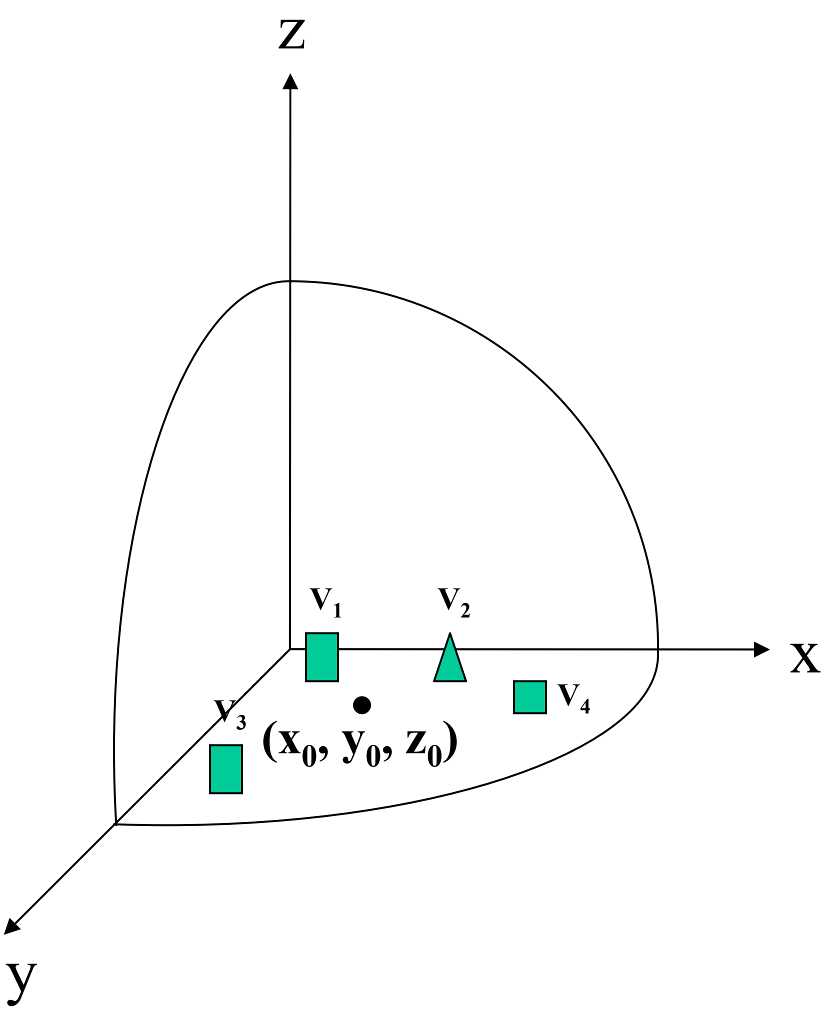
Safe Separation System



Standardized Approach

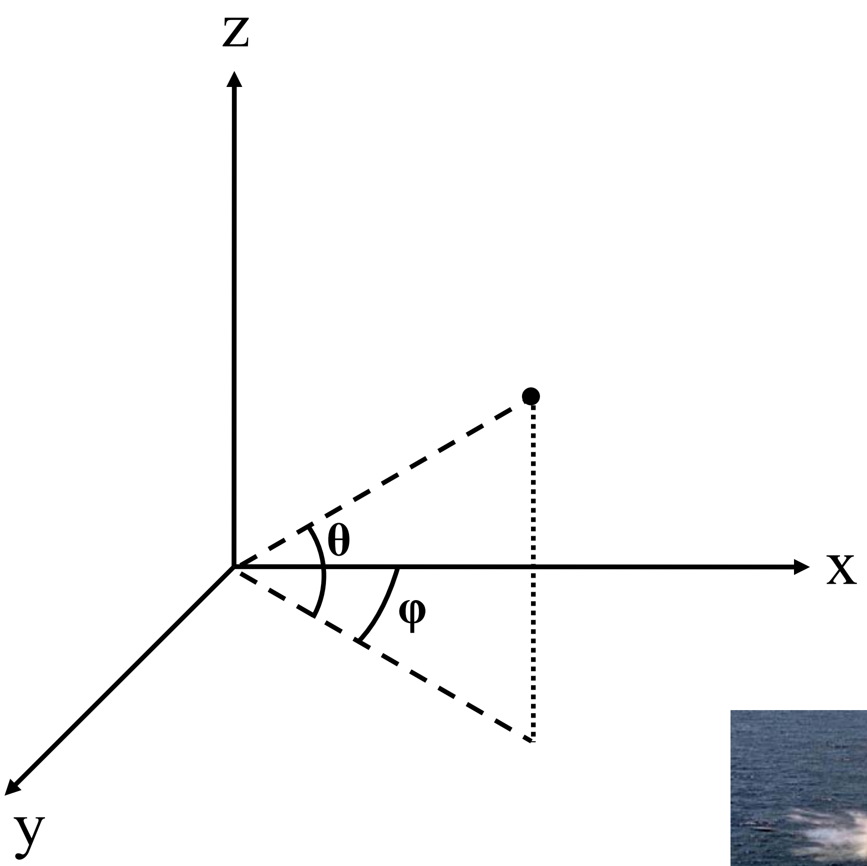
1. Decompose System
2. Determine System Interactions
3. Create Simulation Scenarios
4. Compute Probability & Level of Damage to System Components
5. Compute Total System Probability & Level of Damage
6. Apply Occurrence Probabilities
7. Assess Hazard Level

System Decomposition
GWS Platform



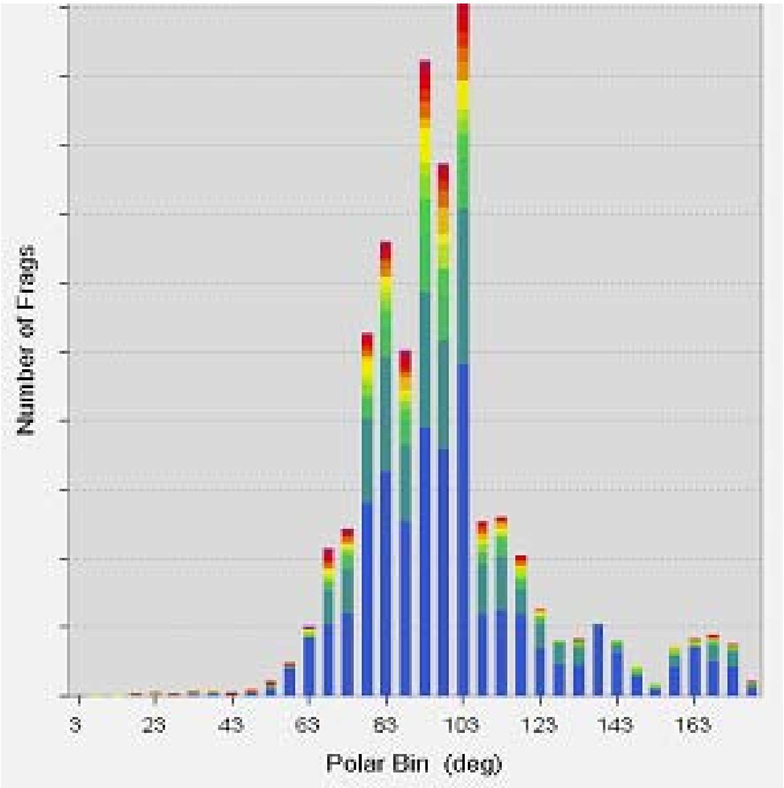
- Component Locations
  - Gun (x_0, y_0, z_0)
  - Additional Components (x_i, y_i, z_i)
    - Personnel
    - Radars
    - Vehicles
    - Stored Ammunition
- Occupied Volumes (V_i)

System Decomposition Launcher/Gun



- Firing Cutouts
  - Azimuth (φ)
  - Elevation (θ)

System Decomposition
Munition



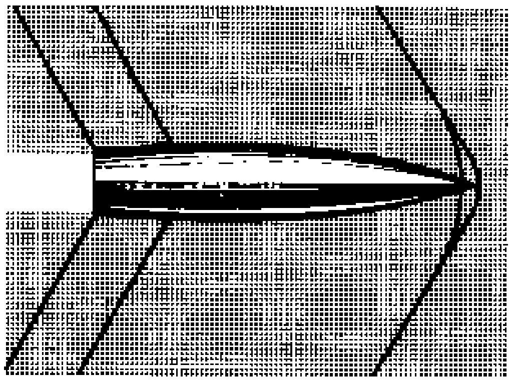
- Kill Mechanisms
  - Fragmentation
    - Polar Zone Data (Z-Data)
  - Blast
  - Incendiary
  - Reactive Materials

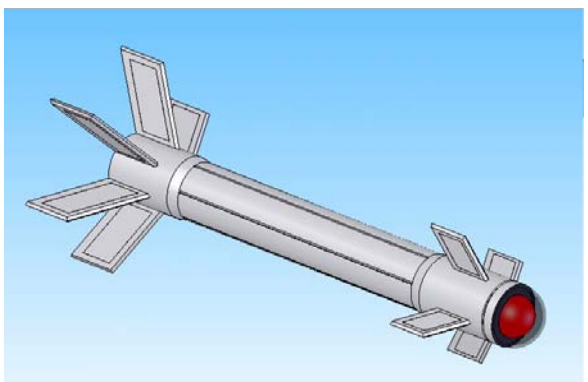
System Decomposition Acceptable Hazard

- MIL-STD-882
  - What level of hazard is acceptable?

	Severity of Occurrence			
Frequency of Occurrence (over the life of an item)	CATASTROPHIC (I)	CRITICAL (II)	MARGINAL (III)	NEGLIGIBLE (IV)
FREQUENT (A) $P > 10^{-1}$	I-A	II-A	III-A	IV-A
PROBABLE (B) $10^{-1} > P > 10^{-2}$	I-B	II-B	III-B	IV-B
OCCASIONAL (C) $10^{-2} > P > 10^{-3}$	I-C	II-C	III-C	IV-C
REMOTE (D) $10^{-3} > P > 10^{-6}$	I-D	II-D	III-D	IV-D
IMPROBABLE (E) $10^{-6} > P$	I-E	II-E	III-E	IV-E

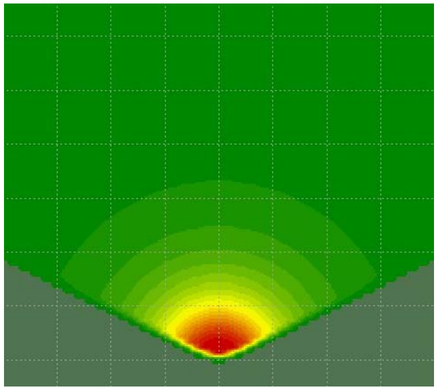
System Interactions
Launch/Flight Dynamics





- Initial Velocity (IV)
  - Propelling Charge Zones
- Thrust
  - Rocket Motor
- Guidance & Control
- Aerodynamics
  - Drag
  - Spin Rate
- Terminal Conditions at Burst

System Interactions
Lethality & Vulnerability



- Component Vulnerability
  - Presented Areas
  - Penetration Equations
    - V_{50}
- Personnel Vulnerability
  - Uniform Penetration Velocity Limits
  - Posture
    - Standing, Prone, Protected
- Munition Lethal Area
  - Target specific

Occurrence Probabilities

- Fuzing
  - Reliability (%)
  - Early Burst Rate (%)
- Munition Availability
  - Magazine Loadouts
- Operational Considerations
  - Tactics
  - Usage Rates

Occurrence probabilities should be stable and are not anticipated to change over time with new tactics, employment, or operational environment.

Creating Simulation Scenarios

1. Partition Firing Cutouts (N_E x N_A)
2. Partition Charge Zones & Initial Velocities (N_Z x $N_{V/Z}$)
3. Partition Guidance & Control Space (N_G)
4. Thrust On vs. Thrust Off (x N_T)
5. Partition slant ranges from gun to munition burst (N_{SR})

$$N = N_E \times N_A \times N_Z \times N_{V/Z} \times N_G \times N_T \times N_{SR}$$

Effective partitioning of the study space is key!!!

Computing Component & Total System Damage

For each Simulation Scenario:

1. Simulate munition detonation and effects against system components to determine probability of damage and level of damage
2. Statistically combine probabilities and damage levels to compute effect to total system

Recommendation:

Using JTCG/ME accredited models and methodologies add validity and credibility to results.

Apply Occurrence Probabilities & Assess Hazard Level

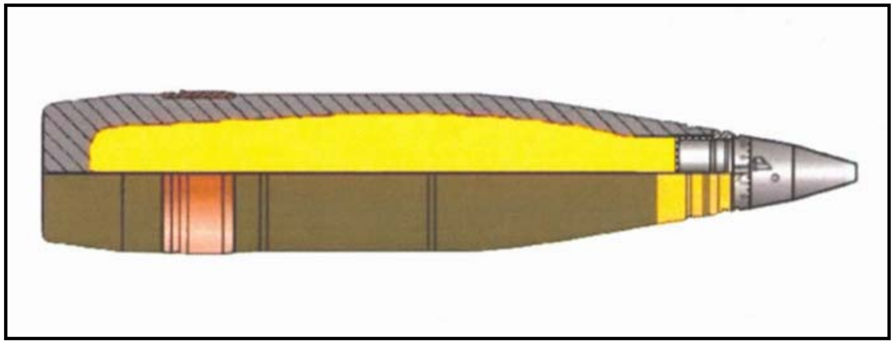
For each Simulation Scenario:

1. Multiply damage probabilities by the occurrence probability to determine final Frequency of Occurrence level
2. Determine Hazard Level (MIL-STD-882)

Safe Separation distance is Slant Range at which all Hazards at that range and beyond are acceptable.

Safe Separation Example

- Platform = US Navy CG-47 Class Cruiser
- Munition = 5” High-Explosive Projectile
  - MK 64 Projectile Body
- Fuze = Generic NATO Artillery Fuze
- Propelling Charges (2)
  - MK 67 Mod 3 – Standard Propelling Charge
  - MK 68 Mod 2 – Reduced Propelling Charge



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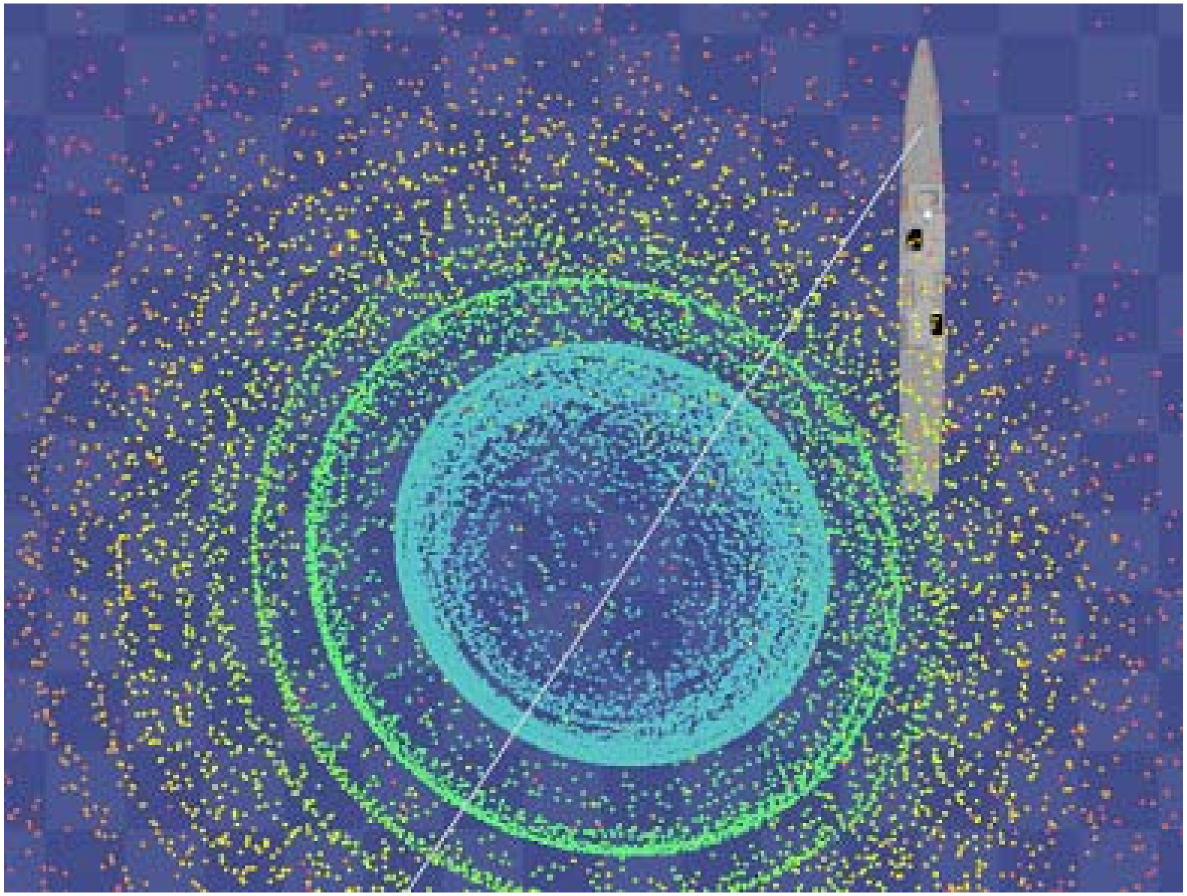
Safe Separation Example

- Three Areas of Highest Hazard
  - High Gun Elevation
    - Exposes ship to “fragment rain” from above
  - High Gun Azimuth (as measured from bow or stern)
    - Exposes more vulnerable area to burst
    - Combined with low gun elevation = direct fragment spray to side of ship
  - Low Initial Velocity (Reduced Propelling Charge)
    - Fragments angled back more towards ship
    - Longer time of flight (TOF) to reach Safe Separation Distance

Safe Separation Example

“Fragment Rain”

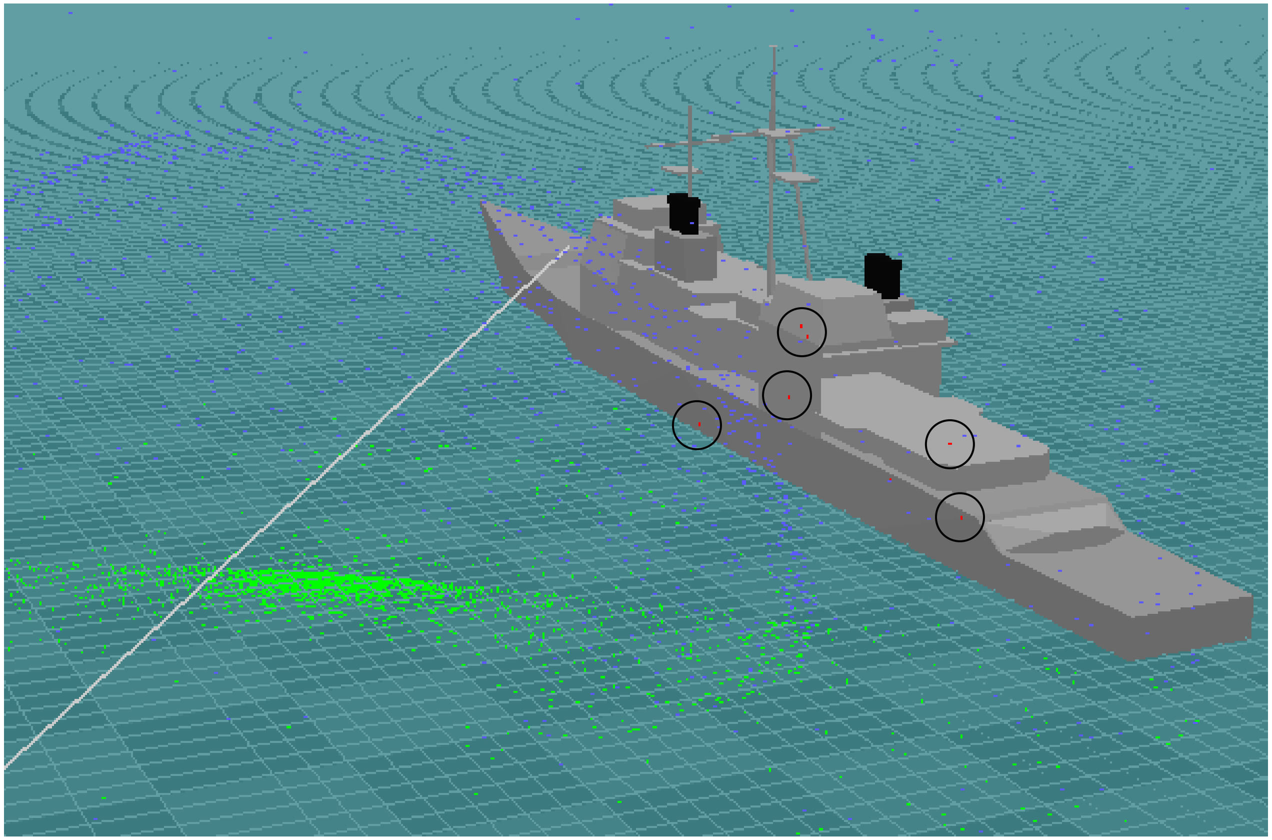
(High Elevation, High Azimuth)



Safe Separation Example

“Direct Spray”

(High Azimuth, Low Elevation)



Conclusions

- Standardized approach gives system view of Safe Separation Problem
  - Provides complete picture of hazard
- Effective partition size is key
  - Too Small = Unmanageable Computation Time
  - Too Large = Missing Critical Hazard Scenarios
- Always use stable Occurrence Probabilities