

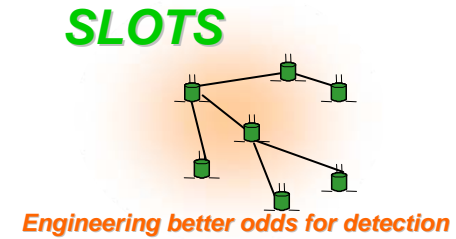
Sensor Location & Optimization Tool Set

**Chemical Biological Information Systems Conference
Albuquerque, NM**

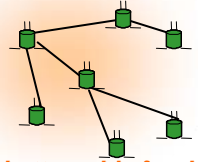
October 2005

Michael J. Smith
ITT Industries
Advanced Engineering & Sciences

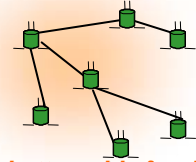
Outline



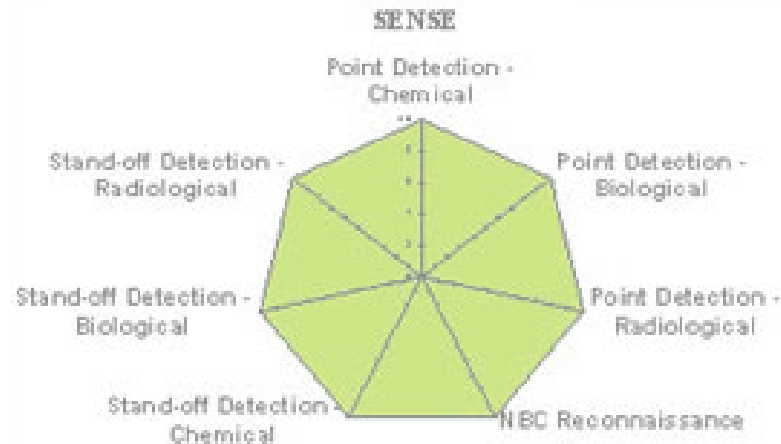
- Sensor Placement
- Modeling & Simulation
- Optimization
- Years One Demonstration
- Summary



Sensor Placement



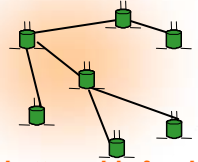
- **SENSE** – The capability to continually provide the information about the CBRN situation at a time and place by detecting, identifying, and quantifying CBRN hazards in air, water, on land, on personnel, equipment or facilities. This capability includes detecting, identifying, and quantifying those CBRN hazards in all physical states (solid, liquid, gas).



Where is the optimal location for sensors in support of the mission?

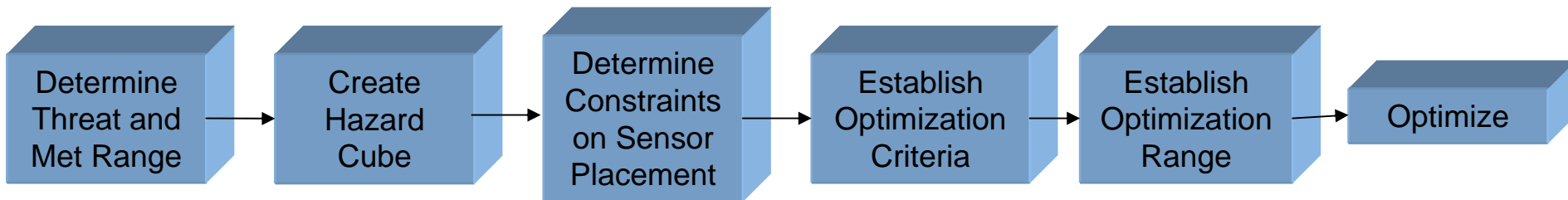
SLOTS Program Definition:

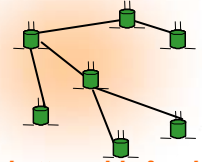
SLOTS



Engineering better odds for detection

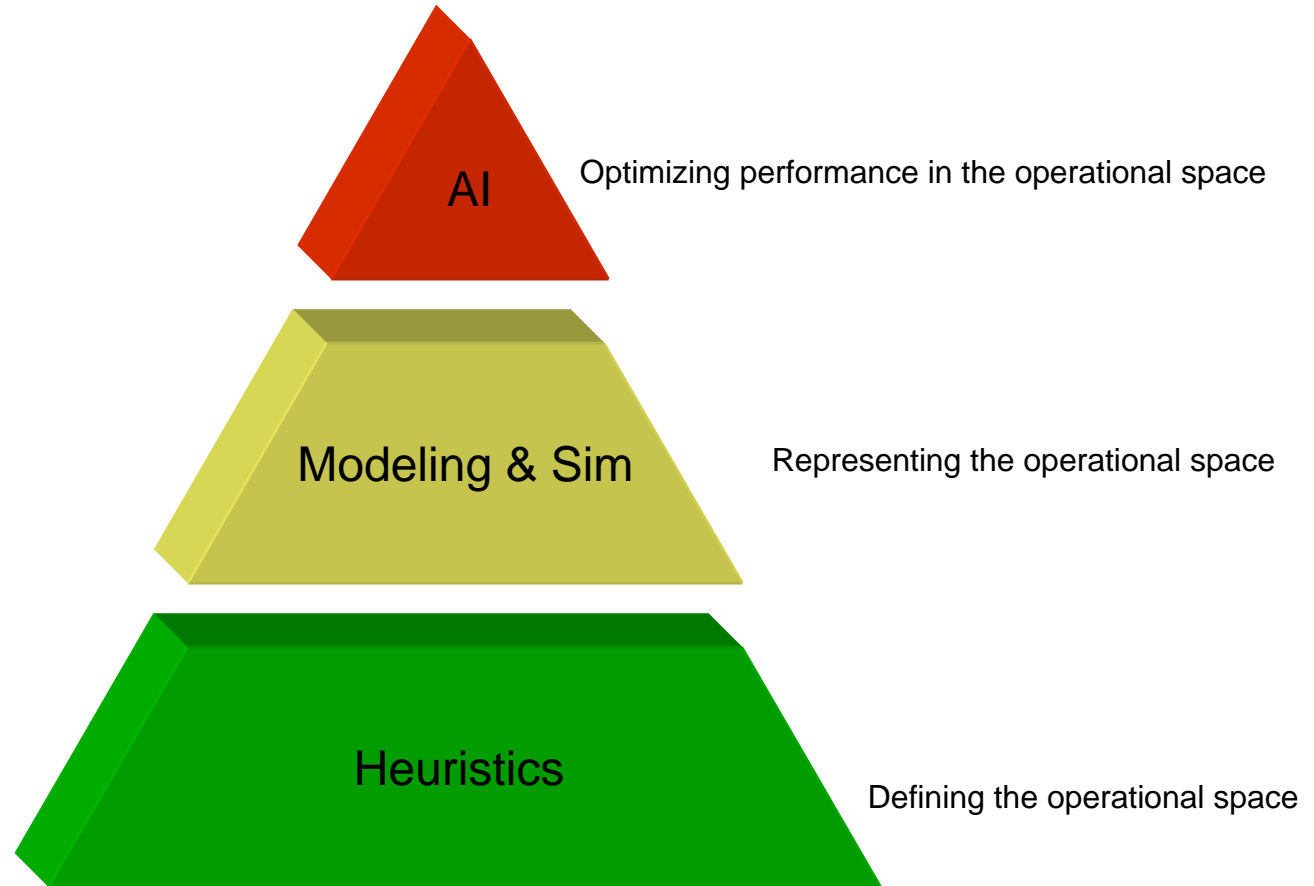
Automate the analytical process and ***optimize*** the location of sensors to detect, identify, and quantify the CBRN hazard in support of the commander's intent.

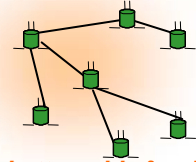




SLOTS Approach:

1. To establish a set of rules governing the emplacement of sensors.
2. Utilize information technologies to automate the sensor placement decision process.
3. Leverage artificial intelligence to optimize the ultimate sensor configuration.





What are the "to detect" requirements?

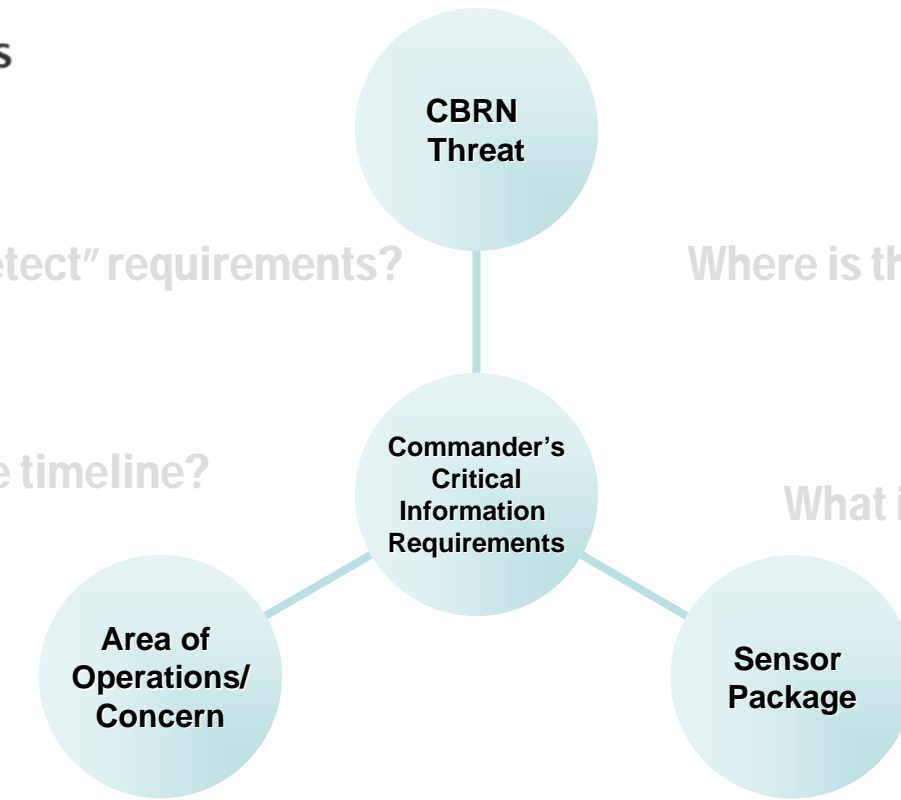
Where is the operating space?

What is the timeline?

What is the range of threats?

What is the supported mission?

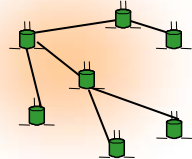
What are the sensors?



- Heuristics**
- 11.1.1 Chemical and Biological Contamination Avoidance
 - 11.1.2 Field Behavior of NBC Agents (Including Smoke and Inc)
 - 11.1.3 NBC Field Handbook
 - 11.1.4 Potential Military CB Agents and Compounds
 - 11.2.1 Multiservice Tactics, Techniques and Procedures for NBC Operations
 - 11.4 Multiservice Tactics, Techniques, and Procedures for NBC Detection
 - 11.21 Multiservice TTP for NBC Aspects of Consequence Management
 - 13-101 Chemical Staff and Units
 - 13-101-2 NBC Reconnaissance Squad/Platoon Operations TTP
 - 13-101-4 Biological Detection Platoon Operations TTP
 - 13-101-6 Biological Defense Company and Corp Staff
 - Joint Pub 3-11 Joint Doctrine for NBC Defense Operations

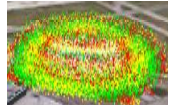
Multi-faceted Dependencies Increase Complexity

SLOTS

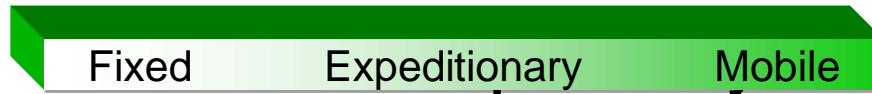


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CBRN Threat



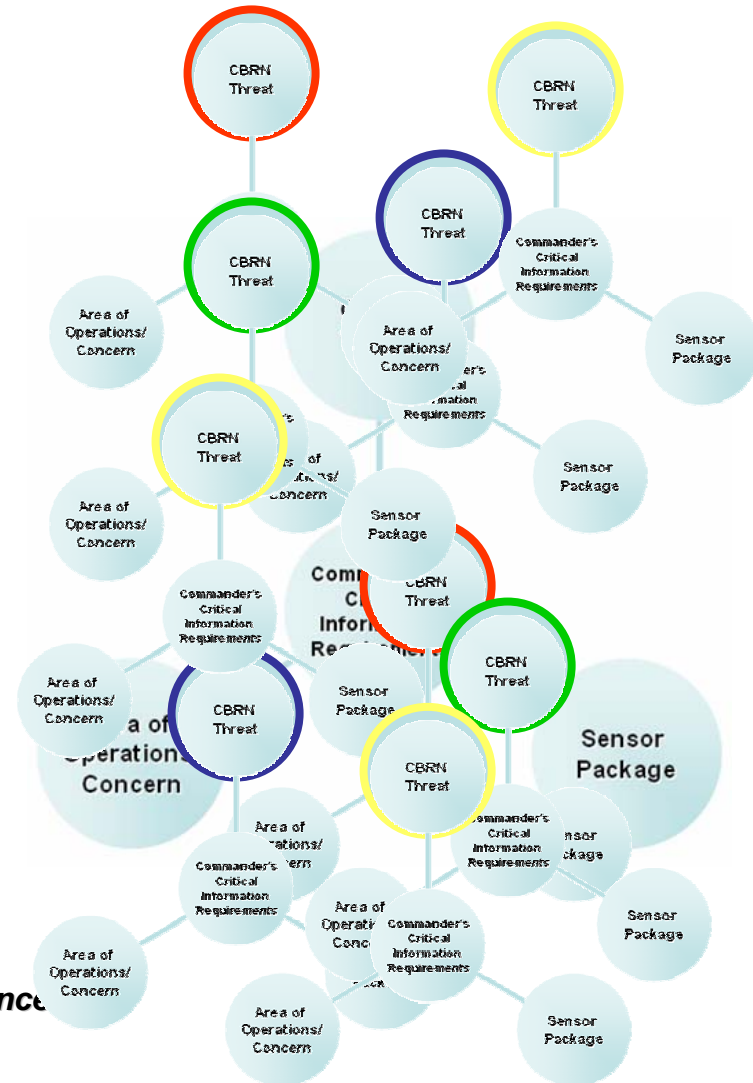
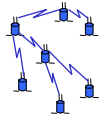
Area of Responsibility

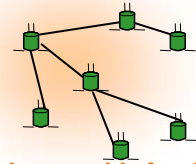


CCIRs

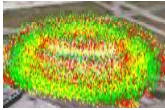


Sensor Network





Defining CBRN Threat

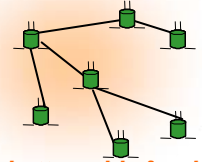


Type A (case 1 & 2)

Type B (Cases 1-6)

Define the CBRN threat – “*Template potential chemical targets or areas of contamination.*” – The enemy order of battle to include agents, weapon systems (warheads and delivery mechanisms), and concepts of employment in the offensive and defensive. Underlying this assessment is an understanding of the field behavior of CBRN agents. This process must reflect time periods of interest, enemy courses of action and named areas of interest.

- Detailed information on enemy CBRN agents capabilities based on the type of units and weapons the enemy has available in the area of operations/area of influence (AO/AI) during a selected time period.
- Detailed information on CBRN weapon systems
- How the enemy would employ chemical, biological, flame, or smoke to support his battle plan.
- Understanding of fill rates associated with the weapons and agents
- Areas of likely employment based on threat employment doctrine.
- Detailed analysis of terrain and weather in the unit's AO during each period of interest and how they could impact on CB, flame, and smoke warfare.
- MOPP guidance for each period of interest (such as, minimum MOPP, automatic masking).

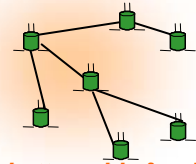


Area of Responsibility



Define the named area of responsibility/influence – “Designate templated areas that affect the scheme of maneuver as named areas of interest.” – After threat source, terrain and weather most directly impact the extent and duration of the hazard. Detailed analysis of named areas of interest and target areas of interest during periods of concern will shed light on the impact of a CBRN release. Information regarding the NAI, TAI, periods of interest is derivative of the overall battlefield assessment process.

- What is the appropriate operational focus for SLOTS?
- What are the size, typical terrain features, and layout of the selected area?
- What are the most probable threats based on the adversary capability and doctrine? What are the name areas of interest, the target areas of interest in the AOR?
- What is the Force Protection Level Assets?
- What is the impact of the threat on the NAI and FPLs to the commanders scheme of maneuver?
- What is the composition of the units conducting the operational mission and their MTOE?
- Who is the user of SLOTS in these units?
- What is the planning time frame?
- What is the availability of terrain and weather data for the AOR in the given planning time frame?



Commander's Critical Information Requirements

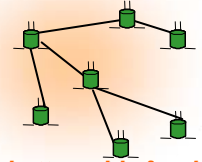


Detect to Warn

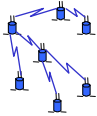
Detect to treat

“A [CBRN] vulnerability assessment ... is the primary means through which the chemical staff advisor participates in the battlefield assessment process.” – The battlefield assessment process is designed to satisfy the commander's intent and reflect the designation of main effort. Information regarding NAIs and TAIs and their constituent critical elements such as C2 facilities, mobility corridors, troop concentrations, and assemble areas will suggest the detection objectives of the sensor arrays. Different detector types and configuration support various detection missions from detect to warn to detect to treat and will be dependent on the METT-TC.

- What are the NAIs and TAIs associated with a mission?
- What is the time period of interest?
- What are the avoidance/protection/recovery objectives for NAI/TAIs?
- What metric supports detect to warning?
- What metric supports detect for treatment?
- What metric supports detect for surface contamination?
- What metric supports detect for unmasking?



Sensor Network



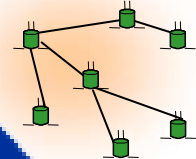
Point

Standoff

A number of sensor technologies are employed to detect CBRN threats. Sensor technology is specific to a class of agent(s) (nerve, blood, blister, choking, TIM), its physical properties (solid, gas, liquid) and its size or concentration. These technologies can be grouped into five major categories: **point**, **stand-off**, analytical, sorbent, and colormetric detectors.

- Chemical / Biological Agents Detected
- TIMs Detected
- Sensitivity
- Resistance to Interferents
- Response Time
- Start-Up Time
- Detection States
- Alarm Capability
- Portability
- Battery Needs
- Power Capabilities
- Environment
- Durability
- Unit Cost
- Operator Skills
- Training

SLOTS



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Sensor Placement Dependencies

Mission = Objective (survey, monitor, recon)

Enemy = CB threat

Time = Timelines & met conditions

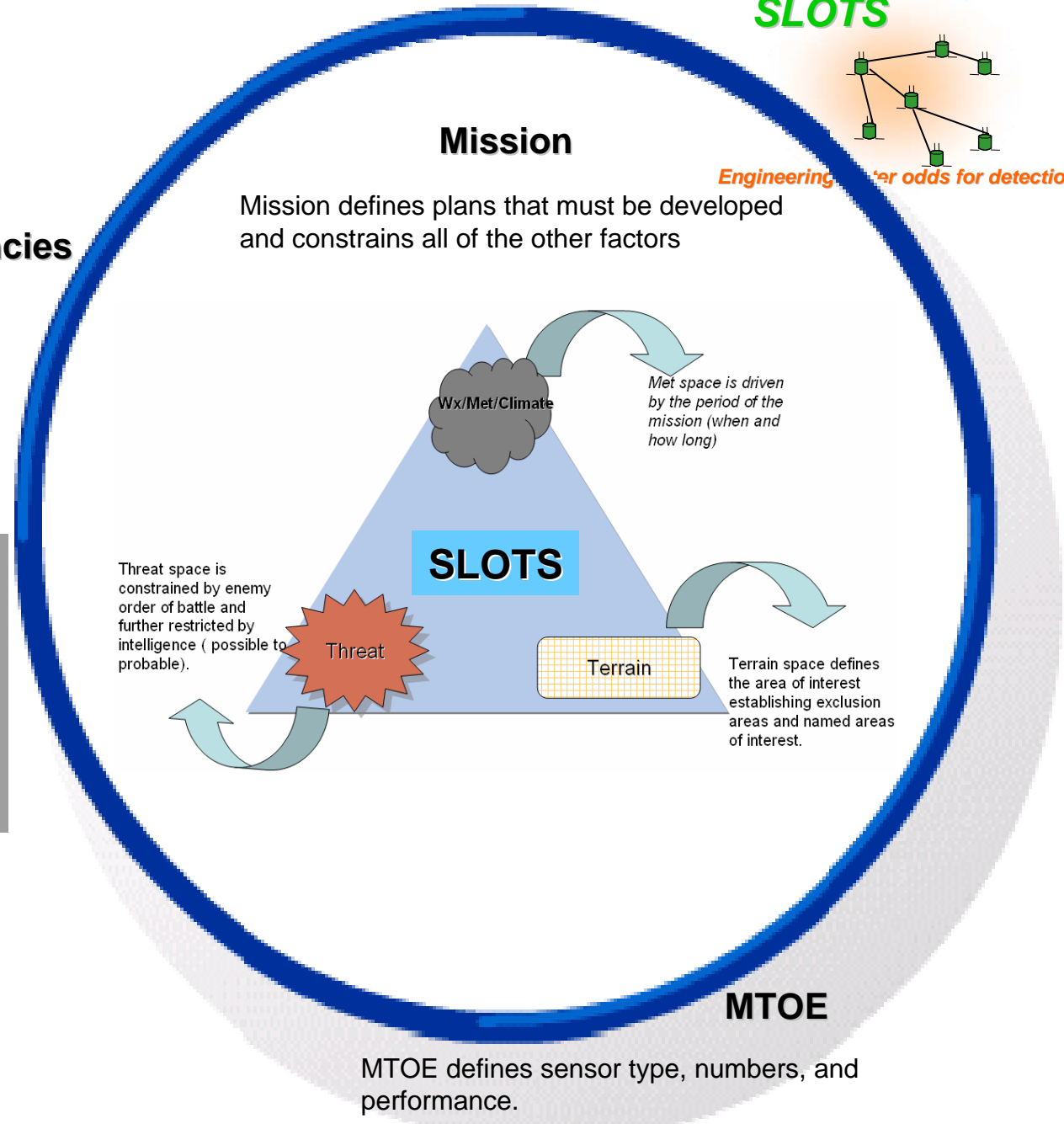
Terrain = Area of operations

Troops = MTOE

C = Civilians

Mission

Mission defines plans that must be developed and constrains all of the other factors



Met space is driven by the period of the mission (when and how long)

Threat space is constrained by enemy order of battle and further restricted by intelligence (possible to probable).

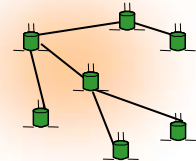
Terrain space defines the area of interest establishing exclusion areas and named areas of interest.

MTOE

MTOE defines sensor type, numbers, and performance.

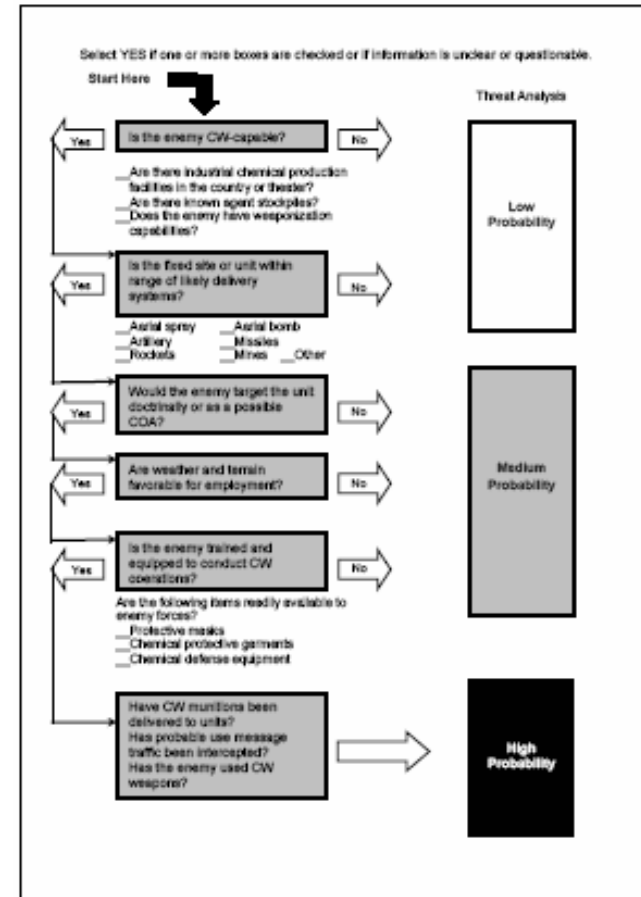
Chemical Biological Radiological and Nuclear Vulnerability Assessment Process

SLOTS



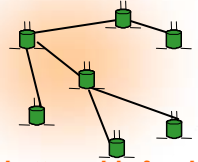
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1. Define the Battlespace Environment.
 - Where might the enemy use NBC weapons?
 - What are capabilities/limitations NBC weapons?
 - Where are the densely populated areas?
 - Does area have TIM storage/production/capabilities?
 - What Intel/surveillance/recon (ISR) is available?
 - ID Limits of Command AO and Battlespace.
 - Establish Area of Interest (AOI) Limits.
2. The Describe the Battlespace Effects.
3. Evaluate the Threat.
4. Determine the Threat COAs.

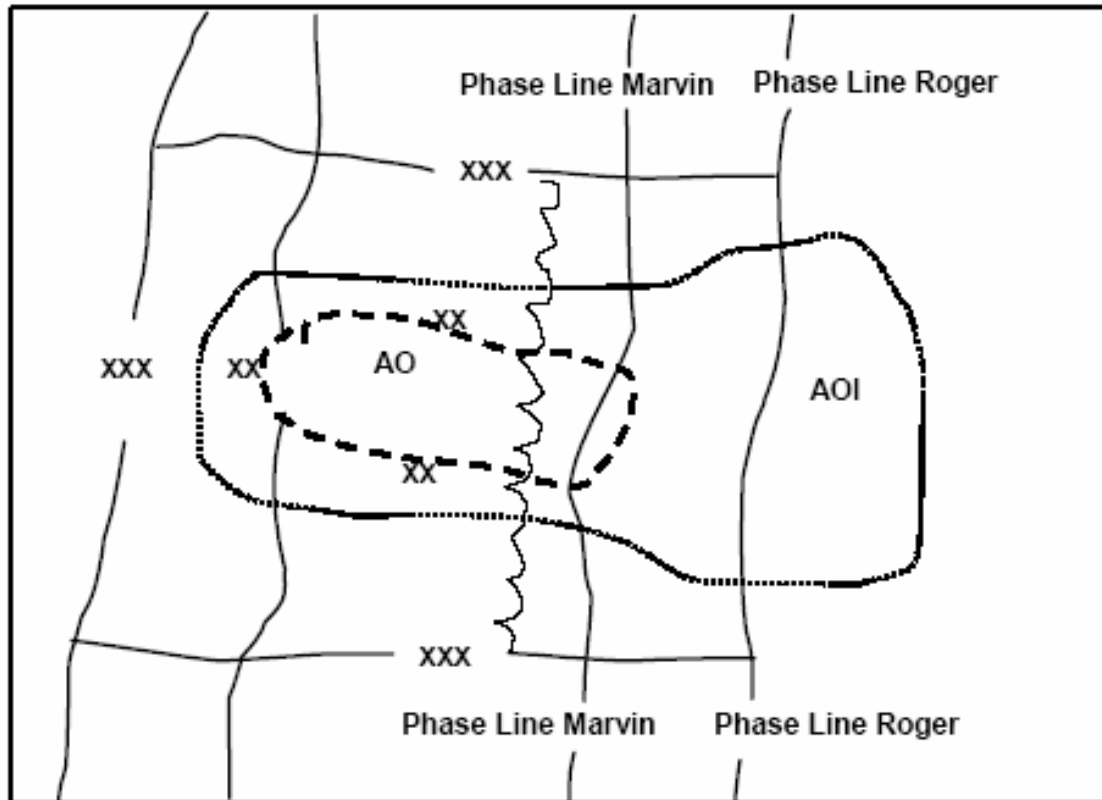


Battlespace

SLOTS

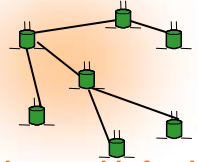


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IPB Results

SLOTS



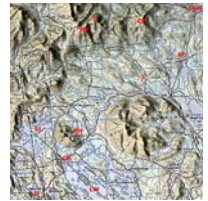
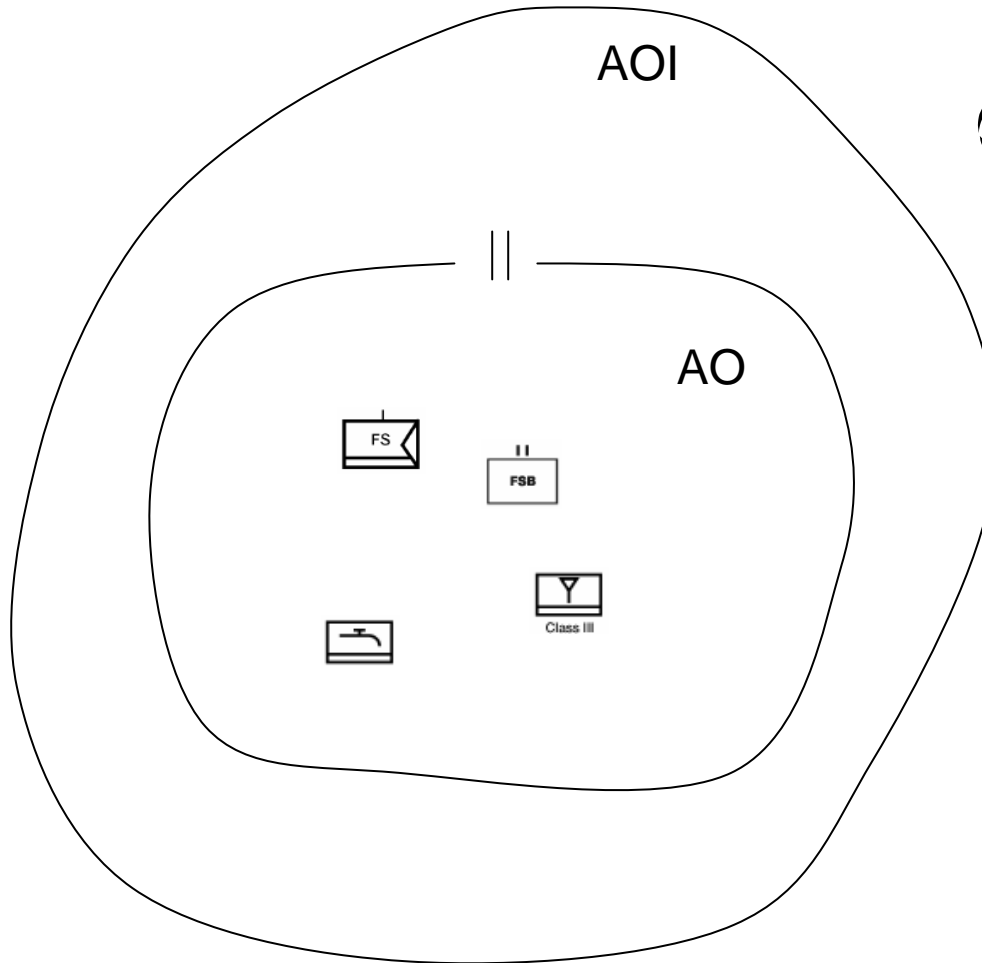
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Define the Battlespace Environment.

The Describe the Battlespace Effects.

Evaluate the Threat.

Determine the Threat COAs.



COA 1

COA 2

NAI

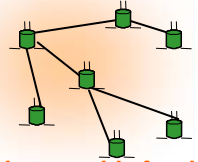
NAI

CCIR

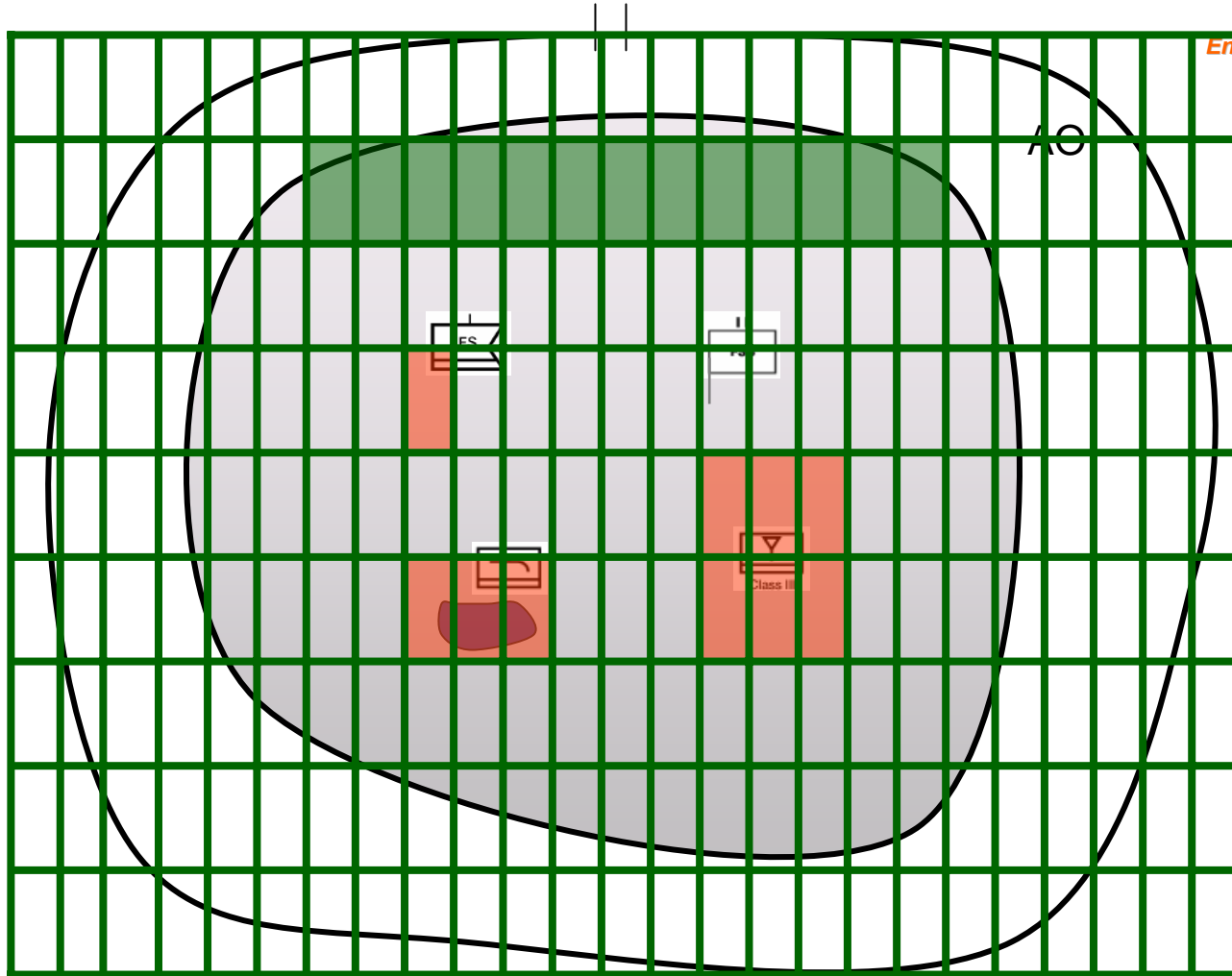
CCIR

Sensor Placement: Yes/No/Maybe

SLOTS

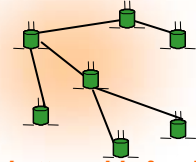


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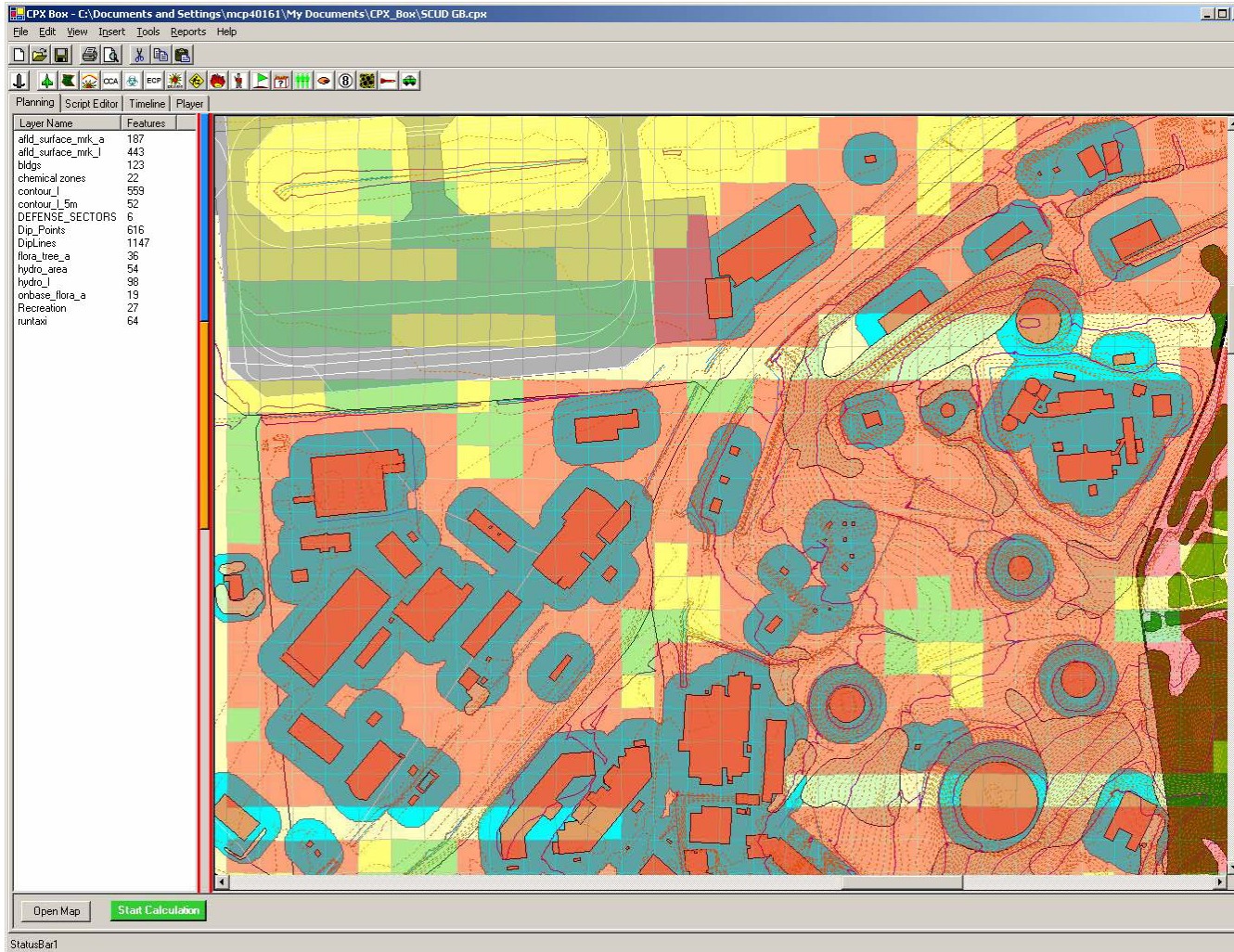


Sensor Placement: Yes/No/Maybe

SLOTS



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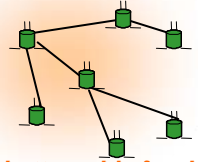
Site Selection

Green – Yes

Red – No

Yellow – Maybe

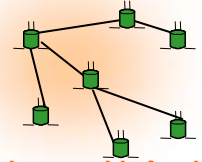
(Blue – Buffers)



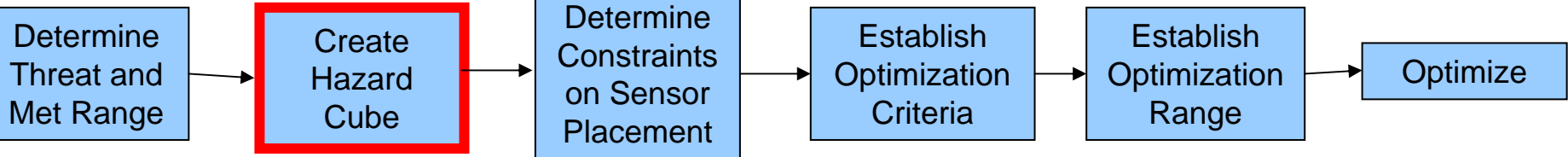
Modeling & Simulation

Fixed Site vs. Maneuver Force Tool

SLOTS

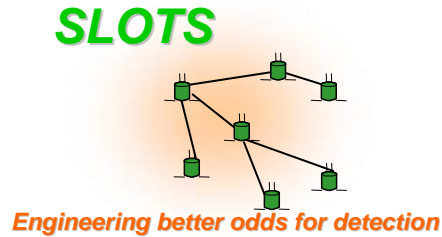


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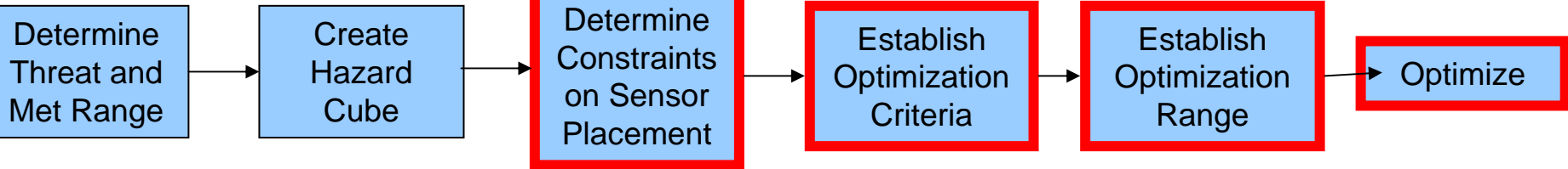
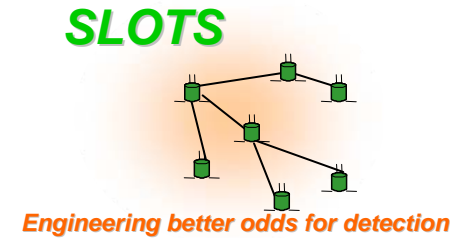
- 2004 proposal envisioned fixed-site tool
- New program requirements require maneuver force support tool
- New requirements place challenge on hazard cube creation task
 - How much time available
 - In-field computing resources
 - Access to world-wide (or AOR) terrain databases

Options for Hazard Cube Creation

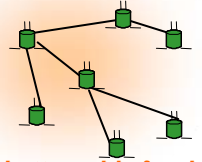


- Pre-run on *homestation* computers for entire region of interest and threat range
 - Likely very large data files
- Develop means to generate in theater to run on target CPU
 - Use METOC forecast as met input
 - How much time available?
 - Potentially lower fidelity
- Develop optimization schema that do not as rely as heavily on time-phases hazard transport phenomena
 - Dose/concentration grids
 - Need to address 3D phenomena for scanning standoff sensors (e.g., JSLSCAD)

SLOTS Will Exploit CB Dial-a-Sensor™ Modules for Sensor Optimization



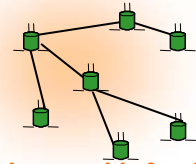
- SLOTS will need to model CB sensors
- CB DAS's PuffTable sensor library will provide sensor modeling
 - Rugged taxonomy for CB sensor definition
 - Point and standoff CB sensors
 - Active and passive (integrating, imaging) CB sensors
 - Easily extensible for new sensor classes/types
 - Standard ANSI C++ (no OS-specific calls)
 - Readily compiled on new OS
- PuffTable is interoperable with SCIPUFF, VLSTRACK, and the architecture supports MESO. . . JEM
- PuffTable has undergone independent verification for ATEC



Optimization

Genetic Algorithms & Sensor Location Optimization

SLOTS

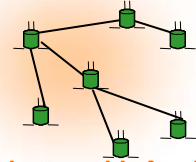


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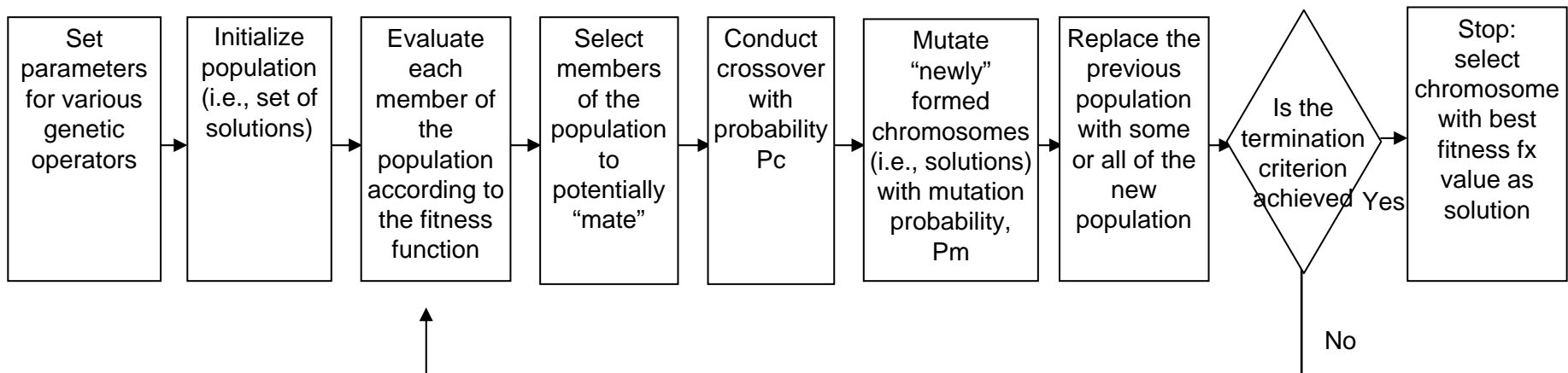
- Decide where to deploy sensors within a given environment.
- Formulated as constrained optimization.
- Consists of three main elements:
 - **Decision variables (solution):**
 - Typically modeled by X_{ij} which is the number of sensor type i at location j .
 - We will restrict to allocating 1 sensor of any particular type to a particular location thus X_{ij} will either be 0 or 1.
 - **Objective/fitness function (performance criterion):**
 - Encodes the performance to be optimized, represented by either a maximization or minimization function (e.g., minimizing detection time).
 - We will utilize sensor characteristic models, terrain, plausible threat attack strategies, met conditions, and agent transport models to evaluate a sensor emplacement scheme's performance.
 - **Constraints:**
 - Aspects which bound a feasible solution set.
 - Example constraints: sensor exclusion zones, critical friendly protection areas, sensor availability, and other SME extracted heuristics.

Genetic Algorithm-based Sensor Location

SLOTS

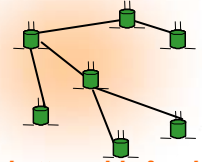


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SLOTS Genetic Algorithm Research & Development Effort

SLOTS

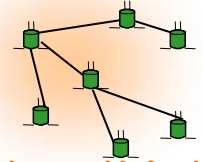


Engineering better odds for detection

- **General GA Research**
 - Research GA implementation in similar optimization problems
 - Extract knowledge to enhance our problem modeling, effectiveness, & efficiency
- **Performance Criterion (i.e., fitness function):**
 - Decide upon the performance criterion
 - Investigate the best method for fitness function evaluation
- **Constraint Handling:**
 - Capture and document domain knowledge and heuristics that will serve as the basis for the constraint set
 - Investigate GA specific constraint handling techniques
 - Select the best technique and model the constraints
- **GA Operators:**
 - Investigate various state of the art GA operators for implementing:
 - Population Size
 - Selection
 - Crossover
 - Mutation
 - Replacement
- **Develop and encode a genetic algorithm to optimize sensor location.**

Year 1

SLOTS



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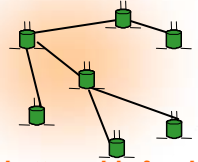
- Conduct Survey of SMEs
- Publish Sensor Placement Handbook

- AODB to CBRN DB Migration Plan
- Constraint identification and modeling
- Wind flow over complex terrain
- SCIPUFF generated transport and dispersion
- Homogeneous chemical point sensor matrix
 - Also, proposed heterogeneous chemical point sensor matrix
- Optimization based on single fitness function (TBD) (e.g., probability of detection)
- Extend to biological point sensor matrix

Summary

- Lots of research to do.
- Starting with the end in mind
 - JOEF Requirements

SLOTS



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Questions?