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Sensor Performance Optimization Tool (SP◎T)

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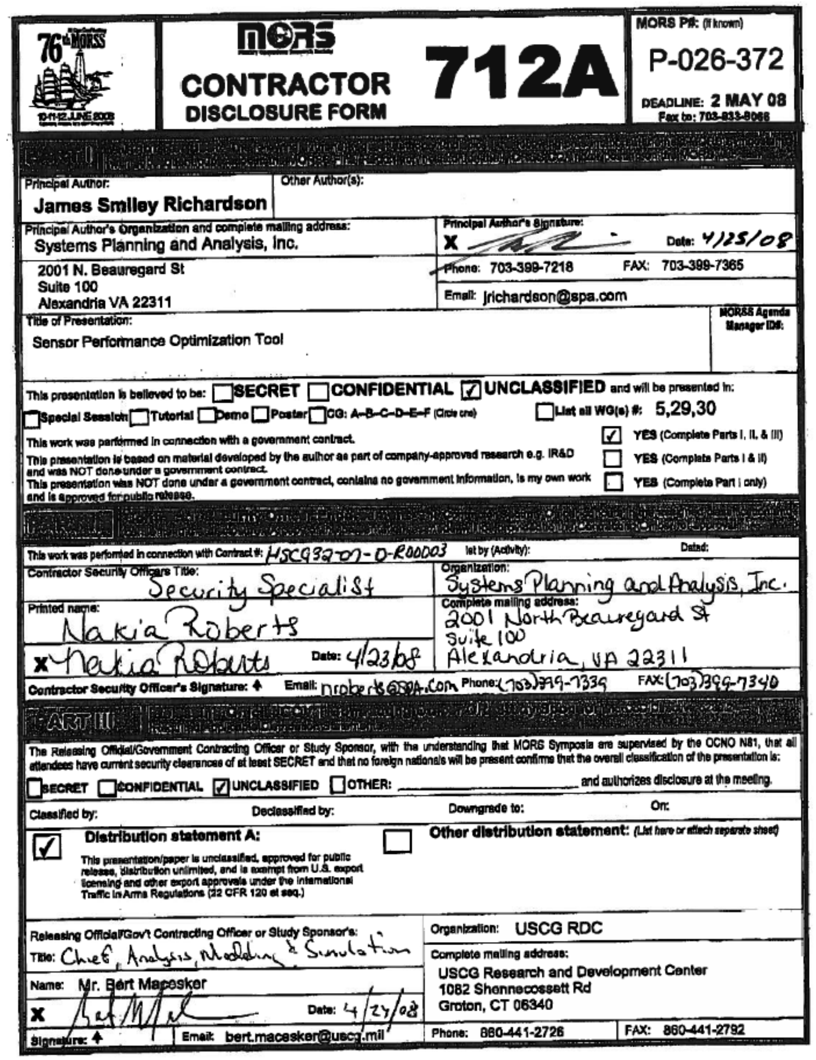

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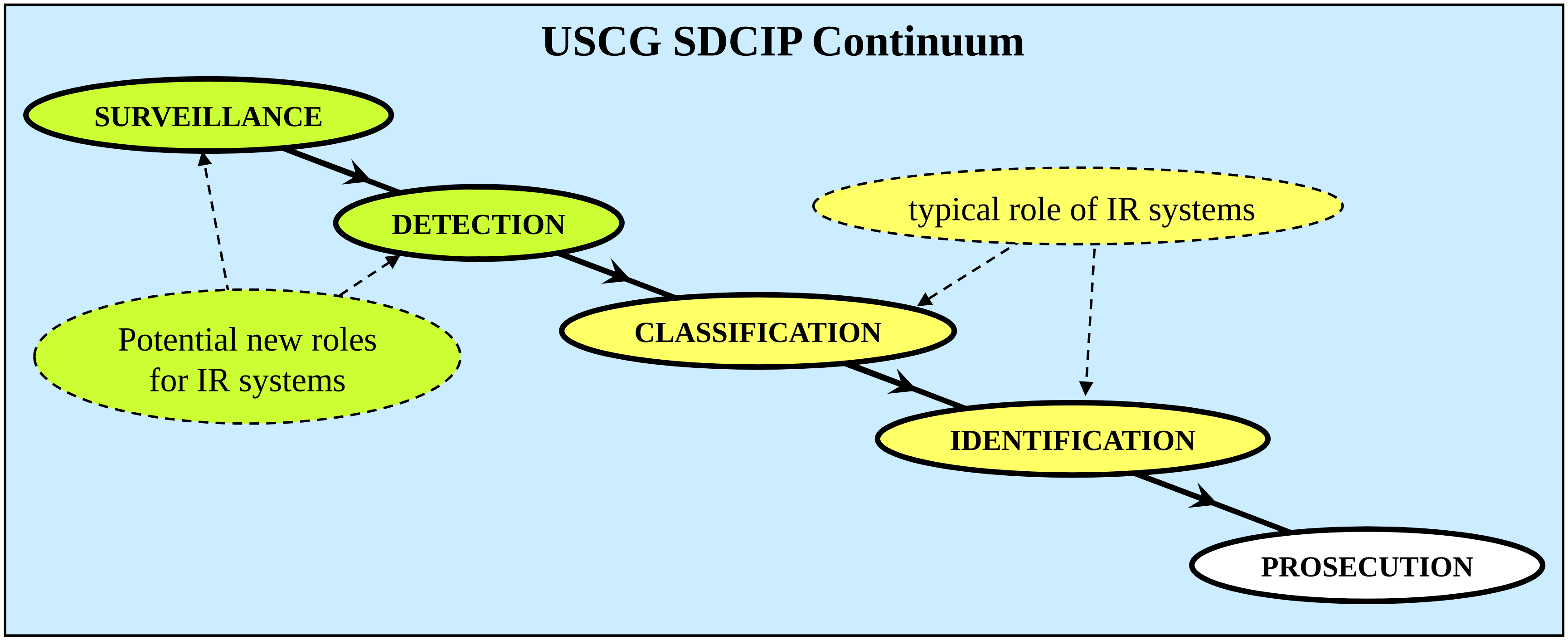
Schedule of Presentations

- **Tuesday 10 June 2008, 10:30 AM**
  - **WG – 5 Homeland Security and Civil Defense**
- **Wednesday 11 June 2008, 10:30 AM**
  - **WG 29 – Modeling, Simulation and Wargaming**
  - **WG 30 – Operational Environment – Factors, Interactions, and Impacts**

Introduction

- **Background**
  - **USCG is in the process of acquiring improved infrared (IR) sensor systems for installation on standard rotary-wing platforms.**
  - **Historically, IR sensor systems have not been used for primary detection work.**

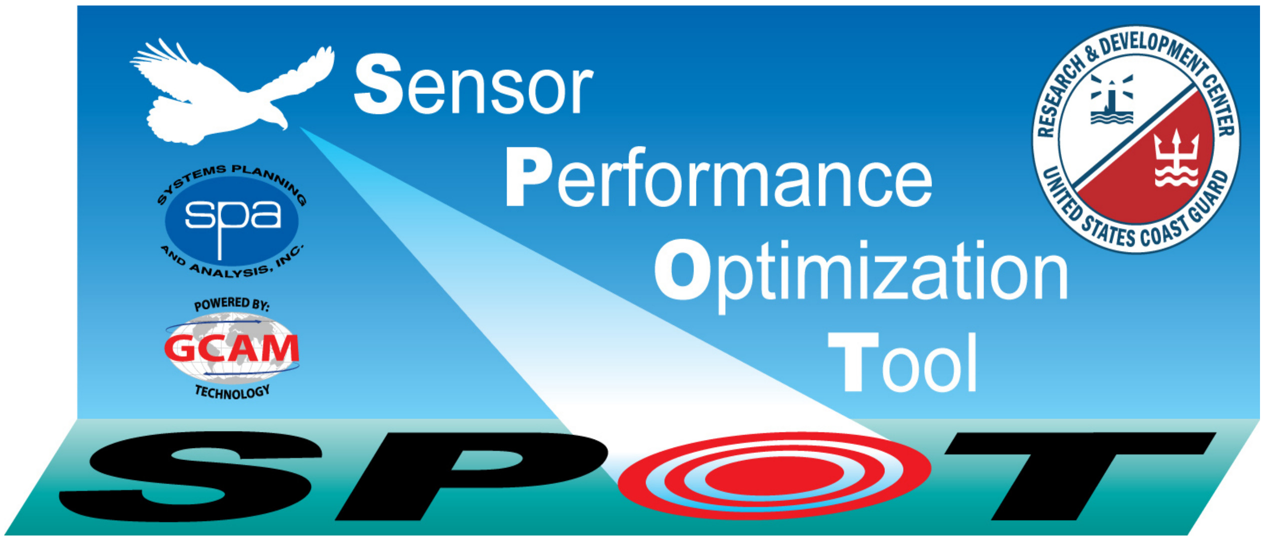


  - **Question remains**

"How can these high-tech sensors be best employed to assist in obtaining initial detections on hard-to-find targets?"

Sensor Performance Optimization Tool (SP◎T)

- **In 2007, collaboration began between the USCG RDC and SPA to develop a software tool that could help analysts and pilots further understand the factors that drive effective searches**



- **The Sensor Performance Optimization Tool is a simulation-based tool that:**
  - **Captures key platform and system performance characteristics**
  - **Visualizes search effectiveness**
  - **Can be used to creates a collection of “best searches” from which analysts and pilots can choose the most operationally feasible search**

SP◎T Overview

The Sensor Performance Optimization Tool (SP◎T)

SPOT.XLS Workbook

- Input specification
- Launch visualization (manual)
- Automation controls
- Results data storage

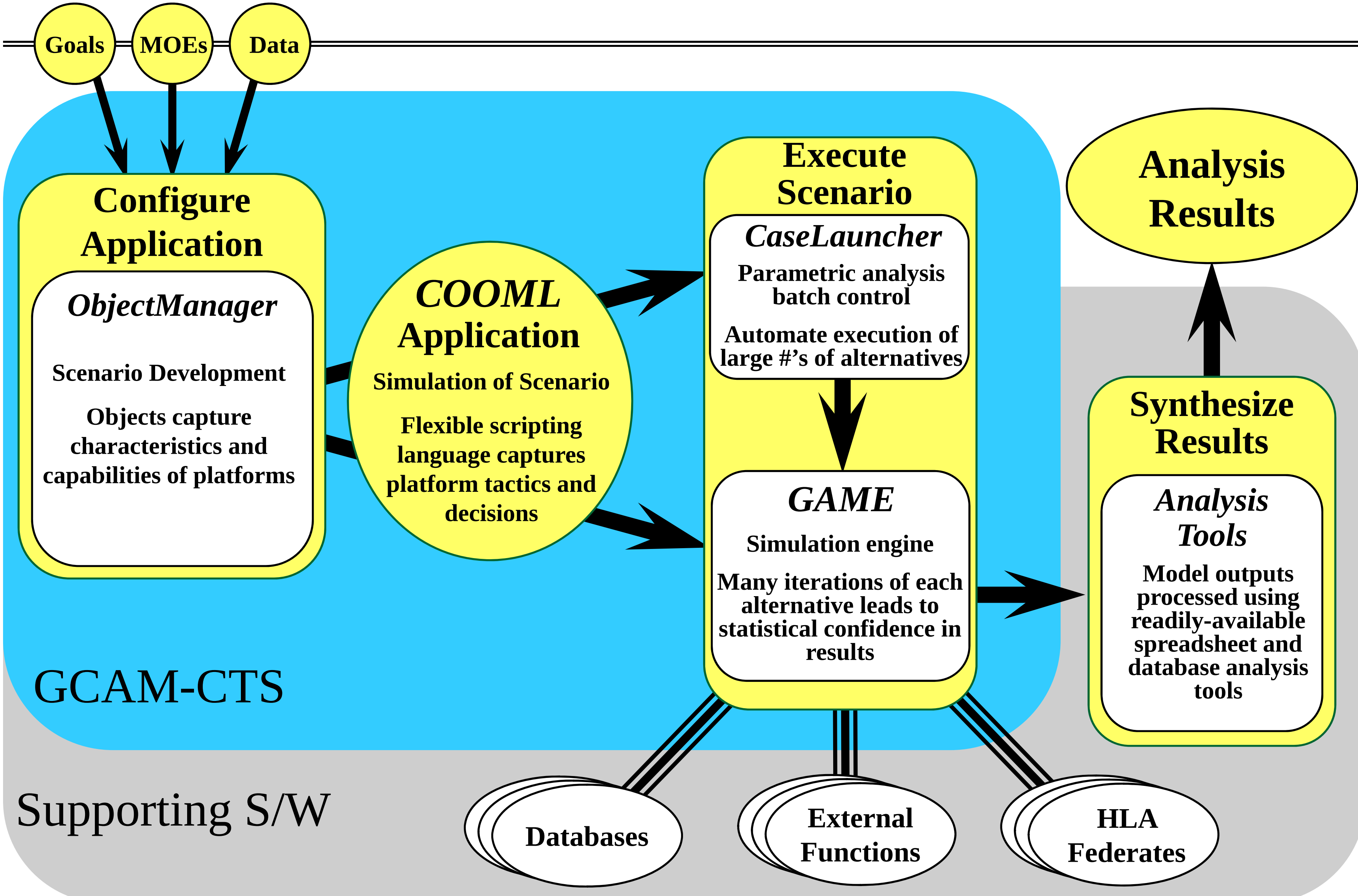
Settings →

← Results

SP◎T GCAM Application

- SP◎T calculations
- animated visualizations
- Video capture for later viewing

GCAM-CTS Elements



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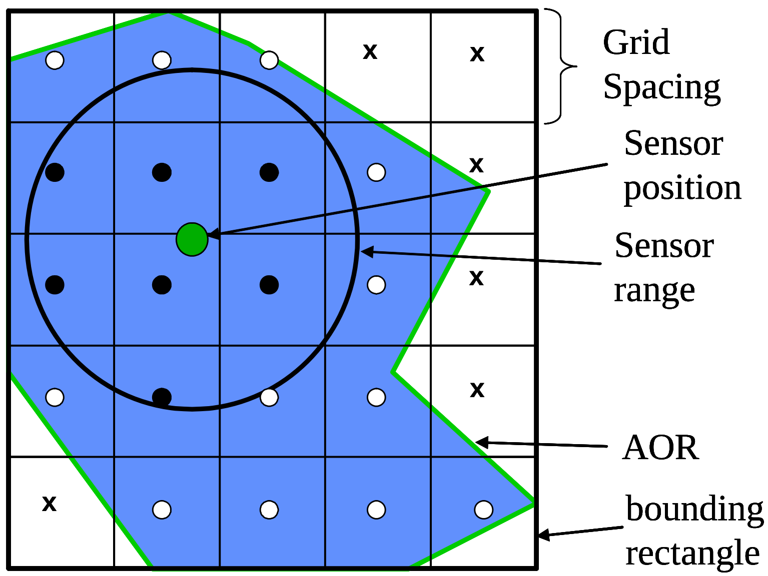
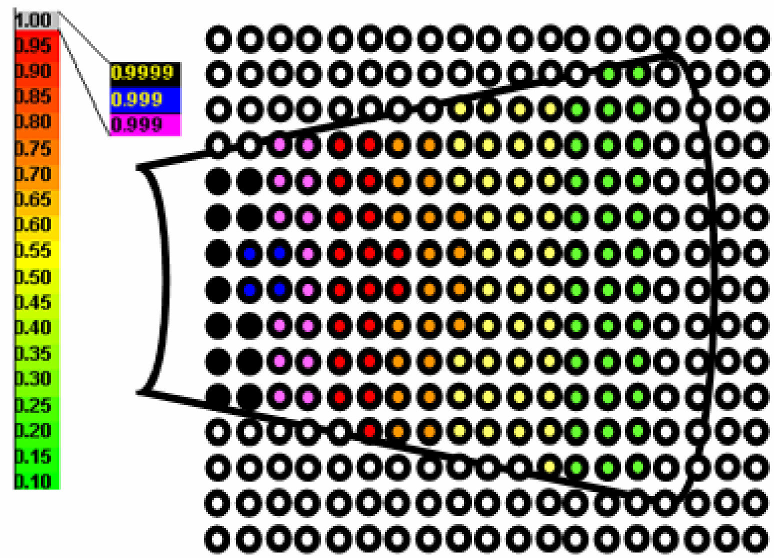
Visualization with GCAM

- **Capitalize on GCAM's native *Area Coverage* functionality**



● *Contributes to P(det) for this time step*
○ *No contribution this time step*
x *No credit possible (outside of AOR)*



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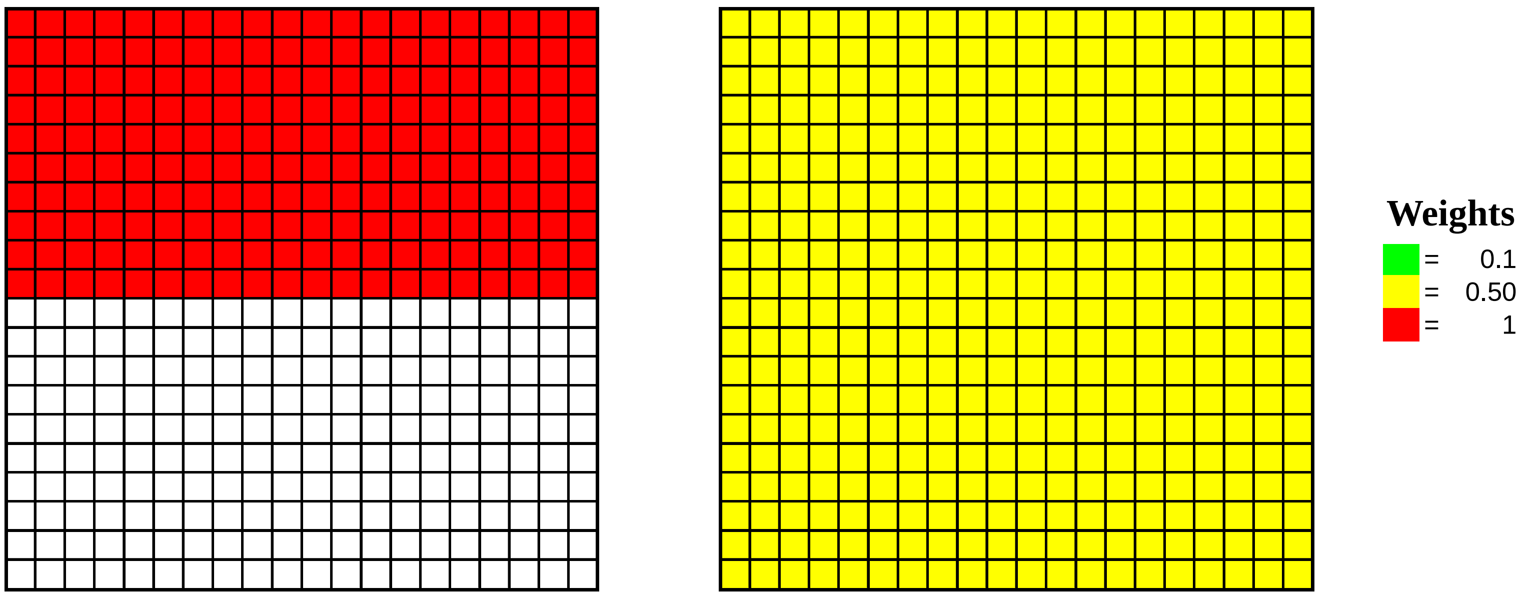
Probability of Detection

- **Historically, Probability of Detection (POD) is calculated POD = A×Q where,**

  A = Area Covered – Percentage painted [percentage]

  Q = Area Coverage Quality of the Area Covered – Weighted percentage of painted region [percentage]

- **POD cannot discriminate between the following two searches:**



POD = 50% **POD = 50%**

- **What then?**

SP◎T Score (◎)

$$◎ (A, Q, T : i, j, k, T_0) = \frac{A^i Q^j}{(T/T_0)^k}$$

- Measured Components (computed by the simulation)
  - A = Area Covered – fraction painted [scalar between 0 and 1]
  - Q = Area Coverage Quality – Weighted percentage of Area Painted [scalar between 0 and 1]
  - T = Total Time to complete search pattern [minutes]
- Settings (established by user prior to any study)
  - i = relative value (weight) for the Area (A) factor
  - j = relative value (weight) for the Quality (Q) factor
  - k = relative value (weight) for the Time (T) factor
  - T_0 = standard (reference) mission time (usually set to max mission time) – Note: 360 minutes is the standard value.

Analysis Method

- Analyst use SP◎T's visualization, platform and sensor representation, and optimization capabilities to determine the best and most operationally feasible search pattern.
  - *Scoping Analysis*
    - Use the visualization capabilities to get a feel for the relationship between the controllable inputs and potential solutions.
    - Selects input variables for formal parametric exploration.
  - *Parametric Analysis*
    - Using the automated features of the system to perform planned parametric analysis
  - *Operational Analysis*
    - Select the most practical solutions from among the optimal and near-optimal search configurations based on operational considerations

An Example

- Deadliest Catch on Discovery Channel
  - It is a cold dark night in the middle of the Bering Sea
  - A 20 foot waves are hitting the boat and a crewman is swept overboard
  - The water is 32 degrees and the crewman needs the US Coast Guard
- The Mission
  - We are searching for a small target in an AOR is 5 nm by 5 nm
  - Cold Weather Climates and a ceiling of 1500 feet
- To Prepare for the mission …
  - How do we select the best flight plan?
  - How should we employ the IR sensor?

Terms of Reference

Scenario Specifications

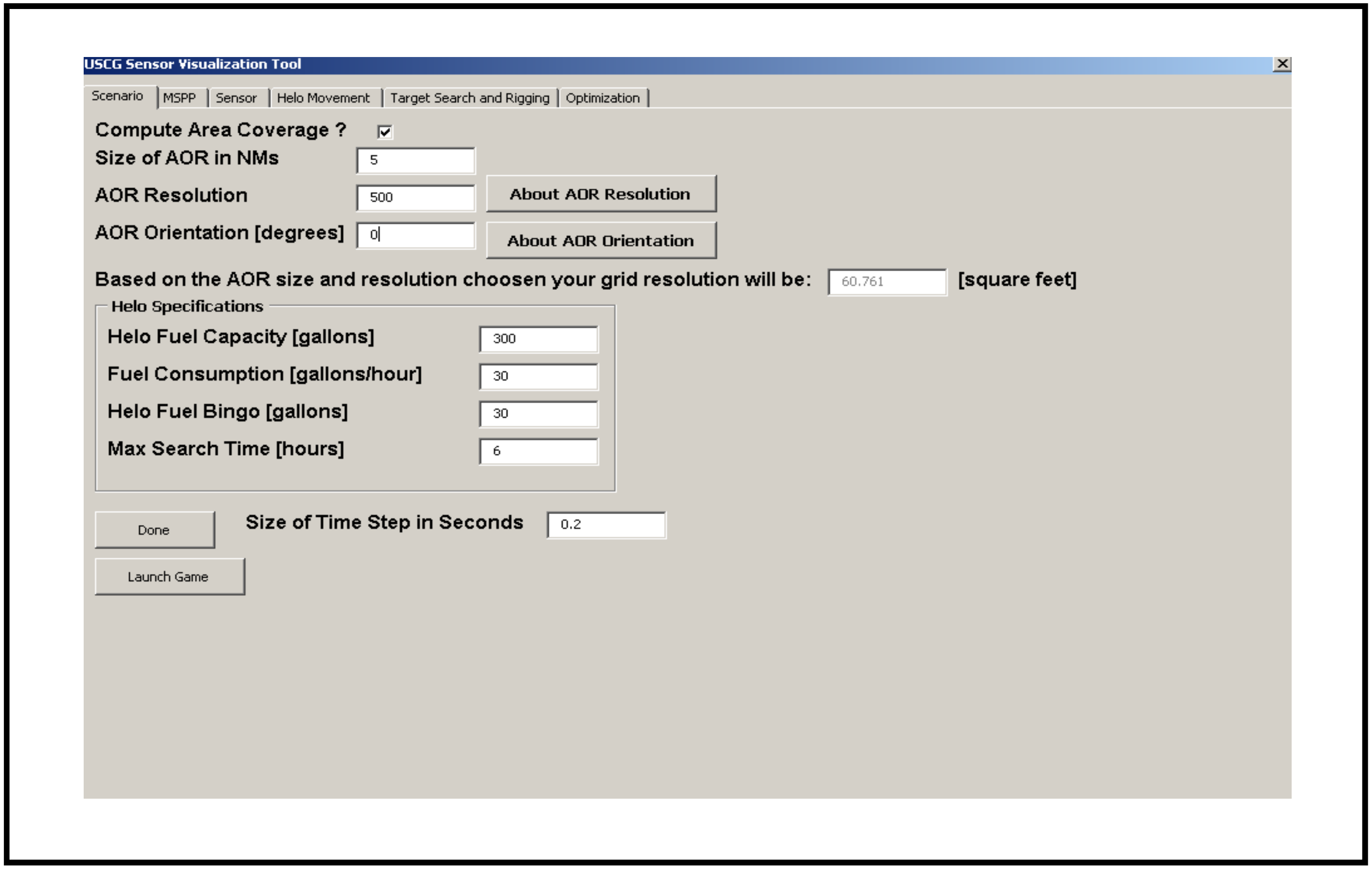
- Target Type
- Environment
  - Location
  - Time of day

Search Configuration Parameters

- Platform Settings
  - Speed (knots)
  - Altitude (feet)
  - Search Pattern Selection (e.g. - Ladder)
    - Start position (x , y)
    - Track Length
    - Track Spacing
    - Creep Length
- Sensor Settings
  - Tilt (declination angle, in degrees)
  - Pointing Method (e.g. - Forward Swing)
    - Center point (relative to heading)
    - Maximum swing (each direction)
    - Swing rate (degrees / second)

Scoping Analysis

Enter Scenario Data



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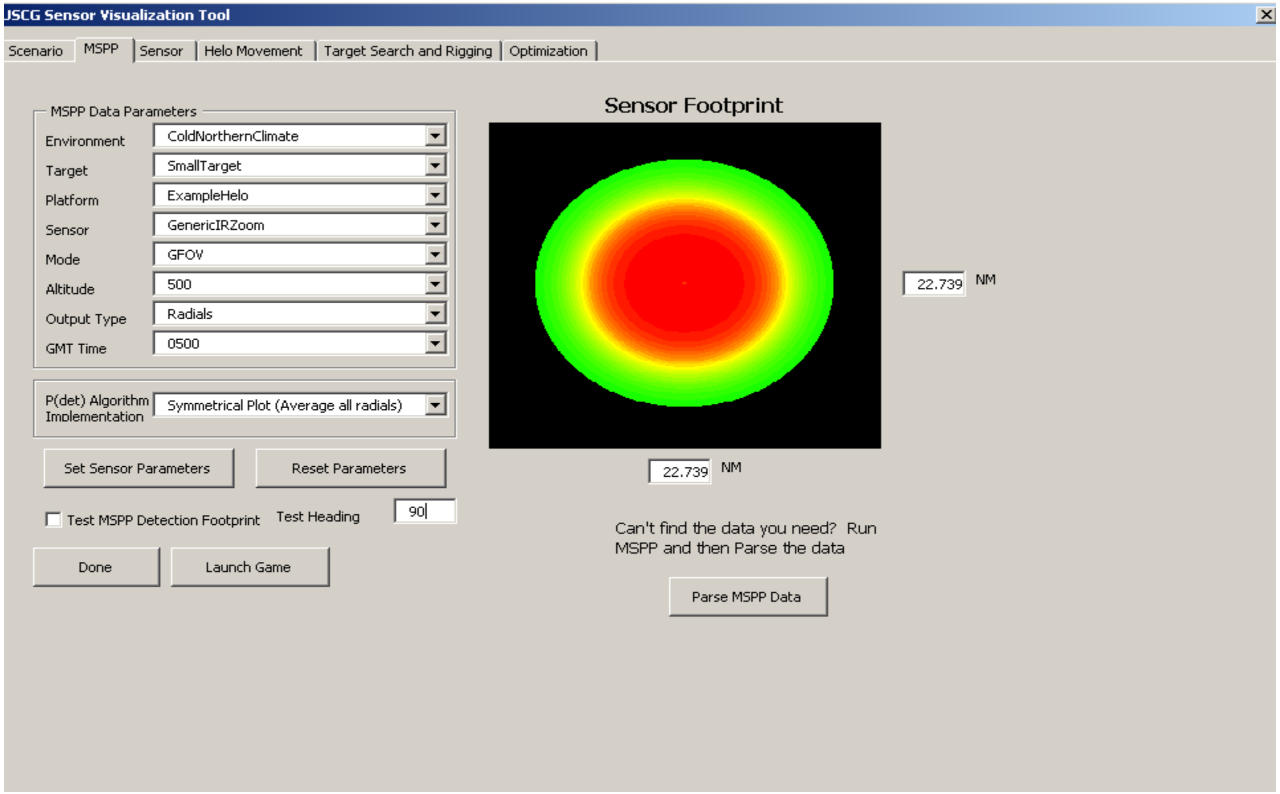
Select Input Data Corresponding to Mission Parameters



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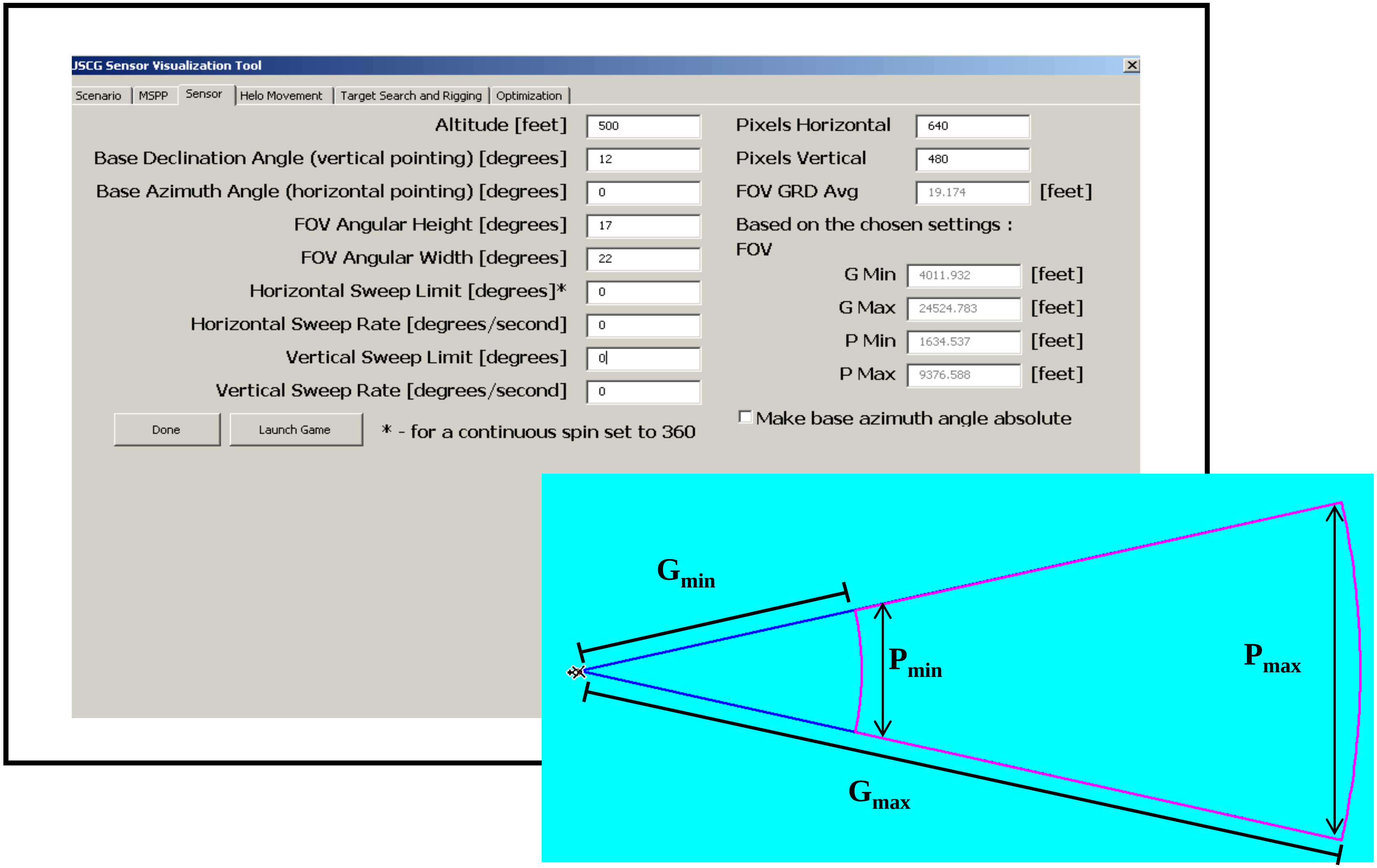
Input Sensor Characteristics and Trial Sensor Utilization Tactics



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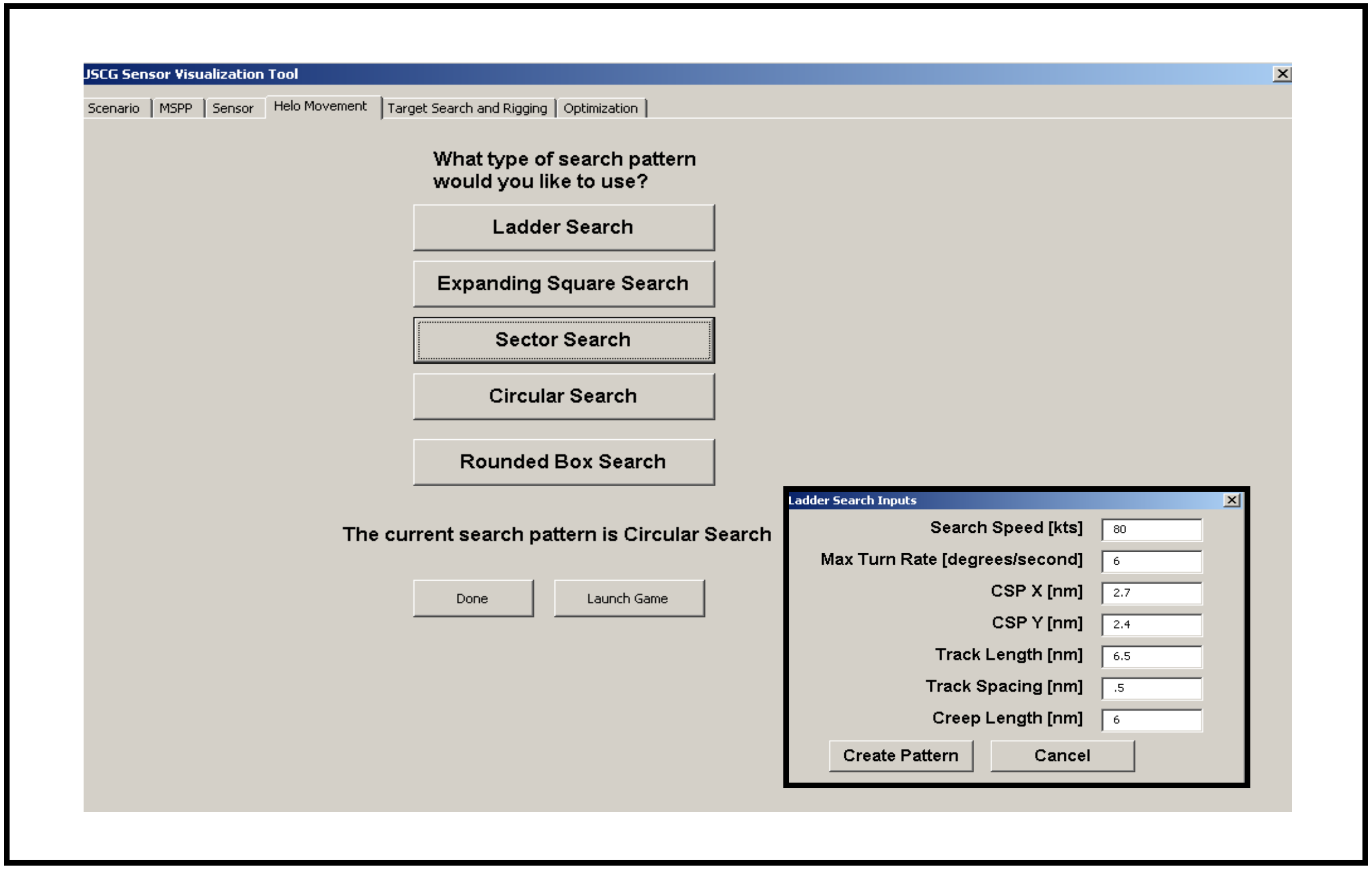
Input Search Pattern Characteristics



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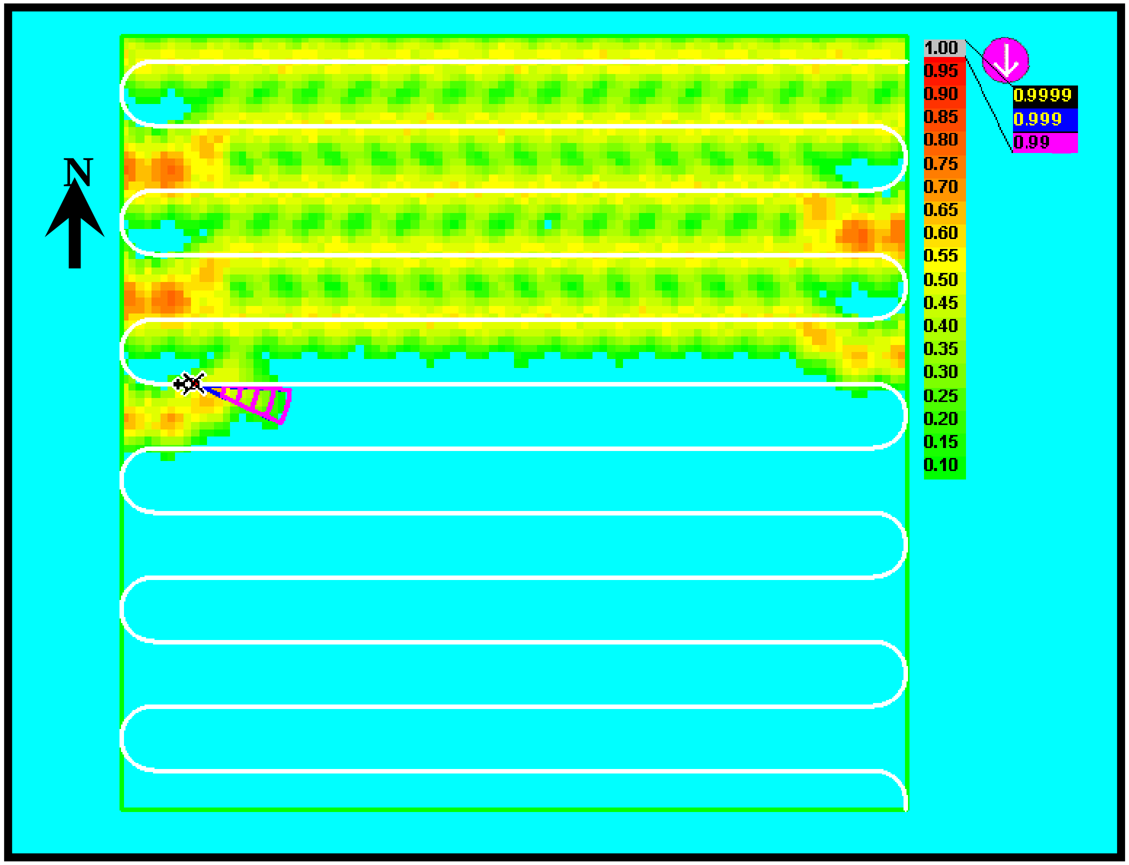
An Ineffective Search



5x5 Search Box, Small Target, 14º tilt, 500 feet altitude
100 knots, Track Length 5 NM, 0.5 nm track spacing

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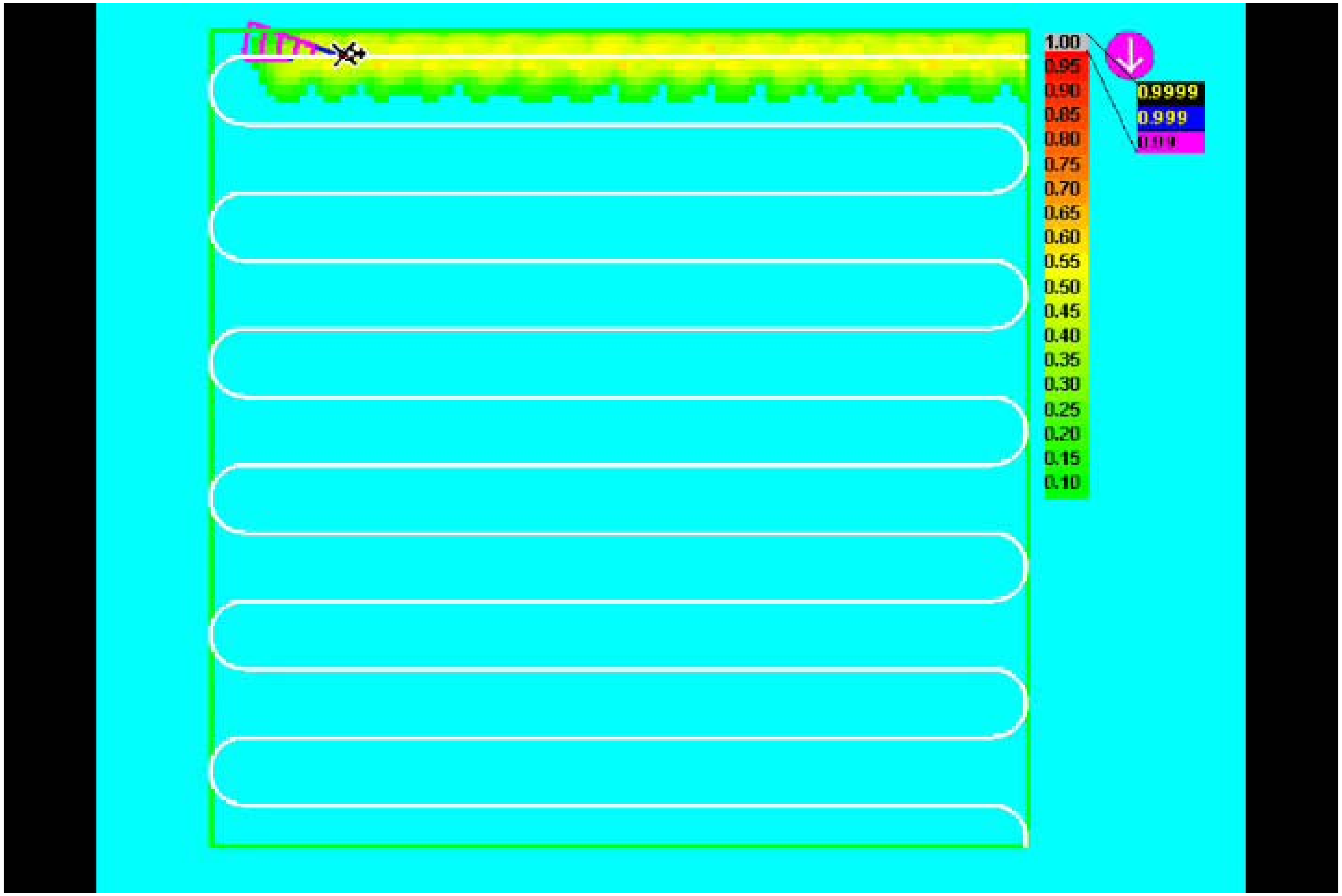
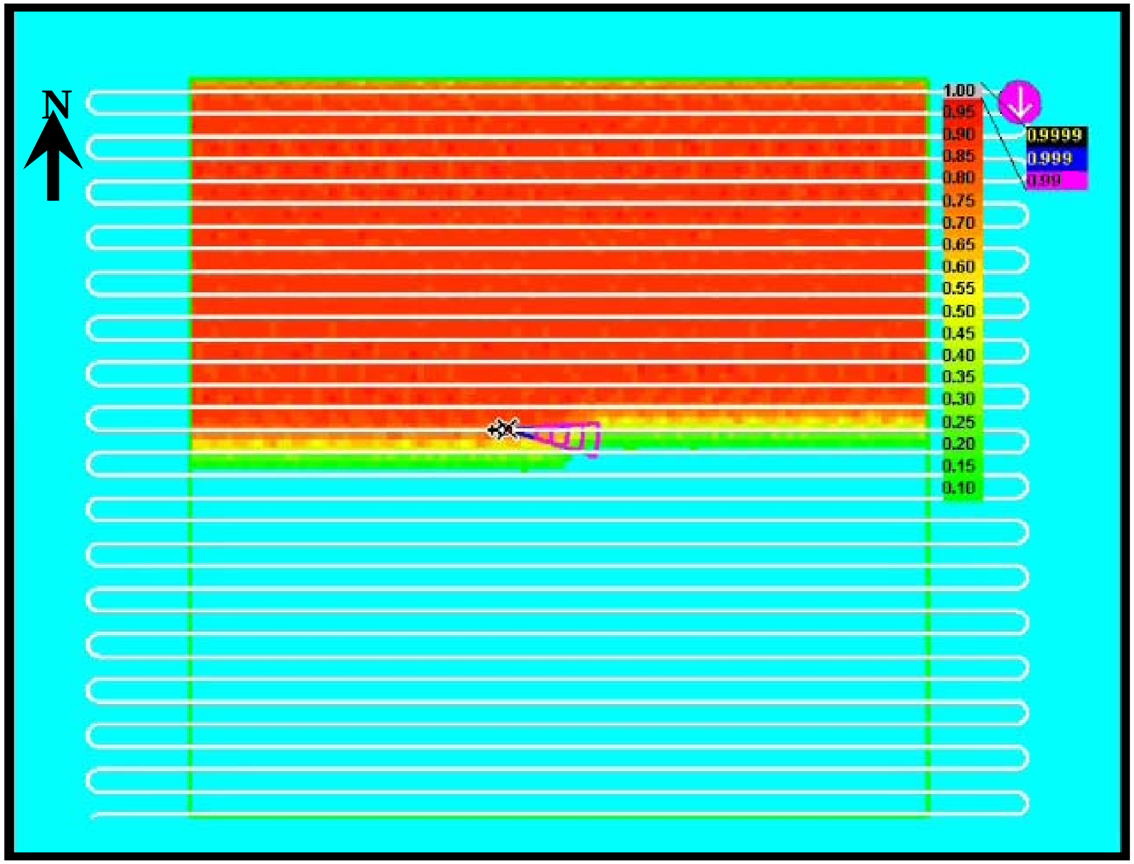
An Ineffective Search

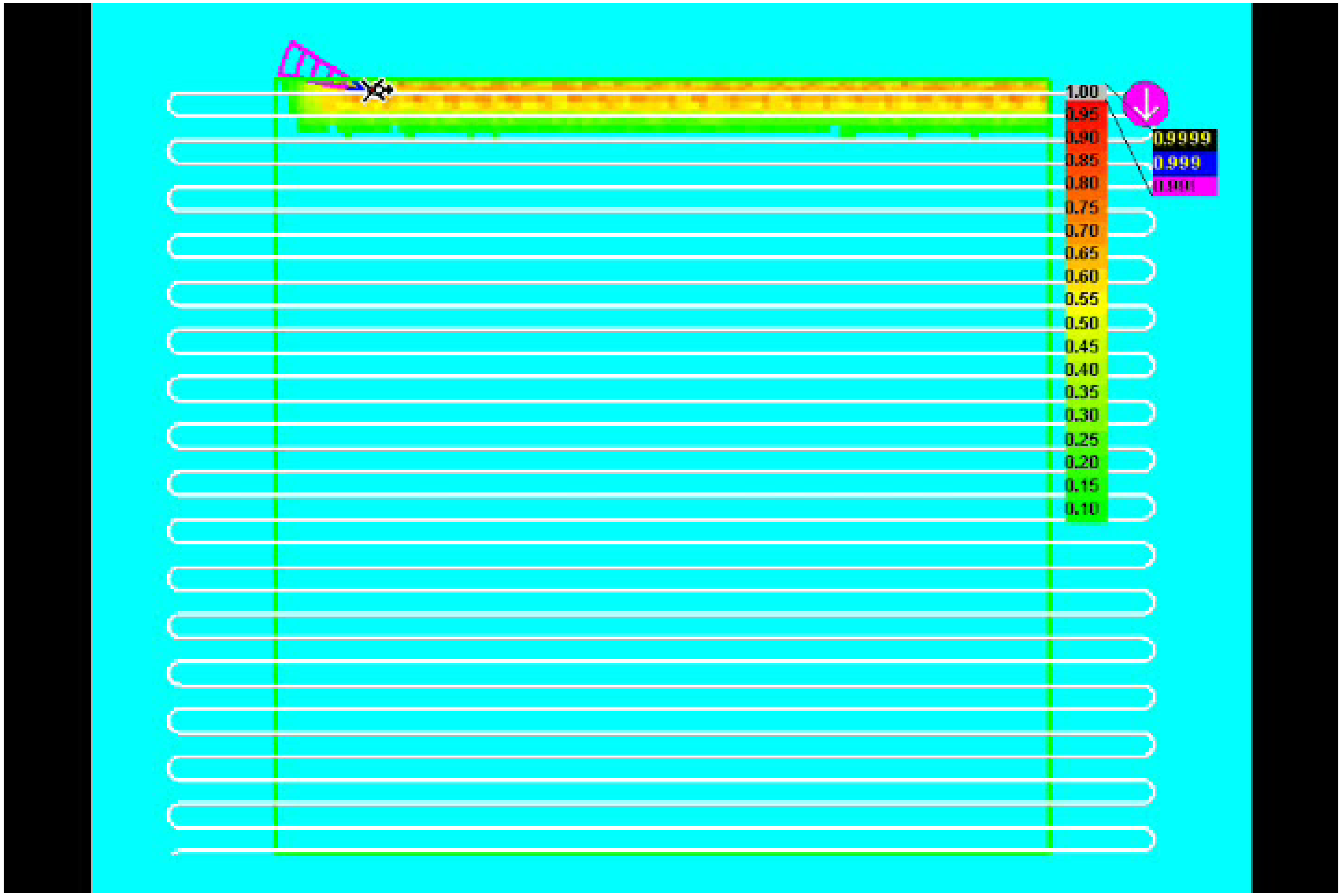


A Better Search

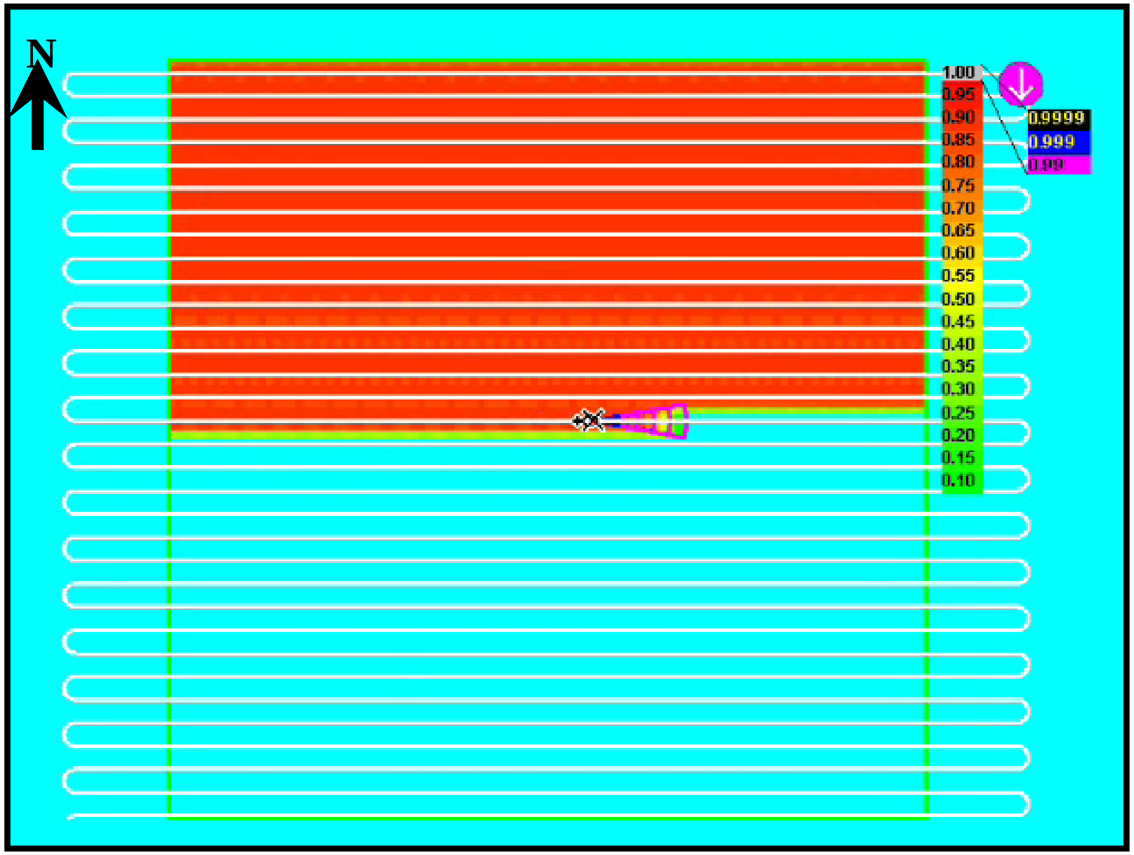


5x5 Search Box, Small Target, 14º tilt, 500 feet altitude
100 knots, Track Length 5.5 NM, 0.3 nm track spacing

A Better Search

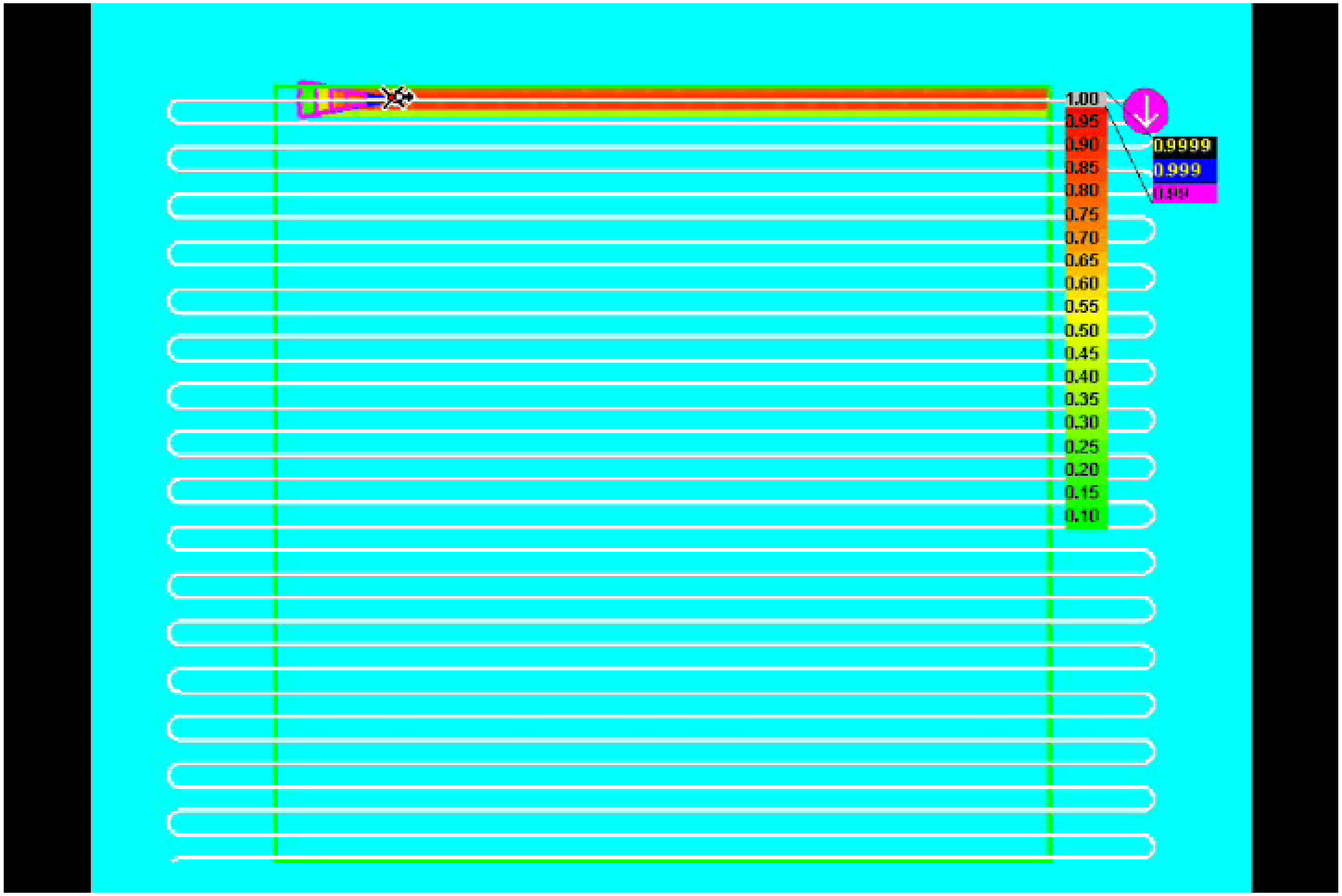


Good Search (Fixed Forward)



5x5 Search Box, Small Target, 14º tilt, 500 feet altitude
100 knots, Track Spacing 5.5 NM, 0.3 nm track spacing

Good Search (Fixed Forward)



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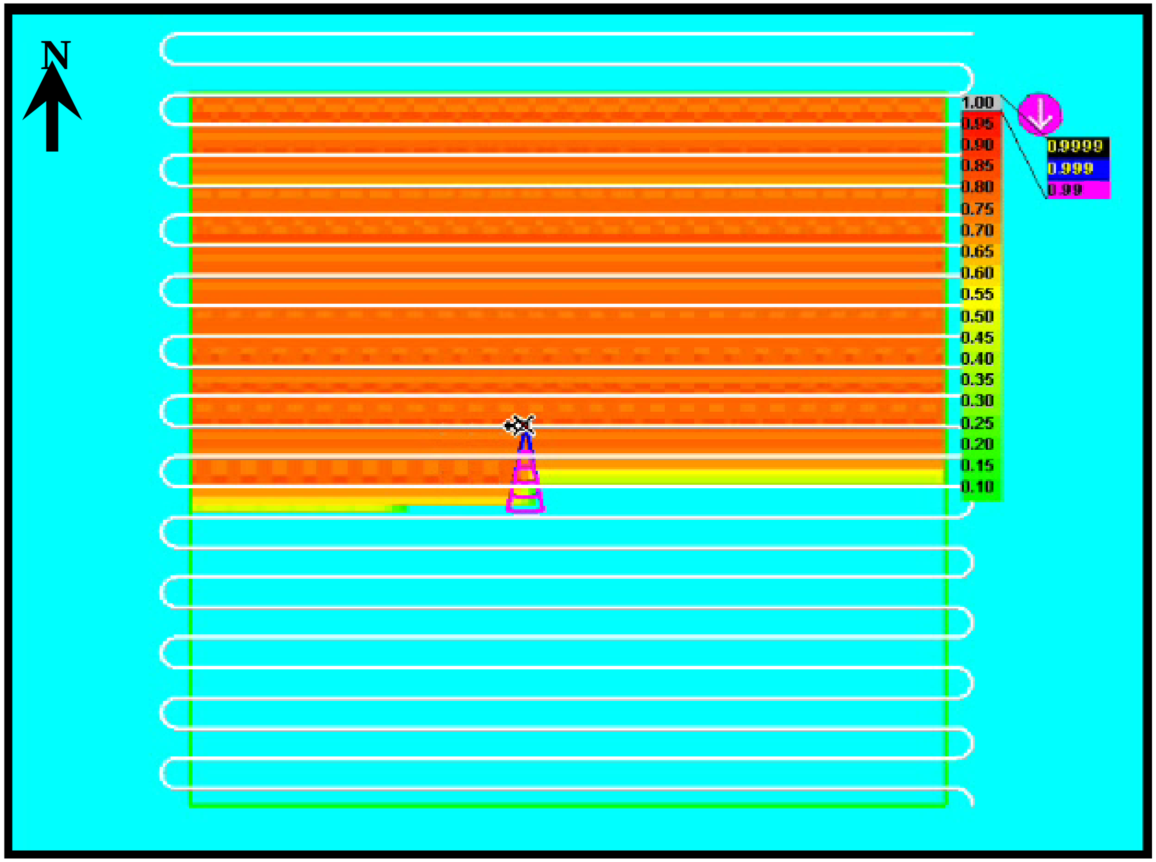
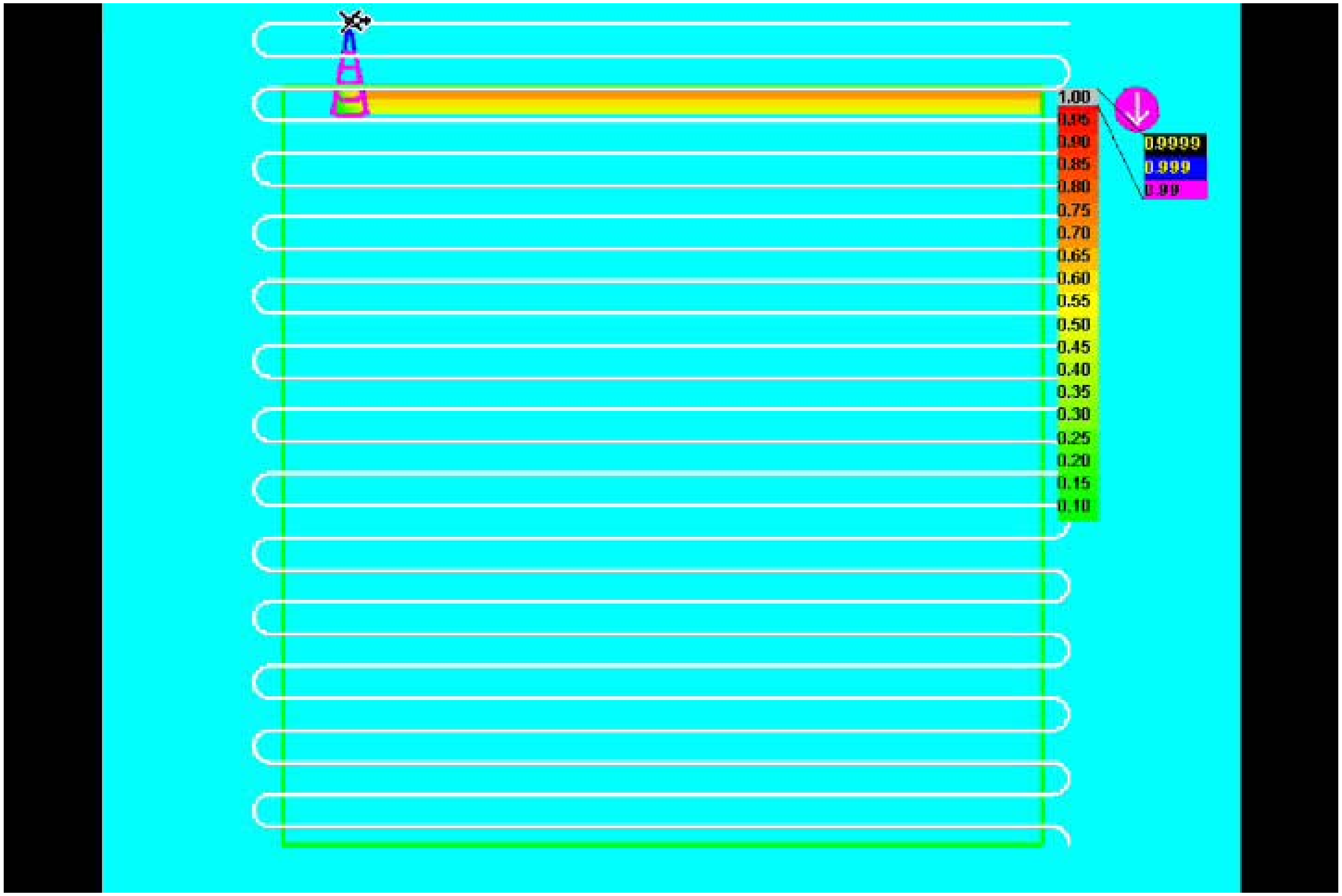
Good Search (Fixed South)



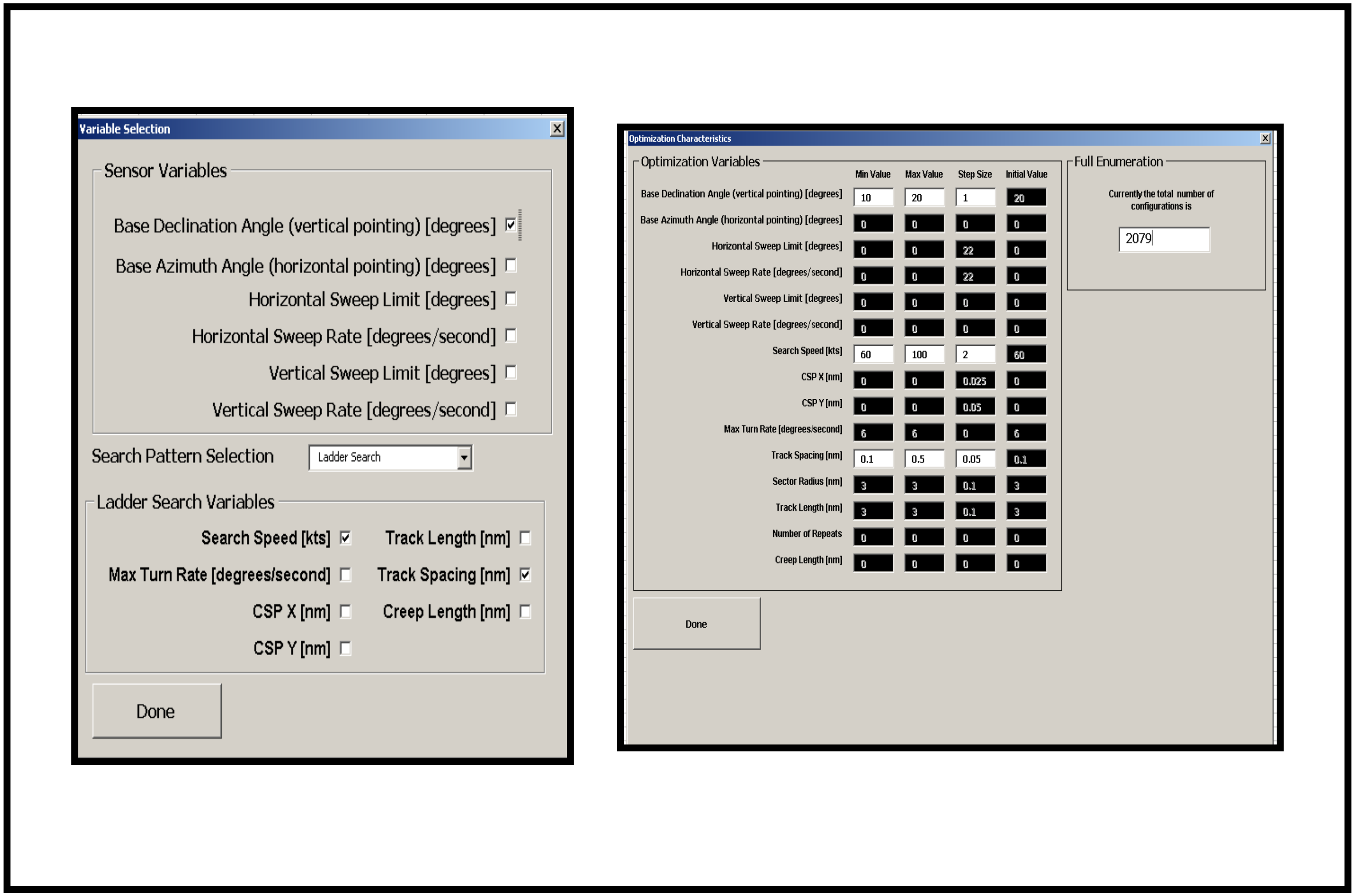
5x5 Search Box, Small Target, 14º tilt, 500 feet altitude
100 knots, Track Spacing 5.2 NM, 0.4 nm track spacing

Good Search (Fixed Direction)



Parametric Analysis

Variable Selection



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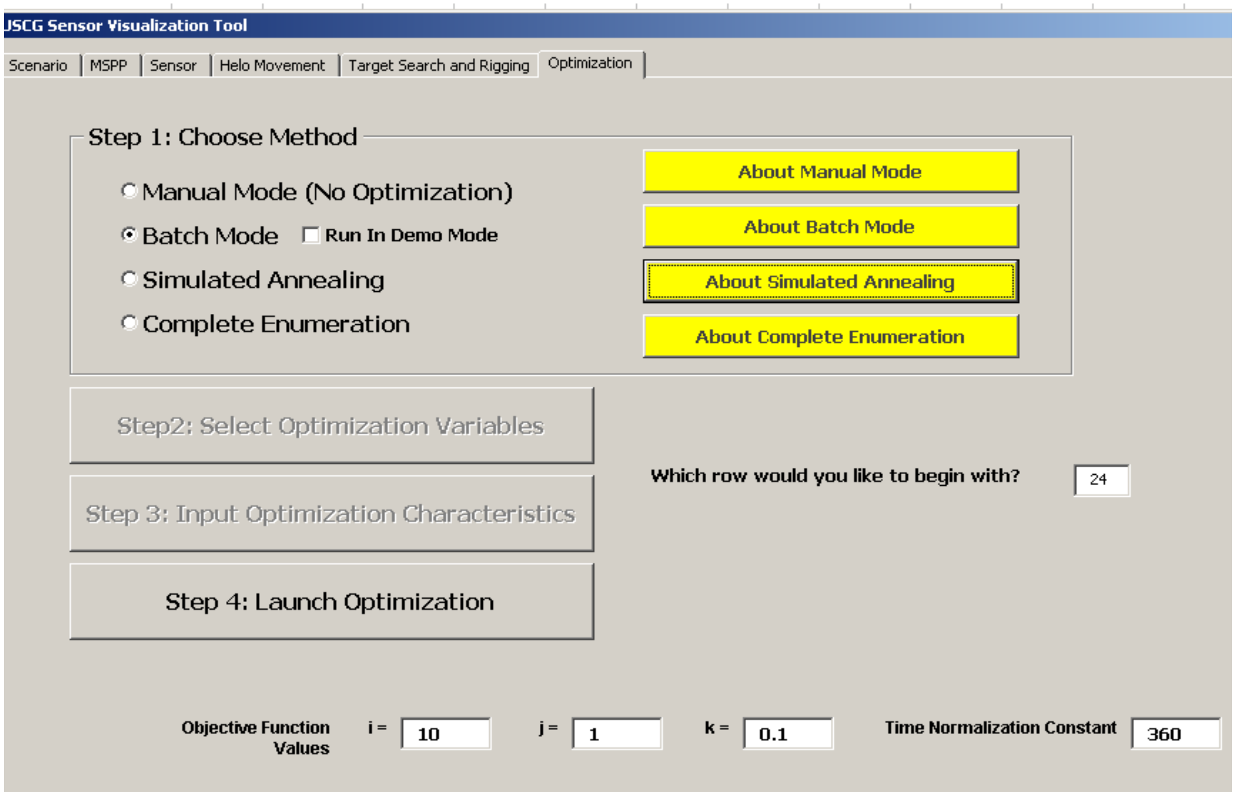
Optimization Inputs



Put the Computers to Work!

Final Results (Unsorted)*

Search Configuration Index	Declination (Tilt) [degrees]	Speed [knots]	Track Spacing [nm]	SP◎T Score [no units]	Area (A) [no units]	Quality (Q) [no units]	Time (T) [minutes]	POD [no units]
1	10	60	0.1	0.5096	0.9903	0.3998	12.0033	0.3959
2	10	60	0.2	0.9646	1.0000	0.7420	26.1067	0.7420
3	10	60	0.3	1.1603	1.0000	0.9214	35.9000	0.9214
4	10	60	0.4	1.1947	1.0000	0.9781	48.6800	0.9781
5	10	60	0.5	1.1931	1.0000	0.9945	58.2767	0.9945
6	10	60	0.6	1.1777	1.0000	0.9986	69.1833	0.9986
7	12	60	0.1	1.2617	0.9998	0.9608	23.1367	0.9606
8	12	60	0.2	1.2307	1.0000	0.9994	44.9033	0.9994
9	12	60	0.3	1.1772	1.0000	1.0000	70.4267	1.0000
10	12	60	0.4	1.1413	1.0000	1.0000	95.9767	1.0000
11	12	60	0.5	1.1146	1.0000	1.0000	121.6433	1.0000
12	12	60	0.6	1.0959	1.0000	1.0000	144.0567	1.0000
13	14	60	0.1	0.9577	0.9813	0.9223	37.4333	0.9051
14	14	60	0.2	1.1554	1.0000	0.9945	80.3467	0.9945
15	14	60	0.3	1.1152	1.0000	0.9997	120.5367	0.9997
16	14	60	0.4	1.0817	1.0000	1.0000	164.0600	1.0000
17	14	60	0.5	1.0584	1.0000	1.0000	204.1233	1.0000
18	14	60	0.6	1.0384	1.0000	1.0000	247.0333	1.0000
19	16	60	0.1	0.9229	0.9998	0.7710	58.4467	0.7709
20	16	60	0.2	1.0605	1.0000	0.9502	120.0833	0.9502
21	16	60	0.3	1.0575	1.0000	0.9894	184.9033	0.9894
22	16	60	0.4	1.0365	1.0000	0.9977	245.8467	0.9977
23	16	60	0.5	1.0148	1.0000	0.9996	309.6667	0.9996
24	16	60	0.6	0.9999	1.0000	0.9999	360.0067	0.9999
25	18	60	0.1	0.5572	0.9802	0.5880	83.4033	0.5763
26	18	60	0.2	0.8901	1.0000	0.8258	170.1800	0.8258
27	18	60	0.3	0.9602	1.0000	0.9291	258.8733	0.9291
28	18	60	0.4	0.9751	1.0000	0.9707	344.0733	0.9707
29	18	60	0.5	0.4914	1.0000	0.4373	112.1167	0.4373
30	18	60	0.6	0.7106	1.0000	0.6795	229.9533	0.6795
31	20	60	0.1	0.8196	1.0000	0.8157	343.3267	0.8157
32	20	60	0.2	0.3595	0.9900	0.3628	144.2800	0.3592
33	20	60	0.3	0.6094	1.0000	0.5970	293.1367	0.5970
34	20	60	0.4	0.3633	0.9900	0.3754	183.2767	0.3717
35	20	60	0.5	0.6046	1.0000	0.6046	360.0067	0.6046
36	20	60	0.6	0.3967	0.9900	0.4179	221.9200	0.4137

- *180 total search configurations*

* *Notional Data - For illustrative purposes only*

Operational Analysis

Sorted Results

Potential Operational Considerations

- **Maintain high POD**
- **Wider versus Narrow track spacing**
- **Pilots' favorite search speed**
- **Mission time versus survivability estimates**
- **Opportunity for counter-detection and alert from target (SAR missions only).**

Search Configuration Index	Declination (Tilt) [degrees]	Speed [knots]	Track Spacing [nm]	SP◎T Score [no units]	Area (A) [no units]	Quality (Q) [no units]	Time (T) [minutes]	POD [no units]
122	14	90	0.2	1.2719	1.0000	0.9779	25.9867	0.9779
84	12	80	0.6	1.2697	[illegible]	[illegible]	[illegible]	[illegible]
7	12	60	0.1	1.2617	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	70	0.4	1.2564	1.0000	0.9965	35.4667	0.9965
[illegible]	[illegible]	90	0.3	1.2393	1.0000	0.9966	40.7100	0.9966
[illegible]	[illegible]	60	0.2	1.2307	1.0000	0.9994	44.9033	0.9994
[illegible]	[illegible]	80	0.1	1.2254	1.0000	0.9989	46.6400	0.9989
45	12	70	0.3	1.2203	0.9972	0.9263	17.2700	0.9237
82	12	80	0.4	1.2093	1.0000	0.9837	45.6767	0.9837
43	12	70	0.1	1.2087	1.0000	0.9827	45.4400	0.9827

Operationally Favorable Track Spacing

Highest SPOT Score

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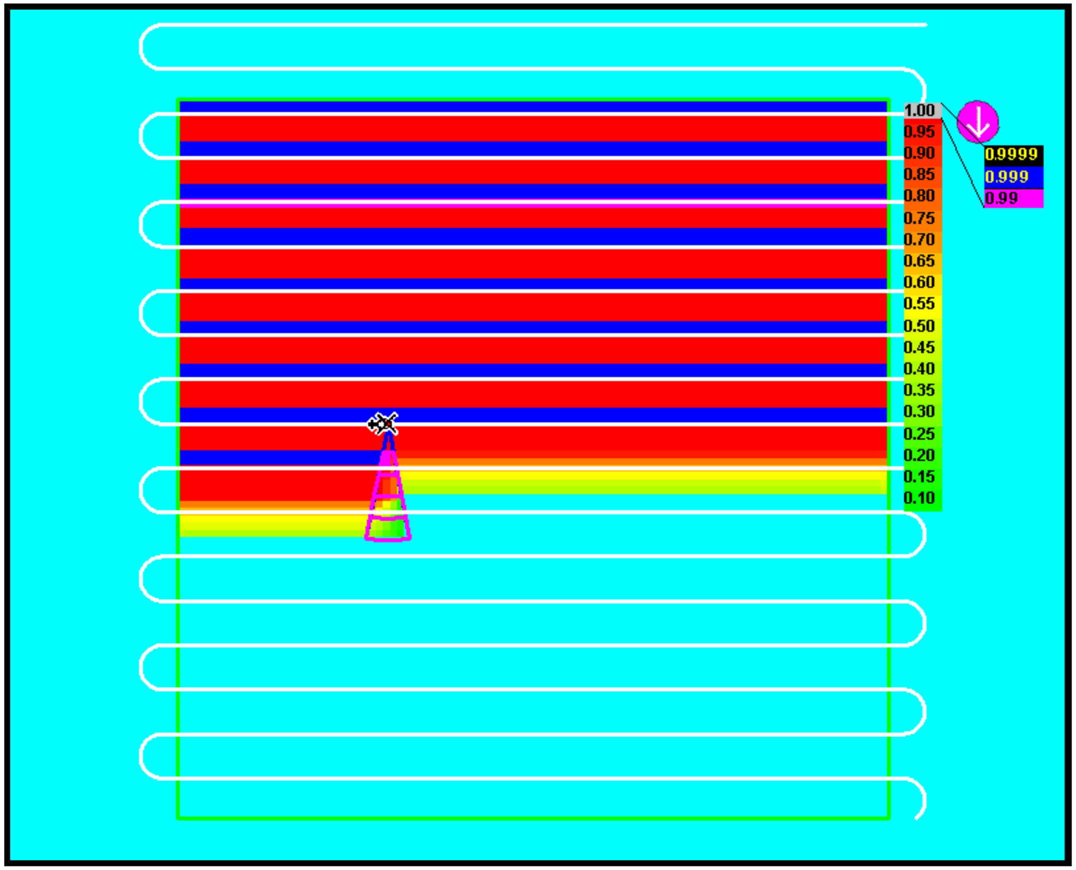
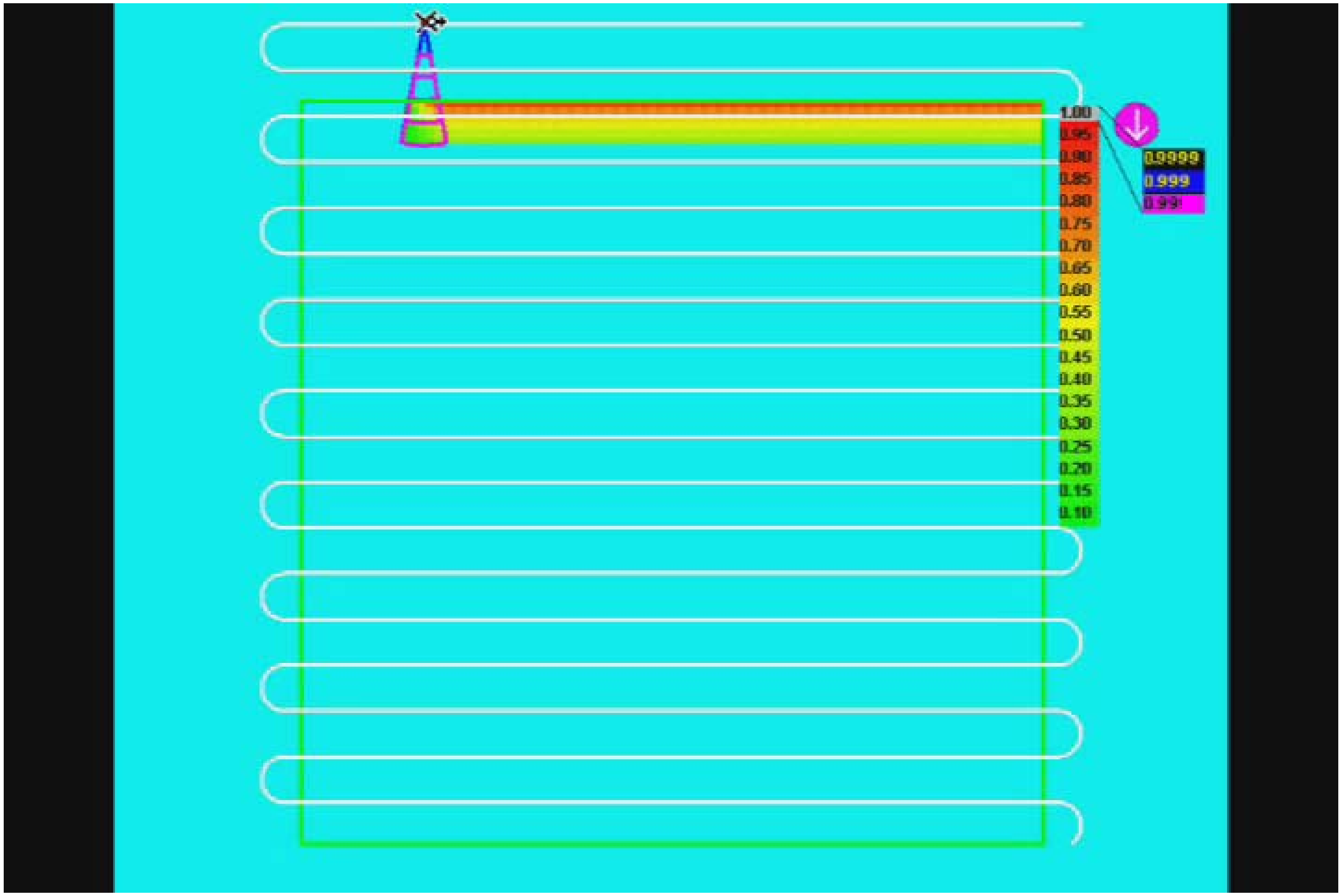
Selected Run



5x5 Search Box, Small Target, 14º tilt, 500 feet altitude
100 knots, Track Spacing 5.2, 0.6 nm track spacing

Selected Run



Key Takeaways

- **The ability to visualize search effectiveness is a powerful aid to search planners and analysts.**
- **The project reveals a need for metrics beyond POD and other traditional measures.**
- **IR-based sensor systems show promise as primary detection devices.**

Acknowledgements

- **About the Authors**
  - ***William Lyle*** **is the Program Manager and Principal Analyst for SPA's M&S-Based Analysis Support to the RDC.**
  - ***James Richardson*** **is a Senior Operations Research Analyst with SPA.**
  - ***Kevin Downer*** **is a Senior Operations Research Analyst at the USCG RDC.**
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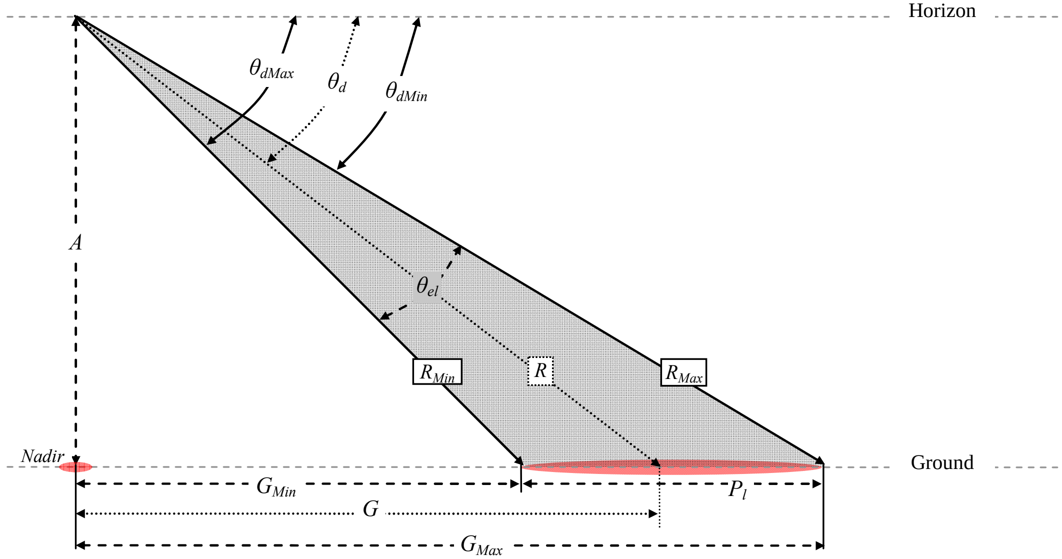
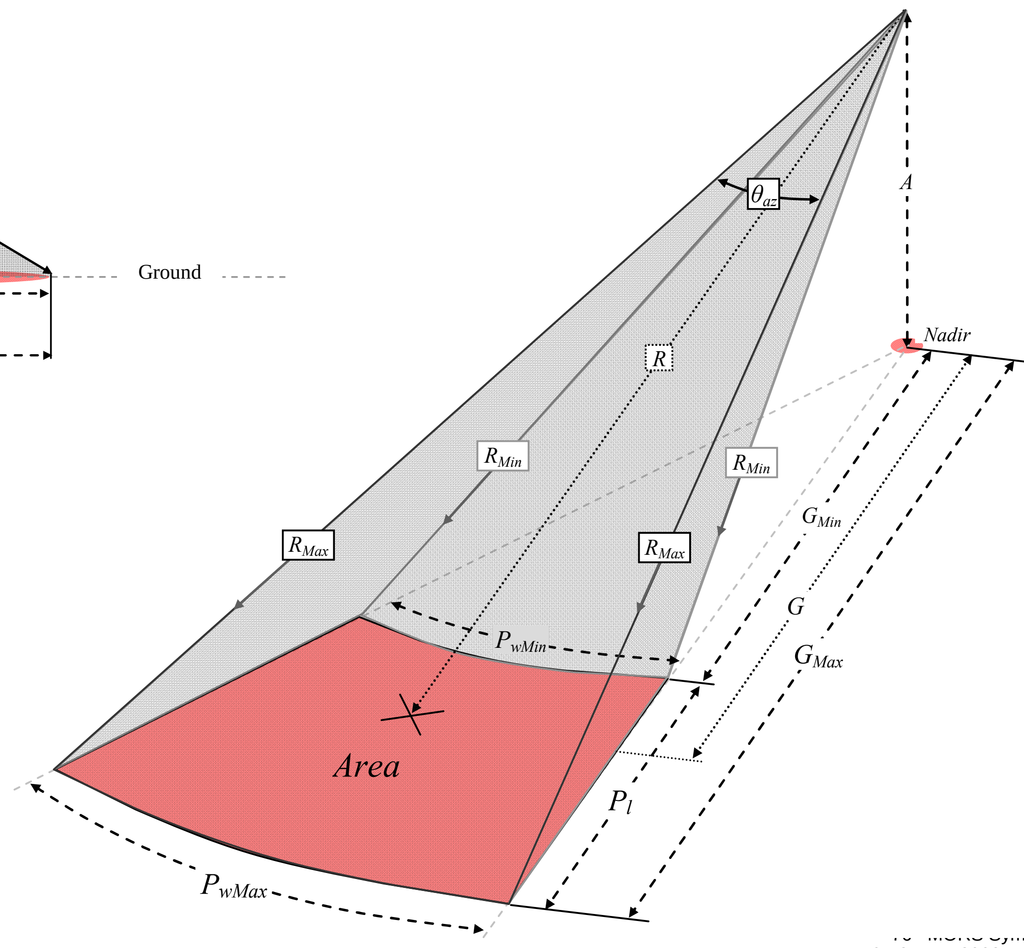
    - **Staff scientists at the USCG RDC – who helped substantially with the validation efforts.**
    - **The flight mechanics and pilots at AR&SC Elizabeth City, ATC Mobile, and Clearwater Air Station – who helped keep the entire team on solid operational footing.**

General Backup

Pointing Sensor Basics





Where: $A \equiv$ Altitude

$R \equiv$ Slant Range (centered in FOV)

$R_{Min} \equiv$ Minimum Slant Range (seen from bottom of FOV)

$R_{Max} \equiv$ Maximum Slant Range (seen from top of FOV)

$\theta_{el} \equiv$ FOV in Elevation

$\theta_{az} \equiv$ FOV in Azimuth

$\theta_d \equiv$ Turret Depression Angle (from horizon to center of FOV)

$\theta_{dMin} \equiv$ Turret Depression Angle (from horizon to top of FOV)

$\theta_{dMax} \equiv$ Turret Depression Angle (from horizon to bottom of FOV)

$G \equiv$ Distance from Nadir to Center Ground Point in FOV

$G_{Min} \equiv$ Distance from Nadir to Nearest Ground Point in FOV

$G_{Max} \equiv$ Distance from Nadir to Furthest Ground Point in FOV

$P_l \equiv$ Ground Projection Length

$P_{wMin} \equiv$ Ground Projection Width at Nearest Point in FOV

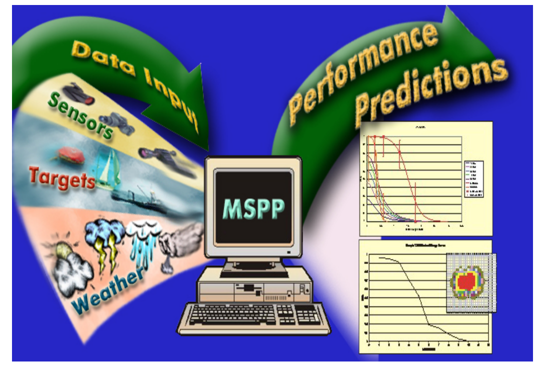
$P_{wMax} \equiv$ Ground Projection Width at Furthest Point in FOV

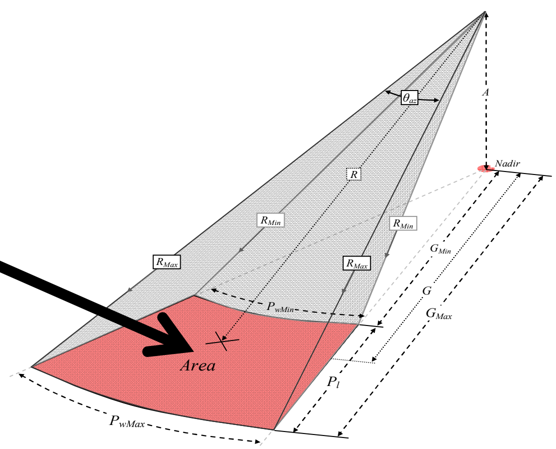
Multi-Sensor Performance Prediction (MSPP)

A VALIDATED SOFTWARE TOOL THAT ASSISTS ANLYSTS IN PREDICTING SENSOR PERFORMANCE FOR CG MISSIONS

Gridded POD Output from MSPP

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0	1	7	10	7	3	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	2	8	45	28	4	7	44	75	77	72	42	7	1	0	0	0	0	0	0	0
0	0	0	0	0	2	15	76	78	71	25	29	92	97	95	90	78	61	6	1	0	0	0	0	0	0
0	0	0	0	1	9	86	93	97	97	85	97	100	100	100	98	90	75	31	2	0	0	0	0	0	0
0	0	0	0	3	31	94	98	100	100	100	100	100	100	100	100	96	84	64	6	0	0	0	0	0	0
0	0	0	1	5	62	97	100	100	100	100	100	100	100	100	100	98	89	69	10	1	0	0	0	0	0
0	0	0	1	6	73	98	100	100	100	100	100	100	100	100	100	98	89	69	11	1	0	0	0	0	0
0	0	0	1	5	63	97	100	100	100	100	100	100	100	100	100	97	85	64	8	0	0	0	0	0	0
0	0	0	0	3	34	95	98	100	100	100	100	100	100	100	99	92	73	51	4	0	0	0	0	0	0
0	0	0	0	1	11	90	95	98	98	94	86	100	100	99	92	75	54	14	1	0	0	0	0	0	0
0	0	0	0	0	3	22	86	89	86	66	26	62	82	78	66	49	35	2	0	0	0	0	0	0	0
0	0	0	0	0	1	3	14	68	58	32	11	6	25	33	32	9	2	0	0	0	[illegible]	0	0	0	0
0	0	0	0	0	0	0	1	3	5	3	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0





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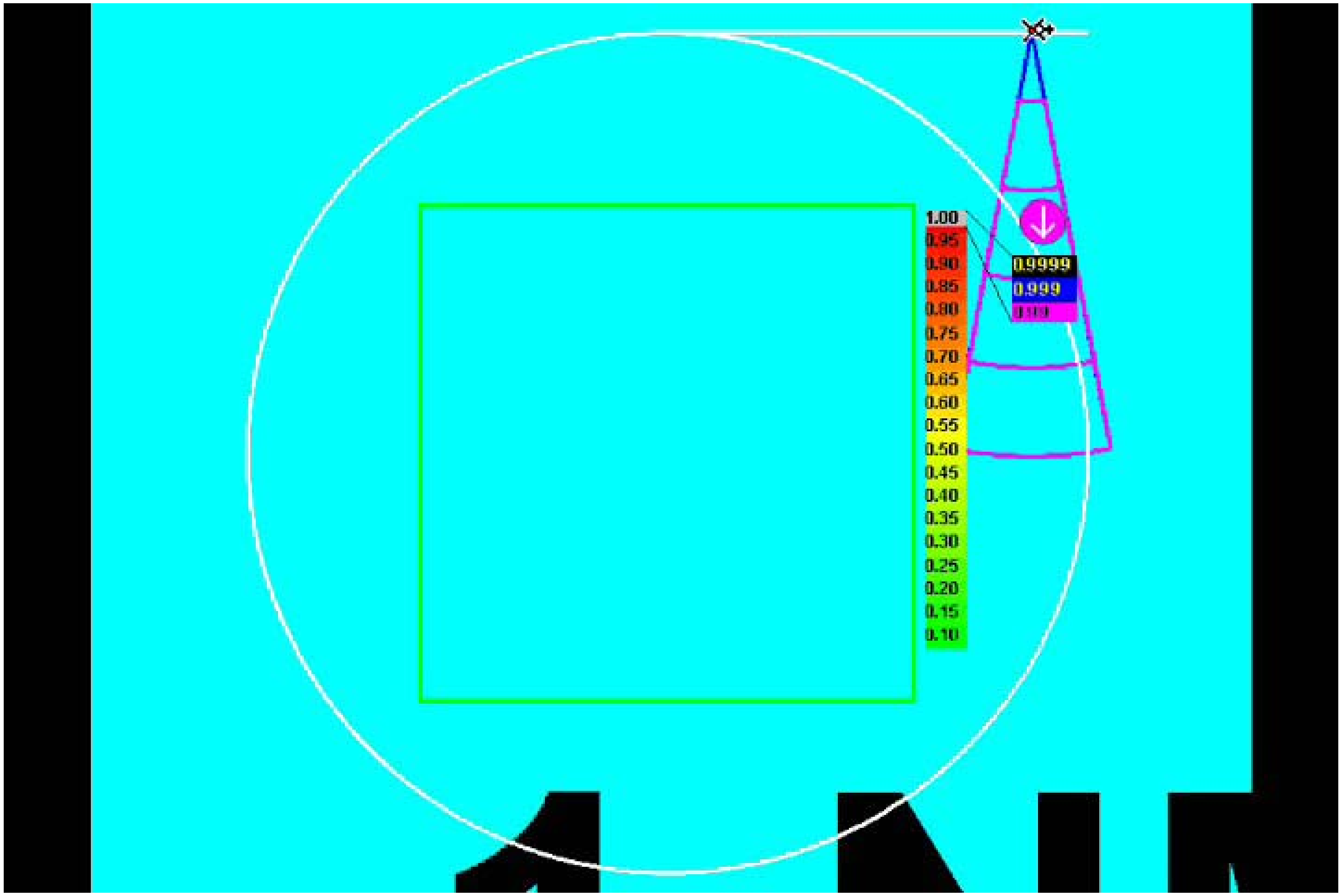
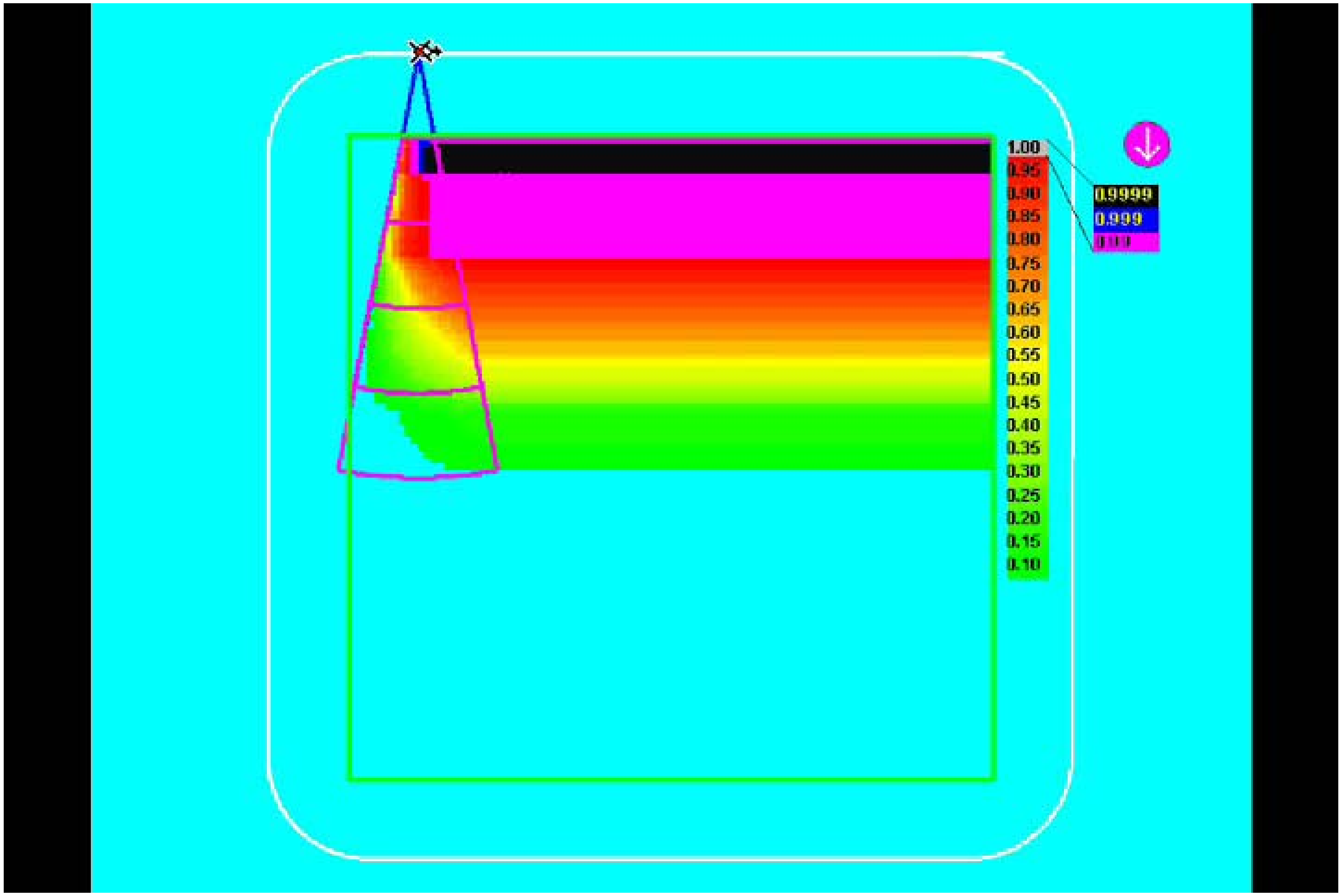
Exotic Circle



Rounded Square



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More about GCAM

Modeling, Simulation, and Analysis Approach

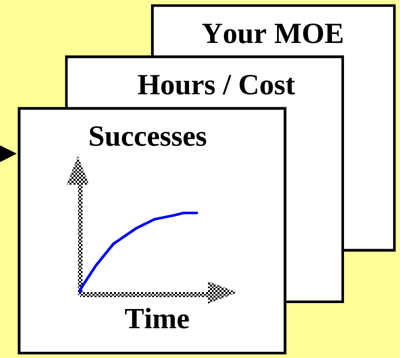
Baseline Analysis

Define Scenario

- Identify real-world operations
- Select operational situations (OPSITS) that place stress on key assets.

GCAM

Create simulation and conduct analysis to establish baseline effectiveness values.



Excursion Analyses

Technology options:

- New technologies
- Replacement technologies
- Performance options

Revise CONOPS w.r.t. selected option:

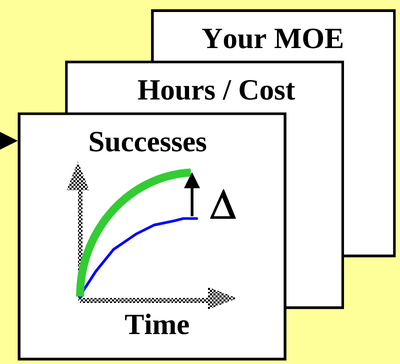
- Force deployment & employment
- Changes to decision-making

GCAM

Repeat model runs with selected options for comparison to baseline effectiveness values.

Use results to refine technology options.

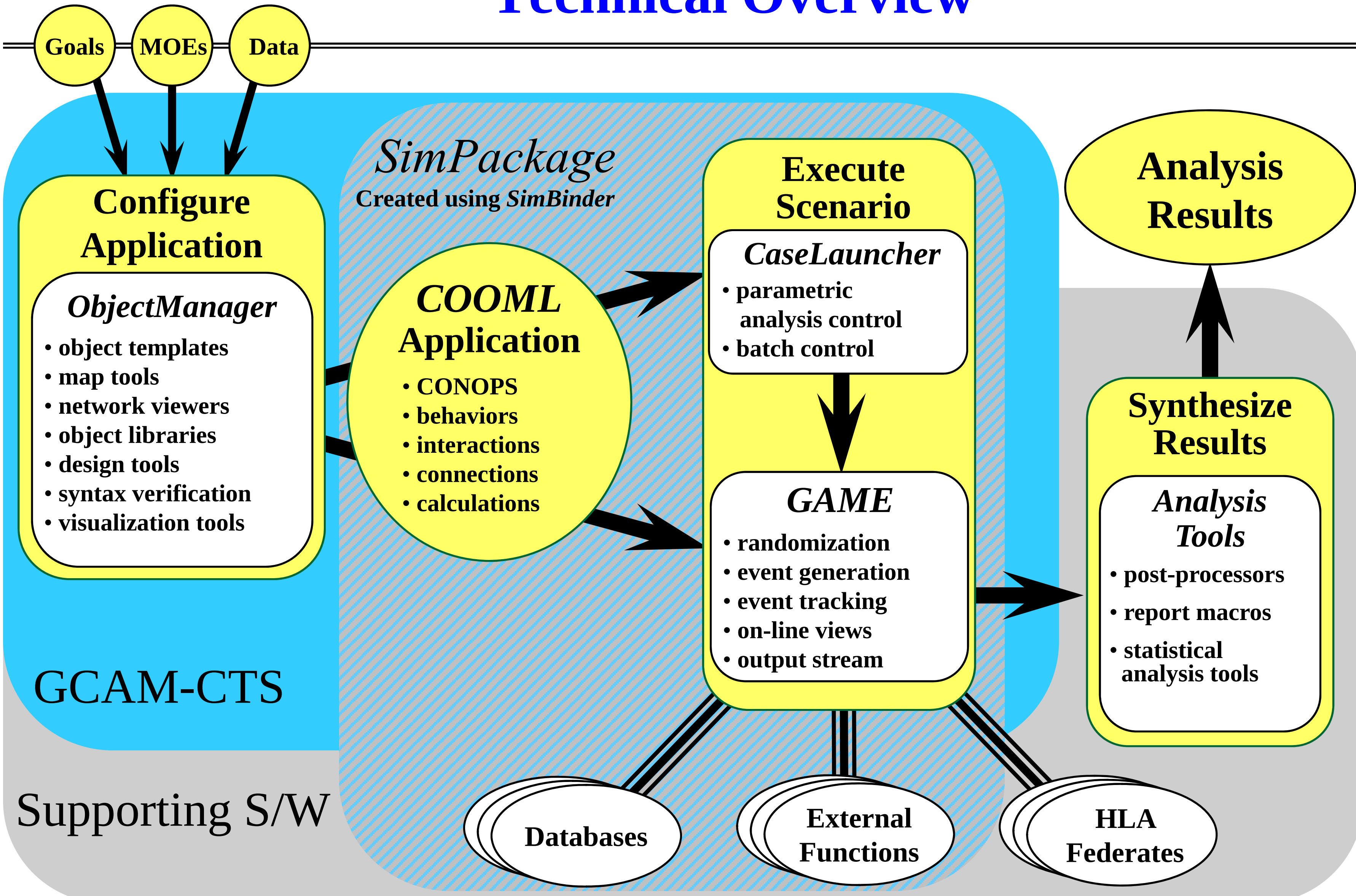
Refine CONOPS.



Key GCAM Capabilities

- Support rapid development and execution of M&S projects
- Provide flexibility to …
  - Employ PCs
  - Use available data with little reformatting
  - Set resolution to match analysis requirements
  - Mix scripted with stochastic behaviors
  - Match operational tempo to required antecedents
    - E.g. actionable intelligence, weapons/platforms availability, …
  - Endow objects with critical decision-making functionality
  - Capture entire hierarchy of MOEs/MOPs
- Leverage large, talented user base – since 1995
- Integrate cutting-edge M&S with military experience and expertise

The GCAM Core Tool Suite Technical Overview



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