712CD

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Chemical-Biological-Radiological Reconnaissance Performance Functional Analysis (PFA)

13 June 2007

Presented to:

MORS Symposium
Working Group #26 – Analysis of Alternatives (AoA)
U.S. Naval Academy
Annapolis, Maryland

Presented by:

Frank Wysocki
Director, Analytical Services

John Bray
Senior Analyst

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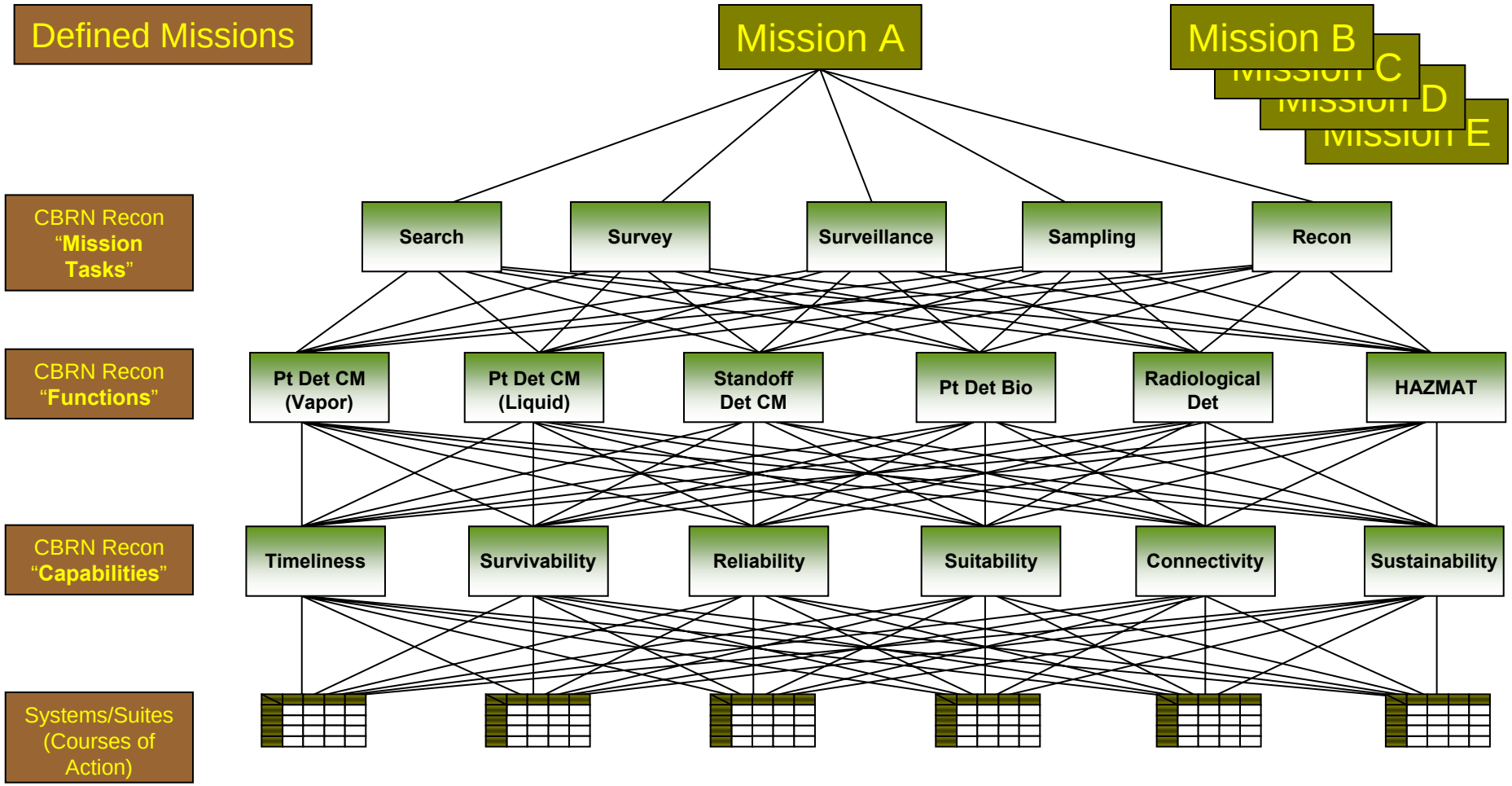
Senior Military Analyst

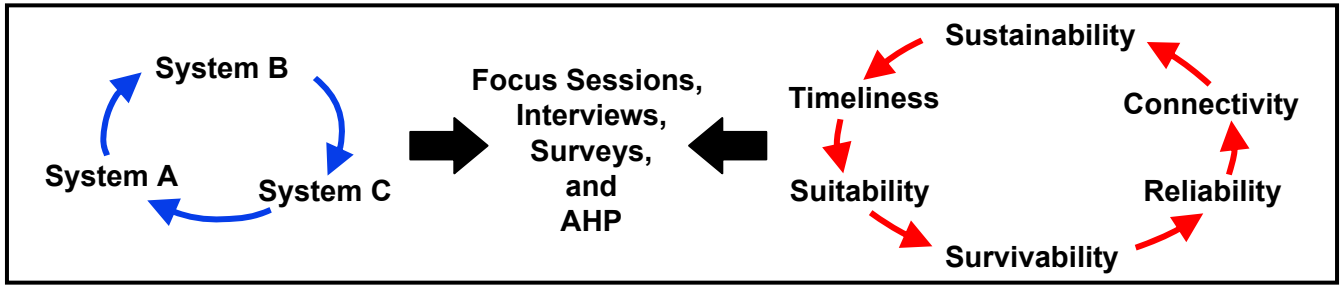
PFA for Recon

- **The Project**
  - Examine all aspects of chemical-biological-radiological reconnaissance.
  - Focus on mission execution, function feasibility, and system performance.
  - Identify capability gaps at various levels.
  - Establish a basis for future acquisition programs and initiatives.
  - Formulate an analytical process that can be replicated in the future.
- **The Process**
  - Questionnaires, interviews, seminars, and technical information research.
  - Free response and qualitative input.
  - Qualitative (Rating) → Quantitative (Ratio).
  - Analytical Hierarchy Process (AHP) – the analytical tool.
- **The Audiences**
  - Junior officers in Chemical School.
  - Senior NCOs in advanced courses.
  - Government employees in program/product management.
  - Staff and faculty at the Chemical School.
  - Reserve officers on active duty.
  - Contractors involved with CBRN issues.
  - Other Subject Matter Experts (SMEs).

PFA – The Structure

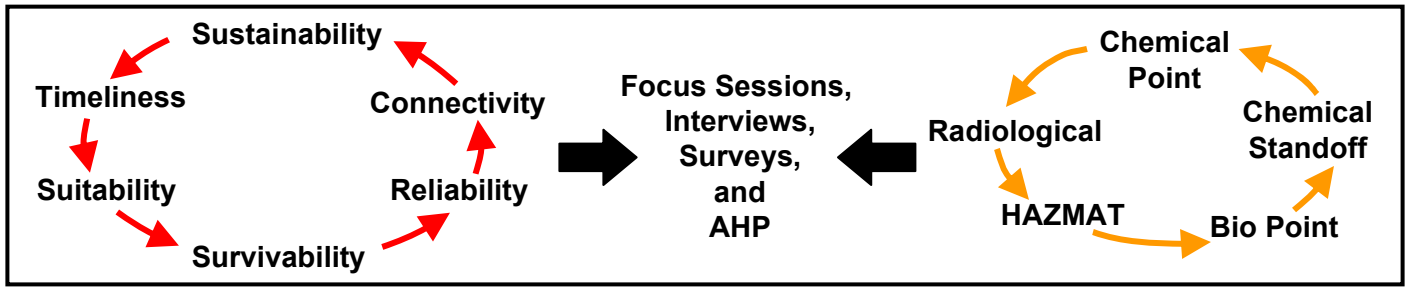


Lower Levels of Analysis
System – Capabilities – Functions



Level #1 Assess Systems with Respect to Capabilities

+



Level #2 Assess Capabilities with Respect to CBRN Functions

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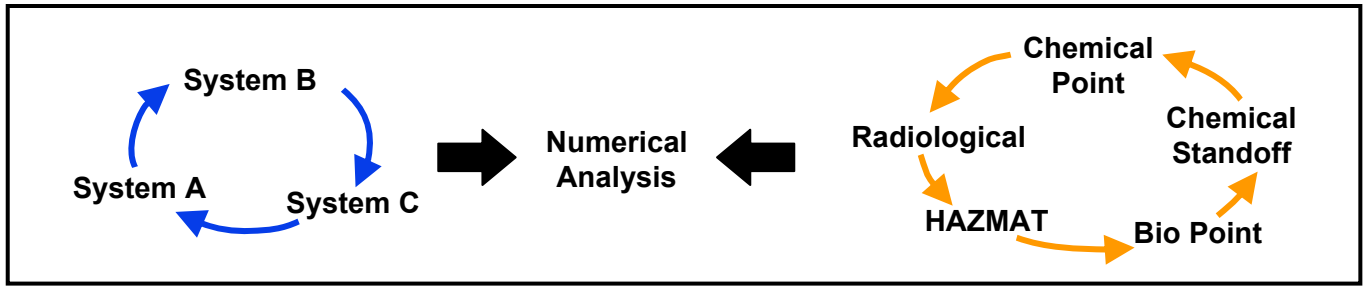
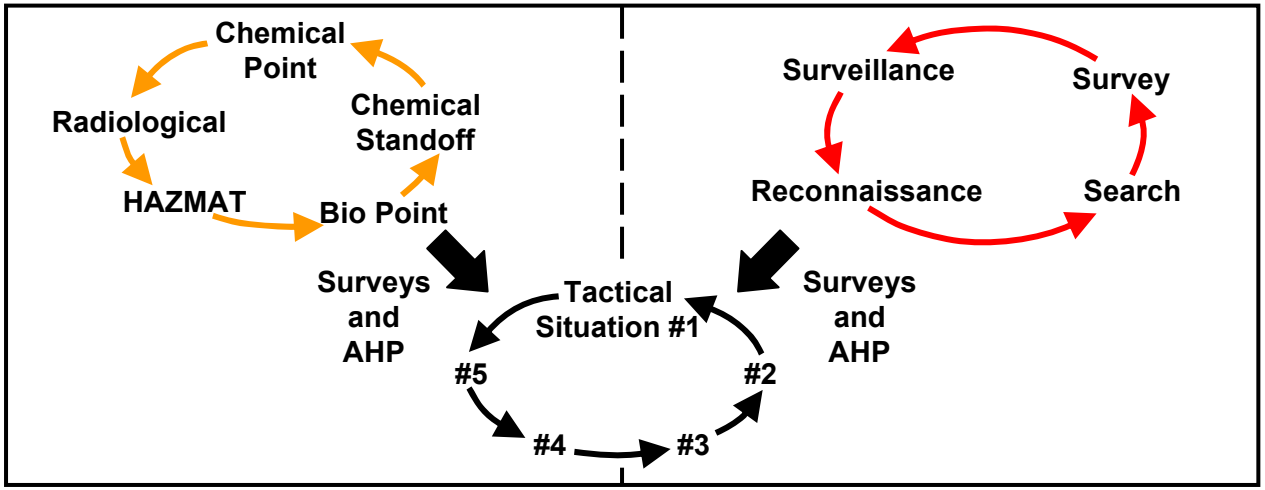


Level #1/2 Assess Systems within CBRN Functional Areas

Higher Levels of Analysis
Functions – Mission Tasks – Situations



Level #3 Assess CBRN Functions with Respect to Tactical Situation

Level #4 Assess Mission Tasks with Respect to Tactical Situation

Analytical Hierarchy Process (AHP)

- "Systematic Method for Comparison of Objectives or Alternatives."
- Founded on setting up a matrix, each cell reflecting a pairwise comparison between two alternatives.
- "A" compared with "B," "A" compared with "C," "B" compared with "C."
- Reasonable with a small number of alternatives; overwhelming with a large number of comparisons.
- 1,144 comparisons in project (372 at the system level).
- "Need another approach …one that is 'doable' "

Desire	Outcome
Mathematical Purity ↕ Flexibility	Rigidity & Apathy ↕ Quality Data

"Workaround" Approach

- Ordinal Ratings
  - Each system with respect to each capability
  - Not pairwise, but independent
  - Scale 1 → 5
- Conversion
  - Ordinal to Pairwise
- Form Comparison Matrix
- Manipulate $[M]^n$ and calculate potential solution vectors
- Convergence to the solution

"Number Flow" Example

Individual Ordinal Ranking
"Rate the capabilities with respect to their importance in Chemical Point Detection" (1 = low; 5 = high).

Capability	Rating
Timeliness	4
Survivability	2
Reliability	5
Suitability	4
Connectivity	3
Sustainability	2

Convert to Pairwise

Translation Scheme

First Item Ordinal Rating	Second Item Ordinal Rating 5	4	3	2	1
5	1 / 1	3 / 1	5 / 1	7 / 1	9 / 1
4	1 / 3	1 / 1	3 / 1	5 / 1	7 / 1
3	1 / 5	1 / 3	1 / 1	3 / 1	5 / 1
2	1 / 7	1 / 5	1 / 3	1 / 1	3 / 1
1	1 / 9	1 / 7	1 / 5	1 / 3	1 / 1

Example #1 Timeliness with Respect to Sustainability

(Ordinal = 4) (Ordinal = 2)

Translation

5/1

Example #2 Survivability with Respect to Reliability

(Ordinal = 2) (Ordinal = 5)

Translation

1/7

Individual Pairwise Comparison

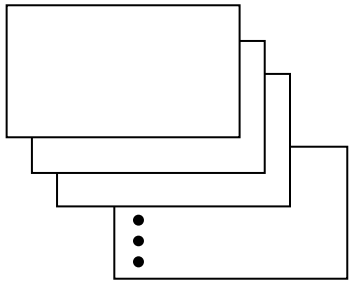
	Timeliness	Survivability	Reliability	Suitability	Connectivity	Sustainability
Timeliness	1.00000	5.00000	0.33333	1.00000	3.00000	5.00000
Survivability	0.20000	1.00000	0.14286	0.20000	0.33333	1.00000
Reliability	3.00000	7.00000	1.00000	3.00000	5.00000	7.00000
Suitability	1.00000	5.00000	0.33333	1.00000	3.00000	5.00000
Connectivity	0.33333	3.00000	0.20000	0.33333	1.00000	3.00000
Sustainability	0.20000	1.00000	0.14286	0.20000	0.33333	1.00000

Ex. #1

Ex. #2

"Number Flow" Example (continued)

Individual Pairwise Comparisons



Collapse

Cell-by-Cell Average by Geometric Mean

$$R = \sqrt[n]{R_1, R_2, \ldots R_n}$$

Group Pairwise Comparison Matrix

	Timeliness	Survivability	Reliability	Suitability	Connectivity	Sustainability
Timeliness	1	2.758377833	0.812289743	1.341347898	1.150410074	1.919471220
Survivability	0.362531916	1	0.604888287	0.726814056	1.505139884	1.200803060
Reliability	1.231087809	1.653197824	1	1.901855432	2.187913648	2.493898362
Suitability	0.745518744	1.375867723	0.525802321	1	1.721459696	0.854751400
Connectivity	0.869255253	0.664390075	0.457056429	0.580902360	1	1.087595747
Sustainability	0.520976814	0.832776026	0.400978651	1.169930813	0.919459278	1

Sum row cells and divide each row by grand total.
Form potential solution vector.
Stop when k^{th} vector ≈ $(k-1)^{ST}$ vector.

Solution Vector

Capability	Vector
Timeliness	0.220738803720
Survivability	0.129842467663
Reliability	0.258669464898
Suitability	0.152424335709
Connectivity	0.119144108758
Sustainability	0.119180819252

Chemical Point Detectors within Capabilities

What is Being Assessed

Basis for Assessment

Capability	M256A1	ICAM	LCD	Ahura Defender	Total
Timeliness	.109	.225	.288	.378	1.000
Survivability	.180	.267	.358	.195	1.000
Reliability	.214	.144	.350	.292	1.000
Suitability	.154	.196	.337	.313	1.000
Connectivity	.119	.174	.422	.285	1.000
Sustainability	.263	.175	.341	.221	1.000

M256A1 – Long history of use, limited in detection of liquid hazards.

Lightweight Chemical Detector (LCD) – Small size, robust detection capability, ease of use, low power requirement.

Capabilities within Functions

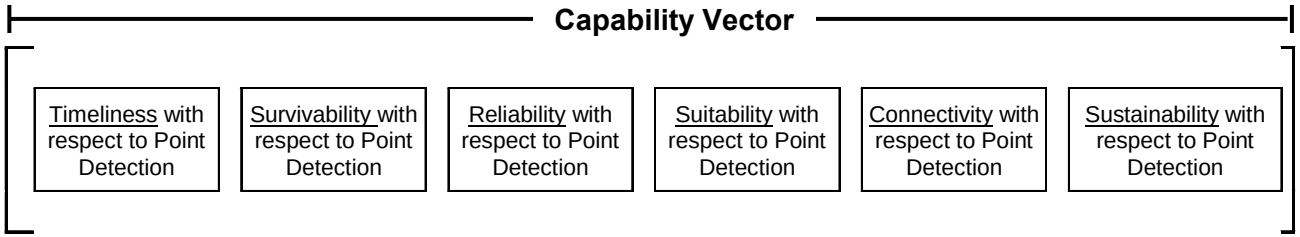
What is Being Assessed

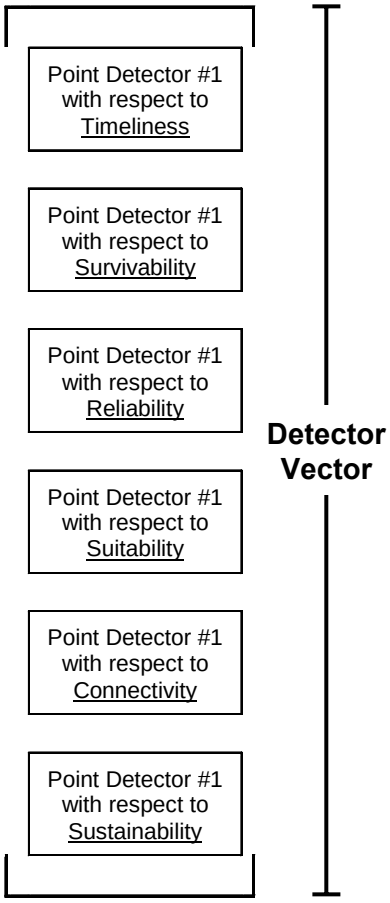
Basis for Assessment

CBRN Function	Timeliness	Survivability	Reliability	Suitability	Connectivity	Sustainability	Total
Chemical Point Detection for Vapor	.212	.120	.278	.170	.109	.111	1.000
Chemical Point Detection for Liquid and Solid	.221	.130	.259	.152	.119	.119	1.000
Chemical Standoff Detection	.161	.103	.341	.148	.152	.095	1.000
Biological Point Detection	.178	.131	.310	.136	.133	.112	1.000
HAZMAT Detection	.198	.113	.271	.140	.161	.117	1.000
Radiological Detection	.198	.104	.321	.151	.115	.111	1.000

“It has to work!!”

Chemical Point Detectors within Functional Area





"Capability within Functional Area" Vector

"Point Detector #1 within Capability" Vector

Yields

"Point Detector #1" within "Point Detection Function" Ranking

Chemical Point Detection Summary

Detection System	[(Timeliness) x (Rating)] + [(Survivability) x (Rating)] + [(Reliability) x (Rating)] +
	[(Suitability) x (Rating)] + [(Connectivity) x (Rating)] + [(Sustainability) x (Rating)] =
M256A1	0.221 x 0.109 + 0.130 x 0.180 + 0.259 x 0.214 +
	0.152 x 0.154 + 0.119 x 0.119 + 0.119 x 0.263 **0.1718**
ICAM	0.221 x 0.225 + 0.130 x 0.267 + 0.259 x 0.144 +
	0.152 x 0.196 + 0.119 x 0.174 + 0.119 x 0.175 **0.1931**
LCD	0.221 x 0.288 + 0.130 x 0.358 + 0.259 x 0.350 +
	0.152 x 0.337 + 0.119 x 0.422 + 0.119 x 0.341 **0.3429**
Ahura Defender	0.221 x 0.378 + 0.130 x 0.195 + 0.259 x 0.292 +
	0.152 x 0.313 + 0.119 x 0.285 + 0.119 x 0.221 **0.2923**
TOTAL	**TOTAL** **1.0000**

CBRN Detection Functions' Relevance and Importance within Tactical Situations

Tactical Situation	Chemical Vapor Point Detection	Chemical Liquid & Solid Point Detection	Chemical Standoff Detection	Biological Point Detection	HAZMAT Detection	Radiological Detection
# 1	.291	.260	.166	.119	.099	.065
# 2	284	.287	.130	.111	.124	.064
# 3	.254	.248	.077	.145	.197	.079
# 4	.224	.231	.129	.203	.148	.065
# 5	.247	.257	.142	.173	.097	.084
# 6	.236	.228	.130	.158	.180	.068
# 7	.187	.211	.324	.087	.107	.084
# 8	.262	.249	.187	.081	.154	.067
# 9	.221	.204	.195	.130	.146	.104
# 10	.283	.300	.130	.097	.103	.087
# 11	.248	.199	.210	.141	.120	.082

CBRN Detection Functions' Capability (Personnel) and Availability (Equipment) within Tactical Situations

Tactical Situation	Chemical Vapor Point Detection	Chemical Liquid & Solid Point Detection	Chemical Standoff Detection	Biological Point Detection	HAZMAT Detection	Radiological Detection
# 1	.298	.270	.117	.093	.115	.107
# 2	.293	.298	.127	.089	.103	.090
# 3	.252	.270	.134	.097	.128	.119
# 4	.276	.298	.141	.078	.097	.110
# 5	.271	.290	.134	.084	.084	.137
# 6	.276	.276	.121	.097	.113	.117
# 7	.239	.304	.151	.101	.094	.111
# 8	.264	.264	.151	.082	.106	.133
# 9	.258	.258	.172	.083	.115	.114
# 10	.294	.274	.153	.082	.076	.121
# 11	.328	.277	.134	.078	.092	.091

CBRN Detection Functions' Ratios of Importance of Functions to Ability in Performance

Tactical Situation	Chemical Vapor Point Detection	Chemical Liquid & Solid Point Detection	Chemical Standoff Detection	Biological Point Detection	HAZMAT Detection	Radiological Detection
# 1	0.977	0.963	1.419	1.280	0.861	0.607
# 2	0.969	0.963	1.024	1.247	1.204	0.711
# 3	1.008	0.919	0.575	1.495	1.539	0.664
# 4	0.812	0.775	0.915	2.603	1.526	0.591
# 5	0.911	0.886	1.060	2.060	1.155	0.613
# 6	0.855	0.826	1.074	1.629	1.593	0.581
# 7	0.782	0.694	2.146	0.861	1.138	0.757
# 8	0.992	0.943	1.238	0.988	1.453	0.504
# 9	0.857	0.791	1.134	1.566	1.270	0.912
# 10	0.963	1.095	0.850	1.183	1.355	0.719
# 11	0.756	0.718	2.692	1.808	1.304	0.901

$$\text{Each Cell} = \frac{\text{Importance Rating}}{\text{Capability Rating}}$$

CBRN Mission Tasks
General Context Assessment

Criteria	Search	Survey	Surveillance	Reconnaissance
	"Find It"	"Define It"	"Watch for It"	"Avoid It"
Frequency of Performance	.327	.172	.144	.357
Difficulty in Execution	.169	.457	.146	.228
Importance to Tactical Mission	.305	.249	.186	.260
Proficiency and Training of Personnel	.274	.192	.260	.274
Preparedness (Quantity and Quality) of Equipment	.303	.231	.163	.303

Recon Performance Functional Analysis Objectives Achieved

- Provided insight into system operator and crew needs and wants.
- Exploited the knowledge of SMEs (operators/crews, trainers, doctrine formulators).
- Made use of diversified audiences at each level (officers, NCOs, instructors, operators, active and reserve).
- Applied concurrent analytical activities.
- Created a tool for future development in doctrine, TTP, and system design.
- Extrapolated knowledge of current systems into future system performance requirements.
- Established a synergistic use of qualitative and quantitative techniques.
- Enabled a “quality control check” by comparison of quantitative results with narrative input (“agreement” between both sources was extremely high).