ISR EXPLOITATION CELLS READINESS ASSESSMENT

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ABSTRACT

The backbone of any situational awareness such as in a military environment is the exploitation capability of the Intelligence Surveillance and Reconnaissance (ISR) Exploitation Cell (ISREC), which, processes, exploits and disseminates the required information to the requester or decision makers. Regardless of scale or resolution, decision makers have the need for accurate, relevant, and timely information, which requires an environment that enables rapid data processing, production of the reports and dissemination of information.

To establish a robust and interactive ISREC infrastructure, a cell requires flexibility to plan the data processing framework using the best possible combination of systems and tools. The outputs of the cell should satisfy the mission requirements in terms of processing and managing all data sources as well as producing and disseminating ISR data. It should also be capable of developing contingency plans as required, in case of unforeseen problems or changes that might arise in terms of system failures and changes in capability requirements.

The objective of this study is to provide a methodology to evaluate the performance and the level of implementation of the exploitation capabilities of participating systems used in the ISREC. This analysis is essential for identifying the strength of certain exploitation capabilities, and the results will help in producing a coherent virtual ISREC environment. An ISREC exploitation capability readiness assessment methodology based on Analytic Hierarchy Process (AHP) has been developed and implemented to meet this objective. The AHP method with respect to current ad-hoc paper based methods provides an environment for structured, more rapidly executable and traceable analysis to select different capabilities and sub-capabilities for different levels of integration. This paper will present the methodology, the selection of criteria and sub-criteria related to exploitation tools available to the ISREC. The paper will conclude by providing an example of assessing an environment using the proposed methodology.

Keywords: Defence, Assessment, Command & Control, Exploitation, AHP, ISR

1. Introduction

The goal of developing enhanced information tools is to improve accuracy and response time, either by providing more relevant and accurate information, or by simplifying the complexity and amount of information available to the user. Regardless of the range of scale and resolution, decision makers have the need for accurate, relevant, and timely information. Whether for strategic or tactical decision makers, there is a need for tools that enable rapid information transfer between all levels. In an ideal situation, decision makers would have near real-time access to any and all information they might require at the time. Historically, information has been passed down from higher-level analysts to whomever they believe needs it. In contrast, a bottom-up request-driven information flow requires sensor processing tools that are able to provide search and alert capabilities, so that individual analysts can filter out irrelevant information. The challenge for researchers is to develop efficient, reliable, robust and accurate methodologies and metrics to properly evaluate the operational effectiveness of any current and new assets. The objective of this paper is present a methodology to evaluate the performance level of exploitation system implementation and demonstrate how this methodology supports analysis to identify the strength of a given exploitation system. In doing so, a military commander or planner will able to:

- Identify and select the ideal combination of systems to improve overall ISREC performance
- Improve the accuracy, quality and dissemination of exploitation products
- Improve a commander's confidence level in the decision making process by assessing the best available capabilities

This paper is organized in the following sections: Exploitation framework capability, Evaluation procedure, Scenario, Results and Analysis, and Conclusions and Recommendations.

2. Exploitation framework capability

The exploitation framework of an ISREC is defined as an environment which can receive and process ISR data and disseminate the ISR products. The framework has to be robust and flexible in order to organize the exploitation systems in order of processing requirements, integration, protecting the processing capability due to system failure, requirement changes and increase in work load. The framework integrates all ISR system's ground segments, exploitations systems, databases and the operators through a robust network architecture. This paper will cover only the parts related to exploitation capability evaluation.

3. Evaluation procedure

The ISREC exploitation framework design and evaluation process is shown in Figure 1. The steps needed for this process are as follows:

- Develop exploitation and network architecture requirements:
  Subject Matter Experts (SMEs) will analyze the operational requirements and produce the exploitation and network architecture requirements
- Evaluate exploitation capability:
  The available systems will be evaluated and gaps in capability will be identified. Additional requirements to either add a new system or upgrade an existing system will be created to address the exploitation gaps.
- Rank the exploitation systems:
  The exploitation systems will be ranked by the SME's based on their overall performance, individual capabilities and sub-capabilities.
- Design the ISREC framework:
  The framework design will be based on operational, exploitation and architecture network requirements with consideration of the ISR exploitation system capability ranking results.
- Test and evaluate:
  The ISREC exploitation framework will be tested and evaluated. If there are gaps in performance or the architecture, new requirements will be added for redesign of the framework.
- Final ISREC exploitation framework:
  The final ISREC exploitation framework should satisfy all operational readiness requirements.

Figure 1 shows all the steps in the exploitation capability evaluation process, and an example is also used to illustrate this process in section 4. The Analytic Hierarchy Process evaluation methodology was selected for evaluating the implementation of different exploitation capabilities by different systems.

Based on reference (Jassemi, 2009), an exploitation tools capability survey was prepared and provided to the exploitation system owners. Each system owner provided their comments on their systems' exploitation capabilities, and these comments were used for an overall performance evaluation of their system's capability and levels of implementation. The green boxes in Figure 1 represent where the AHP method is used.

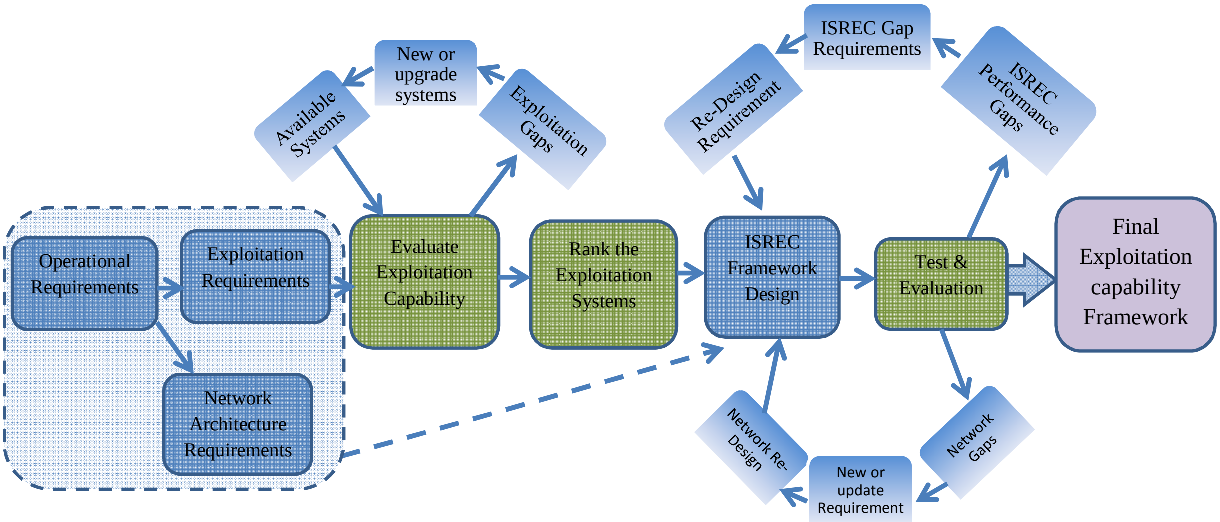

Figure 1. The exploitation capability evaluation process

4. Scenario, results and analysis

The scenario was selected to illustrate the process for the ISREC exploitation framework design and evaluation as shown in Figure 2. It includes 12 exploitation systems and 12 exploitation capability requirements identified by SMEs. These 12 capabilities include 63 sub-capability requirements in total. The goal is to evaluate exploitation capabilities of the systems and identify the level of integration for the ISREC framework.

4.1 Develop exploitation and network architecture requirements

SMEs will analyze the operational requirements and produce the exploitation and network architecture requirements. This paper will be concentrating on exploitation requirements.

4.2 Evaluation of exploitation capability requirements

The AHP method was used for evaluation of exploitation capability. The AHP method is based on different levels of elements including a goal, criteria, sub-criteria and alternatives. These levels can be expanded based on the complexity of the process (Saaty, 1995). As shown in Figure 2, the evaluation of the implementation is divided into three levels of figures of merit (goal, capabilities (or criteria) and sub-capabilities (or sub-criteria)), and the alternatives which represent the list of available exploitation systems. The goal for this evaluation is "Overall Exploitation Capability", and to achieve this goal, there are twelve capabilities and a number of sub-capability for each that have been identified by subject matter experts which are based on mission requirements. The AHP method allows the decision makers to evaluate different levels of integration of exploitation systems not only based on individual systems performance but also with consideration of the network availability and robustness between the systems. As part of this evaluation the following steps are required:

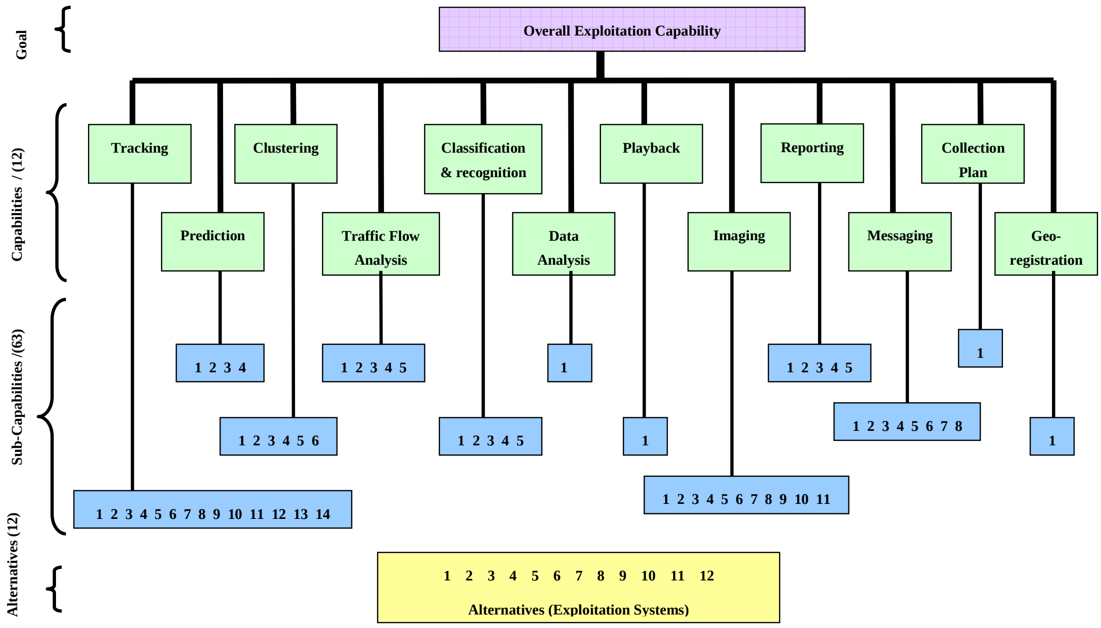

Figure 2. Structure of the evaluation of implementation of exploitation capabilities.

4.2.1 Survey Questionnaire

The questions in this survey were prepared based on all capabilities and sub-capabilities to collect the information required to evaluate the systems. Each system owner provided unclassified comments on their system based on the best of their knowledge (Jassemi, 2009).

4.2.2 Implementation Grading

This analysis is meant to provide an overall evaluation of current capabilities of the systems, and to hide the confidentiality of the systems. Each system was numbered randomly so that there was no way of deducing system performance from a specific system from the results and analysis. The grading level of each implementation could be defined by the AHP method but for this paper to simplify the process; three grading capabilities were selected based on subject matter expert's recommendations:

- Fully Implemented (100%)
  - Implementation of the exploitation tool or capability was fully satisfactory
- Partially Implemented (50%)
  - Implementation of the exploitation tool or capability was partially satisfactory
- Not Implemented (0%)
  - No implementation was done

4.2.3 Evaluation of exploitation system requirements

The evaluation process was conducted in two stages; one based on individual system capabilities (Scenario 1), and a second based on joint systems capabilities (Scenario 2).

Scenario 1: Individual system implementation evaluation

This analysis was conducted for evaluating the implementation of exploitation tools/capabilities within each individual system. This would be considered for situations when there is either no or very weak integration between exploitation systems. Therefore, each system needs to address all related exploitation requirements. There are different options of weighting scales for this type of evaluation. This paper presents two ways that are used in this study to prove the concept:

- Equal capability weighting scenario (S1.1): This evaluation is based on each element at the capability level (12 elements). For this analysis the weight for each element is considered to be equal, and as a result each sub-capability element would have different values. Therefore, each capability has an equal weight of 1/12= 0.08330 and each sub-capability weight is presented in Table 1.
- Equal sub-capability weighting scenario (S1.2): This evaluation is based on individual elements in sub-capability (63 elements). For this analysis, the weights of each sub-capability elements are considered to be equal. , The weight factor for each sub-capability is one over total number of elements (1/63=0.01587). As a result, the elements in each capability level have different weights as shown in the Table 1 with a total of combined weight of 1.

Table 1. The weight factor for individual sub-capability.

#	Capability	# of sub-capability elements	The weight of each sub-capability (S1.1)	Total weight of each capability (S1.2)
1	Tracking (TR)	14	0.00595	0.22218
2	Prediction Tools (PT)	4	0.02083	0.06348
3	Clustering Tools (CT)	6	0.01388	0.09522
4	Traffic Flow Analysis (TFA)	5	0.01666	0.07835
5	Classification and Recognition Tools (CRT)	5	0.01666	0.07835
6	Data Analysis Tools (DA)	1	0.08330	0.01587
7	Playback Tools (PT)	1	0.08330	0.01587
8	Imaging Tools (IT)	11	0.00757	0.17457
9	Reporting Tools (RT)	5	0.01666	0.07835
10	Messaging Tools (MT)	8	0.01041	0.12696
11	Collection plan Tools (CPT)	1	0.08330	0.01587
12	Geo-registration / co-registration Tools (GR)	2	0.04165	0.03174
	Total	63		1.0

- Weight estimation using priority vector computation based on comparison matrix scenario (S1.3): the weight estimation in AHP requires generation of the comparison matrix and inputs from Subject Matter Experts (SME) (Saaty 2009, Jassemi, 2013). Therefore, a comparison matrix was produced with respect to 10 out of 12 criteria. This is due to reducing the sensitivity of AHP methodology respect to large pairwise comparison matrices. The comparison matrix was generated based on SMEs inputs as shown in Table 2, and the results of the weight estimation for each criteria is shown in Table 2.

Table 2. Pairwise comparison matrix & weights for ISREC criteria.

	TR	PT	CG	TFA	CRT	DA	PBT	IT	RT	GR
TR	1.00	7.00	15.00	18.00	5.00	3.00	10.00	3.00	6.00	9.00
PT		1.00	2.00	2.00	0.20	0.40	1.00	0.10	0.40	0.20
CG			1.00	2.00	0.10	0.10	0.20	0.10	0.20	0.10
TFA				1.00	0.20	0.10	0.10	0.10	0.20	0.20
CRT					1.00	1.00	3.00	0.60	1.00	1.00
DA						1.00	3.00	1.00	1.00	3.00
PBT							1.00	0.30	0.30	2.00
IT								1.00	2.00	4.00
RT									1.00	2.00
GR										1.00
Weights	0.358	0.030	0.015	0.013	0.098	0.118	0.055	0.159	0.086	0.067

Scenario 2: Joint systems implementation evaluation

This analysis addresses the joint capability of all systems, which provides an overall capability based on the assumption that there is a robust network integration architecture supporting the systems at ISREC. This allows the commander to take advantage of each system's exploitation capabilities and make decisions based on the best possible information. This environment also provides an opportunity for commanders to select the exploitation systems that provide the best joint capability to address current requirements. This paper presents two ways in which one can combine the capabilities:

- Equal capability weighting (S2.1): This is based on individual elements in the capability level. This is the same scenario as describe in S1.1 and shown in Table 1, however, for this case any alternative system (as shown in Figure 2) can be used to satisfy individual capabilities.

- Equal sub-capability weighting scenario (S2.2): This is based on individual elements in the sub-capability level. This is the same scenario as described in S1.2 and shown in Table 1, however for this case, any alternative system (as shown in Figure 2) can be used to satisfy the individual sub-capability.

4.3. Ranking the exploitation systems

Based on the responses received from the survey questions and applying the implementation grading described in section 4.2.2, the assessment table was produced and only part of it due to releasability restriction is presented in Table 3 (Jassemi, 2009).

Table 3: The subset of results of the implementation grading for each system considered.

			List of Exploitation Systems											
Tools/ Capabilities		**Sub- Cap.**	1	2	3	4	5	6	7	8	9	10	11	12
1	**Tracking Tools**	1	0	0	100	50	50	100	100	100	100	0	0	0
		2-14												
2- 12		15- 63												

The individual implementation evaluation results were conducted based on inputs from Table 1, 2 and 3, and using the following equation:

- Calculation of overall score (S_i) for each system when the capability weight is considered to be constant:

$$s_i = \sum_{j=1}^{m} \sum_{k=1}^{n} \tfrac{1}{n} C_{i.j.k} w_c$$

Where:
- $i = 0 \dots P$ (P= total number of systems)
- $j = 1 \dots m$ (m= total number of capabilities)
- $k = 1 \dots n$ (n=total number of sub-capabilities for each capability)
- $C_{i,j,k}$ = The evaluation score of each sub-capability from Table 4.
- w_c = equal weight for each capability (1/m)

- Calculation of the overall score for each system when the sub-capability weight is the same:

$$s_i = \sum_{j=1}^{m} \sum_{k=1}^{n} C_{i.j.k} w_s$$

Where:
- w_s = equal weight for each sub-capability (1/total number of sub-capabilities)

Figure 3 shows the performance of the individual systems against all exploitation capabilities (Scenarios S1.1, S1.2 and S1.3). Based on these results one can rank the systems from highest to lowest performance based on their capability or sub-capability implementation. The results from fixed weight selection for evaluation shows the difference between evaluation systems at criteria and sub-criteria level, but results using the AHP method shows the distribution of weights based on added relative importance of the criteria from SME point of view, and therefore provides a higher fidelity for evaluation of the systems. This also shows more realistic impact of the systems in the exploitation of data, and as a result helps the decision maker architect an appropriate data exploitation framework.

4.4 Design ISREC Framework

For this paper, the exploitation capability framework design was evaluated for capability and sub-capability levels, with three different configurations considered:

- Using individual systems to support all operational exploitation requirements
- Using available exploitation systems and distribute the exploitation work load based on their capabilities
- Using available exploitation systems and distribute the exploitation workload based on their sub-capability

4.5 Test and evaluation

The three configurations described in sub-section 4.4 were tested and results are provided in the following sub section:

4.5.1 Individual systems framework

As shown in Figure 3, none of the 12 exploitation systems considered provided full support for all the capabilities that are listed in this paper. Therefore, there is a need to integrate the exploitation systems in order to provide a joint environment to support all the capabilities required. This figure also shows that some of the systems provide better performance respect to other systems at the sub-capability level. This is not surprising given that being able to include whether a sub-capability is implemented partially, fully, or not at all, provides a "higher resolution" or finer granularity environment for evaluation.

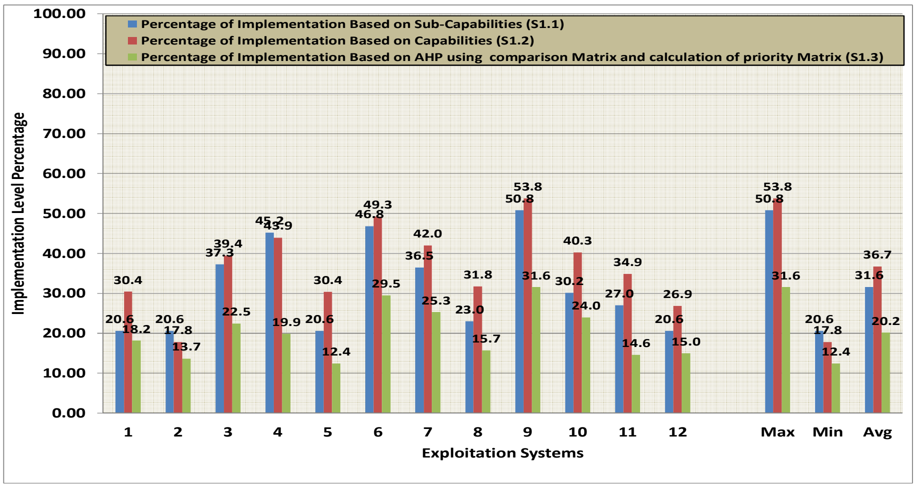

Figure 3. The implementation level for each system (Scenario S1.1, S1.2 and S1.3).

4.5.2 Joint systems at capability level framework

The ISREC can conduct the exploitation requirements at the joint level using different capabilities and sub-capabilities of the exploitation systems. This requires a robust integration between the systems and network architecture, which can be achieved by satisfying the requirements such as data exchange format, latency and availability. Figure 4 shows the number of implemented systems versus each capability. The results show that some of the capabilities are supported by a large number of systems and some are supported by only one or none of the systems. Figure 4 also shows different levels of operational readiness for an ISREC. For this analysis, there are three levels of operational availability of capabilities considered:

- Level 1 (Operational readiness/availability of 70%): at least one system is available
- Level 2 (Operational readiness/availability of 90%): at least two systems are available
- Level 3 (Operational readiness/availability of 95%): at least four systems are available

Therefore, based on these results, the current ISREC readiness for available systems is almost at Level 1 since there is at least one system that satisfies each capability fully with the exception of the "Traffic Flow Analysis" and "Classification and Recognition tools". The decision makers use this type of analysis to identify the gaps in capabilities of the ISREC. In order to improve the readiness of the ISREC, some of the exploitation systems either need to be upgraded or additional systems are required, to address the operational readiness requirements gaps. The results in Figure 4 can also provide a decision maker with the flexibility in assigning the exploitation tasks if they know there are alternate systems that can provide the same capability, thereby possibly optimizing the overall exploitation capability. The selection of which system provides better capability can also be evaluated by using the AHP method but for the joint level it uses score for capability and sub-capability level implementation between systems as long as they satisfy the full implementation requirements.

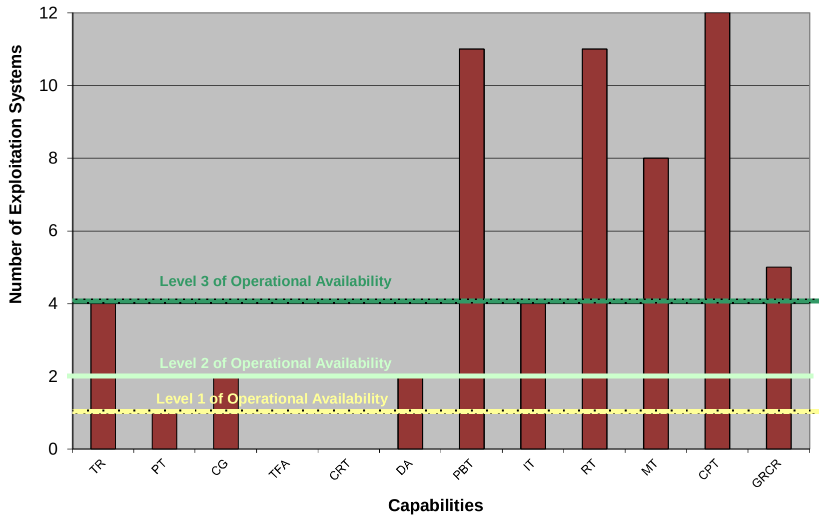

Figure 4. Number of implemented systems for each capability.

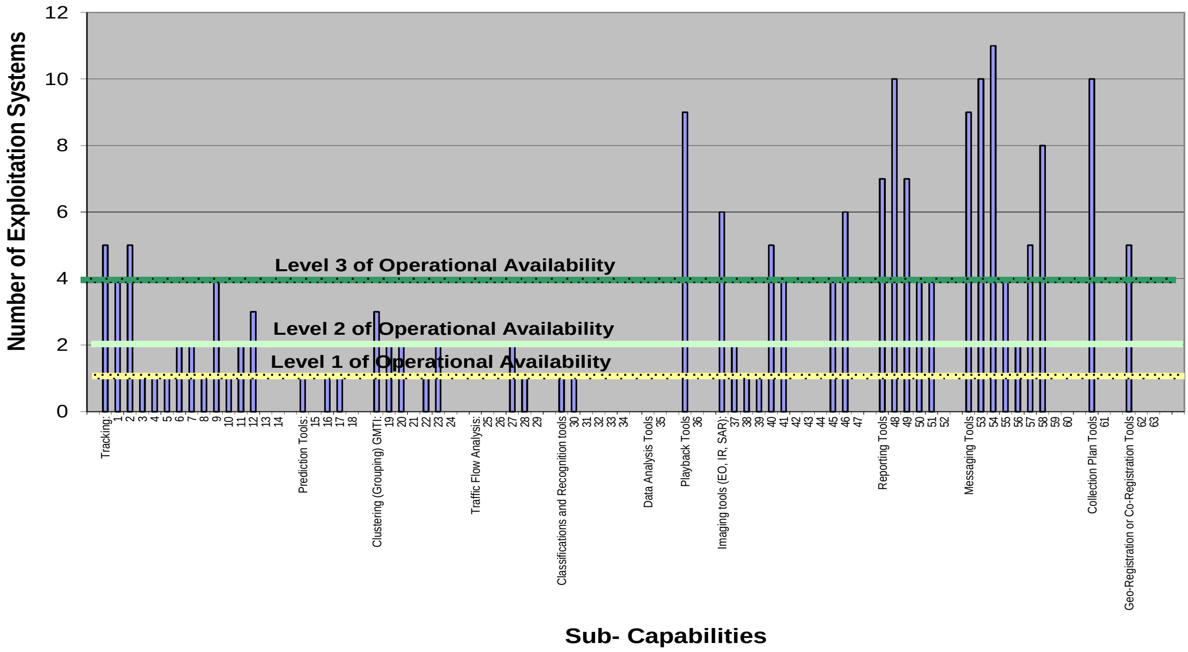

Figure 5. The number of fully implemented systems based on each sub-capability .

4.5.3 Joint systems at sub-capability level framework

Figure 5 shows the number of systems with full implemented sub-capabilities. It also shows the operational availability or readiness of the ISREC. Based on these results, the ISREC design still shows some missing sub-capabilities.

4.5.4 Analysis

Figure 6 shows the relative l performance score for each of individual systems performance (based on Criteria and sub-criteria) verses mixture of systems at joint level (based on criteria and sub-criteria) scenario. The results show that the ISREC with joint capability can improve the best individual system by 45% (51 versus 74). It also shows the joint integration at the sub-capability level can improve the joint level capability performance by 29%. Since the operational availability for different capabilities can be changed based on requirement, the person in charge of the ISREC will base recommendations on the priority and availability of the required capability.

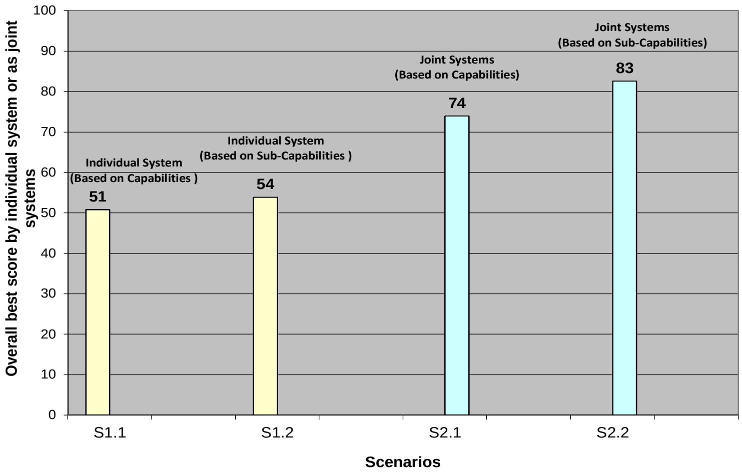

Figure 6. The implementation level of top performing systems .

5. Conclusions and recommendations

The applied AHP method has shown that it can provide the decision makers with an environment that can evaluate the system performance level at capability and sub-capability levels. Secondly, it can identify the level of integration of systems at the joint level to improve the performance of the ISREC. After reviewing all the exploitation capabilities requirements and each of the system capability limitations, it was concluded that the ISREC will be more functional if it acquires the integrated capabilities of all available systems. The results also show that if the capabilities can be divided into a large number of sub-capabilities, this will provide a higher resolution of performance by the systems. This allows the decision makers to make decisions on the final requirements of the exploitation framework for an ISREC environment to attain the highest performance capability.

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