A Prototype for An Intelligent Information System for Jamming and Anti-jamming Applications of Electromagnetic Spectrum.

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Abstract
As the pace of modern battle has increased, headquarters and Electronic Warfare (EW) staff need to process increasing volumes of information in a decreasing amount of time. Assistance in this critical task is proposed by developing the Electronic Warfare Intelligent Information System (EWIIS) that deals with processing of electronic warfare, communications, radar, maps, war missions … etc. This system is aimed at achieving the best performance with a friendly system in spite of the existence of hostile actions. EWIIS deals with different sources of data. It helps visualize mission scenarios and suggests the best combination of weapons to successfully complete the mission with minimum loss.

Keywords
EW, Radar, ESM, ECM, ECCM, SAM, Jamming, Jamming Pods, Pulse, Pulse width, FEBA, Knowledge base, Intelligent system.

# Arabic Text #

نموذج لنظام معلومات ذكي لتطبيقات الإعاقة ( الشوشرة )
ومقاومة الإعاقة في الطيف الكهرومغناطيسي

مع إعتماد أنظمة التسليح الحديثة على التدفق الهائل للمعلومات ورد الفعل السريع لهذه الأنظمة للتناسب وتفاعل مع هذه المعلومات كانت هناك حاجة ماسة لوجود نظام معلومات ذكي للتعامل مع أنظمة وتثبيقات الحرب الإلكترونية والإتصالات والرادار والخسائر والمهام القتالية … إلخ لتحقيق الأداء الأمثل لأنظمة التسليح مما كانت طبيعة البيئة المحيطة وذلك استغلال إمكانيات الحاسب الآلي من ذاكرة كبيرة وتنظيم جيد ومعالجة سريعة للبيانات المتوفرة. كما أنه لابد أن يحقق النظام المقترح القدرة على اكتشاف وتحليل معظم التهديدات وإقلاع الإجراءات الصحيحة للتعامل معها وتحليل النتائج. كما أن النظام المقترح يتعامل مع الخسائر ونطاق مدى الرادارات والتهديدات المعادية لإحراز خطوط السير المقترحة لآداء المهام بأقل خسائر، وكذا تأثير مستودعات الإعاقة ضد الرادارات المعادية بشكل دقيق مع الإعتماد على الخسائر.
1. **Introduction**

In a modern war activity, large number of offensive or defensive weapon systems rely on heavy traffic of information, also through radio links, and on high speed reaction of these systems, whatever the weather and daylight conditions may be. This trend of modern war has led to a sustained development of *Electronic Warfare* (abridged EW), the goal of which is to gain – as completely as possible – the air superiority for electronic signal transmission.

Electronic Warfare (EW) [1, 3, 4, 5] describes techniques that exploit an adversary’s use of the electromagnetic spectrum or defend friendly use of the electromagnetic spectrum. There are three subdivisions of EW: Electronic Support, Electronic Attack and Electronic Protection.

1.1 **Electronic Support** (ES), previously known as *Electronic Support Measures* (ESM), is considered the eyes and ears of the EW effort, in that electronic support is responsible for the detection, processing, recording and identification of electromagnetic energy transmitted by hostile, friendly and neutral radar systems. The main aim of Electronic Support is to gain sufficient information about radar sensors to allow an understanding of the radar’s characteristics including its role, its method of operation, and its strengths and weaknesses. With this information, the Electronic Support system can identify the radar, assess its relative threat and provide information to the operator on how best to manage the radar’s presence.

Many factors have impact on the effectiveness of Electronic Support, but all factors can be classified under one of the following categories [14]:

* Transmitter characteristics including transmitted power, operating frequency, polarization, signal bandwidth;
* Transmitting antenna characteristics including beam width, side lobe levels, and scan patterns;
* Environmental characteristics between the radar and the electronic support equipment including atmospheric and meteorological conditions; and the capability of the electronic support equipment including the receiving antenna characteristics, and the receiver capabilities and sensitivity. Electronic support is a passive activity as the electronic support equipment does not transmit any electromagnetic energy in the performance of its roles. It is important that the adversary remains unaware of the ES activity; because there are many tactics an adversary radar system can employ to make the Electronic Support role even more difficult than it is normally. Additionally, remaining passive lessens the opportunity for the adversary radar to plant false information into the transmissions in an attempt to corrupt or confuse the Electronic Support effort.

1.2 **Electronic Attack** (EA) [1, 5] previously known as Electronic Counter Measures (ECM) is conducted on radar systems to reduce or prevent the radar’s use of the electromagnetic spectrum effectively. Enemy sensors are the main focus of EW action. Active sensors are particularly vulnerable as these sensors are designed to transmit and receive electromagnetic energy. EA tactics and tools look to exploit active sensors by analyzing the transmission (ES) and then attacking the receiver.

EA can be conducted against all electromagnetic systems including communications systems. Radar systems are operated to detect, acquire and track targets with the ultimate view to engaging and destroying the target. To that end, interfering and degrading the performance of radar systems is often of critical value to the targeted platform’s survival and ability to carry out its intended role.
Electronic Protection (EP) [1,5] previously known as Electronic Counter Counter Measures (ECCM), is to ensure continued friendly use of the electromagnetic spectrum despite adversary EA and ES. Countering EA efforts is the main focus of electronic protection although some electronic protection techniques are also designed to make adversary ES more challenging.

EP and EA fields tend to be complimentary and reactive fields of endeavor in that an advance in technology and techniques in one field necessarily results in research, development and advancement in the other.

The designers of military radar systems assume that their systems operate in the most hostile of electronic environments and therefore design the radar with EA and EP in mind. EP is not solely a military concern, however. Civilian radar systems also have to operate in hostile electronic environments and must therefore have EP built-in. The civilian environment is often hostile due to the operation of other radar and electromagnetic systems in the same physical location as the radar system. EP techniques developed for the military domain can allow civilian radar to operate in the presence of other sources of potentially disruptive electromagnetic energy.

The rest of the paper is structured as follows. Section two discusses the motivation behind the effort to develop the system. Global view of the system and its interaction with its environment is given in section three. Detailed discussion about the different components of the system and how they are related is given in section four. Data movement and communications are shown in section five. Section six gives a case study to show the system operation. Section seven concludes the paper and suggests future work.

2. Motivations

To develop intelligent information system that can store, retrieve, process, report information about attacking scenarios that could be placed by users of the system. The system should be robust, efficient, and capable of working in a multi-user environment. Also the system should be capable of detecting and analyzing modern threats and developing the proper techniques. These systems can provide the developing countries with capabilities that not easily reachable. From now on we call our proposed system Electronic Warfare Intelligent Information System (EWIIS).

3. Typical Environment for EWIIS

As normal information system development life cycle [6,9,22] we need to analyze the requirements and tasks of the proposed system, the different input sources, output expected in order to guarantee the fulfillment of the requirements. Figure 1 shows the main input/processing/output of EWIIS and the different categories of users expected to interact with it. For EWIIS to fulfill its mission which is to suggest and test tactics to complete a mission with the suggestion of the best platform to use among set of prescribed platforms; it should be fed with parameters about the ESM. This input is supplied by the EW officers. Mission data and an initial plan is given by the Planning officers. Information about the different platforms available for the system is given once and may be updated by technical officers. EWIIS starts from the initial scenario and with the information given about the type and location of radar starts to analyze this scenario and looks for opportunities for enhancement. The successive enhancement processes depend on studying the different
parameters for all of platforms, radar and geographical area of the target stored in EWIIS knowledge base. Possibly ending with more than one scenario; EWIIS recommends best path for certain platforms that guarantees successful completion of the mission. Suggested tactics, results reports and suitable techniques will be offered to EW, planning and technical officers. More elaboration of knowledge base system will be given in the next section.

Figure 1. EWIIS Environment
4. The Proposed EWIIS Architecture

This section introduces the components of EWIIS and their functionality. It also describes the interactions among these components. Figure 2 summarizes these components and their relationships.

![Figure 2 Overall Architecture of EWIIS](image-url)
4.1 Data Acquisition and storage requirements

This component is responsible for accepting all the data about threats, Electronic support measures of the scenario needed to be tested. As most of these data are of visual nature as maps, radar locations, target locations; it should be taken into consideration that they must be fed to the system in the same way as they are dealt with in real life. Due to Data visualization [16] and their huge volume, we have to store the following data, among others:

* Map information.
* Radar location.
* Target location.
* Mission path.

we have to choose between storing all these information in one container for each mission scenario, or to divide this information into layers where each layer is concerned with separate aspect of the mission data. The second choice provides high level of reusability. Reusability comes from the fact that the same map is needed to be stored once in the map layer and can be linked to more than one scenario. Indeed this also leads to another big benefit of storage optimization which is a challenge for any system that deals with massive information. For our case study, presented in section 6, the standalone data file needed 6443 KB every mission scenario while the layered method took only 5KB to store the differences between sequenced mission scenarios. The 6443 KB is stored once in all scenarios.

4.2 Intelligent Information System (IIS)

This is the major component of EWIIS that makes the analysis of mission paths and makes suggestions of enhancements. This is the component where the intelligence comes into the scene in EWIIS. The Knowledge Base contains four different parts; verifier , selector, position identifier, and result analyzer.

4.2.1 The Verifier: Plays two roles: Firstly it checks the input data consistency such as ensuring the correctness of radar parameters. Secondly it ensures the consistency between the given input and the resulted output data based on set of rules which were given by the planner. For example air craft should have 10% of fuel after finishing mission.

4.2.2 The Selector: Simply the objective of this part is to select between alternatives (choose best radar to be jammed by fighter) or select between mutually exclusive options (choose which radars will be jammed by support jammer and which radar will be jammed by fighter).

4.2.3 The Position identification: specifies the optimum location of some activities such as optimum location of support jammer umbrella based on some rules related to the victim radar.

4.2.4 The Result analyzer: It analyzes and evaluates EWIIS results then proposes suitable recommendations to get better solutions.

5. Data Movement and System Components

From a data-oriented point of view we have developed a categorization of the different battle field variables:

* Radar
  - Early Warning radar.
  - Acquisition radar.
  - Fire control radar.

EWIIS uses the following list to differentiate between radar.
List of Radar parameters:

<table>
<thead>
<tr>
<th>Min. Frequency</th>
<th>Max. Frequency</th>
<th>Pulse width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>Gain transmitted</td>
<td>Gain received</td>
</tr>
<tr>
<td>Polarization</td>
<td>Wave length</td>
<td>Band width</td>
</tr>
<tr>
<td>Pulse repetition frequency</td>
<td>Beam width</td>
<td>Listening time</td>
</tr>
<tr>
<td>Radar cross section</td>
<td>Scan rate</td>
<td>Transmission losses</td>
</tr>
<tr>
<td>Reception losses</td>
<td>Azimuth antenna coverage</td>
<td>Elevation antenna coverage</td>
</tr>
<tr>
<td>Max. range</td>
<td>ECM techniques</td>
<td></td>
</tr>
</tbody>
</table>

* Platforms: by platforms we mean the planes that will do the mission and it could be one from the following:

1 - Bomber and fighter.
   * Bomber; which carry bombs in order to destroy the target in addition to self protection jamming pod.
   * Fighter; which carry missiles in order to protect the bombers in addition to self protection jamming pod.

2 - EW Aircraft; which carry supporting jamming pods to deal with early warning radar from out of missile ranges.

EWIIS uses the following list to differentiate among platforms.

List of Platform parameters:

<table>
<thead>
<tr>
<th>Range</th>
<th>Endurance</th>
<th>ECM pod</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armament</td>
<td>Speed</td>
<td>Ceiling</td>
</tr>
<tr>
<td>Radar type</td>
<td>EW equipment</td>
<td></td>
</tr>
<tr>
<td>Max. weight</td>
<td>Base</td>
<td></td>
</tr>
</tbody>
</table>

* Jamming Pods.
   - Self protection pods.
   - Supporting jamming pods.

EWIIS uses the following list to differentiate among jamming pods.

List of Jamming pods parameters:

<table>
<thead>
<tr>
<th>Platform</th>
<th>Power</th>
<th>Frequency range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Azimuth antenna coverage</td>
<td>Elevation antenna coverage</td>
<td>Gain transmitted</td>
</tr>
<tr>
<td>Victim radar</td>
<td>Available techniques</td>
<td></td>
</tr>
<tr>
<td>Losses</td>
<td>Internal / external</td>
<td></td>
</tr>
</tbody>
</table>

To introduce the system in a simple and clear way, we may look at the system from the data movement point of view[10]. Data moves as shown in Figure 3 from users (raw mission data) and from library (radar, platforms, jamming pods, terrain heights, maps and restricted areas data) through interfaces module to calculation module. Results will be verified.
by the rules which were fed to the knowledge base system. Then a report will be printed including recommendations for solving the possible problems. Figure 4 shows the main two components of the system: data component and manipulation and control component.

Figure 3 Data Flow and Interaction
5.1 Data Component

This component includes radar, platforms, jamming pods, mission and maps data which were stored in the library and updated frequently. These data were discussed in section 5 and some examples of parameters were mentioned.
5.2 **Manipulation & Control Component**

This component includes mainly different types of modules to provide an environment for mission data filling in addition to a set of aiding tools to support users with all utilities which cover their requirements. This component contains two main modules: traditional and intelligent modules.

5.2.1 **Traditional module**

The traditional module contains all interfaces module in addition to calculation module.

**Interfaces module**

This module will represent the main menus seen by the user and they are the connection between the user and the library, and the other modules.

**Mission plan generator** (calculation and conversion module)

This module is used to calculate different required calculations such as Radar ranges and jamming effects.

Figure 5 shows the algorithm used for Radar range calculation and Figure 6 shows the algorithm used to calculate the effects of jamming pods on radar [3, 4, 17, 21].

<table>
<thead>
<tr>
<th>Initialization (default values, variables zeroising)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Get radar frequency (Fr) : from radar library</td>
</tr>
<tr>
<td>Compute wave length (λ) : ( \lambda = \text{light speed / Fr} )</td>
</tr>
<tr>
<td>Get gain received (Gr) : from radar library</td>
</tr>
<tr>
<td>Compute area equivalent(Ae) : ( \text{Ae} = (2*\lambda)/(4* \pi) )</td>
</tr>
<tr>
<td>Get power transmitted (Pt) : from radar library</td>
</tr>
<tr>
<td>Get gain transmitted (Gt) : from radar library</td>
</tr>
<tr>
<td>Get radar cross section (σ) : from radar library</td>
</tr>
<tr>
<td>Get radar sensitivity (s Min) : from radar library</td>
</tr>
</tbody>
</table>

Compute radar range value =

\[ (((Pt \times Gt \times \sigma \times Ae) / ((4 \pi)^{**3} \times s \text{ Min}))^{**0.25} \]

**Figure 5** The Algorithm for Radar Range Calculation
According to the common KADS methodology [2, 10, 12, 16, 18], a knowledge base system is a collection of different component types (domain, inference and task knowledge), each of which has its own nature and role. Since our proposed tool is designed to be used in a specific application domain which is the Electronic Warfare field, the knowledge base component would contain the knowledge related to this application area.

Our knowledge base component plays an important role in three areas: mission planning, jamming techniques area and restricted areas avoidance.

In these areas the knowledge base component plays three roles. First role is to check and fix any mission plan parameters such that the mission plan becomes verified and validated to form a safe plan at the end. The second role of the knowledge component is to monitor and verify the jamming activity. The third role is to monitor the selected set of way points such that they do not pass across some restricted areas. So, a part of this knowledge base contains knowledge about these restricted regions and how to avoid them.

Example of rule types used in this part are given in Figure 7 [3, 4, 7, 17, 21].
1. **If** Fighter is close to built-in restricted areas by 15 Km **then** mission will not be accepted. *(Ex. for restricted areas rules).*

2. **If** the remaining fuel after calculating the required fuel for the mission is more than 10% from the total air craft fuel capacity **then** the mission is successful **else** mark the mission as not safe. *(Ex. for mission planning area rules).*

3. **If** radar type which protects the target equal fire control type or Acquisition type **then** deal with self protection jammer **else** deal with support jammer. *(Ex. for jamming area rules).*

4. **If** the platform carries the required jamming pod **then** accept the mission **else** reject. *(Ex. for jamming area rules).*

5. **If** the ground terrain height during the cross country is higher than flight height **then** mark the flight as not safe and suggest suitable actions. *(Ex. for mission planning area rules).*

**Figure 7** Example of Rule Types

**The first rule.** As shown in **Figure 7,** means that the fighter air craft should fly away by 15 kilo meters from the built-in restricted areas. Indeed, the information required to activate this type of rules, is obtained by executing another type of rules ( **chained** ), which monitor and calculate dynamically the position of the plane from the center of any built-in restricted area. Also this type of rules activates its result which will be passed to another set of rules that concern the report generator to explain the reasons behind the acceptance / rejection of the mission plan. As indicated above we referred to the rules as types, not as occurrences, for instance there is a number of instances for the built-in restricted area (18 built-in restricted areas) and about 30 occurrences for the user-defined restricted areas).

**The second rule** means that after calculating the fuel used during the trip, 10% from the total quantity (capacity) should remain for safety to guarantee the safe return to the base. This type of rules is used to predict the safety factor of the mission. Calculating the fuel consumption for completing the mission safely is based on a set of flight parameters (height, velocity, weight). This rule type is highly related to another set of rules which generate reports about the actions to be taken when violation occurs.

**The third rule** means that the self protection jamming pod will deal only with fire control radar and acquisition radar but support jamming pod will deal with early warning radar.

The objective of this type of rules is to specify the jammer type based on radar type and target location. Again this type of rules has several instances according to the number of radar around the victim target (usually up to 32 radar).
The fourth rule means that the fighter aircraft should carry the suitable jamming pod. This type of rule plays a role of hard constraint. It measures the mission plan compatibility between platform (aircraft type) and jamming pod. This rule occurs several times in the knowledge base based on the number of available platforms and jamming pods types.

The fifth rule means that the fighter aircraft altitude should be higher than the terrain to guarantee safety. The goal of this rule is to specify the terrain heights through the flight path (cross country) and the plane height. The system reports suitable recommendations in case of risks due to unsafe heights. This type of rules is related to cross country, height of flight and ground features heights during the flight path.

In fact all these mentioned type of rules are distributed among the four inferences knowledge; verifier, selector, position identifier, and result analyzer, which appear in figure 3 and represented using a table structure in which the columns of this table play the role of rule premises (conditions) and conclusions (actions). In such representation a tuple of this table represents a single rule in which its premises are all “ended”. It is worth noticing that rules are running in a data driven (forward chaining) manner since they receive data and proceed toward their actions.

6. Case Study

The objective of this case study is to verify the normal operation of EWIIS and to be sure that it accepts the inputs data (map, radars, mission plan), accepts map calibration, calculates radars ranges and jamming effects in accurate way and generate and saves outputs in normal and safety way that achieves storage optimization. Figure 8 shows main user interface in EWIIS.

6.1 Inputs and procedures of the EWIIS:

The steps of the mission are the following:

1 - Insert available map (Figure 9).
2 - Calibrate\(^1\) the map (Figure 10) by choosing two different points and inserting the correct locations of the two points then be sure that the correct location of the cross point location is displayed in the cursor location window (Figure 11) 31-46-7-N & 32-14-8-E. In the position indicators on the map, N means north (Y axis) and E means east (X axis).
3 - Locate the target pointed to by the letter T which is protected by acquisition radar with range of 91.38 kilometers ... This radar should discover any aircraft that approaches T (Figure 12).
4 - Draw the mission plan to attack T starting from waypoint # 1 to waypoint # 2 to T to waypoint # 3 ending with waypoint # 4 (Figure 13).
5 - Use the bomber air craft as platform and the self-protection jamming pod.
6 - Save the mission in the two ways standalone way and layering way (refer to section 4.1).

\(^{1}\) Map calibration is used to allow location adjustment of points on the map as well as the interactive manipulation of the map on the screen.
6.2 Results

1 - The self protection jamming pod successfully activated against the victim acquisition radar.

2 - The radar range will be reduced from 91.38 Km to 22.84 Km then the bomber will not be detected during its mission to the target. (Figure 14).

3 - The remaining fuel is sufficient for safety return of the plane.

4 - Successful avoidance of restricted areas during the mission.

5 - Saving the mission data in layering method will clearly reduce the storage size. Normally we have repeated missions for different situations and we need to save the data about the mission and this need huge storage size, so we adopted a layered technique to optimize the storage space (specially for the maps). We keep one copy of the basic map and generate files for the differences between the issues of the missions. Differences are about target, radar, mission plan, FEBA, heights, user-defined restricted areas…..etc.

6.2 Functions concerning map usage

1 - Authorization is found to provide security for the package and differentiate among the access rights of the users.

2 - Front Edge of Battle (FEBA) is plotted automatically as a red line by the system due to some stored constraints.

3 - There are many types of jamming pods for self protection and support jamming, then user has to choose the suitable pod for the mission.

4 - Trajectory of the plane performing the mission displayed in real-time or as simulated.

5 - Cursor location and ground heights at cursor position appears in the left console (cursor location window and height window).

6 - Distance of aircraft from FEBA appears in the left console (distance from FEBA window).

7 - Height of flight during the mission appears in the left console (height of flight window).

8 - Pointing to the center of the radar by mouse shows name, range, type, and location of the radar.

9 - Pointing to any way points by mouse shows way point name, location and height.

10 - Right click on any way point allows the user to update on line (among the rights given to the mission planner).

11 - Appropriate report are generated according to the case.

12 - The system provides the mission administrator with the function of determining the location of the plane at any point or time during the mission.
Main Menu
1 – file (new, open, save, save as and exit).
2 – library (platform, radar, pods, restricted areas and edit automatic options).
3 – pre-mission aids (standard conversions, fuel consumption, distance and direction, calculator).
4 – users (edit user, log off users, log on users, minimize all, cascade windows and tile H & V).
5 – help (contents and tip of the day).

Left Console
Task Bars
1 – Map (New map, map calibration, load map, save map and hide map).
2 – Radar (Radar setting, open list and save list).
3 – Mission (way points setting, support jammer, FEBA, start mission).
4 – Restricted areas (built-in and user input).

Map Data Windows
1 – Cursor location.
2 – Cursor position height.
3 – Distance between plane and FEBA.
4 – Height of flight.

Tool Bar
1 – New mission.
2 – Open mission.
3 – Save mission.
4 – Air craft simulated speed.
5 – Play/pause fighter.
6 – Play/pause support jammer.
7 – Manual jamming for support jammer.
8 – Early warning radar.
9 – Acquisition radar.
10 – Fire control radar.
11 – open activity.
12 – Save activity.
13 – Reset the mission start time.
14 – Get real status now.
15 – Get real status every specific time.
16 – Get real status after specific time.
17 – Cross country report.
18 – EW report.
19 – Restricted areas report.
20 – EW diagram.

Figure 8 Main User Interface
Figure 9 Raw Map, No Data (latitude and longitude) for ( ) Sign in Cursor Location Window

Figure 10 Calibration Process
Figure 11
Map After Calibration, Correct Data (latitude and longitude) for (⿰) Sign in Cursor Location Window

Figure 12 Acquisition Radar with Range (red circle) of 91.38 km
Figure 13 Mission Plan Path (black line) Showing Waypoints in Sequence 1, 2, T, 3 and 4

Figure 14 Reduction of The Acquisition Radar Range from 91.38 km to 22.84 km due to Jamming Effect


7. **Conclusion and Future Work**

This paper has addressed the problem of dealing with the processing of the huge data of electronic warfare communications, radar, airplanes missions, etc to achieve the best performance with our system in spite of the existence of hostile actions.

An intelligent information system has been designed and built to store, retrieve, process, correct, analysis and report information about attacking scenarios that could be placed by users of the system. The system is robust and efficient. It is capable of analyzing all kinds of modern threats and capable of working in a multi-user environment. The proposed system is called Electronic Warfare Intelligent Information System (EWIIS).

EWIIS deals with a graphical user interface in a convenient way. A case study is used to demonstrate the capability of EWIIS and to verify its normal operation. The case study has achieved accurate and promising results.

EWIIS currently supports missions that work with self protection pods where it selects the best platform for the mission. It selects best pods and mission path and the suitable altitude.

To summarize, the manual system of mission planning and execution suffers from slow processing and difficulties of choosing the best between the alternatives of the mission plans and also the possible errors in calculations. On the other hand the proposed system overcomes these shortcomings and makes use of the visual presentation and manipulation of the required maps. Also EWIIS provides the possibilities of saving and retrieving the different experienced situations to improve the productivity and the efficiency of the EW officers.

We suggest as future work to support these functionalities with Early Warning radar. The reporting component with reasonable recommendations for ideal missions is intended as a future work for our research.

**References**


