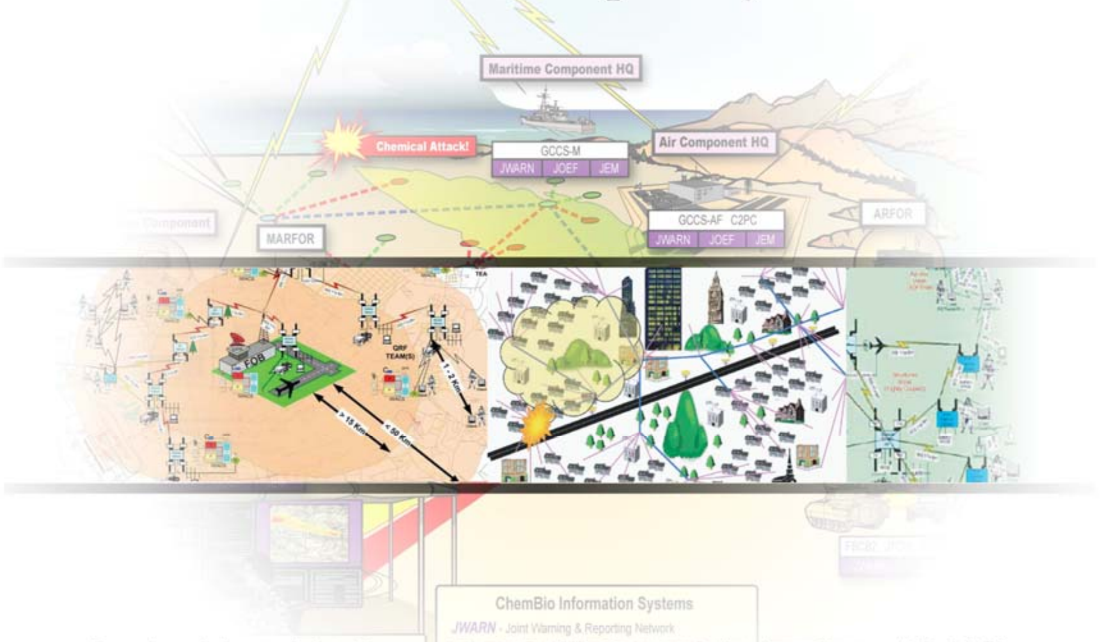
Analysis of Alternatives (AoA)

for the

JOINT WARNING AND REPORTING NETWORK (JWARN)

Wireless Capability



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List of Acronyms

ACADA	Automatic Chemical Agent Detection Alarm
ACAT	acquisition category
AHP	Analytical Hierarchy Process
AoA	analysis of alternatives
AP	access point
CAISI	Combat Service Support Automated Information System Interface
CDMA	Code Division Multiple Access
CITS	Combat Information Transport System
CONOPS	concept of operations
COTS	commercial off-the-shelf
CSEL	Combat Survivor/Evader Locator
DS&A	Decision Support and Analysis
EMI	electromagnetic interference
FIPS	Federal Information Processing Standards
FOB	forward operating base
FY	fiscal year
GOTS	government off-the-shelf
GSM	Global System for Mobile
GUI	graphical user interface
IDS	intrusion detection system
IPT	Integrated Process Team
IOC	initial operational capability
ISM	industrial, scientific, and medical
JBPDS	Joint Biological Point Detection System
JBSDS	Joint Biological Standoff Detection System
JCAD	Joint Chemical Agent Detector
JCID	JWARN Component Interface Device
JMAS	JWARN Mission Application Software
JPEO-CBD	Joint Program Executive Office for Chemical and Biological Defense
JPM IS	Joint Program Manager Information Systems
JRO-CBRND	Joint Requirements Office for Chemical, Biological, Radiological, and Nuclear Defense
JSRC	Joint Search and Rescue Centers
JVID	JWARN Vehicle Interface Device
JWARN	Joint Warning and Reporting Network
LSN	local sensor network
MAN	metropolitan area network
MAUT	Multi-Attribute Utility Theory
MTBF	mean time between failures
NRE	nonrecurring engineering
NSA	National Security Agency
ORD	Operational Requirements Document
OTH	over the horizon

PAN	personal area network
PDA	personal digital assistant
QoS	quality of service
RBWN	Robust Battlefield Wireless Network
RF	radio frequency
ROM	rough order of magnitude
SME	subject matter expert
TDMA	Time Division Multiple Access
USAF	U.S. Air Force
WEP	wired equivalent privacy
WLAN	wireless local area network

1.0 EXECUTIVE SUMMARY

For the Joint Warning and Reporting Network (JWARN) Joint Program Office to meet a key program warfighter requirement, it must provide wireless connectivity between Component Interface Device (JCID) units as close to initial operational capability (IOC) as possible. The Analysis of Alternatives (AoA) efforts summarized in this report are a first step towards achieving that goal in time for either a JWARN Increment II IOC implementation or as a preplanned product improvement (P3I) for the fielded JWARN Increment I solution.

The AoA was conducted using a rigorous and structured approach, combining engineering-based technology collection, downselect, and analysis efforts with facilitated decision support efforts utilizing the Analytical Hierarchy Process (AHP). This process enabled the study team to consider a broad array of possible technologies, to progress into identification and analysis of viable candidates, and to facilitate stakeholders to contribute key nontechnical objectives that could be used in conjunction with technical data to select the best technology.

Stakeholders involved throughout discussions included the JWARN Program Office, U.S. Army (G8, Army Combat Developers), U.S. Air Force (Langley, HSG/TBB, AFCESA, A7CXR), USMC MCCDC, USN OPNAV N767, JRO-CBRND, JWARN Program Office, Battelle, and Northrop Grumman. Stakeholders voting within decision support sessions included the U.S. Army (G8, Army Combat Developers), the U.S. Air Force (Langley, HSG/TBB, AFCESA, A7CXR), and JRO-CBRND.

The AoA considered a wide array of technologies as possible means to enable wireless connectivity between JCIDs, with research conducted on specific vendor products within each technology category. While government programs and vendor solutions were also researched, in most cases these efforts utilized other vendors' wireless products to construct a solution. Thus, while knowledge of these efforts assisted our efforts, and in the case of the U.S. Air Force (USAF) Force Protection Battle Laboratory formed part of our recommendations, our effort focused on analyzing original equipment manufacturers of wireless products. The technologies considered within the AoA included the following:

- 802.11 (including ad hoc, Harris SecNet, Mesh)
- 802.16/WiMAX
- Handheld radio
- Radio modems
- Cellular
- Satellite modem
- Bluetooth
- Laser
- ZigBee
- Infrared

As part of the AoA, scenarios for JWARN usage were refined in a group setting with key Service stakeholders present, and the final versions approved by those Service representatives. The three scenarios developed, which cut across all Services, were critical for subsequent establishment of quantified user objectives and criteria. Summary versions of the final three scenarios are as follows:

- Fixed Sites: Fixed sites are static installations in well-controlled areas where sensors are not likely to be under constant observation, with Air Force bases as the primary consideration. These are considered mixed deployment environments and include both stationary installation locations where the sensor is temporarily deployed for increased threat conditions and stationary installations where the sensor is permanently installed.

- Garrison/Provisional: Garrison/provisional sites are static installations in less well-controlled areas as compared to fixed sites, where sensors are not likely to be under constant observation. The primary consideration is Army tactical garrisons, Air Force expeditionary provisional wings, and Air Force forward operating bases. These are temporary deployment environments where the sensor network is appropriately employed to meet threat conditions.

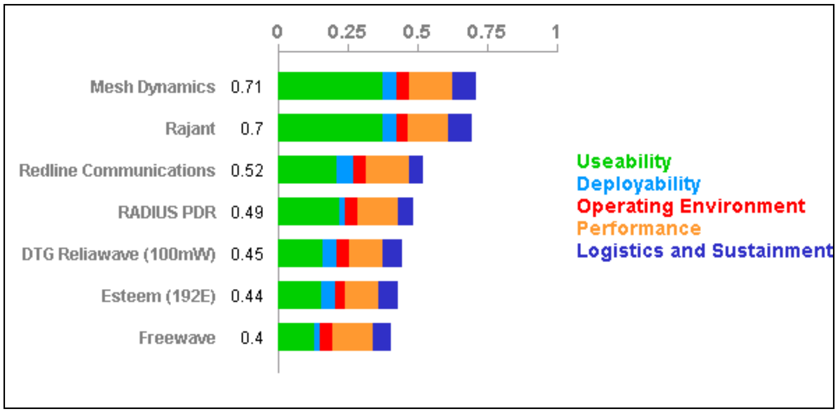
- Mobile Dismounted: Mobile dismounted sites are represented by Army units and military platforms operating within a hostile environment, where sensors are not likely to be under constant observation. There are two primary deployment environments: mobile installations where the sensor is carried within vehicle under physical control and stationary installations where the sensor is carried from the vehicle.

For each of these three scenarios, a prioritization of factors by Joint forces users and the Joint Requirements Office for CBRN Defense (JRO-CBRND) enabled the study team to apply technical requirements against stated needs of the system. Finally, this quantitative prioritization and technical scoring was used to rank order the performance of wireless products, which was supported via sensitivity analyses and cost estimates. The seven leading products within the remaining technology categories, which were scored for each scenario, are Mesh Dynamics (802.11 mesh), Rajant (802.11 mesh), Redline Communications (802.16/WiMax), DTG Reliawave (802.11 ad hoc), Esteem (802.11 ad hoc), Radius PDR (radio modem), and Freewave (radio modem). The final results of the decision modeling and technical analysis is as follows for each of the three scenarios:

- Fixed Sites: The top-level priorities for fixed sites were quantified by the users as follows, with percentages indicating the weight placed upon each objective (which was used in weighting the technical scores):

    1. Usability (43%)
    2. Logistics and sustainment (22%)
    3. Performance (17%)
    4. Operating environment (9%)
    5. Deployability (9%)

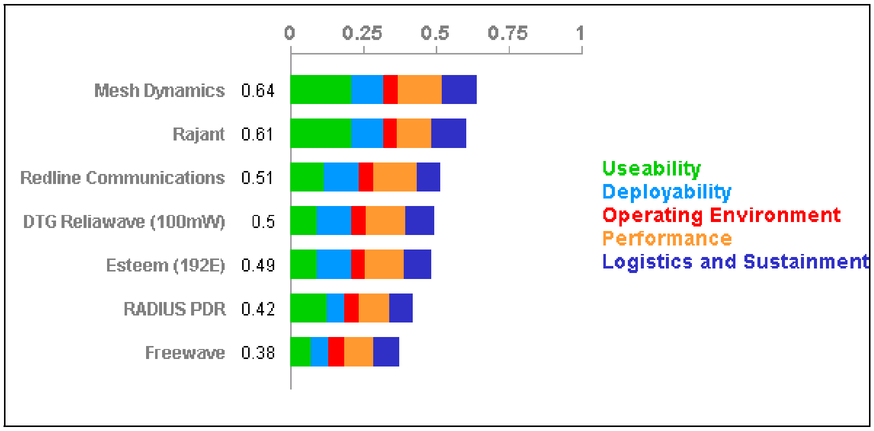
    The 802.11 mesh network technologies were the top-performing technologies. Both technologies provide user-friendly interfaces and valuable network management capabilities while being able to perform effectively with respect to transmission range, bandwidth efficiency, and channel flexibility. The following figure shows the rank ordering of products and their overall score (in relation to a perfect score of 1):



- Garrison/Provisional: The top-level priorities for garrison/provisional sites were quantified by the users as follows, with percentages indicating the weight placed upon each objective (which was used in weighting the technical scores):

  1. Usability (26%)
  2. Performance (24%)
  3. Logistics and sustainment (20%)
  4. Deployability (20%)
  5. Operating environment (10%)

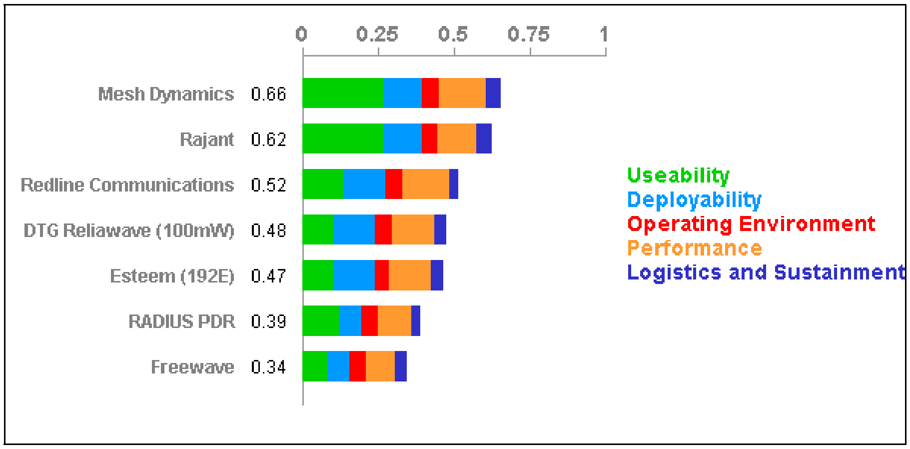
  The 802.11 mesh network technologies were the top-performing technologies. Similar to the fixed site scenario, both technologies provide user-friendly interfaces and valuable network management capabilities while being able to perform effectively with respect to transmission range, bandwidth efficiency, and channel flexibility. The key differentiator in this scenario is the ability to minimize their power consumption while transiting and managing power usage when transmitting at shorter ranges and through sleep model or other limited functional modes. The following figure shows the rank ordering of products and their overall score (in relation to a perfect score of 1):



- Mobile Dismounted: The top-level priorities for mobile dismounted sites were quantified by the users as follows, with percentages indicating the weight placed upon each objective (which was used in weighting the technical scores):

  1. Usability (33%)
  2. Performance (24%)
  3. Deployability (21%)
  4. Logistics and sustainment (12%)
  5. Operating environment (10%)

  The mesh network technologies Mesh Dynamics and Rajant are, again, the top performers, followed somewhat more closely by Redline Communications (WiMax) technology. User-friendly interfaces, valuable network management capabilities, and effective performance, combined with the ability to minimize their power consumption, are what drive the rankings and result in the mesh network products being the top recommendations.



To provide the JCID with wireless capability, 802.11 mesh networking is recommended (specifically products from Mesh Dynamics or Rajant) in combination with an approach that upgrades the JCID to provide on-board encryption, via software or on-board chips, at the FIPS 140-2 level. Key factors in recommending mesh technologies include the following:

- Mesh network solutions received the highest score out of the evaluated technologies for each of the scenarios, particularly in the critical areas of usability and performance.

- The cost for mesh network solutions is favorable, with this approach comparable to 802.11 ad hoc (despite mesh technologies having much greater usability) and less expensive than WiMax and radio modems.

- Mesh networking technology is available now for prototyping systems and fielding implementations.

- Products from both Mesh Dynamics and Rajant are already compatible with Fortress Technology encryption software, an important consideration as Fortress software is already certified by the National Security Agency (NSA) and is the most likely method of providing encryption on the JCID given its current design.

- Mesh network solutions also lend themselves well to rapid fielding; e.g., users can rapidly field a wireless capability at slightly greater cost by using a mesh node with Fortress software at each JCID, possibly reducing and/or eliminating the immediate need for JCID modifications, while the same mesh nodes can then be used to field a larger number of JCIDs after encryption modifications are made, enabling the use of inexpensive Fortress-compatible PCMCIA cards at the JCID.

- Mesh vendors are looking at WiMAX as the next expansion for mesh networking; therefore, the benefits of this new technology (e.g., increased bandwidth efficiency and range) are likely to be available even after choosing mesh network products initially.

Based upon the results of this study, and to enable the JWARN Program Office to complete a detailed engineering solution, the following suggestions are provided:

1. Begin discussions with Mesh Dynamics and Rajant to determine how much flexibility they may offer the program office in providing custom solutions to meet NSA and program requirements, and at what cost.

2. Begin a dialogue with the USAF Force Protection Battle Laboratory concerning its Robust Battlefield Wireless Network (RBWN), which uses the Mesh Dynamics products and which consistently achieved the highest scores in each of the three use scenarios.

3. Concurrently with the first two efforts, investigate with the current prime contractor a new design for the JCID that will incorporate Federal Information Processing Standards–approved security algorithms (at the appropriate ISO layer) into the JCID as a software or chip-set enhancement to the current JCID solution.

4. Maintain a capability to continue to monitor the wireless communication market for potential new solutions or enhancements to the chosen prototype and development effort. In this way, throughout system design, prototyping, testing, and NSA certification efforts, JWARN can decide to evaluate alternative technologies that may provide a better or more cost-effective solution for the warfighter.

2.0 INTRODUCTION

2.1 Background

The Joint Warning and Reporting Network (JWARN) is an ACAT III Sentinel program within Joint Program Manager Information Systems (JPM IS) under the Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD). The JWARN program has been operated out of U.S. Navy Space and War Command as a Joint Service program since its transition out of U.S. Marine Corps Systems Command in 2003.

The JWARN system (hereafter "JWARN") will provide Joint forces with a comprehensive analysis and response capability to minimize the effects of hostile nuclear, biological, and chemical attacks and accidents or incidents. JWARN collects output from chemical and biological sensors, analyzes data to produce appropriate alerts, processes data into properly formatted message and positional plots and delivers them to appropriately designated users, and supports immediate decision making to respond to threats (Figure 2-1). Within this top-level functionality, JWARN accomplishes other important objectives such as connecting both legacy and newly developed sensors to local platforms and C4ISR (command, control, communications, computers, intelligence, surveillance, and reconnaissance) systems, networking sensors into a more fault-tolerant mesh, and providing for rapid consequence management decision making.

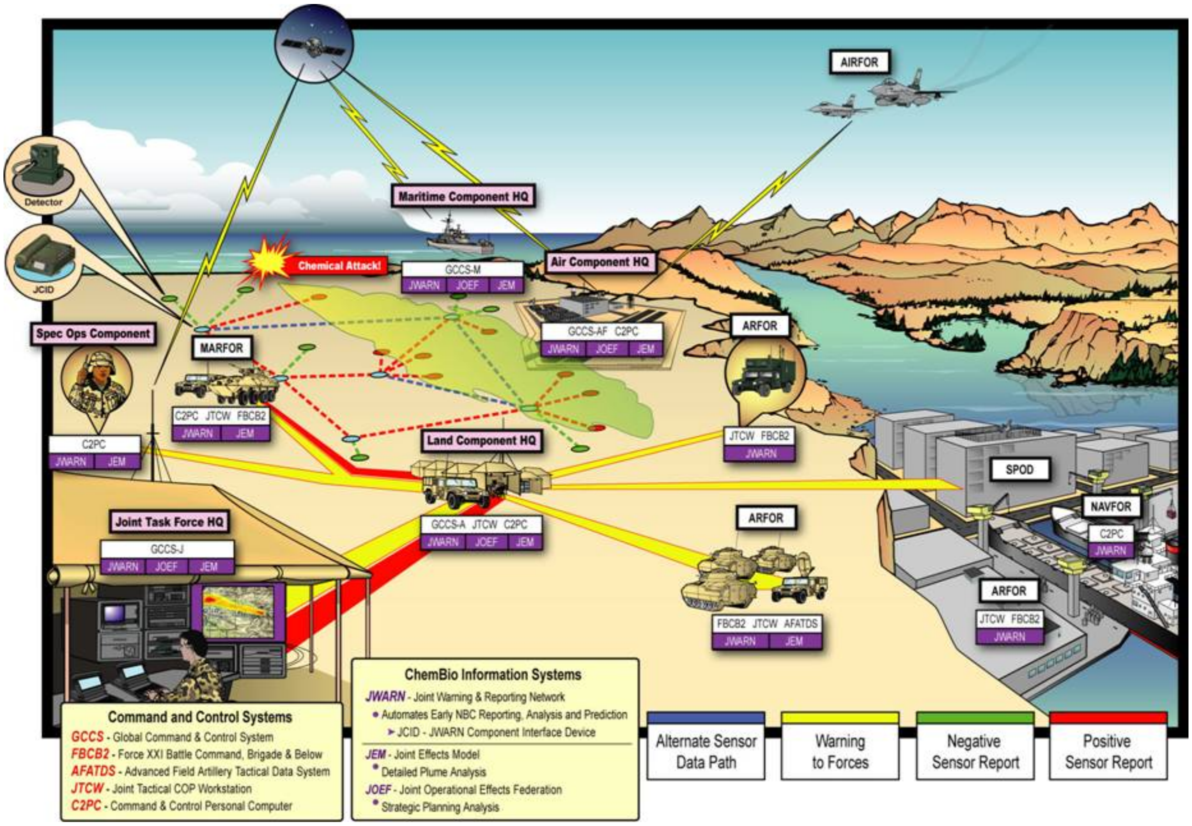
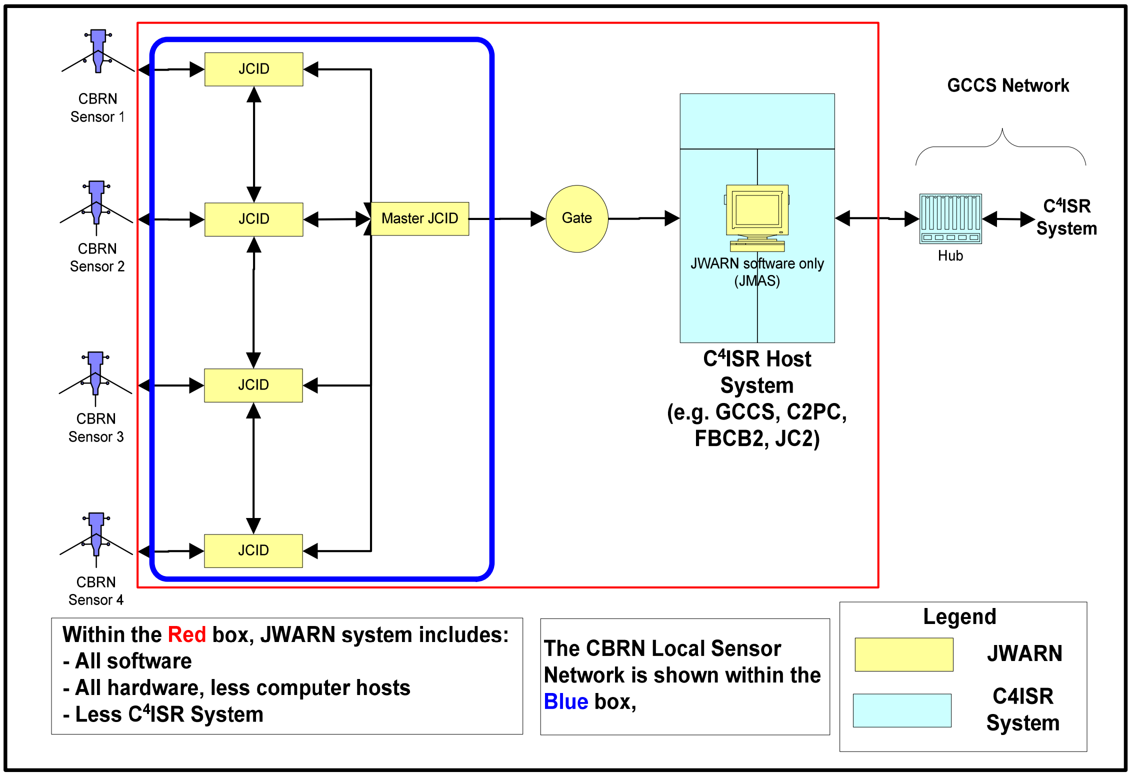


Figure 2-1. JWARN High-Level Operational View (OV-1)

JWARN comprises the JWARN Mission Application Software (JMAS) and the JWARN Component Interface Device (JCID). As the primary software component of the system, JMAS is tailored to operate on a variety of host platforms and is the primary system interface, providing core functions such as system control, data exchange, and message formatting and delivery. Each JCID is a small, portable hardware unit that contains software for data processing and network management and is used to connect sensors into a fault-tolerant network. A JWARN network is constructed through the appropriate placement of sensors, several of which are connected via cabling to a JCID, which is in turn connected to an interim JCID or to a final master JCID and the JMAS controlling software (see Figure 2-2).



Within the Red box, JWARN system includes:
- All software
- All hardware, less computer hosts
- Less C^4ISR System

The CBRN Local Sensor Network is shown within the Blue box,

Figure 2-2. JWARN Notional System

JWARN will be developed in two primary increments, with initial operational capability (IOC) for Increment I in FY08. JWARN Increment I will deliver a wired JCID capability to Joint forces, whereby sensors and JCIDs will be networked via cabling from sensor to JCID, and JCID to an interim JCID or master JCID. Along with additional functionality, JWARN Increment II will deliver a wireless JCID capability, whereby connectivity of sensor to JCID will remain via cabling but connectivity of JCID to another (i.e., interim or master) JCID will be through a wireless link. However, a goal of the JWARN program and an impetus for this analysis of alternatives (AoA) is to deliver an early wireless JCID capability to the warfighters, after IOC but before Increment II.

The JWARN Operational Requirements Document (ORD), which was updated and approved in FY05 to better reflected program changes since the original 1999 ORD, mandates that the secure wireless capability for Increment II be delivered using the Joint Tactical Radio System (JTRS).

JWARN wireless requirements are, therefore, either explicitly or implicitly based upon expected JTRS capabilities.

2.1.1 Joint Tactical Radio System

JTRS is an acquisition program led by the Marine Corps System Command, which is developing a family of tactical radios that provide interoperable line-of-sight and beyond line-of-sight wireless capability. Many sources, including substantial material from the JTRS program office itself, indicate that the program is experiencing cost overruns and schedule slips. Cost overruns and schedule slips are particularly problematic for JWARN, given its requirement to use JTRS as its Increment II wireless capability. A larger-than-expected per-unit JTRS cost would increase the JWARN procurement costs substantially, as Joint forces have requested a large number of wireless JCIDs. Additionally, a delay in JTRS development would delay fielding of JWARN wireless capability, particularly as the JTRS small form factor is mandated for use with the JCID and this form factor is the last development cluster (Cluster 5, see Figure 2-3) for the program. Currently, the Cluster 5, Spiral 2 small form factor JTRS radio is estimated to cost roughly $10,000 per radio and is not likely to be ready until after FY12, which is IOC for JWARN Increment II. The JWARN program office, therefore, determined that, to meet its ORD requirements on time and at an affordable cost, it would need to use a wireless communication solution other than JTRS, and an AoA was deemed necessary.

Figure 2-3. JTRS Cluster 5

2.2 Scope

This AoA was conducted to determine the best alternative wireless solution for use in the JCID, replacing the currently mandated JTRS. All modes of wireless communication were included as part of the analysis, including, but not limited to, the following: 802.11, 802.11 mesh, 802.16/WiMax, cellular, satellite, radio modem, handheld radio, laser, infrared, and Bluetooth. The analysis also included encryption software, chipsets, and modules to identify the best system-level approaches to providing secure wireless functionality, and—by separating encryption from the wireless product—the number of available wireless products under consideration was increased while known and expected security requirements were accommodated.

In addition to encryption, there were several other important study factors. With the JCID nearing low-rate initial production, form-factor was an important consideration. The JCID was designed to accommodate a PCMCIA radio; however, if no viable alternatives were available, alternatives were sought that met the maximum number of requirements and user priorities with as minimal retrofitting or redevelopment efforts on the part of the lead system developer as possible. Finally, the JWARN program would not fund new development by commercial vendors or other government programs, so alternatives had to be completed commercial off-the-shelf (COTS) or government off-the-shelf (GOTS) products.

The AoA was conduced from Q3FY05 until Q2FY06. Contractor efforts were primarily performed in Arlington, Virginia and Columbus, Ohio. Briefings and facilitation with program office and Service personnel were conducted in Arlington, Virginia and San Diego, California.

2.3 Methodology

The AoA was conducted using a rigorous and structured approach that has been used frequently both inside and outside of Battelle. The approach combined engineering-based technology collection, downselect, and analysis efforts with facilitated decision support efforts using the Analytical Hierarchy Process (AHP). This process, which is described in steps below as performed during the AoA, enabled the study team to consider a broad array of possible technologies, progress into identification and analysis of viable candidates, and facilitate stakeholders to contribute key nontechnical objectives that could be used in conjunction with technical data to select the best technology. Starting with the broad range of candidate technologies, the AoA was conducted according to the following steps:

2.3.1 Determination of Initial Criteria

Initial criteria were developed to ensure the capture of all important technical requirements of the JWARN wireless capability. Additional criteria were added to reflect initial operating assumptions of the JWARN system. Appendix A includes a list of all initial criteria developed.

2.3.2 Initial Assessment of Concept of Operations

The Concepts of Operations (CONOPS) from each of the Joint forces needed to be reviewed and further refined to support decision making. To provide a more detailed notional operational view of how JWARN would be used, which is critical to a determination of the best wireless capability, the AoA study team initially worked with the JWARN program office. Several operational scenarios for JWARN use, which cut across Services, were developed and included: fixed, semifixed, mobile, and vehicle-mounted. These initial four scenarios were further refined in decision support efforts, and the final scenarios refined by Joint forces representatives can be found in Section 5.2.

2.3.3 Iteration of Initial Criteria

The criteria initially developed were reviewed by wireless subject matter experts (SMEs) and were refined into those that were most meaningful and capable of differentiating technologies from one another. The criteria were further refined by program office requirements personnel, Service liaisons, and Service personnel into “desirable” or “nice-to-have” features, which provided an indication of which criteria it may be possible to relax, subject to appropriate waiver procedures. Finally, several security SMEs collaborated to ensure that information assurance, encryption, and other security concerns were addressed. The final list of criteria can be found in Appendix A along with the definition for each criterion.

2.3.4 Initial Research of Candidate Technologies

Wireless experts on the study team collected a broad list of vendors and government programs that could provide viable products to meet the JWARN wireless functionality. Using the refined criteria, the study team began to eliminate technologies that were not viable due to criteria that were not likely to be relaxed, resulting in a list of candidate products that could be researched more thoroughly. See Section 3 for a description of initial research and technology elimination.

2.3.5 Assessment of Viable Products

Detailed research was initiated on those wireless products that could likely achieve Federal Information Processing Standards (FIPS) Level 1 compliance, either alone or in combination with encryption on the JCID. During this research, technical data were collected for each of the wireless products and used to score against the refined criteria.

2.3.6 Decision Support Process and Model Creation

A facilitated decision support process was used to incorporate user involvement and feedback with the technical analyses being performed. Specifically, three final decision models that ranked the products for each of the three scenarios were created, along with supporting sensitivity analyses to demonstrate possible system tradeoffs. This approach was chosen to ensure that conflicting concerns from different user groups were addressed and that the final solution would be better supported by all stakeholders. The full theory behind the specific decision support process and its underlying mathematics are provided in Appendix B.

2.3.7 Final Analyses and Recommendations

The final models containing the wireless product ranking within each scenario were used to conduct sensitivity analyses. Analyses were conducted to understand important drivers that led to the final rankings as well as how sensitive the rankings were to perturbations in user priority. The final rankings, analyses, and recommendations for fixed, garrison/provisional, and mobile dismounted scenarios are discussed in the final decision model sections in the body of this report, while the complete models may be found in Appendix C.

3.0 TECHNOLOGY ANALYSIS

3.1 Initial Technology Research

The initial research conducted for a wireless solution on the JCID was driven by the starting criteria that the technology be available in a PCMICIA form factor for installation in the JCID, that the technology provide FIPS 140-2 encryption (Level 1-3), and that the technology be an existing COTS or GOTS product. The initial search covered over 550 companies (see Appendix C for complete listing) producing equipment available in PCMCIA form factor under the following topics: wireless modems, radio modems, network interface cards, component manufacturers, and specialty communications. Out of this search 70 radio frequency (RF)-based

PCMCIA products were identified. Of those, only one is available with encryption—the Harris SecNet11 PCMCIA card. The SecNet11 is an 802.11 product with encryption levels from FIPS 140-2 up to Type 1 Secret.

With so few candidate technologies available, the search was expanded to include other small form factor wireless solutions in addition to PCMCIA, enlarging our candidate pool. Due to the continued emphasis on FIPS 140-2 encryption as a minimum requirement, the list of vendors provided by the National Institute of Standards and Technology that had previously received FIPS 140-1 or 140-2 validation was used to create an exhaustive set of encryption-certified wireless technologies. This search was later expanded to include the products on the FIPS prevalidation list (as of mid-January 2006) as well.

The majority of wireless vendors found on the FIPS 140-2 validation list are manufacturers of 802.11 or WLAN security gateways, also known as “enterprise solutions,” for use with existing corporate wireless networks. These security gateways monitor network traffic, enforce network administrator rules, and alert/prevent rogue wireless access to larger secure wired networks. These vendors often do not provide any radio interface that could be used directly with the JCID; however, this type of component could be incorporated into the JWARN wireless network if required. This type of device would be most likely implemented at a fixed site in conjunction with wired solution (intranet) since most are designed for enterprise applications.

Despite the inclusion of vendors on the FIPS validation and prevalidation lists, there was still an insufficiently large pool of wireless technologies. To further expand the pool of wireless technologies under consideration for the JCID, methods of providing encryption separate from the radio/wireless device were considered. Options included installing encryption software on the JCID, embedding a chipset in the JCID for encryption, or using a PCMCIA encryption card, and existing FIPS-validated vendors offering these types of products are available. Handling encryption on the JCID further opened the pool of candidate technologies to those that had been precertified to work with any of these encryption methods.

With this final expanded group of vendors providing either wireless products and/or encryption products, a complete list of technologies and vendors was established.

3.2 Technologies Considered

3.2.1 802.11 Overview

802.11 is currently the most widely used wireless local area network (WLAN) standard, available in protocols a, b, and g. 802.11a operates at 5.8 GHz with a maximum data rate of 54 Mbps while 802.11b/g operate at 2.4 GHz at 11 Mbps and 54 Mbps, respectively. 802.11 b and g equipment have dominated the market due to their inherently better propagation range over the 802.11a standard. While some hardware operates on only one of the three standards, the current trend has manufacturers producing equipment compatible with all three standards through the use of two antennas to cover both frequency bands. Equipment currently appears in a wide array of network architectures to support infrastructure, ad hoc, and mesh networks.

The majority of 802.11 hardware falls into two categories: client devices and internet appliances. Client devices usually employ software, drivers, and small hardware (such as PC Cards, Compact Flash, or embedded radio cards) to interface with an 802.11 network. The larger internet appliances are usually access points, repeaters, and security gateways, where access points and/or security gateways are often the interface to larger infrastructure such as the Internet or company intranets.

Within the 802.11 technologies, the ad hoc, Harris (SecNet11), and mesh applications are seen as distinct solutions and are considered separately for the purpose of evaluating wireless solutions for JWARN. Networks using any of these solutions can easily have a node connecting into an existing wired network of fixed sites, if desired, and there are many ways in which to combine a wired network with a wireless network.

3.2.1.1 Ad Hoc

The ad hoc network is the simplest implementation of a wireless network. In an 802.11 ad hoc network, depending on the location and distance between the communication devices, one JCID can communicate directly to its master JCID or communicate through a COTS wireless repeater used to extend the range. At a minimum, each JCID would have an 802.11 PC Card, and they would communicate directly to each other—a point-to-point communication link. Not including any nonrecurring engineering (NRE) on the JCID, the price per JCID for the PC Cards would be between $50 and $200.

3.2.1.2 Harris SecNet11

Harris currently produces a PCMCIA card 802.11 product, the SecNet11, which is certified by the NSA for Type 1 Secret communications. A SecNet11 at each node of a wireless network will create a secure network with security options ranging from sensitive up to Secret (NSA Type 1). A SecNet11 card would have to be installed in each JCID as well as any supporting 802.11 equipment, access points, repeaters, etc. The SecNet11 solution cost is approximately $3200 per JCID. SecNet11 can be used for infrastructure, ad hoc, and mesh networking.

3.2.1.3 Mesh

In a mesh network, the individual nodes create a self-forming, self-healing 802.11 network. Most mesh nodes will contain two or more radios so that bandwidth is not reduced with each hop in a mesh configuration (e.g., bandwidth without multiple radios = ½ * number of hops and sometimes as high as ½ n). A mesh node can be connected to a JCID through an Ethernet port or through an 802.11 PC Card, assuming the JCID has the appropriate client/encryption software installed, to create an encrypted link. Mesh node products are unique because they require virtually no network administration. Client software would need to be used in this application to provide FIPS Level 1 security. Rajant and Mesh Dynamics are examples of manufacturers of mesh network hardware. Mesh Dynamics’ products are currently being evaluated by the U.S. Air Force (USAF) Force Protection Battle Lab under a separate wireless study.

3.2.2 802.16/WiMAX

The IEEE 802.16 Air Interface Standard addresses the efficient use of wireless bandwidth in the 2–11 GHz and 10–66 GHz range. The first products were certified by the WiMax Forum[1] under the 802.16-2004 standards at the end of 2005. Currently, these WiMax products operate at 3.5 GHz and are designed for use as the last mile of broadband connection. There are other, proprietary, noncertified COTS 802.16 products available, but products from different vendors may not operate together.

The WiMAX solution is recommended as a technology to watch for the future. Implementation would be similar to the 802.11 solutions. Configurations for point-to-point, point-to-multipoint, mesh networking, and seamless mobile connectivity are all planned for this standard. WiMAX has the potential for longer-range communication, but the pool of available WiMAX-certified products is slim (the first WiMAX-certified product was released in December 2005).

Without changes to the JCID or the addition of supplemental equipment, this technology will not score well as a JWARN wireless solution. Currently, there are no WiMax or 802.16 vendors with FIPS validation; however, both Fortress and Cryptek plan to support the 802.16 standard with their security gateways and client software. PC Cards or other small form factors will most likely be available for use with the JCID in the future. As with 802.11 solutions, drivers will have to be developed due to the Windows CE 5.0 OS being used on the JCID. We anticipate the WiMAX market to grow similarly to 802.11, with a large base of COTS amplifiers and antennas available to extend the range between network nodes. The price of a small form factor WiMAX product should also be similar 802.11, with an initial per unit cost of $200–$500 and, as more vendors enter the market, drifting down to $50–$200.

Given the broad frequency range of 802.16, there will be other standards of 802.16 available in the future. This is a technology to watch for its long range communication (4–6 miles typical up to 30 miles) potential. Within the WiMax forum, efforts by Intel and Motorola are currently under way to promote the 802.16e standard, which will specifically address the mobility of broadband wireless.

3.2.3 Handheld Radio

Handheld radios have been in production for many years, and several manufacturers make products with encryption options. These radios are generally used by first responders and emergency personnel. Most handheld radios are in the UHF/VHF/800 MHz band and are used for medium-range communication. Longer-range communication is possible through the addition of infrastructure (e.g., repeater towers). In conventional operation, the voice or data is broadcast and received by any compatible radio operating on the same channel.

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[1] http://www.wimaxforum.org/about: The WiMAX Forum™ is working to facilitate the deployment of broadband wireless networks based on the IEEE 802.16 standard by helping to ensure the compatibility and interoperability of broadband wireless access equipment. The organization is a nonprofit association formed in June of 2001 by equipment and component suppliers to promote the adoption of IEEE 802.16–compliant equipment by operators of broadband wireless access systems. Why WiMAX Forum certified? Today every solution is custom and not interoperable. Every piece of WiMAX Forum–certified equipment will be interoperable with other WiMAX Forum–certified equipment. WiMAX Forum certified means a service provider can buy equipment from more than one company and be confident everything works together. WiMAX Forum certified means a more competitive industry. WiMAX Forum certified means lower costs. WiMAX Forum certified means faster growth for broadband wireless – everywhere around the globe.

Handheld radios maybe a viable option for sites with existing infrastructure. Though there are several manufacturers and models on the market, the motivation to score this option are based on the ability to use existing radios already owned by the Services. The Motorola XTS5000 units support both USB and RS232 communication connections that could be used to interface to the JCID. It is still to be determined whether the encryption available on the radios is adequate for the JWARN application. Though the radios may already be a sunk cost to the Services, additional engineering on both the JCID and handheld radio may be required. Additional radio infrastructure may also be required to add networking functionality (such as a server for network administration) to XTS5000 radios.

3.2.4 Radio Modems

Radio modems have been designed as a wireless replacement for serial cables, and general operation represents a serial data stream over a point-to-point communication link. Some vendors have models and/or software to implement point-to-multipoint protocols and mesh networks. An advantage of radio modems over other technologies is that the technology has been implemented over a variety of frequencies, including 400 MHz, VHF/UHF, 1.9 GHz, and military bands. The transmit power will vary from vendor to vendor but can be as low as fractional watts and as high as tens of watts. The range capabilities of this technology will vary with transmit power and frequency, but units can generally be found to meet the range requirements of the JWARN application with less supplemental equipment when compared with 802.11 (standard transmit power of 100 mW.) This technology tends not to use bandwidth as efficiently as other technologies.

Currently no radio modems are validated under FIPS 140-2; therefore, encryption would have to be handled on the JCID. The cost per JCID after NRE would be in the range of $1500–$5500 for a radio modem.

3.2.5 Cellular

Cellular solutions are broken down into three camps: GSM (Global System for Mobile communications), CDMA (Code Division Multiple Access), and TDMA (Time Division Multiple Access). Only the 3G and GSM-based cellular systems currently support FIPS-certified encryption, and only one encryption device is validated under FIPS 140-2 (a small encrypting module that plugs into the data connector of GSM handsets). Currently, no FIPS-certified PCMCIA cell cards are available for use as a wireless modem, so encryption would need to be implemented on the JCID.

At first glance, cellular solutions look very promising for fixed installations where cellular service providers have already invested in providing the infrastructure (e.g., towers, control hardware). In general, PCMCIA modems are low cost (~$250) and have good range and connectivity. However, in locations underserved by service providers, an extensive infrastructure would need to be developed, including towers, relays, network administration, and a phone routing database.

A recent offering from Ericsson, the QuicLINK, is a rapidly deployable cellular solution that would enable a cellular infrastructure on site where it does not currently exist. This system was used in the disaster recovering efforts after Hurricane Katrina. With QuicLINK, communication from the JCID could be achieved by using a PCMCIA cellular modem card. As with a traditional cellular network, all calls would be routed by the base station or QuicLINK; therefore, the data routing would be JCID to base station to Master JCID. The QuicLINK system cost will be ~$400K.

3.2.6 Satellite Modem

Satellite solutions are similar to the cellular solution, only with greater range. Where the cellular solution requires cell towers to be in proximity to the hardware, the area coverage by a satellite is much greater. Current military satellite bandwidth is overused, but civilian satellite options are available. Satellite modems would be external to the JCID, connecting to the Ethernet, USB, or serial data port. The satellite modems would relay data communication between the JCID and a satellite. From the satellite, data could be sent directly to another JCID via the Internet or central alerting station.

Satellite systems provide good bandwidth and long range for remote areas. Satellite BGAN (broadband global area network) power consumption tends to be higher than cellular solutions but less than radio modems. Devices and antennas can vary in size from 8.5 × 11 inches and weigh from a two to several hundred pounds. If the encryption requirements can be handled on the JCID, some of the more recent satellite hardware is promising. NAL Research is currently producing small satellite burst modems for use with the Iridium Satellite network (low bandwidth). The hardware and antennas for this network are relatively small. The Iridium Satellites travel in a low earth orbit, and—with the high number of satellites available—the network provides truly global coverage. Another small form factor hardware option is Inmarsat Nera terminal (high bandwidth). Equipment pricing for satellite modems could range $500–$3500 per JCID plus monthly air-time fees.

3.2.7 Bluetooth

Bluetooth (802.15.1) is a wireless standard originally developed to eliminate the increasing number of cables connecting consumer devices. It is also used for short-range communication between mobile devices. Bluetooth uses radio frequencies in the 2.45 GHz range to transmit information over short distances of generally less than 33 feet (10 m).

3.2.8 Laser

Laser communications are limited to infrastructure uses where line of sight can be maintained. These systems are often used to extend connectivity to adjacent buildings in an urban setting where the cost of running wire or the cost of leasing fiber lines is prohibitive. Systems are available with communications rates up to 1 Gbps and ranges up to several miles. No FIPS-certified products are currently available.

3.2.9 ZigBee

ZigBee is the set of specifications built around the IEEE 802.15.4 wireless protocol. The name is derived from the erratic zigging patterns many bees make between flowers when collecting pollen—evocative of the invisible webs of connections existing in a fully wireless environment. Devices, which operate on the 2.4 GHz industrial, scientific, and medical (ISM) band, are actively limited to a through-rate of 250 Kbps compared to the Bluetooth pipe of 1 Mbps. They are less complex and therefore less expensive than Bluetooth. In industry ZigBee is being used for next-generation automated manufacturing. In the consumer market it is being explored for linking low-power household devices.

3.2.10 Infrared

Infrared was designed to be a short-range wireless communication system. It is widely used for remote controls, personal digital assistants (PDAs), laptops, and printers. Most systems are designed for indoor use with ranges of less than 20 feet. Infrared modems are available for portable devices and are designed for short ranges and low data rates with small data files. There are no currently FIPS-certified devices in this category.

3.3 Technology Downselect

For a variety of reasons, several of the technologies under review as potential candidates for the JWARN wireless requirements did not meet those basic requirements, so there is no need at this time to consider them as candidates for development of a prototype wireless solution. However, while these technologies are not viable for consideration at this time, they deserve continued monitoring as part of further or continued JWARN wireless marketing survey(s), since the faults found with any one of them could be solved, making them worthy or reconsideration.

3.3.1 Harris SecNet

The Harris PCMCIA card, 802.11, SecNet11 product was initially considered to be the best candidate for a JWARN wireless capability. However, the product is certified by NSA for Type I Secret communications, which would preclude its use in an unmanned or unattended scenario. In addition, this card is quite expensive. For both reasons, this product will not be further reviewed at this time.

3.3.2 Handheld Radio

The USAF has a large investment in handheld radios (primarily Motorola) that are used in and about airfields and bases. This technology category was thought to have potential viability in a Fixed or Garrison/Provisional Scenario, where the existing handheld radios could be reused as the wireless connectivity between JCIDs boxes. However, since the handheld radios do not have an easy-to-use graphical user interface (GUI) and they do not possess a capability for self-forming, self-healing networks, they are will not be further reviewed at this time.

3.3.3 Cellular

There was considerable initial interest in cellular technologies as a viable solution for the Fixed and Garrison/Provisional Scenarios. However, since cellular solutions do not have an easy-to-use

GUI and they do not possess a capability for self-forming, self-healing networks, they are will not be further reviewed at this time. In addition, the cost of deploying cellular towers with their associated servers, as well as the special training involved to operate and maintain them, may have led to further issues with additional analysis.

3.3.4 Satellite Modem

The cost and complexity involved in deploying a satellite network dedicated to JWARN is prohibitive, and existing bandwidth on military satellite networks is a very scarce commodity. As a result, this technology will not be further reviewed at this time.

3.3.5 Bluetooth

Bluetooth technology was originally developed to provide a wireless interface between PCs and peripherals (printers, PDAs, etc.) in close proximity. It is not too surprising, therefore, that this technology does not fulfill the requirement for range, nor does it have any capability for self-forming, self-healing networks. As a result, this technology will not be further reviewed at this time.

3.3.6 Laser

Lasers are being used in built-up areas to transmit digital signaling, so they were considered as a potential wireless candidate for JWARN. However, no FIPS-certified units are currently available. In addition, the complexity and high cost of this technology, which has significant weight, size, and infrastructure requirement as well as high costs, have led this technology to not be further reviewed at this time.

3.3.7 ZigBee

For the same reasons as with Bluetooth, this technology does not fulfill the requirement for range, nor does it have any capability for self-forming, self-healing networks. As a result, this technology will not be further reviewed at this time.

3.3.8 Infrared

Infrared capability has been available as a normal PC wireless communication capability for years, providing limited-range wireless connectivity primarily for printers and PDAs. Infrared has an extremely low bandwidth, very short range (at the level of inches or few feet), and it does it have any capability for self-forming, self-healing networks. As a result, this technology will not be further reviewed at this time.

3.4 Technology Candidates

Upon eliminating these technologies, a subset of technologies remained for further analysis. However, an important assumption was made to set the foundation for follow-on analyses and recommendations. With the lack of options available when requiring the wireless technology itself to be FIPS encryption certified, the assumption was made that the JCID will be modified to handle encryption requirements. Encryption on the JCID could likely be handled in software or hardware or a combination of both. The operating system on the JCID is Windows CE 5.0, which has an associated encryption module that is certified for FIPS 140-2, Level 1. The encryption implemented by the operating system results in a Layer 6 encryption ("layer" is in reference to the OSI-7 layer model). While it has yet to be determined what encryption level will be sufficient for wireless transmissions, most FIPS-certified wireless devices are encrypted on Layer 2, which protects the routing information. The layer at which encryption occurs will influence the type of equipment required to complete a wireless link between a JCID and master JCID. Therefore, when scoring the various wireless solutions, we have made assumptions regarding the encryption implementations to compare representative systems for each operational scenario.

Assuming that encryption requirements can be met on the JCID through additional software (e.g., Fortress) or embedded hardware, PCMCIA cards would need to be compatible with the encryption solution used and, in the case of software, have drivers written for use in the JCID. In both cases, it is desirable to use a PC Card without an antenna or with a removable patch antenna so that there is an external connector (usually MMCX) available to connect to the antenna port of the JCID. To complete the communication links, Fortress (or similar encryption software) would be needed on each piece of communication hardware (e.g., access points) in addition to the JCID if the encryption is to be implemented on Layer 2.

The following technologies were retained in the analysis, and more detailed research was conducted for top products in each category.

3.4.1 802.11 Ad Hoc

802.11 solutions can be made to meet most range requirements with a wide range of available antennas and amplifiers. It is currently the most widely used wireless standard. Due to the abundance of COTS vendors' creating supporting equipment, it is easy to find and has a low cost. Thus, due to the low cost and networking tools available, this technology has been kept for future evaluation.

3.4.2 802.11 Mesh

In addition to the rationale for retaining the 802.11 ad hoc (above), the automated network-forming, self-maintenance, and ease of user interface for this technology indicated that it should be kept for future evaluation.

3.4.3 802.16/WiMax

This technology has been kept due to its potential to meet the requirements in the near future. It is not expected that components will be readily available for 1+ years.

3.4.4 Radio Modems

Radio modems have been kept on the list for further evaluation due to their use of military frequency bands.

3.5 Potential Government Solutions

As part of our study, JWARN Program Office staff and various stakeholders suggested GOTS systems for consideration as potential candidates to meet the JWARN wireless capability. As those systems were suggested, they were added to the list of potential technologies and reviewed against the evaluation criteria. Below is the list of candidate GOTS solutions that have been suggested and, where time permitted, reviewed, along with any associated analysis.

3.5.1 USAF Force Protection Battle Laboratory, Robust Battlefield Wireless Network (RBWN)

From the Force Protection Battle Laboratory, "the objective of this project is to evaluate the field applicability of a dynamic hybrid radio mesh network in a simulated battle 'infosphere.' The simulated battle infosphere network will span metropolitan area networks (MANs), WLANs, and personal area networks (PANs) through the use of 2-4 radio mesh nodes and single radio extended network clients. Quality of service measures will be identified and evaluated in the field system. The ability to control QoS for low (VOIP, streaming video, etc.) and high latency protocols (http, sensor-XML) will be evaluated in various mobile and stationary network topologies." Details of the effort include the following:

- Integrated/Agile IBD C4ISR Communication Backbone
- VOIP (Voice over Internet Protocol) <=> Tactical Radio
    - "Global/local "inter-/intra-team and point-to-point communications
    - Coexists/augments "legacy" tactical radios
- Robust operation
    - Agile frequency allocation/usage optimized over the battlefield
    - "Zero" order system: self-managing, self-configuring, zero IT/Commfootprint
    - Quality-of-service (QoS) optimization: latency and bandwidth
    - All required "services" provided by mobile access point (AP)
    - Real-time battlefield authentication
- Integration with "smart" jamming systems
    - Coordinated RBWN frequency changes with jammer "activity"
    - Proactive RBWN Client Intrusion Detection
    - Identification and prosecution (denial of service) of RBNW "bad actors" within RBNW frequency channels
    - Coordinate channel changes/jamming channels based on cognitive review of jammer/RBNW activities

The RBWN is notable for its use of Mesh Dynamics mesh network technology and its attempted incorporation of multilevel security encryption through an already NSA-approved methodology. In addition, the system is already prototyped and tested, and the Battle Laboratory is getting ready for possible NSA certification, which may be jointly pursued with the JWARN program, if appropriate.

The RBWN, however, may not have considered all key security differentiators between their solution target and the JWARN requirements. Notably, the Mesh Dynamics technology may have extraneous software/capabilities included that may have to be removed to enable it to receive a favorable NSA certification.

3.5.2 U.S. Army Combat Service Support Automated Information System Interface (CAISI)

CAISI is a tactical wireless LAN using wireless access points and workgroup bridges from Cisco Systems and encryption and access control technology from Fortress Technologies. Specifically, the system uses 802.11b under wired equivalent privacy (WEP), its access points share one encryption key, and the system will use the Triple Data Encryption Standard with AirFortress.

The study team had already reviewed products from Cisco and Fortress, including 802.11b and AirFortress encryption software, so CAISI did not provide any additional wireless technologies for consideration.

3.5.3 U.S. Navy Combat Survivor/Evader Locator (CSEL)

More than just a handheld radio, CSEL is a complete, multifunction communication system solution. The system is based on a flexible, modular communication architecture that provides multiple satellite links for dependable, secure low probability of intercept/low probability of detection (LPI/LPD), over-the-horizon (OTH) communications; line-of-sight voice communications; global geoposition; navigation; and beacon functions. CSEL is an end-to-end system composed of three segments: a user segment that includes a handheld radio, an OTH segment for satellite communications, and a ground segment consisting of multiple command, control, and communications (C3) workstations located in Joint Search and Rescue Centers (JSRCs).

The study team had already reviewed satellite modems from Hughes and NAL Research. CSEL is a low-bandwidth, purpose-driven system. Being part of the JSRC system limits its use outside of search and rescue.

3.5.4 USAF Combat Information Transport System (CITS)

The CITS program is an Air Force multiyear initiative to provide a high-speed, broadband, digital information transport system responsible to integrate existing data systems and provide the capability to integrate all existing and planned voice, video, imagery, and sensor systems including classified systems. CITS comprises the Information Transport System (ITS), the Network Operations/Information Assurance (NO/IA), Telecommunications Management System (TMS), and the Voice Switching System (VSS). CITS is intended as the backbone network for all active duty and reserve Air Force bases.

CITS is notable for its goal of providing high-speed broadband capabilities. However, it is a complex system, containing management systems and switching systems, and was felt to be inappropriate for consideration as part of the JCID, particularly for garrison/provisional and mobile dismounted applications. CITS may provide some value to fixed sites, but this is likely to be on a case-by-case basis and was, therefore, not pursued for this JWARN wireless capability.

3.5.5 NSA Cryptology Group (Lackland)

It was suggested that the NSA, through a Cryptology Group based out of Lackland Air Force Base, was developing a secure wireless sensor integration capability. However, after discussions with the USAF Force Protection Battle Laboratory, which is located at Lackland and is currently collaborating with NSA to achieve security accreditation for its RBWN system (see above), no known effort or related points of contact were found. Further, Force Protection Battle Laboratory personnel indicated that it was unlikely that NSA was pursuing a solo effort to create such a solution, as their role is one of oversight and accreditation. After these efforts, no further research was possible as this potential solution was received very late during the AoA.

3.5.6 JFCOM Joint Experimentation Directorate

U.S. Joint Forces Command’s Joint Experimentation Directorate recently earned recognition at a major industry trade show for work on creating a highly secure wireless network inside of the Joint Futures Laboratory facilities. This potential solution was received too late during the AoA to be analyzed.

3.6 Link Budget Analysis

Following the downselection of candidate technologies to the remaining four categories, a link budget analysis was initiated on the leading candidates within each category. The link budget analysis was important as it was used to establish the transmission range capability of each product, which was, in turn, used to establish notional solutions for each of the scenarios. The link budget analysis methodology, which enabled the final technology scoring in the next section, is described below.

Because the transmission range capabilities of any piece of wireless equipment can vary greatly with terrain and environmental conditions, we performed a basic link budget calculation to compare equipment range. At the most basic (assuming line of sight), transmission range is a function of transmission power, free-space loss, antenna gain, and receiver sensitivity. For each product scored we assumed an external 6 dBi antenna would be used with the product, with the exception of WiMAX. Because the WiMAX standard is new to the market, we were limited to one subscriber-level product (that had published specs at the time of the survey). This WiMAX subscriber station unit has a built-in 14 dBi panel antenna, so 14 dBi was used for the WiMAX link budget calculations. In all other cases it is feasible to purchase 6 dBi COTS antenna for use with the specific frequencies of the other products. Our basic link budget is calculated as follows:

> Transmission power (dBm) + transmit antenna gain (dBi) – free space loss (dB) + receive antenna gain (dBi) = signal level at receiver.

The value of the “signal level at the receiver” was then compared to the given receiver sensitivity (on the data sheet) for that particular product. Since our model does not take into account connector losses, cable losses, foliage, or other RF absorption in the environment, we used a signal margin of ~20 dB to determine whether or not we can get a communication link with a particular product at a given distance (1000 or 5000 m). We assumed an antenna gain, the transmission power and receiver sensitivity are usually known from the data sheets, but free space loss needs to be calculated for a given distance at the operating frequency of the product. We calculated free space loss for 1000 and 5000 m for each products operating frequency:

$$\text{Free space loss} = 32.45 + 20 * \text{LOG}_{10}(\text{distance (km)} * \text{frequency (MHz)})$$

Example of the link budget calculation for a freewave radio modem:

Distance = 5000 m, or 5 km
Frequency = 400 MHz
Free space loss = $32.45 + 20 * \text{LOG}_{10}(5 * 400) = 98$ dB

Transmission power = 4 W or 36 dBm
Transmit antenna gain = 6 dBi
Receive antenna gain = 6 dBi
Receiver sensitivity = -103 dBm

Signal level at receiver = transmission power (dBm) + transmit antenna gain (dBi) – free space loss (dB) + receive antenna gain (dBi)
Signal level at receiver = 36 + 6 – 98 + 6 = –50 dBm

Signal margin = Signal level at receiver – receiver sensitivity
= (–50) – (–103)
= 53 dB of signal margin

In this case, at 5000 m we have a signal margin of much greater than 20 dB; therefore, we can be well assured of a communication link.

4.0 FINAL TECHNOLOGY SCORING

The following section covers the scoring received under each criterion for a given product along with the data or calculations supporting the score. For those criteria that do not have numerical data to score against, engineering judgment that takes in to account prior experience with similar hardware and systems was used to develop the score. Definitions of the scoring scale and criteria appear in Appendix A of this report.

4.1 802.11, DTG Reliawave (100 mW)

The DTG Reliawave is a 100 mW 802.11b PCMCIA card solution. This product was chosen as one of the top two representatives of 802.11 ad hoc due to its receiver sensitivity and its low power consumption. In addition, the DTG Reliawave is one of the few PCMCIA 802.11 cards that do not have a built-in antenna. It is designed to support an industrial clientele, and therefore has a better operational temperature range and will be more ruggedly built.

	Score	Value
1.0 Performance		
Transmission Range	0.75	1000 m with >20 dB of signal margin
Power Management	0.25	Ability to turn off radio
Transmit Power at the JCID	1	Draws ≈2.4 W during transmit

Standby Power at the JCID	1	Draws ≈1.4 W during receive
2.0 Deployability		
Frequency Flexibility	0.75	11 Channels
Bandwidth Efficiency	0.5	Data rate per MHz of radio space
Main Site Weight	1	PCMCIA card <50 grams
Main Site Volume		Calculated for each CONOPS
Main Site Number of Boxes		Calculated for each CONOPS
JCID Weight	1	PCMCIA card <50 grams
JCID Number of Boxes	1	PCMCIA in JCID, one external box for antenna
3.0 Operating Environment		
Operational Temperature	1	–35°C to 65°C
Storage Temperature	0.8	Not published, assume –35°C to 65°C
Shock/Vibe	0.25	COTS
Electromagnetic Interference (EMI)	0.5	Commercial standards
4.0 Usability		
Supports Multiple Center-Line Channels	1	Yes
Operates in Military Frequency Bands	0.7	Not MIL STD, but previously used by Services
Remote Enable/Disable Transmission	0.6	Can remotely disable transmission
Reconfiguration	0	Manual configuration
Initial Configuration	0	Manual configuration
Ongoing Management	0.5	Requires specialized skill set
Local CBRN Network Operational Picture	0.25	Can assume visual alarm
Support-Level Training and Manpower	0.5	Will require special training
5.0 Logistics and Sustainment		
Required Sparing		Calculated for each CONOPS
Consumables	1	Will get power from JCID battery
Technical Data	0.25	Published data not adequate for DoD

4.2 802.11, Esteem (192E)

The Esteem is a 200 mW 802.11b PCMCIA card solution. This product was chosen as one of the top two representatives of 802.11 ad hoc due to its temperature range and low power consumption. In addition, the Esteem WLANC11-2 is one of the few PCMCIA 802.11 card that does not have a built-in antenna. It is designed to support an industrial cliental and therefore has a better operational temperature range and will be more ruggedly built.

	Score	**Value**
1.0 Performance		
Transmission Range	0.75	1000 m with >20 dB of signal margin
Power Management	0.25	Ability to turn off radio
Transmit Power at the JCID	1	Draws ≈2.5 W during transmit
Standby Power at the JCID	1	Draws ≈1.4 W during receive
2.0 Deployability		
Frequency Flexibility	0.75	11 Channels
Bandwidth Efficiency	0.5	Data rate per MHz of radio space
Main Site Weight	1	PCMCIA card <50 grams
Main Site Volume		Calculated for each CONOPS
Main Site Number of Boxes		Calculated for each CONOPS
JCID Weight	1	PCMCIA card <50 grams
JCID Number of Boxes	1	PCMCIA in JCID, one external box for antenna
3.0 Operating Environment		
Operational Temperature	0.75	0°C to 60°C
Storage Temperature	0.8	–15°C to 75°C
Shock/Vibe	0.25	COTS
EMI	0.5	Commercial standards
4.0 Usability		
Supports Multiple Center-Line Channels	1	Yes

Operates in Military Frequency Bands	0.7	Not MIL STD, but previously used by Services
Remote Enable/Disable Transmission	0.6	Can remotely disable transmission
Reconfiguration	0	Manual configuration
Initial Configuration	0	Manual configuration
Ongoing Management	0.5	Requires specialized skill set
Local CBRN Network Operational Picture	0.25	Can assume visual alarm
Support-Level Training and Manpower	0.5	Will require special training
5.0 Logistics and Sustainment		
Required Sparing		Calculated for each CONOPS
Consumables	1	Will get power from JCID battery
Technical Data	0.25	Published data not adequate for DoD

4.3 802.16 WiMax, Redline Communications

The Redline Communications RedMAX SU-O is a subscriber unit that operates in the 3.3–3.5 GHz range. This product was chosen as a representative of this technology due to its availability of documentation. WiMAX is still a new standard, and few products are readily available.

	Score	**Value**
1.0 Performance		
Transmission Range	1	5000 m with >20 dB of signal margin
Power Management	0.25	Ability to turn off radio
Transmit Power at the JCID	1	Draws ≈2.5 W during transmit[2]
Standby Power at the JCID	1	Draws ≈1.4 W during receive[3]
2.0 Deployability		
Frequency Flexibility	1	35 Channels
Bandwidth Efficiency	1	Data rate per MHz of radio space
Main Site Weight	0.5	4.5 lbs
Main Site Volume		Calculated for each CONOPS
Main Site Number of Boxes		Calculated for each CONOPS
JCID Weight	0.5	4.5 lbs
JCID Number of Boxes	0.8	Two external boxes, subscriber unit and power
3.0 Operating Environment		
Operational Temperature	1	–40°C to 65°C
Storage Temperature	0.8	Not published, assume –40°C to 65°C
Shock/Vibe	0.25	COTS
EMI	0.5	Commercial standards
4.0 Usability		
Supports Multiple Center-Line Channels	1	Yes
Operates in Military Frequency Bands	0.25	No prior use by services
Remote Enable/Disable Transmission	0.6	Can remotely disable transmission
Reconfiguration	1	Assumed automatic
Initial Configuration	1	Assumed automatic
Ongoing Management	0.75	Semiautomatic
Local CBRN Network Operational Picture	0.5	Can assume text based interface
Support-Level Training and Manpower	0.5	Will require special training
5.0 Logistics and Sustainment		
Required Sparing		Calculated for each CONOPS
Consumables	0.75	Can choose MIL battery
Technical Data	0.25	Published data not adequate for DoD

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[2] This 802.16 product has the same transmit output power (100 mW) as the Esteem 802.11 product; therefore, we estimate that the WiMAX transmit power draw will be the same or less than that of the 802.11 product.

[3] This 802.16 product has the same transmit output power (100 mW) and similar receive sensitivity as the Esteem 802.11 product; therefore, we estimate that WiMAX standby power draw will be the same or less than that of the 802.11 product.

4.4 802.11 Mesh, Mesh Dynamics

The Mesh Dynamics is a mesh networking solution provider. This product was chosen as one of the top two representatives of mesh networking due to its being evaluated by the Air Force Battle Laboratory. In addition, the Mesh Dynamics is a Fortress-capable device, which will enable meeting the encryption requirements.

	Score	**Value**
1.0 Performance		
Transmission Range	1	5000 m with >20 dB of signal margin
Power Management	0.25	Ability to turn off radio
Transmit Power at the JCID	1	Draws ≈2.4 W during transmit
Standby Power at the JCID	1	Draws ≈1.4 W during receive
2.0 Deployability		
Frequency Flexibility	0.75	11 Channels
Bandwidth Efficiency	0.5	Data rate per MHz of radio space
Main Site Weight	0.8	3.0 lbs.
Main Site Volume		Calculated for each CONOPS
Main Site Number of Boxes		Calculated for each CONOPS
JCID Weight	0.8	3.0 lbs.
JCID Number of Boxes	1	PCMCIA in JCID, one external box for antenna
3.0 Operating Environment		
Operational Temperature	1	–40°C to 85°C
Storage Temperature	0.8	Not published, assume –40°C to 85°C
Shock/Vibe	0.25	COTS
EMI	0.5	Commercial standards
4.0 Usability		
Supports Multiple Center-Line Channels	1	Yes
Operates in Military Frequency Bands	0.7	Not MIL STD, but previously used by Services
Remote Enable/Disable Transmission	0.6	Can remotely disable transmission
Reconfiguration	1	Fully automatic configuration
Initial Configuration	1	Fully automatic configuration
Ongoing Management	0.75	Moderately intuitive
Local CBRN Network Operational Picture	1	Full graphic interface
Support-Level Training and Manpower	1	Minimal training
5.0 Logistics and Sustainment		
Required Sparing		Calculated for each CONOPS
Consumables	1	Plugger batteries and PCMCIA power by JCID
Technical Data	0.75	Quality manuals, would need translate to DoD

4.5 802.11 Mesh, Rajant

The Rajant is a mesh networking solution provider. The BreadCrumb product was chosen as one of the top two representatives of mesh networking for the variety of configurations that can be ordered. In addition, the Rajant BreadCrumb is a Fortress-capable device, which will enable meeting the encryption requirements.

	Score	**Value**
1.0 Performance		
Transmission Range	1	5000 m with >20 dB of signal margin
Power Management	0	
Transmit Power at the JCID	1	Draws ≈2.4 W during transmit
Standby Power at the JCID	1	Draws ≈1.4 W during receive
2.0 Deployability		
Frequency Flexibility	0.75	11 Channels
Bandwidth Efficiency	0.5	Data rate per MHz of radio space

Main Site Weight	0.8	1.5–3.9 lbs.
Main Site Volume		Calculated for each CONOPS
Main Site Number of Boxes		Calculated for each CONOPS
JCID Weight	0.8	1.5–3.9 lbs.
JCID Number of Boxes	1	PCMCIA in JCID, one external box for antenna
3.0 Operating Environment		
Operational Temperature	0.85	–20°C to 60°C
Storage Temperature	0.8	Not published, assume –20°C to 60°C
Shock/Vibe	0.25	COTS
EMI	0.5	Commercial standards
4.0 Usability		
Supports Multiple Center-Line Channels	1	Yes
Operates in Military Frequency Bands	0.7	Not MIL STD, but previously used by Services
Remote Enable/Disable Transmission	0.6	Can remotely disable transmission
Reconfiguration	1	Fully automatic configuration
Initial Configuration	1	Fully automatic configuration
Ongoing Management	0.75	Moderately intuitive
Local CBRN Network Operational Picture	1	Full graphic interface
Support-Level Training and Manpower	1	Minimal training
5.0 Logistics and Sustainment		
Required Sparing		Calculated for each CONOPS
Consumables	1	Plugger batteries and PCMCIA power by JCID
Technical Data	0.75	Quality manuals, would need translate to DoD

4.6 Radio Modems, RADIUS PDR

The RADIUS PDR is a 2000 mW military frequency radio modem solution. This product was chosen as one of the top two representatives of radio modem due to its available GUI software tools to manage the radio network.

	Score	**Value**
1.0 Performance		
Transmission Range	1	5000 m with >20 dB of signal margin
Power Management	0	
Transmit Power at the JCID	0.6	Draws ≈13.2 W during transmit
Standby Power at the JCID	0.9	Draws ≈1.98 W during receive
2.0 Deployability		
Frequency Flexibility	0	
Bandwidth Efficiency	0.5	Data rate per MHz of radio space
Main Site Weight	0.9	≈1.4 lbs.
Main Site Volume		Calculated for each CONOPS
Main Site Number of Boxes		Calculated for each CONOPS
JCID Weight	0.9	≈1.4 lbs.
JCID Number of Boxes	0.6	Three boxes, modem + power + antenna
3.0 Operating Environment		
Operational Temperature	1	–40°C to 60°C
Storage Temperature	0.8	Not published, assume –40°C to 60°C
Shock/Vibe	0.25	COTS
EMI	0.5	Commercial standards
4.0 Usability		
Supports Multiple Center-Line Channels	1	Yes
Operates in Military Frequency Bands	1	Yes
Remote Enable/Disable Transmission	0.6	Can remotely disable transmission
Reconfiguration	0	Manual configuration
Initial Configuration	0	Manual configuration
Ongoing Management	0.75	Semiautomatic
Local CBRN Network Operational Picture	1	Full graphic interface

Support-Level Training and Manpower	0.5	Will require special training
5.0 Logistics and Sustainment		
Required Sparing		Calculated for each CONOPS
Consumables	0.75	Can choose MIL battery
Technical Data	0.25	Published data not adequate for DoD

4.7 Radio Modems, Freewave

The Freewave DGBR-115W is a 4000 mW military frequency radio modem solution. This product was chosen as one of the top two representatives of radio modem for its available data rate, ability to support master slave configurations, and its current use in the military.

	Score	**Value**
1.0 Performance		
Transmission Range	1	5000 m with >20 dB of signal margin
Power Management	0.25	Data rate per MHz of radio space
Transmit Power at the JCID	0.1	Draws ≈30 W during transmit
Standby Power at the JCID	0.1	Draws ≈3 W during receive
2.0 Deployability		
Frequency Flexibility	1	64 selectable channels
Bandwidth Efficiency	0.5	Data rate per MHz of radio space
Main Site Weight	0.9	≈1.4 lbs.
Main Site Volume		Calculated for each CONOPS
Main Site Number of Boxes		Calculated for each CONOPS
JCID Weight	0.9	≈1.4 lbs.
JCID Number of Boxes	0.6	Three boxes, modem + power + antenna
3.0 Operating Environment		
Operational Temperature	1	–40°C to 75°C
Storage Temperature	1	–55°C to 85°C
Shock/Vibe	0.25	COTS
EMI	0.5	Commercial standards
4.0 Usability		
Supports Multiple Center-Line Channels	1	Yes
Operates in Military Frequency Bands	1	Yes
Remote Enable/Disable Transmission	0.6	Can remotely disable transmission
Reconfiguration	0	Manual configuration
Initial Configuration	0	Manual configuration
Ongoing Management	0.5	Requires specialized skill set
Local CBRN Network Operational Picture	0	Not available
Support-Level Training and Manpower	0.25	Will require high degree of special training
5.0 Logistics and Sustainment		
Required Sparing		Calculated for each CONOPS
Consumables	0.75	Can choose MIL battery
Technical Data	0.5	Published data OK but needs translation for DoD

5.0 DECISION MODELING

5.1 Overview

A facilitated decision support process was used to incorporate user involvement and feedback with the technical analyses being performed and to create three final decision models to rank products within each of the three scenarios. This approach was chosen to ensure that conflicting concerns from different user groups were addressed and that the final solution would be better supported by all stakeholders.

With only notional CONOPS scenarios used to this point, the study team felt it imperative to refine these in a group setting with all stakeholders present. The four initial scenarios were substantially refined and discussed, and the final versions, approved by all members, are in Section 5.2.

Using refined scenarios, the technical criteria used to guide data collection efforts were reformulated in terms of notional user impacts. This process was used to ensure that users could appreciate the nontechnical tradeoffs that they were making when stipulating technical requirements. A facilitated session was then used with stakeholders to refine these notional user impacts into well-defined system objectives. The system objectives were voted on by user representatives, which resulted in a set of decision models for each of the three scenarios—fixed, garrison/provisional, and mobile dismounted—that explicitly defined the users' objective and priorities for the JCID's wireless functionality. Section 5.3 highlights the output from this effort and characterizes the users' intent in their voting, including their priority weighting.

Stakeholders were then supported in reviewing the technical criteria used to score candidate wireless products and helped to group the scores into scales that were relevant to their intended use of JWARN. These efforts further ensured that users could appreciate the nontechnical tradeoffs that they were making when stipulating technical requirements. The final criteria used within in the three decision models, including scaling and associated metrics, are included in Appendix A.

Finally, upon completion of decision support, wireless SME study members updated the technical scores for candidate technologies. The output of these scores was incorporated into each of the three final decision models, and the final ranking of recommended products for each scenario was produced. The ranking was, therefore, according to the technical performance of candidate technologies in the areas weighted according to priority by Joint forces users.

The theory behind the specific decision support process is provided in Appendix B.

Stakeholders involved throughout discussions included the JWARN Program Office, U.S. Army (G8, Army Combat Developers), U.S. Air Force (Langley, HSG/TBB, AFCESA, A7CXR), USMC MCCDC, USN OPNAV N767, JRO-CBRND, JWARN Program Office, Battelle, and Northrop Grumman. Stakeholders voting within decision support sessions included the U.S. Army (G8, Army Combat Developers), the U.S. Air Force (Langley, HSG/TBB, AFCESA, A7CXR), and JRO-CBRND. The U.S. Navy and U.S. Marine Corps declined to participate.

5.2 Scenarios

The four initial scenarios were substantially refined and discussed with all stakeholders and Joint forces user representatives. The refined scenarios were critical for subsequent establishment of quantified user objectives and criteria. The four scenarios were refined into the following four.

5.2.1 Fixed Sites

Fixed sites are defined as static installations in well-controlled areas. The primary consideration is Air Force bases. The time between likely modifications to JWARN system configuration is on the order of months to years. These are considered mixed deployment environments and include both stationary installation locations where the sensor is temporarily deployed for increased threat conditions and stationary installations where the sensor is permanently installed. Sensors are not likely to be under constant observation. Additional issues related to fixed sites, which underscore important user concerns, are as follows:

- Transmission range minimum of 1000 m with no repeaters and maximum of 5000 m with up to two repeaters (assumes line of sight/near line of sight between JCIDs through some vegetation or other obstruction, either directly or through the use of antennas)
- Latency, defined as time from when a sensor goes off to when the JWARN host system receives notice and includes sensor to JCIDs as well as point-to-point between JCIDs
- Desire ability for remote enable/disable of the JCID from JMAS software, with physical JCID enable/disable length of time expected to be 10–15 minutes
- Must be integrated into the installation’s communication plan
- Expect use of external antenna, with directional antenna optional
- Desire the ability to support different channels and that the frequency be reconfigurable
- Need to consider impacts of operating in more complex EMI environments
- Desire a single wireless solution that is universally deployable
- Assume that there will be a fixed primary power source, with secondary power from batteries
- Notional USAF fixed site is approximately 3 × 5 km

5.2.2 Garrison/Provisional

Garrison/provisional sites are defined as static installations in areas less well controlled than those of fixed sites. The primary consideration is Army tactical garrisons, Air Force expeditionary provisional wings, and Air Force forward operating bases. The time between likely modifications to JWARN system configuration is on the order of weeks to months. These are temporary deployment environments where the sensor network is appropriately employed to meet threat conditions. Sensors are not likely to be under constant observation. Additional issues related to garrison/provisional sites, which underscore important user concerns, are as follows:

- Transmission range minimum of 1000 m with no repeaters and maximum of 5000 m with up to two repeaters (assumes line of sight/near line of sight between JCIDs through some vegetation or other obstruction, either directly or through the use of antennas)
- Latency, defined as time from when a sensor goes off to when the JWARN host system receives notice, and includes sensor to JCIDs as well as point-to-point between JCIDs
- Desire ability for remote enable/disable of the JCID from JMAS software, with physical JCID enable/disable length of time expected to be 10–15 minutes
- Expect to monitor status of JCID via multiple methods: physical control, visual observation, and via network notified if the sensor is missing
- Expect use of antenna attached to the JCID, where operators could elevate the JCID or replace the antenna to achieve range requirement, with directional antenna optional so long as they do not require special storage

5.2.3 Mobile-Dismountable Sensor

The primary consideration is Army units and military platforms operating within a hostile environment. The time between likely modifications to JWARN system configuration is on the order of weeks. There are two primary deployment environments: mobile installations where the sensor is carried within vehicle under physical control and stationary installations where the sensor is carried from the vehicle. Sensors are not likely to be under constant observation. Additional issues related to mobile-dismounted scenarios, which underscore important user concerns, are as follows:

- Transmission range minimum of 1000 m with no repeaters and maximum of 5000 m with up to two repeaters (assumes line of sight/near line of sight between JCIDs through some vegetation or other obstruction, either directly or through the use of antennas)
- Latency, defined as time from when a sensor goes off to when the JWARN host system receives notice, and includes sensor to JCIDs as well as point-to-point between JCIDs
- Desire ability for remote enable/disable of the JCID from JMAS software, with physical JCID enable/disable length of time expected to be 10–15 minutes
- Expect to monitor status of JCID via multiple methods: physical control, visual observation, and via network notified if the sensor is missing
- Expect use of antenna attached to the JCID, where operators could elevate the JCID or replace the antenna to achieve range requirement, with directional antenna optional so long as they do not require special storage
- Desire the ability to support different channels and that the frequency be reconfigurable
- Desire a single wireless solution that is universally deployable.

5.2.4 Mobile-Mounted Sensor

Mobile-mounted sensors define a scenario for a JCID wired to a mobile platform, where the vehicle’s communications capability would be used to wirelessly transmit JCID data and/or JMAS messaging. The primary consideration was Army vehicle platforms. This scenario represents the JWARN Vehicle Interface Device (JVID) solution concept and is being pursued within a different study within the JWARN program.

NOTE: This scenario was not considered within this AoA.

5.2.5 Other Issues

Finally, other issues that were not specific to any of the four scenarios but which underscore important user concerns were discussed and are as follows:

- Legacy sensors under consideration:
    - Air Force—ACADA, JBPDS, JBSDS
    - Army—ACADA, JCAD, VDR2 Radiac
- Solution must satisfy the worst case regarding latency and data rate, with a temporary description of worst case as 128 sensors alarming at once and one JCID per sensor

- Wireless capability must continue to allow the JCID to be an unmanned solution requiring minimal physical observation, e.g., no more than battery change-out and/or power requirements
- Wireless antenna requirement will be at least a 3 dB and will allow for attaching different antenna types (directional, omnidirectional)
- COTS technologies understood as not likely to meet operational requirements for operating and storage temperatures for JCID

5.3 Objectives

Refined scenarios were used to reformulate existing technical criteria in terms of notional user impacts, ensuring that users could appreciate the nontechnical tradeoffs that they were making when stipulating technical requirements. Through discussion and voting, well-defined system objectives were created, and weighted priorities were derived for each of the three scenarios. Following are the five top-level objectives within the three models, with a brief description of user concerns and desires regarding the wireless capability on the JCID. Full details of all objectives may be found in Sections 6.3, 7.3, and 8.3 for each of the three final models.

5.3.1 Performance

Performance issues that impacted Joint forces operators were the focus within decision support modeling, while additional technical requirements with less impact on users were handled in the subsequent analyses. User representatives stipulated that primary considerations should be the transmission range and the battery life associated with a wireless product. A greater transmission range was desired, but the distance beyond a certain range (i.e., 1800 m) was of less value. As long a battery life as possible was desired. Ranking of performance as compared to other top-level priorities was as follows:

- In fixed: third most important, with 18% of the total weighting
- In garrison/provisional: second most important, with 24% of the total weighting
- In mobile dismounted: second most important, with 24% of the total weighting

5.3.2 Deployability

Deployability was a concern, particularly as the JWARN solution required more mobility. User representatives stipulated that primary considerations should be the ease of integration of the solution with a given unit’s communication plan and the physical load of the system (both at a central site and at each JCID/sensor location). The maximum ease of integration was desired, while the least physical load was required. Ranking of deployability as compared to other top-level priorities was as follows:

- In fixed: fifth most important, with 9% of the total weighting
- In garrison/provisional: fourth most important, with 20% of the total weighting
- In mobile dismounted: third most important, with 21% of the total weighting

5.3.3 Operating Environment

Operating environment was the consistently lowest concern across all three scenarios, but still a top-level priority of the system. User representatives stipulated a desire for the maximum level of operational and storage temperature range available, the maximum resistance to shock and vibration, and the maximum ability to operate within a high EMI environment. Criteria scoring reflected the value placed upon each of these, recognizing that costs rise prohibitively when providing maximum durability. Ranking of operating environment as compared to other top-level priorities was as follows:

- In fixed: fourth most important, with 9% of the total weighting
- In garrison/provisional: fifth most important, with 10% of the total weighting
- In mobile dismounted: fifth most important, with 10% of the total weighting

5.3.4 Usability

Usability was the consistently highest concern across all three scenarios. User representatives stipulated that primary considerations should be the wireless transmission frequency range, remote enable/disable the JCID wirelessly, network management, and support-level training and manpower requirements. The most flexibility for transmission frequency range was desired. The ability to remotely enable/disable the JCID through wireless communication was strongly desired. A system providing the maximum ease of network management was desired. Finally, a system with the least amount of required support-level training and manpower was strongly desired. Ranking of usability as compared to other top-level priorities was as follows:

- In fixed: first most important, with 43% of the total weighting
- In garrison/provisional: first most important, with 26% of the total weighting
- In mobile dismounted: first most important, with 33% of the total weighting

5.3.5 Logistics and Sustainment

Logistics and sustainment was a middle-level concern across all three scenarios, but still a top priority. User representatives stipulated that primary considerations should be the required sparing, consumables, and available technical data associated with the chosen wireless system. The minimum amount of sparing and consumables was desired, while the maximum amount of technical data regarding the solution was desired. Ranking of logistics and sustainment as compared to other top-level priorities was as follows:

- In fixed: second most important, with 22% of the total weighting
- In garrison/provisional: third most important, with 21% of the total weighting
- In mobile dismounted: fourth most important, with 13% of the total weighting

6.0 FINAL DECISION MODEL: FIXED SITES

6.1 Assumptions

For the final fixed-site decision model, it was assumed that the encryption requirements can be met on the JCID with software or hardware modifications. It was also assumed that drivers can be written when the solution requires a PCMCIA card installed in the JCID. Whenever an external antenna is used in a notional example, an antenna with 6 dBi of gain (with the exception of WiMAX which is 14 dBi due to a built-in antenna) was assumed. When calculating power draw at the JCID, it was assumed the radio is operating with a 50% duty cycle (transmitting half the time, receiving the other). To evaluate the data bandwidth available with each technology, the assumed maximum data rate for one JCID with four attached sensors is 19.2 kbps, a value which is used to determine how many receivers are required at the main site for each product. The notional layout examples that follow are for visualization only and do not represent final system implementations. The layout examples are supported by the product data sheets as well as link budget calculations discussed in previous sections.

6.2 Notional Example

The fixed example scenario assumes an airbase that is 3 × 5 km in area and has 35 JCID with four sensors each which will communicate back to a main site (Figure 6-1). This example uses a notional WiMAX implementation. The range given for WiMAX is 5.2 km at a data rate of 3.4 Mbps. Signal capabilities beyond 5.2 km will be at a decreased data rate. Based on our assumption of 19.2 kbps per JCID, the total data bandwidth needed at the main site for this implementation is 672 kpbs, which is much less than 3.4 Mbps (single subscriber). Therefore, we need only one WiMAX base station at the main site. The WiMAX base station and its antenna will require mounting on a building or tall antenna tower to maintain coverage over the airbase.

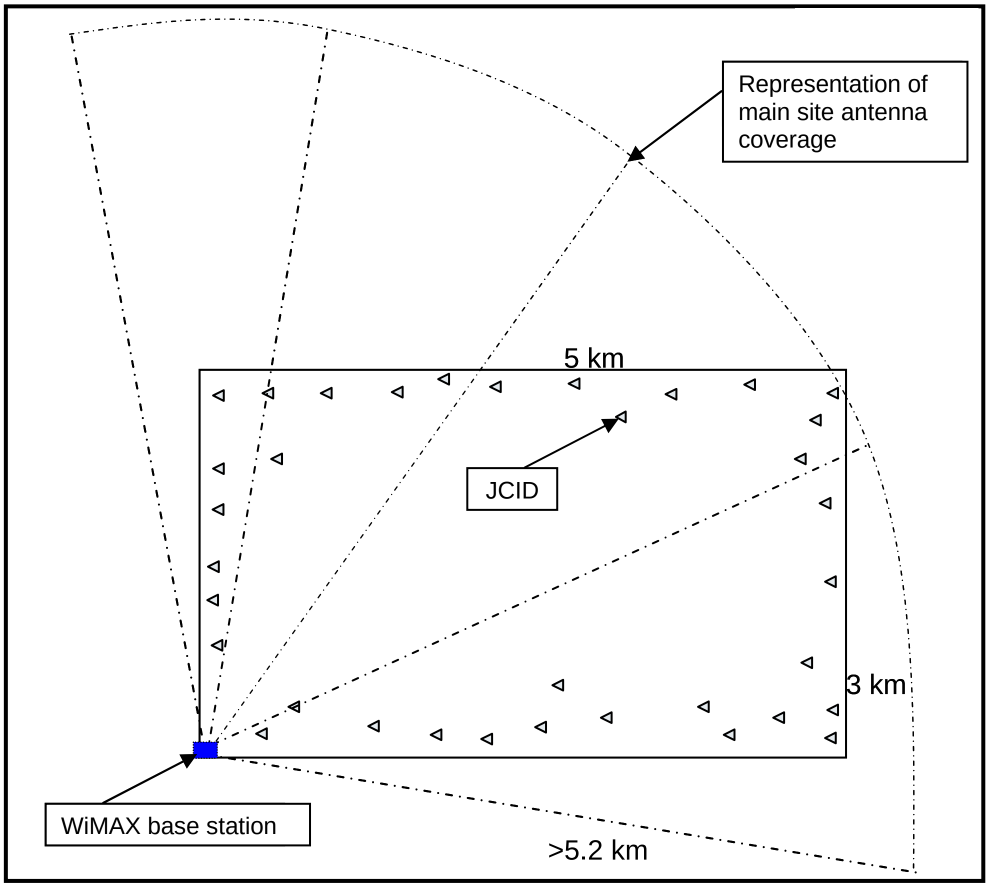


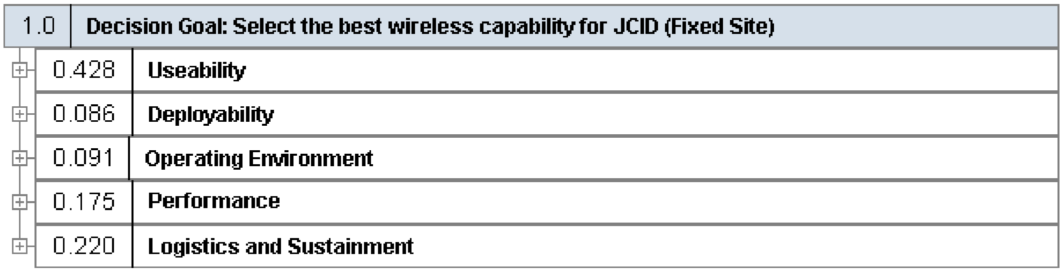
Figure 6-1. Fixed Example Scenario

Main site: WiMAX base station, power, directional antenna = 3 boxes
Sensor site (now): Subscriber station, power = 2 boxes
Sensor site (future ~2007): PCMCIA card, antenna = 1 box

Total boxes (now): 3 + 2 * 35 = 73
Total boxes (future ~2007): 3 + 1 * 35 = 38

6.3 Objectives and Priorities

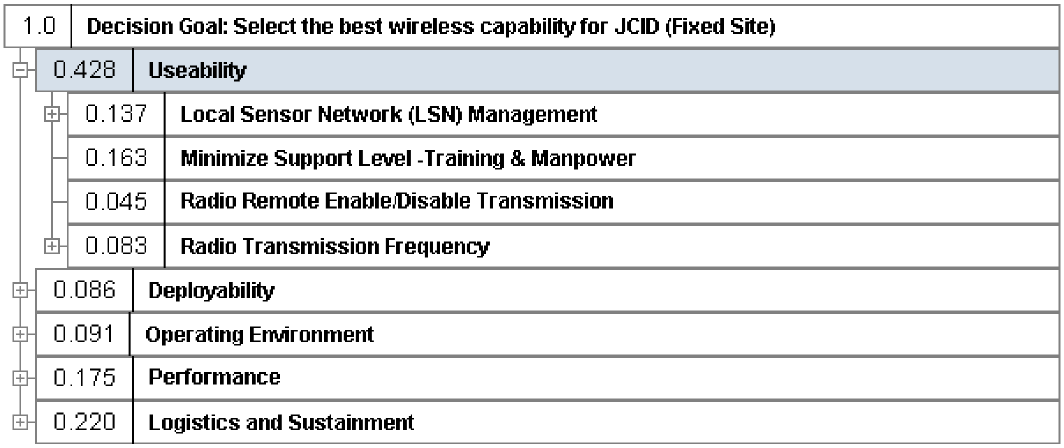
The major user concern in this operational scenario was the usability of the system once deployed, particularly in terms of providing local sensor network (LSN) management, operation in high-traffic frequency bands, and the ability to remotely disable sensors from the network. It was agreed that operation in a well-controlled area with available resources would render the deployment time and the complexity of the initial configuration less important objectives. Similarly, the fixed JCID solution would most likely utilize a primary power source, rendering battery life a less important objective. Finally, it was expected that in most cases, the LSN would be installed in specific locations and housed in permanent fixtures to maximize range and performance (e.g., mitigating line-of-sight issues, increasing power to achieve greater range of transmission). Figure 6-2 summarizes the final top-level objectives, weighted by priority, for fixed-site installations.



1.0	**Decision Goal: Select the best wireless capability for JCID (Fixed Site)**
0.428	**Useability**
0.086	**Deployability**
0.091	**Operating Environment**
0.175	**Performance**
0.220	**Logistics and Sustainment**

Figure 6-2. Fixed-Site Top-Level Priorities

As usability of the solution once deployed is the key operational consideration, it is instructive to understand what comprised this objective in the decision model. Figure 6-3 demonstrates the objectives related to usability, weighted by priority, which define how usable a system is within a fixed site.



1.0	Decision Goal: Select the best wireless capability for JCID (Fixed Site)
0.428	Useability
0.137	Local Sensor Network (LSN) Management
0.163	Minimize Support Level -Training & Manpower
0.045	Radio Remote Enable/Disable Transmission
0.083	Radio Transmission Frequency
0.086	Deployability
0.091	Operating Environment
0.175	Performance
0.220	Logistics and Sustainment

Figure 6-3. Fixed-Site Usability Criteria and Priorities

6.4 Results

The 802.11 mesh technologies, i.e., the Mesh Dynamics and the Rajant alternatives, were the top-performing technologies in the fixed-site scenario. Both technologies provide user-friendly interfaces and valuable network management capabilities while being able to perform effectively with respect to transmission range, bandwidth efficiency, and channel flexibility.

Key differentiation points among the technologies are relative ease of initial configuration of the LSN, robust ongoing management capabilities, and the ability to visually represent a graphical picture of network. Both Mesh Dynamics and Rajant are easily initiated and configured, provide remote network management, and have intuitive visualizations of network health. Figure 6-4 shows the summary performance across criteria category for each of the technologies. The total score is the sum across criteria and is broken out by major criteria category.

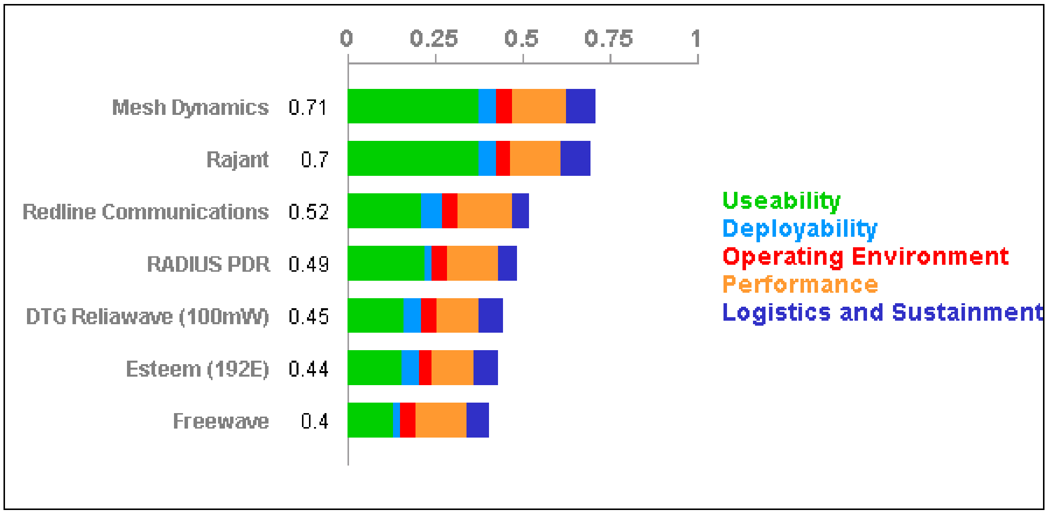


Figure 6-4. Fixed-Site Evaluation Results

The Table 6-1 shows the technologies performance scores across the entire criteria set. The score in the cell is the value associated with the performance of the technology on those criteria. 1.0 is the highest value in each of the criteria; 0 is the lowest. To calculate the total score for each of the technologies, multiply the performance score by the criteria weight for each of the categories. The summation of these products is the total score.

Table 6-1. Fixed-Site Scenario Technology Performance Scores

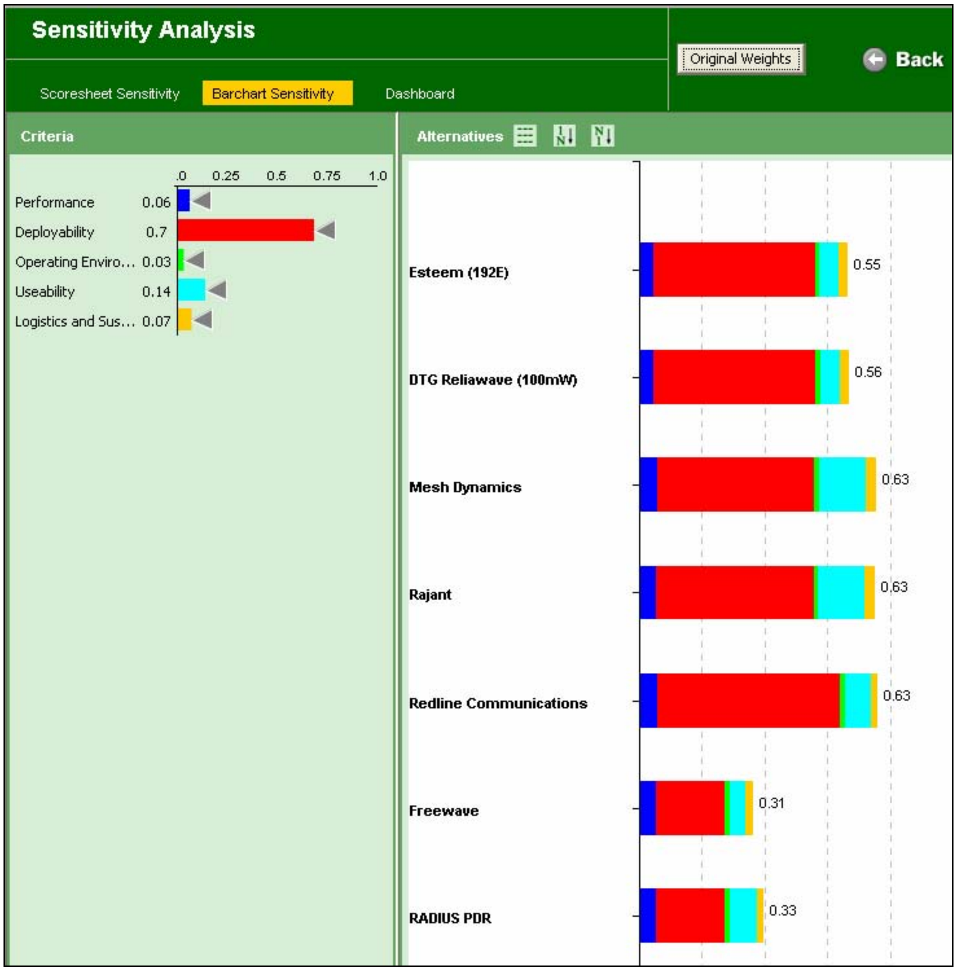
Technology Alternatives	Total Score	Transmission Range (0.134)	Power Management (0.028)	Transmit Power (0.008)	Standby Power (0.004)	Frequency Flexibiliity (0.031)	Bandwidth Efficiency (0.012)	MS Weight (0.002)	MS Volume (0.004)	MS Number of Boxes (0.003)	Weight (0.006)	Volume (0.012)	Number of Boxes (0.016)	Operational Temperature (0.032)	Storage Temperature (0.01)	Shock & Vibration (0.013)
Mesh Dynamics	**0.709**	1	0.25	1	1	0.75	0.5	0.8	0	0	0.8	0	1	1	0.8	0.1
Rajant	**0.697**	1	0	1	1	0.75	0.5	0.8	0	0	0.8	0	1	0.85	0.8	0.1
Redline Communications	**0.521**	1	0.25	1	1	1	1	0.5	0	0	0.5	0	0.8	1	0.8	0.1
RADIUS PDR	**0.486**	1	0	0.6	0.9	0	0.5	0.9	0	0	0.9	0	0.6	1	0.8	0.1
DTG Reliawave (100mW)	**0.446**	0.75	0.25	1	1	0.75	0.5	1	0	0	1	0	1	1	0.8	0.1
Esteem (192E)	**0.435**	0.75	0.25	1	1	0.75	0.5	1	0	0	1	0	1	0.75	0.8	0.1
Freewave	**0.403**	1	0.25	0.1	0.1	0	0.5	0.9	0	0	0.9	0	0.6	1	1	0.1

Technology Alternatives	Total Score	EMI (0.036)	Supports Multiple Centerline Frequencies (0.056)	Operates in Military Frequency Band (0.028)	Radio Remote Enable/Disable Transmission (0.045)	Ease of LSN Reconfiguration (0.023)	LSN Initial Configuration (0.014)	LSN Management (0.041)	LSN Operational Picture (0.059)	Minimize Support Level - Training & Manpower (0.163)	Minimize Required Sparing (0.125)	Minimize Consumables (0.062)	Technical Data (0.034)
Mesh Dynamics	**0.709**	0.1	1	0.7	0.4	1	1	0.5	1	1	0	1	0.75
Rajant	**0.697**	0.1	1	0.7	0.4	1	1	0.5	1	1	0	1	0.75
Redline Communications	**0.521**	0.1	1	0.25	0.4	1	1	0.5	0.5	0.25	0	0.75	0.25
RADIUS PDR	**0.486**	0.1	1	1	0.4	0	0	0.5	1	0.25	0	0.75	0.25
DTG Reliawave (100mW)	**0.446**	0.1	1	0.7	0.4	0	0	0.25	0.25	0.25	0	1	0.25
Esteem (192E)	**0.435**	0.1	1	0.6	0.4	0	0	0.25	0.25	0.25	0	1	0.25
Freewave	**0.403**	0.1	1	1	0.4	0	0	0.25	0	0.1	0	0.75	0.5

6.5 Sensitivity Analysis

Sensitivity analysis is performed to test model robustness and investigate the potential for future impacts to significantly alter preferences among technology alternatives. Simulating changing priorities among the evaluation criteria highlights situations where one alternative becomes preferred over the current top-performing technology.

Overall, the fixed-site evaluation model was not sensitive to changes in priority of the top-level criteria. As the importance of usability criteria increases, the value of the both Mesh Dynamics and Rajant increase proportionally. Therefore, the driver in terms of priority for this scenario is not sensitive to change. Similar nonsensitivities occur when both performance and logistics are increased. The most sensitive criterion in this model is deployability. Figure 6-5 illustrates that, as the priority of deployabilty increases from (10% to 70% of the decision), the Redline Communications alternative becomes equal to the overall score of the previous top performers Mesh Dynamics and Rajant.



Performance 0.06
Deployability 0.7
Operating Enviro... 0.03
Useability 0.14
Logistics and Sus... 0.07

Figure 6-5. Fixed-Site Deployability Sensitivity Chart

6.6 Cost for Notional Example

6.6.1 Cost for Mesh Network

The cost for the notional design for the fixed-site example is a rough order of magnitude (ROM) and is not intended to be an exact figure. The cost does not take in to consideration all the system components, including cables, JCID modifications, security appliances, intrusion detection system (IDSs), antennas, enclosures, and battery packs. The number is meant to provide a number for comparison only. For the fixed site example, we start with a mesh node cost of $5K and a PCMCIA card cost of $100 each. We need two nodes and 35 PCMCIA cards, for a cost of $13.5K per fixed site. Assuming 30 sites, the incremental hardware costs to provide mesh network wireless functionality at fixed sites is approximately $400K, not including initial JCIDs (batteries, cabling), JCID modifications, installation costs, or other necessary items.

6.6.2 Cost for WiMAX

The cost for the notional design for the fixed-site example is a ROM and is not intended to be an exact figure. The cost does not take in to consideration all the system components, including cables, JCID modifications, security appliances, IDS, antennas, enclosures, and battery packs. The number is meant to provide a number for comparison only. For the fixed site example, if we start with the cost numbers provided by the WiMAX forum for the base station $10K–$75K (we use $42.5K) and use a PCMCIA card cost of $500 each, we come up with $60K per fixed site. Assuming 30 sites, the incremental hardware costs to provide WiMax wireless functionality at fixed sites is approximately $1.8 million, not including initial JCIDs (batteries, cabling), JCID modifications, installation costs, or other necessary items.

6.6.3 Cost for 802.11 Ad Hoc

The cost for the notional design for the fixed-site example is a ROM and is not intended to be an exact figure. The cost does not take in to consideration all the system components, including cables, JCID modifications, security appliances, IDS, antennas, enclosures, and battery packs. The number is meant to provide a number for comparison only. For the fixed site example, we start with an access point cost of $1100, a repeater cost of $1100 each, and PCMCIA card cost of $100 each. We need one access point, eight repeaters, and 35 PCMCIA cards for a cost of $13.4K per fixed site. Assuming 30 sites, the incremental hardware costs to provide 802.11 ad hoc wireless functionality at fixed sites is approximately $400K, not including initial JCIDs (batteries, cabling), JCID modifications, installation costs, or other necessary items.

6.6.4 Cost for Radio Modem

The cost for the notional design for the fixed-site example is a ROM and is not intended to be an exact figure. The cost does not take in to consideration all the system components, including cables, JCID modifications, security appliances, IDS, antennas, enclosures, and battery packs. The number is meant to provide a number for comparison only. For the fixed site, we start with the cost of a Freewave radio modem at $3750 and use a ratio of 5:1, or five slave units per every master radio modem, resulting in a cost of $157.5K per fixed site. Assuming 30 sites, the incremental hardware costs to provide radio modem wireless functionality at fixed sites is approximately $4.7 million, not including initial JCIDs (batteries, cabling), JCID modifications, installation costs, or other necessary items.

7.0 FINAL DECISION MODEL: GARRISON/PROVISIONAL

7.1 Assumptions

For the final garrison/provisional decision model, it was assumed that the encryption requirements can be met on the JCID with software or hardware modifications. It was also assumed that drivers can be written when the solution requires a PCMCIA card installed in the JCID. Whenever an external antenna is used in a notional example, an antenna with 6 dBi of gain (with the exception of WiMAX which is 14 dBi due to a built-in antenna) was assumed. When calculating power draw at the JCID, it was assumed the radio is operating with a 50% duty cycle (transmitting half the time, receiving the other). To evaluate the data bandwidth available with each technology, the assumed maximum data rate for one JCID with four attached sensors is 19.2 kbps, a value which is used to determine how many receivers are required at the main site for each product. The notional layout examples that follow are for visualization only and do not represent final system implementations. The layout examples are supported by the product data sheets as well as link budget calculations discussed in previous sections.

7.2 Notional Example

The garrison/provisional example scenario assumes an area of 3 × 5 km that has 35 JCIDs with four sensors each which will communicate back to a main site. This example uses a notional 802.11 mesh implementation. We have calculated the range of the mesh node here as having a good signal at up to 3000 m. In Figure 7-1, a radius of 2000 m is shown for the antenna coverage. At the maximum range of 802.11b, the data rate drops to 1.5 Mbps. Based on our assumption of 19.2 kbps per JCID, the total data bandwidth needed at the main site for this implementation is 672 kpbs, which is below the 1.5 Mbps available bandwidth. We show using two mesh nodes for both area coverage and robust bandwidth. An 802.11b PCMCIA card would be installed at each JCID with an external antenna to communicate to the mesh node.

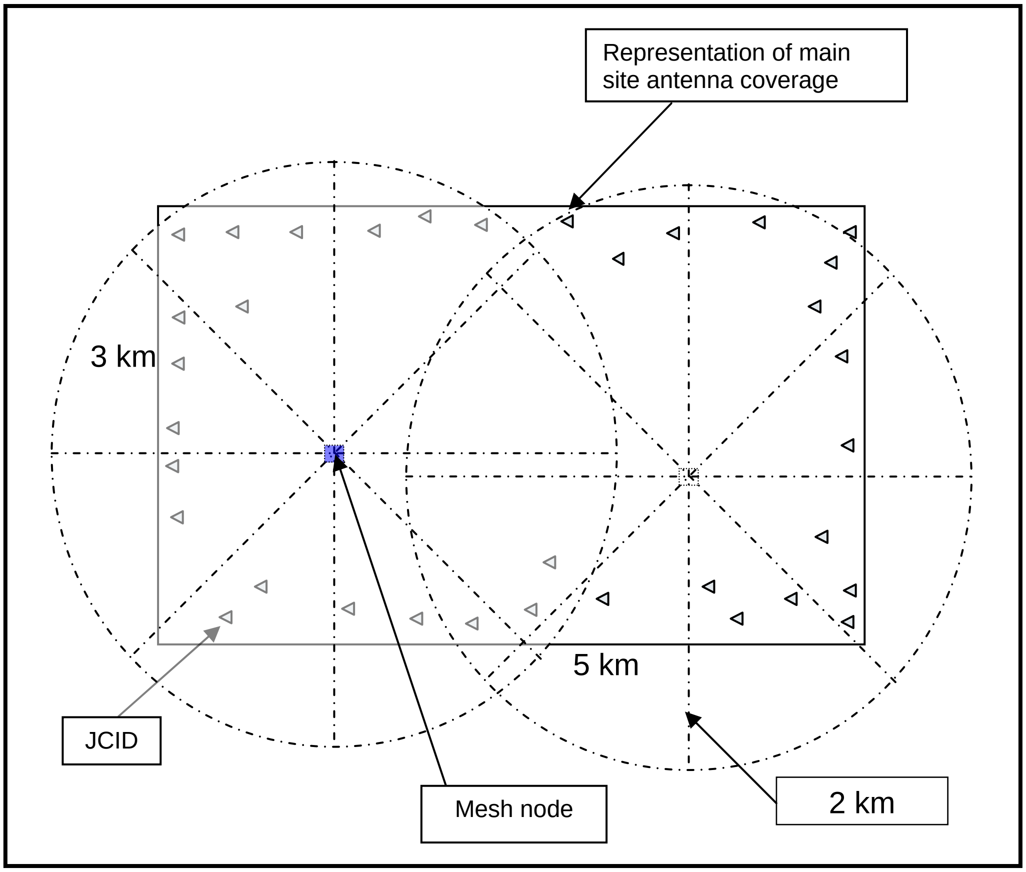


Figure 7-1. Garrison/Provisional Example Scenario

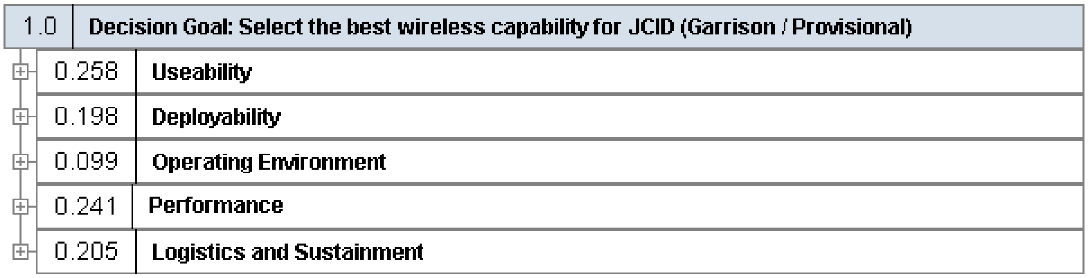
Main site:
Two mesh nodes (battery included), two omnidirectional antenna = 4 boxes

Sensor site:
802.11 PCMCIA card (in JCID), antenna = 1 box

Total boxes: 4 + 1 * 35 = 39

7.3 Objectives and Priorities

Unlike the fixed-site scenario, where there was a clear driver, in this scenario the top priorities are very close. Figure 7-2 summarizes the top-level objectives, weighted by priority, for the garrison/provisional scenario and shows a somewhat more even distribution of priority across objectives. Usability is the top priority, as for fixed sites, but performance (e.g., battery power, transmit and standby power consumption rates) is an almost equal objective. Additionally, deployability and logisitics and sustainment, each with 20% weighting in the model, are important objectives.

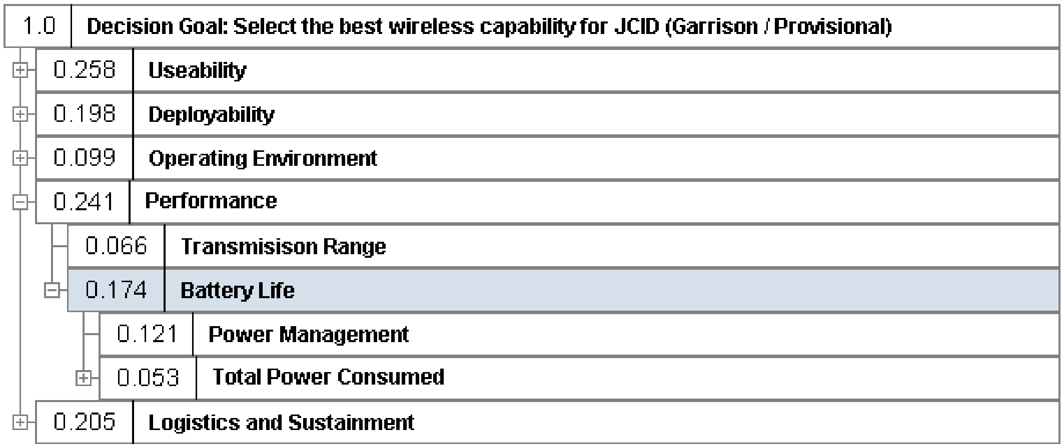


1.0 **Decision Goal: Select the best wireless capability for JCID (Garrison / Provisional)**
- 0.258 **Useability**
- 0.198 **Deployability**
- 0.099 **Operating Environment**
- 0.241 **Performance**
- 0.205 **Logistics and Sustainment**

Figure 7-2. Garrison/Provisional Top-Level Priorities

The performance of the solution has become more important because of the use of battery power at the sensor location. This factor also impacts the range over which the wireless technology can transmit effectively, representing the major tradeoff in this scenario.

Figure 7-3 shows that battery life is the major factor in the technologies performance attributes because of the dependant relationship between power consumption and range (i.e., the increased range requires higher power consumption). The user priorities suggest that some range will be sacrificed to accommodate a longer battery life. This prioritization also takes into consideration the ability of the technology to manage power consumption in both transmit and standby modes.



1.0 **Decision Goal: Select the best wireless capability for JCID (Garrison / Provisional)**
- 0.258 **Useability**
- 0.198 **Deployability**
- 0.099 **Operating Environment**
- 0.241 **Performance**
  - 0.066 **Transmisison Range**
  - 0.174 **Battery Life**
    - 0.121 **Power Management**
    - 0.053 **Total Power Consumed**
- 0.205 **Logistics and Sustainment**

Figure 7-3. Garrison/Provisional Performance Criteria and Priorities

7.4 Results

The mesh network technologies including the Mesh Dynamics and the Rajant alternatives were the top-performing technologies in the garrison/provisional scenario. Similar to the fixed-site scenario, both technologies provide user-friendly interfaces and valuable network management capabilities while being able to perform effectively with respect to transmission range, bandwidth efficiency, and channel flexibility. The key differentiator in this scenario is the ability to minimize power consumption while transiting and managing power usage when transmitting at shorter ranges through “sleep” or other limited-functional modes. Figure 7-4 shows the summary performance across criteria category for each of the technologies Table 7-1 shows the technologies’ performance scores across the entire criteria set.

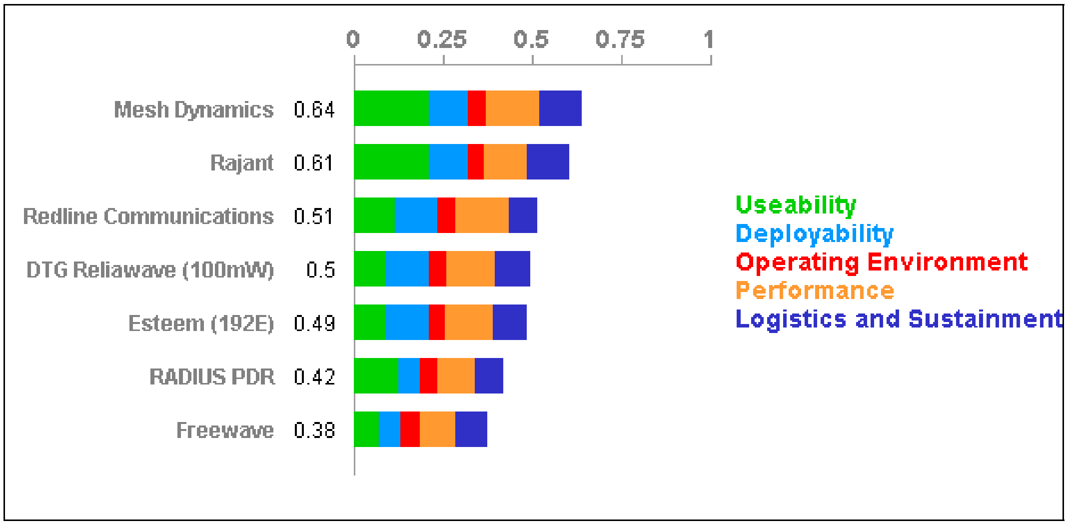


Figure 7-4. Garrison/Provisional Evaluation Results

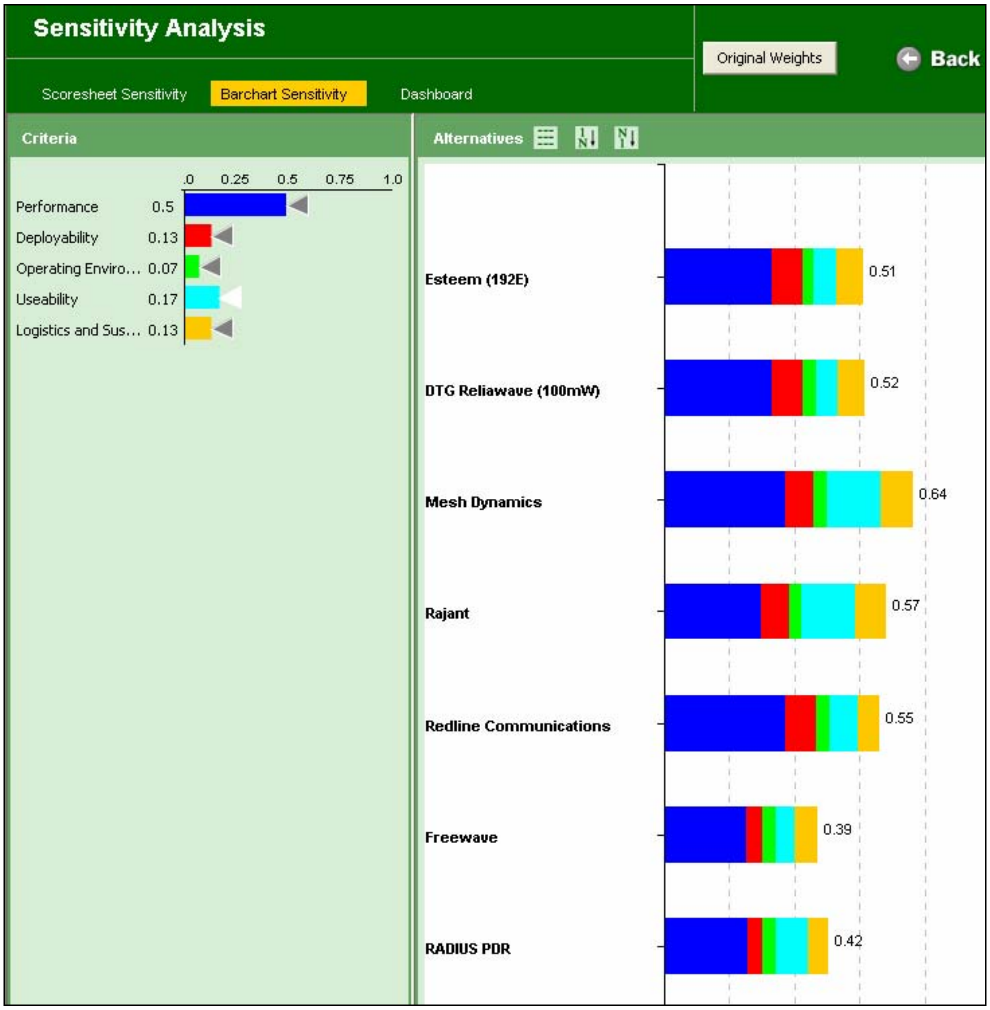
Table 7-1. Garrison/Provisional Scenario Technology Performance Scores

Technology Alternatives	Total Score	Transmisison Range (0.066)	Power Management (0.121)	Transmit Power (0.037)	Standby Power (0.016)	Frequency Flexibiliity (0.054)	Bandwidth Efficiency (0.021)	MS Weight (0.005)	MS Volume (0.013)	MS Number of Boxes (0.011)	Weight (0.028)	Volume (0.032)	Number of Boxes (0.034)	Operational Temperature (0.034)	Storage Temperature (0.016)	Shock & Vibration (0.017)
Mesh Dynamics	**0.643**	1	0.25	1	1	0.75	0.5	0.8	0	0	0.8	0	1	1	0.8	0.1
Rajant	**0.608**	1	0	1	1	0.75	0.5	0.8	0	0	0.8	0	1	0.85	0.8	0.1
Redline Communications	**0.515**	1	0.25	1	1	1	1	0.5	0	0	0.5	0	0.8	1	0.8	0.1
DTG Reliawave (100mW)	**0.495**	0.75	0.25	1	1	0.75	0.5	1	0	0	1	0	1	1	0.8	0.1
Esteem (192E)	**0.487**	0.75	0.25	1	1	0.75	0.5	1	0	0	1	0	1	0.75	0.8	0.1
RADIUS PDR	**0.419**	1	0	0.6	0.9	0	0.5	0.9	0	0	0.9	0	0.6	1	0.8	0.1
Freewave	**0.378**	1	0.25	0.1	0.1	0	0.5	0.9	0	0	0.9	0	0.6	1	1	0.1

Technology Alternatives	Total Score	EMI (0.032)	Supports Multiple Centerline Frequencies (0.016)	Operates in Military Frequency Band (0.02)	Radio Remote Enable/Disable Transmission (0.05)	Ease of LSN Reconfiguration (0.013)	Ease of LSN Initial Configuration (0.009)	LSN Management (0.025)	LSN Operational Picture (0.03)	Minimize Support Level - Training & Manpower (0.094)	Minimize Required Sparing (0.076)	Minimize Consumables (0.097)	Technical Data (0.033)
Mesh Dynamics	**0.643**	0.1	1	0.7	0.4	1	1	0.5	1	1	0	1	0.75
Rajant	**0.608**	0.1	1	0.7	0.4	1	1	0.5	1	1	0	1	0.75
Redline Communications	**0.515**	0.1	1	0.25	0.4	1	1	0.5	0.5	0.25	0	0.75	0.25
DTG Reliawave (100mW)	**0.495**	0.1	1	0.7	0.4	0	0	0.25	0.25	0.25	0	1	0.25
Esteem (192E)	**0.487**	0.1	1	0.7	0.4	0	0	0.25	0.25	0.25	0	1	0.25
RADIUS PDR	**0.419**	0.1	1	1	0.4	0	0	0.5	1	0.25	0	0.75	0.25
Freewave	**0.378**	0.1	1	1	0.4	0	0	0.25	0	0.1	0	0.75	0.5

7.5 Sensitivity Analysis

The evaluation model is sensitive to change in both the performance and deployability criteria categories. The first element of change is illustrated in Figure 7-5 and occurs when performance is increased to 50% of the evaluation model. In this circumstance, Mesh Dynamics begins to separate from both Rajant and Redline Communications, surpassing Rajant because of power management capabilities and Redline Communications because of the deployability of the solution—Mesh Dynamics has a reduced physical load associated with the weight, volume, and number of boxes as well as the ability to operate in the military frequency bands.



Performance 0.5
Deployability 0.13
Operating Enviro… 0.07
Useability 0.17
Logistics and Sus… 0.13

Figure 7-5. Increase in Priority of Performance Criteria in the Garrison/Provisional Scenario

7.6 Cost for Notional Example

7.6.1 Cost for Mesh Network

The cost for the notional design for the garrison/provisional example is a ROM and is not intended to be an exact figure. It does not take in to consideration all the system components, including cables, JCID modifications, security appliances, IDS, antennas, enclosures, and battery packs. The number is meant to provide a number for comparison only. For the garrison/ provisional example, we start with a mesh node cost of $5K and use a PCMCIA card cost of $100 each. We need two nodes and 35 PCMCIA cards, for a cost of $13.5K per garrison/ provisional site. Assuming 5,000 of the 35,000 JCIDs will be for garrison/provisional sites, or ~150 sites (i.e., 5,000 JCIDs divided by 35 JCIDs per garrison/provisional sites), the incremental hardware costs to provide mesh network wireless functionality at these sites is approximately $2.0 million, not including initial JCIDs (batteries, cabling), JCID modifications, or other necessary items.

7.6.2 Cost for WiMAX

The cost for the notional design for the garrison/provisional example is a ROM and is not intended to be an exact figure. It does not take in to consideration all the system components, including cables, JCID modifications, security appliances, IDS, antennas, enclosures, and battery packs. The number is meant to provide a number for comparison only. For the garrison/ provisional example, if we start with the cost numbers provided by the WiMAX forum for the base station $10K–$75K (we use $42.5K) and use a PCMCIA card cost of $500 each, we come up with $60K per garrison/provisional site. Assuming 5,000 of the 35,000 JCIDs will be for garrison/provisional sites, or ~150 sites (i.e., 5,000 JCIDs divided by 35 JCIDs per garrison/provisional sites), the incremental hardware costs to provide WiMax wireless functionality at these sites is approximately $9.0 million, not including initial JCIDs (batteries, cabling), JCID modifications, or other necessary items.

7.6.3 Cost for 802.11 Ad Hoc

The cost for the notional design for the garrison/provisional example is a ROM and is not intended to be an exact figure. It does not take in to consideration all the system components, including cables, JCID modifications, security appliances, IDS, antennas, enclosures, and battery packs. The number is meant to provide a number for comparison only. For the garrison/provisional example, we start with an access point cost of $1100, a repeater cost of $1100 each, and PCMCIA card costs of $100 each. We need one access point, eight repeaters, and 35 PCMCIA cards for a cost of $13.4K per garrison/ provisional site. Assuming 5,000 of the 35,000 JCIDs will be for garrison/provisional sites, or ~150 sites (i.e., 5,000 JCIDs divided by 35 JCIDs per garrison/provisional sites), the incremental hardware costs to provide 802.11 ad hoc wireless functionality at these sites is approximately $2.0 million, not including initial JCIDs (batteries, cabling), JCID modifications, or other necessary items.

7.6.4 Cost for Radio Modem

The cost for the notional design for the garrison/provisional example is a ROM and is not intended to be an exact figure. It does not take in to consideration all the system components, including cables, JCID modifications, security appliances, IDS, antennas, enclosures, and battery packs. The number is meant to provide a number for comparison only. For the garrison/ provisional example, we start with the cost of a Freewave radio modem at $3750 and use a ratio of 5:1, or five slave units per every master radio modem, resulting in a cost of $157.5K per garrison/provisional site. Assuming 5,000 of the 35,000 JCIDs will be for garrison/provisional sites, or ~150 sites (i.e., 5,000 JCIDs divided by 35 JCIDs per garrison/provisional sites), the incremental hardware costs to provide radio modem wireless functionality at these sites is approximately $23.6 million, not including initial JCIDs (batteries, cabling), JCID modifications, or other necessary items.

8.0 FINAL DECISION MODEL: MOBILE DISMOUNTED

8.1 Assumptions

For the final mobile dismounted decision model, it was assumed that the encryption requirements can be met on the JCID with software or hardware modifications. It was also assumed that drivers can be written when the solution requires a PCMCIA card installed in the JCID. Whenever an external antenna is used in a notional example, an antenna with 6 dBi of gain (with the exception of WiMAX which is 14 dBi due to a built-in antenna) was assumed. When calculating power draw at the JCID, it was assumed the radio is operating with a 50% duty cycle (transmitting half the time, receiving the other). To evaluate the data bandwidth available with each technology, the assumed maximum data rate of one JCID with four attached sensors is 19.2 kbps, a value which is used to determine how many receivers are required at the main site for each product. The notional layout examples that follow are for visualization only and do not represent final system implementations. The layout examples are supported by the product data sheets as well as link budget calculations discussed in previous sections.

8.2 Notional Example

The mobile dismounted example scenario assumes an area of 1 × 1 km that has five JCIDs with four sensors each which will communicate back to a main site. This example shows a notional 802.11 mesh implementation. We have calculated the range of the mesh node here as having a good signal at up to 3000 m. Figure 8-1 shows a radius of 1000 m for the antenna coverage. At the maximum range of 802.11b, the data rate drops to 1 Mbps. Based on our assumption of 19.2 kbps per JCID, the total data bandwidth needed at the main site for this implementation is 96 kpbs which is much less than 1 Mbps. We show one mesh node for area coverage. An 802.11b PCMCIA card would be installed at each JCID with an external antenna to communicate to the mesh node.

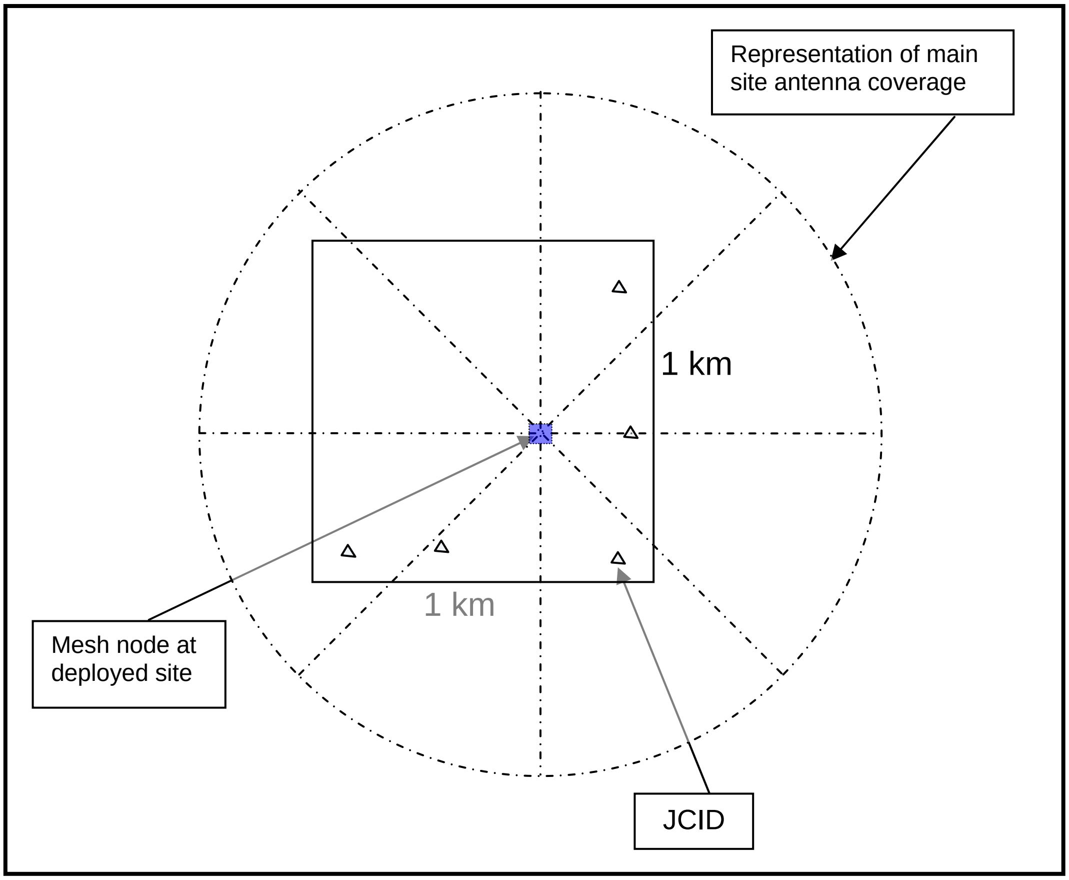


Figure 8-1. Mobile Dismounted Example Scenario

Main site:
One mesh node (battery included), one omnidirectional antenna = 2 boxes

Sensor site:
802.11 PCMCIA card (in JCID), antenna = 1 box

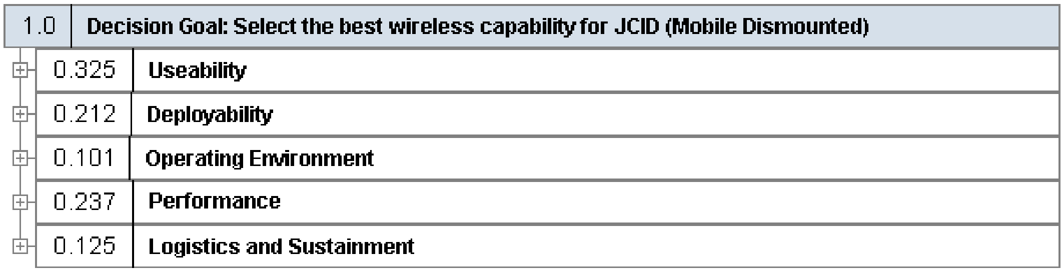
Total boxes: 2 + 1 * 5 = 7

8.3 Objectives and Priorities

In this scenario usability is again a clear driver, while the priority for both deployability and performance are almost unchanged from the garrison/provisional scenario. There is, however, more of a tradeoff between usability and logistics and sustainment.

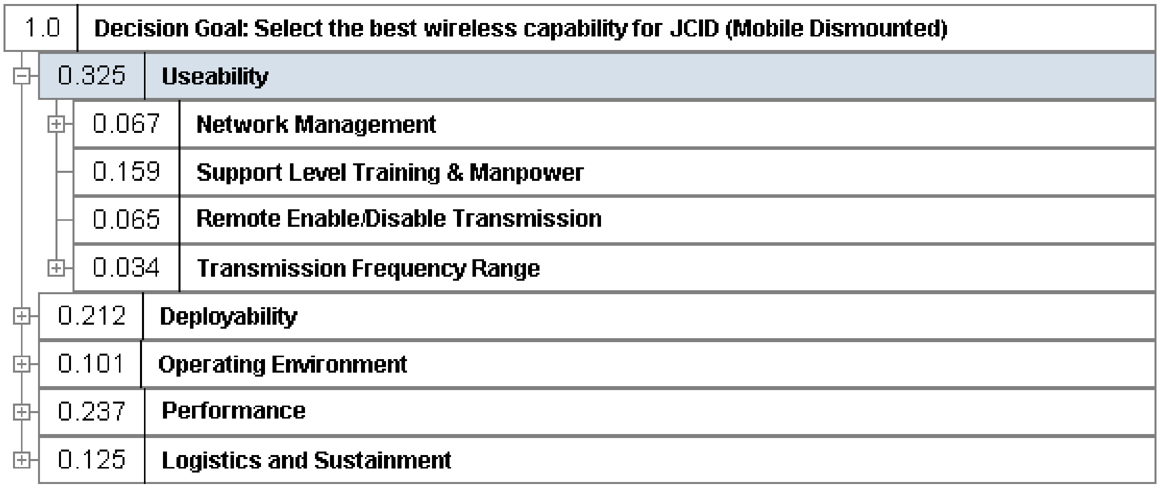
The importance of logistics and sustainment is reduced based on the tradeoff with usability. This effect is due to a major change in the CONOPS, where the vehicle becomes the LSN main site with the sensor remote sites configured at distance from the vehicle. The duration of LSN operation in a mobile dismounted scenario has a direct impact on the logistics and sustainment of the solution. Because the vehicle is the operating center in this scenario, the user will be able to accommodate only a limited amount of spares and consumables. This is not to say that logistics is undervalued, but users addressed in the deployability criteria category much of the concern with spares and consumables, such as the weight, volume, and number of boxes required to support the LSN.

Figure 8-2 provides the user priorities for the mobile dismounted scenario, and Figure 8-3 shows additional considerations to usability in terms of LSN management and operational picture and the remote enable/disable function, which provides the capability to potentially disengage the network for stealth purposes. Performance is relatively unchanged from the garrison/provisional scenario.



1.0	Decision Goal: Select the best wireless capability for JCID (Mobile Dismounted)
0.325	Useability
0.212	Deployability
0.101	Operating Environment
0.237	Performance
0.125	Logistics and Sustainment

Figure 8-2. Mobile Dismounted Top-Level Priorities



1.0	Decision Goal: Select the best wireless capability for JCID (Mobile Dismounted)
0.325	Useability
0.067	Network Management
0.159	Support Level Training & Manpower
0.065	Remote Enable/Disable Transmission
0.034	Transmission Frequency Range
0.212	Deployability
0.101	Operating Environment
0.237	Performance
0.125	Logistics and Sustainment

Figure 8-3. Mobile Dismounted Usability Priorities

8.4 Results

The mesh network technologies Mesh Dynamics and Rajant are again the top performers, followed closely by Redline Communications (WiMax) technology (see Figure 8-4 and Table 8-1).

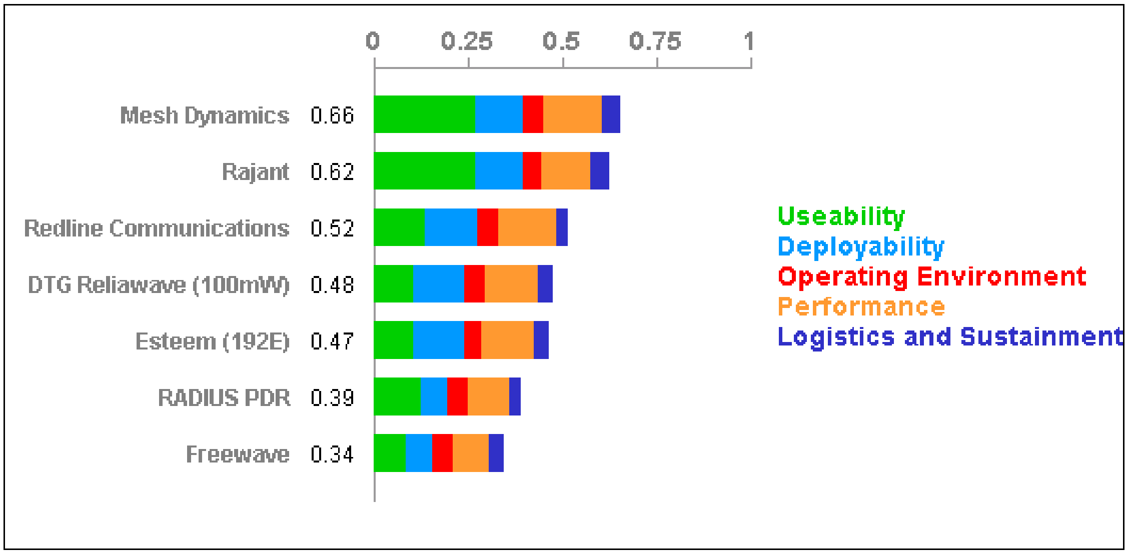


Figure 8-4. Mobile Dismounted Scenario Evaluation Results

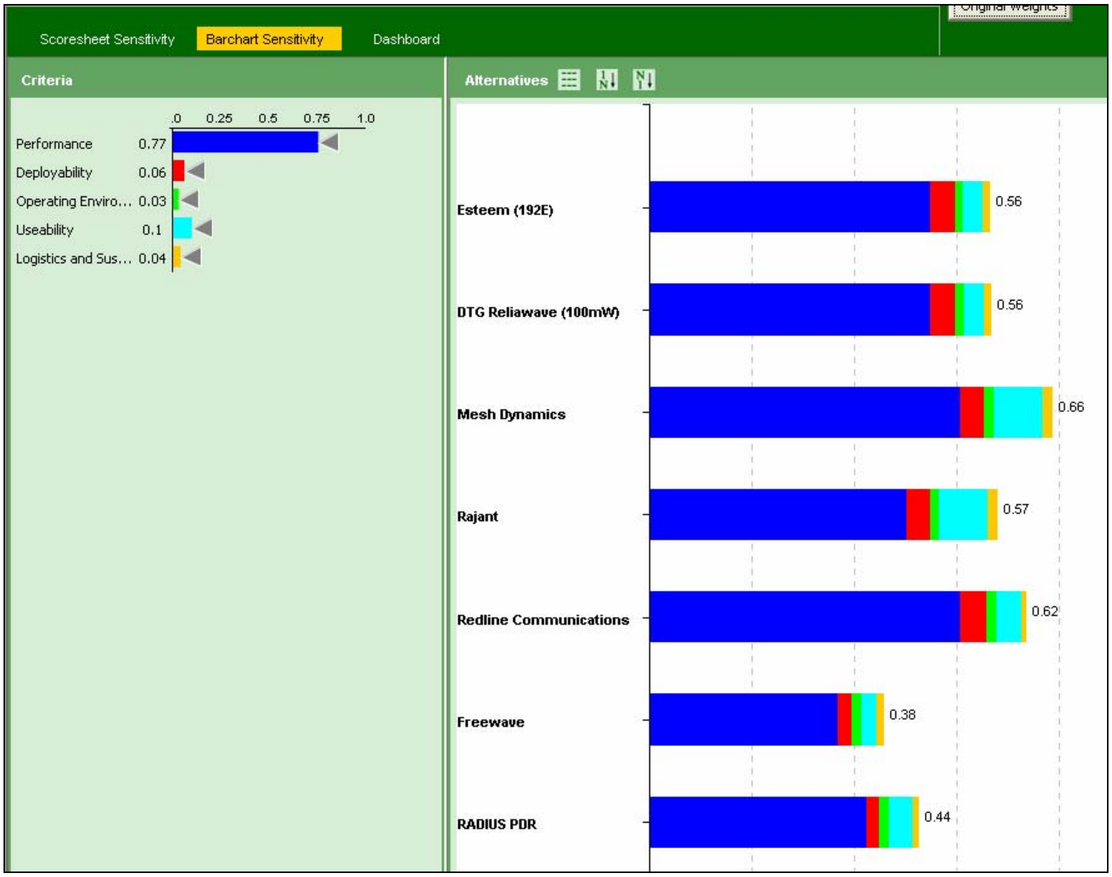
Table 8-1. Mobile Dismounted Scenario Technology Performance Scores

Technology Alternatives	Total Score	Transmission Range (0.061)	Power Management (0.108)	Transmit Power (0.044)	Standby Power (0.024)	Frequency Flexibiliity (0.062)	Bandwidth Efficiency (0.031)	MS Weight (0.005)	MS Volume (0.011)	MS Number of Boxes (0.009)	Weight (0.035)	Volume (0.025)	Number of Boxes (0.033)	Operational Temperature (0.037)	Storage Temperature (0.014)	Shock & Vibration (0.034)
Mesh Dynamics	**0.657**	1	0.25	1	1	0.75	0.5	0.8	0	0	0.8	0	1	1	0.8	0.1
Rajant	**0.624**	1	0	1	1	0.75	0.5	0.8	0	0	0.8	0	1	0.85	0.8	0.1
Redline Communications	**0.517**	1	0.25	1	1	1	1	0.5	0	0	0.5	0	0.8	1	0.8	0.1
DTG Reliawave (100mW)	**0.476**	0.75	0.25	1	1	0.75	0.5	1	0	0	1	0	1	1	0.8	0.1
Esteem (192E)	**0.467**	0.75	0.25	1	1	0.75	0.5	1	0	0	1	0	1	0.75	0.8	0.1
RADIUS PDR	**0.392**	1	0	0.6	0.9	0	0.5	0.9	0	0	0.9	0	0.6	1	0.8	0.1
Freewave	**0.343**	1	0.25	0.1	0.1	0	0.5	0.9	0	0	0.9	0	0.6	1	1	0.1

Technology Alternatives	Total Score	EMI (0.016)	Supports Multiple Centerline Frequencies (0.016)	Operates in Military Frequency Band (0.018)	Radio Remote Enable/Disable Transmission (0.065)	Ease of LSN Reconfiguration (0.021)	Ease of LSN Initial Configuration (0.007)	LSN Management (0.028)	LSN Operational Picture (0.011)	Minimize Support Level - Training & Manpower (0.159)	Minimize Required Sparing (0.068)	Minimize Consumables (0.038)	Technical Data (0.019)
Mesh Dynamics	**0.657**	0.1	1	0.7	0.404	1	1	0.5	1	1	0	1	0.75
Rajant	**0.624**	0.1	1	0.7	0.404	1	1	0.5	1	1	0	1	0.75
Redline Communications	**0.517**	0.1	1	0.25	0.404	1	1	0.5	0.5	0.25	0	0.75	0.25
DTG Reliawave (100mW)	**0.476**	0.1	1	0.7	0.404	0	0	0.25	0.25	0.25	0	1	0.25
Esteem (192E)	**0.467**	0.1	1	0.7	0.404	0	0	0.25	0.25	0.25	0	1	0.25
RADIUS PDR	**0.392**	0.1	1	1	0.404	0	0	0.5	1	0.25	0	0.75	0.25
Freewave	**0.343**	0.1	1	1	0.404	0	0	0.25	0	0.1	0	0.75	0.5

8.5 Sensitivity Analysis

Based on the users' judgments, the usability criteria category is the highest priority and is not sensitive to change. As the weight of usability is increased, the top-performing alternatives—Mesh Dynamics and Rajant—become increasingly preferred. In both the performance and deployability criteria categories, the Mesh Dynamics alternative is the top performer. Figure 8-5 shows that the Redline Communications (WiMax) alternative becomes more preferable than the Rajant technology as performance is increased to 75%. This change would be considered at low sensitivity or not likely to occur; however, it does point to the value that the WiMax alternative can offer under performance attributes.



Performance 0.77
Deployability 0.06
Operating Enviro... 0.03
Useability 0.1
Logistics and Sus... 0.04

Figure 8-5. Performance Criteria Sensitivity in the Mobile Dismounted Example

8.6 Cost for Notional Example

8.6.1 Cost for Mesh Network

The cost for the notional design for the mobile dismounted example is a ROM and is not intended to be an exact figure. It does not take in to consideration all the system components, including cables, JCID modifications, security appliances, IDS, antennas, enclosures, and battery packs. The number is meant to provide a number for comparison only. For the mobile dismounted example, we start with a mesh node cost of $5K and use PCMCIA card cost of $100 each. We need one node and five PCMCIA cards for a cost of $5.5K per mobile dismounted unit. Assuming 30,000 of the 35,000 JCIDs will be for mobile dismounted purposes, or ~6,000 units (i.e., 30,000 JCIDs divided by 5 JCIDs per mobile dismounted unit), the incremental hardware costs to provide mesh network wireless functionality to these units is approximately $33.0 million, not including initial JCIDs (batteries, cabling), JCID modifications, or other necessary items.

8.6.2 Cost for WiMAX

The cost for the notional design for the mobile dismounted example is a ROM and is not intended to be an exact figure. It does not take in to consideration all the system components, including cables, JCID modifications, security appliances, IDS, antennas, enclosures, and battery packs. The number is meant to provide a number for comparison only. For the mobile dismounted example, if we start with the cost numbers provided by the WiMAX forum for the base station $10-$75K (we use $15K for this instance) and use PCMCIA card cost of $500 each, we come up with $17.5K per mobile dismounted unit. Assuming 30,000 of the 35,000 JCIDs will be for mobile dismounted purposes, or ~6,000 units (i.e., 30,000 JCIDs divided by 5 JCIDs per mobile dismounted unit), the incremental hardware costs to provide WiMax wireless functionality to these units is approximately $105.0 million, not including initial JCIDs (batteries, cabling), JCID modifications, or other necessary items.

8.6.3 Cost for 802.11 Ad Hoc

The cost for the notional design for the mobile dismounted example is a ROM and is not intended to be an exact figure. It does not take in to consideration all the system components, including cables, JCID modifications, security appliances, IDS, antennas, enclosures, and battery packs. The number is meant to provide a number for comparison only. For the mobile dismounted example, we start with an access point cost of $1100, a repeater cost of $1100, and PCMCIA card cost of $100 each. We one access point, two repeaters, and five PCMCIA cards, for a cost of $3.8K per mobile dismounted unit. Assuming 30,000 of the 35,000 JCIDs will be for mobile dismounted purposes, or ~6,000 units (i.e., 30,000 JCIDs divided by 5 JCIDs per mobile dismounted unit), the incremental hardware costs to provide 802.11 ad hoc wireless functionality to these units is approximately $22.8 million, not including initial JCIDs (batteries, cabling), JCID modifications, or other necessary items.

8.6.4 Cost for Radio Modem

The cost for the notional design for the mobile dismounted example is a ROM and is not intended to be an exact figure. It does not take in to consideration all the system components, including cables, JCID modifications, security appliances, IDS, antennas, enclosures, and battery packs. The number is meant to provide a number for comparison only. For the mobile dismounted example, we start with the cost of a Freewave radio modem at $3750 and use a ratio of 5:1, or five slave units per master radio modem. We come up with a cost of $22.5K to implement the radio modem solution for the mobile dismounted scenario. Assuming 30,000 of the 35,000 JCIDs will be for mobile dismounted purposes, or ~6,000 units (i.e., 30,000 JCIDs divided by 5 JCIDs per mobile dismounted unit), the incremental hardware costs to provide radio modem wireless functionality to these units is approximately $135.0 million, not including initial JCIDs (batteries, cabling), JCID modifications, or other necessary items.

9.0 SUMMARY RECOMMENDATION

9.1 Recommendation

For the JWARN Joint Program Office to meet a key program warfighter requirement, it must provide wireless connectivity between JCID units as close to IOC as possible. The AoA efforts summarized in this report are a first step towards achieving that goal in time for either a JWARN Increment II IOC implementation or as a preplanned product improvement (P3I) for the fielded JWARN Increment I solution. While this report does not provide a completed engineering solution, it does provide a current market analysis of wireless technologies and products currently available, prioritized against government-developed criteria, resulting in a recommendation of technologies and vendors that could be integrated towards creation of a prototype wireless JCID system.

To provide the JCID with wireless capability, 802.11 mesh networking is recommended (specifically products from Mesh Dynamics or Rajant) in combination with an approach that upgrades the JCID to provide on-board encryption, via software or on-board chips, at the FIPS 140-2 level. Mesh technology is recommended as it received the highest score out of the evaluated technologies for each of the scenarios, particularly in the critical areas of usability and performance. In addition, the cost for mesh network solutions is favorable, with this approach comparable to 802.11 ad hoc (despite mesh technologies having much greater usability) and less expensive than WiMax and radio modems.

9.2 Considerations

Mesh networking technology is available now for prototyping systems and fielding implementations, unlike WiMAX, which is still under development. In addition, since the mesh network is based on 802.11 technologies, there is a variety of supporting software and hardware available to implement the recommended on-board encryption requirements for the JCID. Both vendors' nodes shown in this report are already compatible with Fortress Technology encryption software. Fortress is a well know encryption software with versions available for many operating systems and hardware configurations. NSA's familiarity with Fortress should help accelerate the certification process versus the use of an unknown product.

The mesh network solution also lends itself well to rapid fielding. For example, users can rapidly field a wireless capability with slightly greater cost by using a mesh node with Fortress software at each JCID (i.e., direct-wired Ethernet connection from the node to the JCID). This configuration reduces and/or eliminates JCID modifications and allows for a limited rapid fielding. However, the same mesh nodes can then be used to field a larger number of JCIDs after modifications are made to the JCID to incorporate encryption, thus enabling the use of inexpensive but Fortress-compatible PCMCIA cards at the JCID. Finally, several mesh vendors are looking at WiMAX as the next expansion for mesh networking; therefore, the benefits of this new technology (e.g., increased bandwidth efficiency and range) are likely to be available even after choosing mesh products initially.

9.3 Next Steps

For the Program Office to complete a detailed engineering solution, the following suggestions are provided:

1. Begin discussions with Mesh Dynamics and Rajant to determine how much flexibility they may offer the Program Office in providing custom solutions to meet NSA and program requirements, and at what cost.

2. Begin a dialogue with the USAF Force Protection Battle Laboratory concerning its Robust Battlefield Wireless Network, which uses the Mesh Dynamics products and which consistently achieved the highest scores in each of the three use scenarios. The Battle Lab has already developed a network solution with some future multilevel security technologies as well, which could be the nucleus for a JWARN prototype or provide a solution for JWARN as a GOTS system. Additionally, the Battle Lab's RBWN is being prepared to seek NSA certification in the very near future. Therefore, if it is determined that this system could meet JWARN requirements, a teaming between the Battle Lab and JWARN could significantly shorten the development schedule and reduce the cost of developing a prototype to take to NSA for test and certification.

3. Concurrently with the first two efforts, investigate with the current prime contractor a new design for the JCID that will incorporate FIPS-approved security algorithms (at the appropriate ISO layer) into the JCID as a software or chip-set enhancement to the current JCID solution. This JCID upgrade is required as a first step to incorporate wireless technologies that do not inherently contain the FIPS security accreditation level that will be required for the JWARN wireless network capability.

4. Finally, maintain a capability to continue to monitor the wireless communication market for potential new solutions or enhancements to the chosen prototype and development effort. In this way, throughout system design, prototyping, testing, and NSA certification efforts, JWARN can decide to evaluate alternative technologies that may provide a better or more cost-effective solution for the warfighter.

APPENDIX A. FINAL CRITERIA (SCALES AND METRICS)

1.0 Objectives and Criteria Measurement Scales

The warfighters, with the help of the AoA IPT, and the Technical Team developed a set of scales to be used by the Technical Team for evaluating the technologies. The AoA IPT and the study teams will guide the user group in setting the parameters within the scales. This information will also be used to shape the value scales and data utility curves used to score the alternatives under the evaluation criteria. The objectives are structured the same under each set of CONOPS, but the models were scored differently in order to emphasize the differences in priority the users have in the context of each operating scenario.

One of the most crucial aspects of the wireless technology selection process and subsequent analysis was formulating a set of criteria that all study working group participants understood, and were comprehensive enough that each candidate compound could be objectively and thoroughly evaluated.

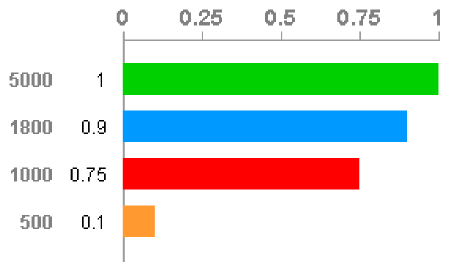
Evaluation Criteria	Criteria Definition
Performance	Primary performance considerations detailed by Joint forces that impact all subsequent CONOPs when using a JCID wireless solution
Transmission Range	Distance (range) of transmission from remote sensor to main site
Battery Life	Power consumption and required replacement cycle for LSN battery operation
Power Management	Ability to remotely control the modes and mechanisms of the wireless technology at the sensor location
Total Power Consumed	Function of both the technology's transmit consumption rate and the standby consumption rate
Transmit Power	Power consumption rate during wireless transmission
Standby Power	Power consumption rate during standby mode
Deployability	Ability to deploy the LSN for multiple operational scenarios—primary considerations are the integration into the communications plan at the installation or forward operating base and the physical load associated with setting up the LSN
Ease of Communications Plan Integration	Ease of adding the JCID LSN wireless solution into existing communication plans
Frequency Flexibility	Degree to which the technology can operate on multiple channels
Bandwidth Efficiency	Efficiency of the technology when using frequency bandwidth to transmit data
Physical Load	Physical characteristics of the boxes required for LSN operation
JWARN Node	Main site or operating center
Weight	The physical weight of the boxes required at the JWARN node for LSN operation

Volume	The physical volume of the boxes required at the JWARN node for LSN
Number of Boxes	The physical number of the boxes required at the JWARN node for LSN operation
Per Sensor Location	Remote Sensor Location
Weight	The physical weight of the boxes required for LSN operation at the remote site
Volume	The physical volume of the boxes required for LSN operation at the remote site
Number of Boxes	The physical number of the boxes required for LSN operation at the remote site
Operating Environment	Ability of the technology to operate under extreme conditions
Storage Temperature	Range of temperature in which the technology can be stored
Operational Temperature	Range of temperature in which the technology will successfully operate
Shock and Vibration	Ability of the technology to meet applicable shock and vibration profiles
EMI	Ability of the technology to meet all applicable EMI profiles
Usability	Ease of use and summary capabilities of the LSN once setup—includes primary and secondary modes and mechanisms for remote use
Radio Transmission Frequency	Ability of the technology to operate in military environments, e.g., installations and forward operating bases
Supports Multiple Center-Line Frequencies	Extent to which the technology is flexible to use alternate channels to support operations in different geographic locations
Operates in Military Frequency Bands	Degree to which the technology has been proven to work within military frequency bands
Radio Remote Enable/Disable Transmission	Positive control of the transmission of signal
Local Sensor Network Management	Degree to which the technology provides network management capabilities. e.g., self-healing/load balancing fixing, and skills required for troubleshooting network issues to support real-time continuous operations
Ease of LSN Reconfiguration	Ease of adding or removing sensor nodes from the network—may include fully remote, semiremote and/or manual control
LSN Initial Configuration	Initial setup and configuration of sensor net—includes managing the hardware/software licenses to support initial setup
LSN Management	Self-healing/load balancing fixing and troubleshooting network issues—real-time continuous operations
LSN Operational Picture	Ability to graphically depict network health, transmission rates, and sensor node configuration
Minimize Support-Level Training and Manpower	People requirement, specialized training, to sustain sensor net operations—can be influenced by the CONOPs; mobile and provisional scenarios need a simplistic solution that can be rapidly deployed by a range of personnel

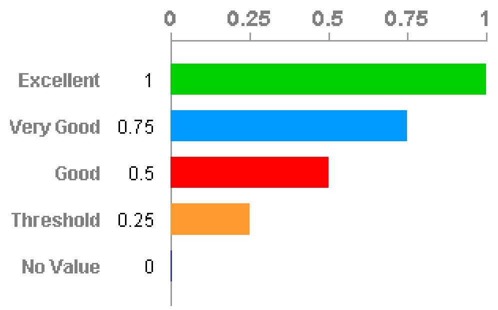
Logistics and Sustainment	Primary considerations are the required sparing, consumables, and available technical data associated with the chosen wireless system
Minimize Required Sparing	Based on the reliability and required unit sparing to accomplish mission
Minimize Consumables	Minimize the number and type of batteries that the LSN nodes require to support ongoing operations—military standard batteries are preferred
Technical Data	Quality of associated technical manuals and drawings (most will need to be reworked for military use)

2.0 Measurement Scales and Metrics

2.1 Transmission Range

Definition: Range of wireless transmission	
Scale: Numerical 1 km (threshold) 5 km (objective) using up to two repeaters from the master JCID	

2.2 Power Management

Definition: Ability to remotely control the modes and mechanisms of the wireless technology at the sensor location	
• Excellent: Highly flexible mechanisms for power management; provides all capabilities for fully automated power management control—1 • Very Good: Highly flexible mechanisms w/remote management functions—0.75 • Good: Remote on/off or remote high/low—0.50 • Threshold: Have to physically go out and turn on/off at the sensor—0.25 • No Value: Cannot physically turn off—0	

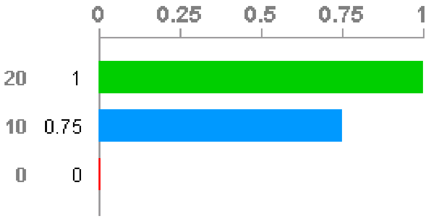
2.3 Transmit Power

Definition: Power consumption rate during wireless transmission	
Scale: Numerical	

2.4 Standby Power

Definition: Power consumption rate during standby mode	
Scale: Numerical	

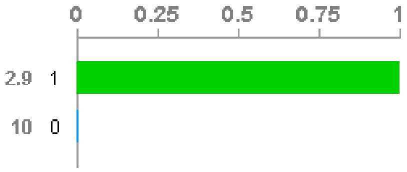
2.5 Frequency Flexibility

Definition: Degree to which the technology can operate on multiple channels	
Scale: Numerical 20 channels thought to be a high value for the technologies under consideration Linear scale from 10 channels to 0 channels	

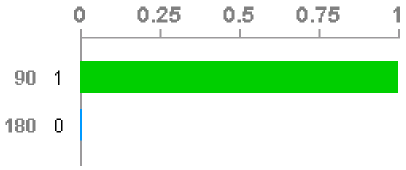
2.6 Bandwidth Efficiency

Definition:	
Scale: Numerical	

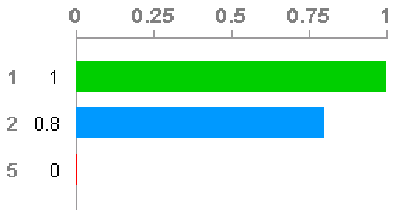
2.7 Per Sensor Location Weight

Definition: The physical weight of the boxes required at the JWARN node for LSN operation	
Scale: Numerical Linear scale from 2.9 lbs. (current weight requirement for JCID) up to 10 lbs., which would render the solution a no value for the user	

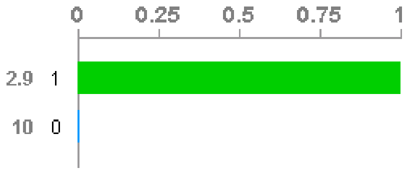
2.8 Per Sensor Location Volume

Definition: The physical volume of the boxes required at the JWARN Node for LSN operation	
Scale: Numerical Linear scale: 90 cubits plus radio cubits—Max is up to twice current size of PCMCIA card	

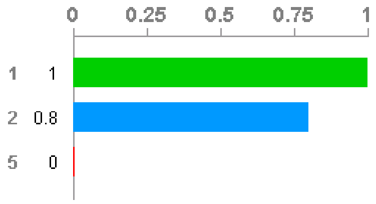
2.9 Per Sensor Location Number of Boxes

<table>
<tr><td colspan="2">Definition: The physical number of the boxes required for LSN operation</td></tr>
<tr><td>Scale: Numerical
• 1 box—1
• 2 boxes—0.80
• 5 boxes—0
Linear decreasing scale between 2 and 5 boxes</td><td> </td></tr>
</table>

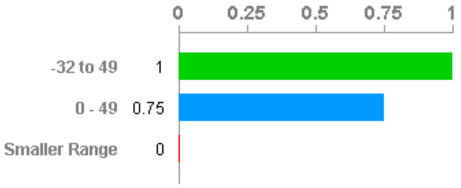
2.10 JWARN Node Weight

<table>
<tr><td colspan="2">Definition: The physical weight of the boxes required for LSN operation (CONOPs and configuration specific)</td></tr>
<tr><td>Scale: Numerical
Linear scale from 2.9 lbs. (current weight requirement for JCID) up to 10 lbs., which would render the solution a no value for the user</td><td> </td></tr>
</table>

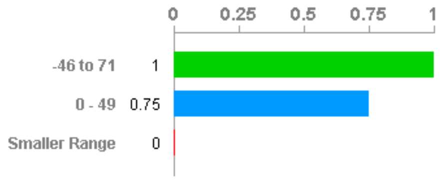
2.11 JWARN Node Number of Boxes

<table>
<tr><td colspan="2">Definition: The physical number of the boxes required for LSN operation (CONOPs and configuration specific)</td></tr>
<tr><td>Scale: Numerical
• 1 box—1
• 2 boxes—0.80
• 5 boxes—0
Linear decreasing scale between 2 and 5 boxes</td><td> </td></tr>
</table>

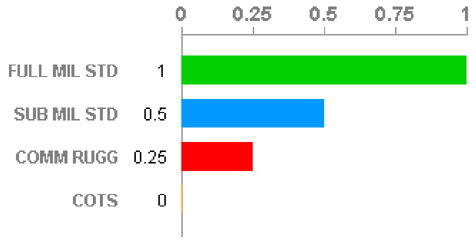
2.12 Operational Temperature

<table>
<tr><td colspan="2">Definition: Range of temperature in which the technology will successfully operate</td></tr>
<tr><td>Scale: Step scale (numerical)
• Step 1: Operation in the range of –32°C to 49° (mil. spec.)
• Step 2: Operation at 0°C to 49°C
• Step 3: Smaller range</td><td> </td></tr>
</table>

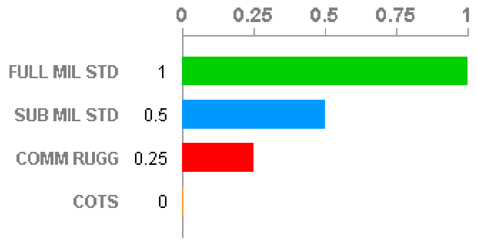
2.13 Storage Temperature

<table>
<tr><td colspan="2">Definition: Range of temperature in which the technology can be stored</td></tr>
<tr><td>Scale: Step scale (numerical)
• Step 1: Storage in the range of –46°C to 71°C (mil. spec.)
• Step 2: Storage in the range of 0° to 49°C
• Step 3: Smaller range</td><td>
</td></tr>
</table>

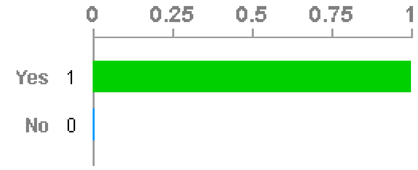
2.14 Shock and Vibration

<table>
<tr><td colspan="2">Definition: Ability of the technology to meet applicable shock and vibration profiles</td></tr>
<tr><td>Scale: Subjective rating
• Full MIL STD: Meets all applicable vibration profiles—1
• Subset MIL STD: Meets some but not all of the applicable vibration profiles, e.g., meets restrained cargo but not airborne shock (unrestrained cargo), for vehicle shock (platform unmounted)—0.50
• Commercial ruggedized: Some modifications to increase shock/vibe resistance—0.25
• COTS: Manufacturer/retail—0</td><td>
</td></tr>
</table>

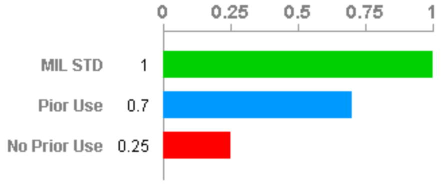
2.15 EMI

<table>
<tr><td colspan="2">Definition: Ability of the technology to meet all applicable EMI profiles</td></tr>
<tr><td>Scale: Subjective rating
• Full MIL STD: Meets all applicable EMI profiles—1
• Subset MIL STD: Meets some but not all of the applicable EMI profiles—0.50
• Commercial ruggedized: Some modifications to reduce EMI—0.25
• COTS: Manufacturer/retail—0</td><td>
</td></tr>
</table>

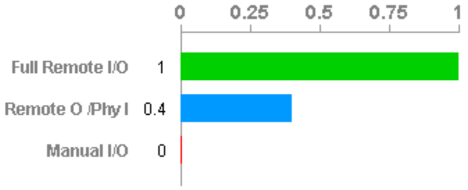
2.16 Supports Multiple Center Line

<table>
<tr><td colspan="2">Definition: Extent to which the technology is flexible to use alternate channels to support operations in different geographic locations</td></tr>
<tr><td>Scale: Subjective rating
• Yes—1
• No—0</td><td> </td></tr>
</table>

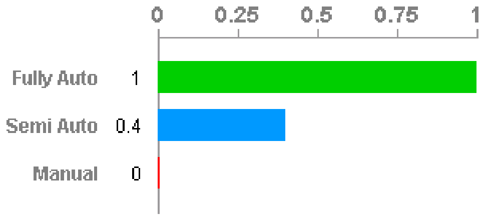
2.17 Operates in Military Frequency Band

<table>
<tr><td colspan="2">Definition: Extent to which the technology is flexible to use alternate channels to support operations in different geographic locations</td></tr>
<tr><td>Scale: Subjective rating
• MIL STD—1
• Prior use—0.7
• No prior use—0.25</td><td> </td></tr>
</table>

2.18 Remote Enable/Disable Transmission

<table>
<tr><td colspan="2">Definition: Positive control of the transmission of signal</td></tr>
<tr><td>Scale: Subjective rating
• Fully remote I/O—1
• Remote O/physical (manual) I—0.40
• Manual I/O—0</td><td> </td></tr>
</table>

2.19 Ease of LSN Reconfiguration

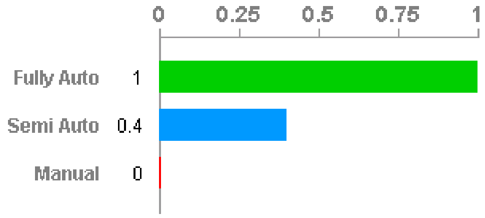
<table>
<tr><td colspan="2">Definition: Ease of adding or removing sensor nodes from the network—may include fully remote, semiremote and/or manual control</td></tr>
<tr><td>Scale: Subjective rating
• Fully automatic—1
• Semiautomatic—0.40
• Manual reconfiguration—0</td><td> </td></tr>
</table>

2.20 Ease of LSN Initial Configuration

Definition: Initial setup and configuration of sensor net—includes managing the hardware/software licenses to support initial setup

Scale: Subjective rating

- Fully automatic—1
- Semiautomatic—0.40
- Manual configuration—0

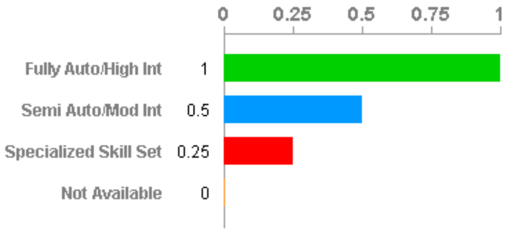


2.21 LSN Management

Definition: Self-healing/load balancing fixing and skills required for troubleshooting network issues to support real-time continuous operations

Scale: Subjective rating

- Fully automatic/highly intuitive interface—1
- Semiautomatic/moderately intuitive interface—0.50
- Specialized skill set required—0.25
- Not available—0

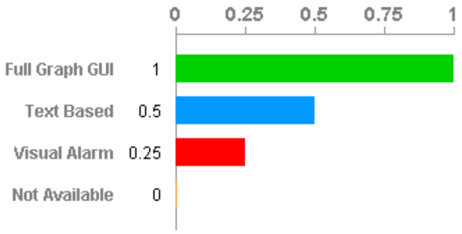


2.22 Local CBRN Network Operational Picture

Definition: Self-healing/load balancing fixing and troubleshooting network issues, real-time continuous operations

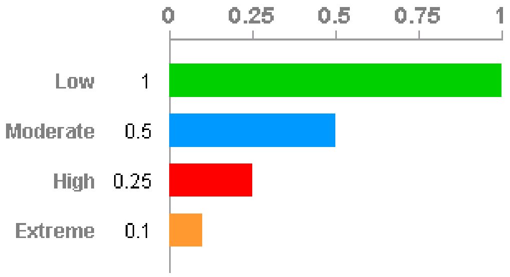
Scale: Subjective rating

- Full graphic GUI—1
- Text based—0.50
- Visual alarm—0.25
- Not available—0



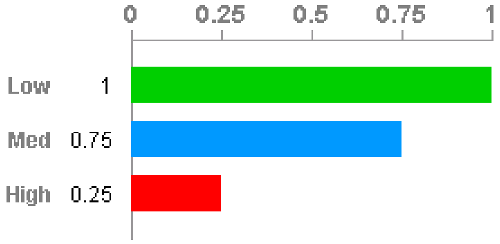
2.23 Minimize Support-Level Training and Manpower

<table>
<tr><td colspan="2">Definition: People requirement, specialized training, to sustain sensor net operations—can be influenced by the CONOPs, mobile and provisional deployment needs a simplistic solution</td></tr>
<tr><td>Scale: Subjective rating

• Low: Low complexity, easy to train (<8 h), <2 people to complete—1
• Mod: Moderate complexity, training >8 h, ≥2 people to complete—0.50
• High: High degree of complexity, training ≥16 h, ~ 4 people to complete—0.25
• Extreme: High degree of complexity, training ≥24 h, >5 people to complete—0.10</td><td>
</td></tr>
</table>

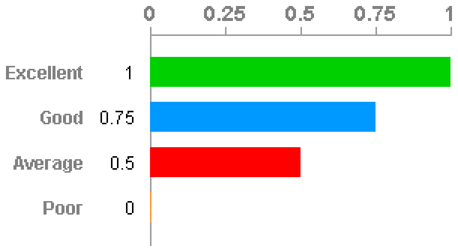
2.24 Minimize Required Sparing

<table>
<tr><td colspan="2">Definition: Based on the reliability and required unit sparing to accomplish mission</td></tr>
<tr><td>Scale: Subjective rating

• Low: Low mean time between failures (MTBF) rate, technology is not difficult to acquire, transport, or deliver—1
• Med: Medium MTBF rate, technology may be difficult to acquire, transport, or deliver (special order)—0.75
• High: High MTBF rate, technology is not readily available, transportable, or deliverable—0.25</td><td>
</td></tr>
</table>

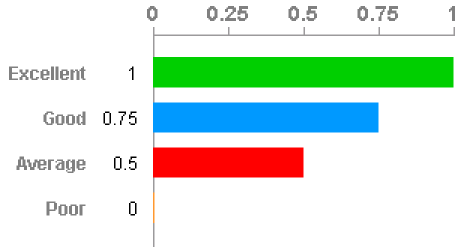
2.25 Minimize Consumables

<table>
<tr><td colspan="2">Definition: Based on the reliability and required unit sparing to accomplish mission</td></tr>
<tr><td>Scale: Subjective rating

• Excellent: Uses Plugger rechargeable batteries, no additional consumables—1
• Good: Uses standard military battery, no additional consumables—0.75
• Average: Not military standard–0.25
• Poor: Commercial nonstandard (specialized)—0</td><td>
</td></tr>
</table>

2.26 Technical Data

<table>
<tr><td colspan="2">Definition: Quality of the accompanying manuals & drawings for military operational use</td></tr>
<tr><td>Scale: Subjective rating

• Excellent: High-quality tech data, written to DoD compliance—1
• Good: Quality manual available, must be translated to DoD format—0.75
• Average: Less than quality tech data, significant rework required—0.50
• Poor—0</td><td> </td></tr>
</table>

APPENDIX B. DECISION ANALYSIS METHODOLOGY

The evaluation methodology used in this study employed two formal multicriteria decision analysis techniques: the Analytic Hierarchy Process (AHP) for decision making and Multi-Attribute Utility Theory (MAUT). By using these techniques, the emphasis was placed on facilitating an exchange of information regarding critical wireless and operational issues. The study panel employed AHP to accurately determine user priorities and used MAUT techniques to develop measurement scales that capture the utility associated with the criteria. Note that even formal decision making is subjective, but a formal process forces one to indicate what attribute(s) is important, why is it important, and how much emphasis is paid to the attribute(s) as it relates to decision making. Using these methods provided an objective framework for the evaluation wireless technologies to support the JWARN JCID and helped focus research and data-gathering efforts on those factors that have the most impact on the analysis and selection of the best wireless solution for each operational scenario.

The AHP methodology established a structured and intuitive process for addressing complex problems of evaluation and choice that capture and quantifies both technical and expert knowledge, as well as user-level knowledge and judgments. This approach is logical, rational, and has been mathematically validated. With the use of the decision analysis and support software tool Decision Lens™, the process was flexible, worked well with both qualitative and quantitative measures, and accommodated a wide variety of knowledge, expertise, and background of working group participants. These analysis techniques also facilitated an exchange of information by study team members and aided in developing working group consensus via a structured, documented, and auditable process (Figure B-1).

AHP is an established strategy for addressing complex problems of evaluation and choice. Successful exercises in which the AHP is used for prioritization and project portfolio design are well documented. The AHP is an intuitive evaluation methodology that captures and quantifies expert knowledge and judgments. An AHP exercise works by decomposing general aspects of a decision problem into major factors or criteria. Each major criterion is then further decomposed in more specific subcriteria to provide a finer level of attribute detail. Additional levels of subcriteria can be added until levels of distinction prove meaningful enough to the decision makers so that they can confidently prioritize alternatives. Weights for criteria and subcriteria are then derived using a pair-wise comparison process unique to AHP. The same process is used to compare the relative importance of alternatives against each other based on the subcriteria to which they refer. AHP decision criteria are structured as a tree-like decision hierarchy that provides an effective visual representation of criteria and alternative relationships. Criteria and alternatives are labeled as nodes on the branches of the tree. The most important criteria reside at the top level of the hierarchy, and their related children are attached as lower level branches. The nodes at the lowest levels of the tree correspond to the alternatives.

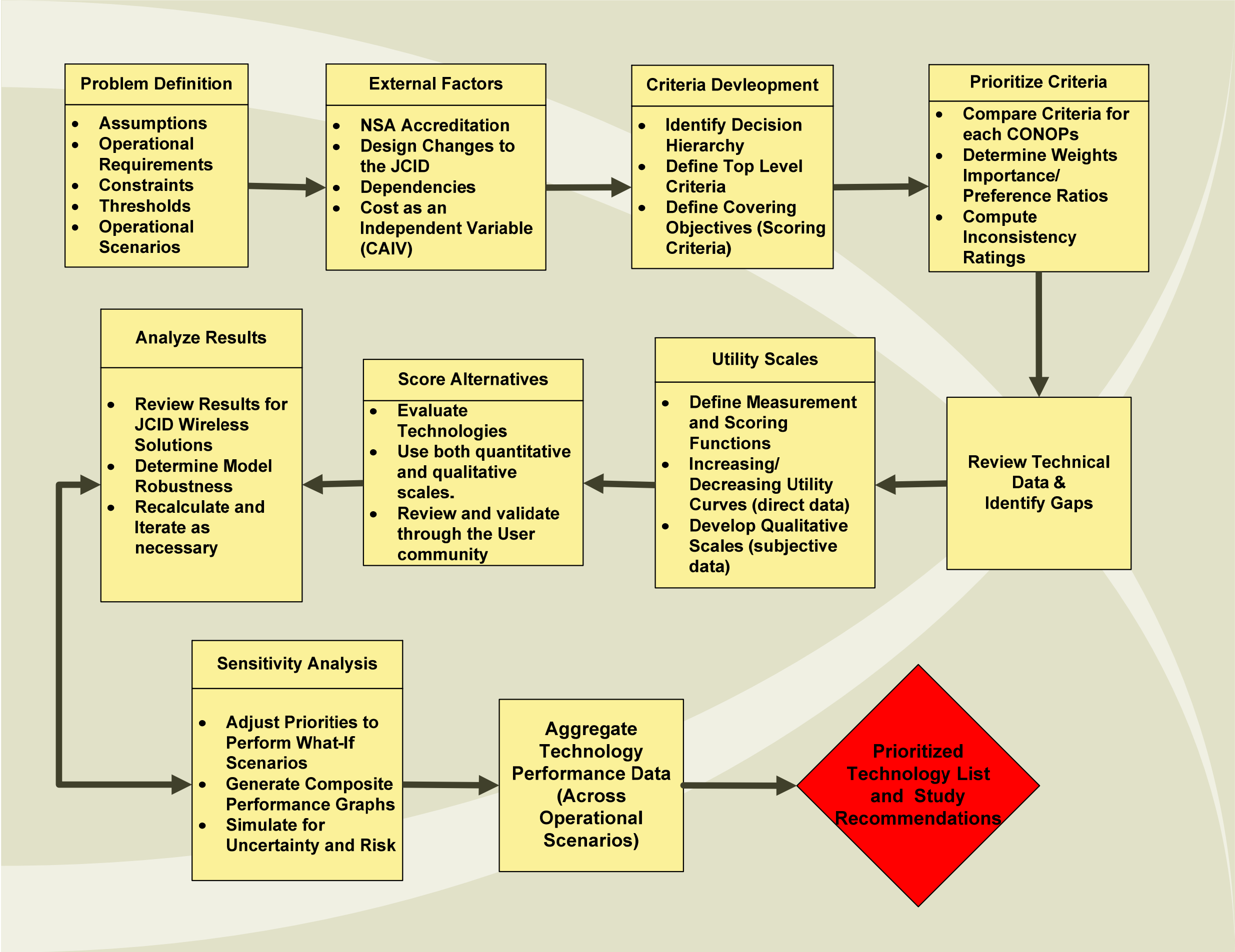


Figure B-1. Decision Analysis Process Overview

Decision Lens Software, a group-enabled version of AHP, is used as the supporting software. The process is implemented with computer projection hardware and remote control polling. Voting by the participants is done interactively and in real time using electronic keypads linked to Decision Lens. Each participant is entitled to one vote. Votes are collected with attribution. As comparisons are made, they are presented on a screen. Discussion is encouraged during the process to allow the decision makers to voice their rationale in making specific judgments. The Decision Lens software calculates group priorities in a collective model and simultaneously built individual models for each participant based on their inputs. Decision Lens also conducts secondary calculations to track the logical consistencies of the participants/decision makers. When consistencies are noted to be out of recommended bounds, model judgments are reviewed and adjusted if a logic flaw is acknowledged by the decision maker. Selection of the proper decision model and weighting criteria is critical to decision makers to obtain the most realistic and relevant results. The model also has to be sufficiently detailed to yield realistic guidance to the decision makers, yet straightforward enough for them to evaluate. Once the criteria model is defined and agreed upon, the decision makers evaluate the objectives as to their importance with respect to their goal through pairwise comparisons and each objective receives a weight.

AHP offers several important benefits to the decision makers. Extraneous issues do not complicate the evaluation. The process also quantifies differences of opinion among the participants and encourages discussion, leading to a better understanding of the goal. The AHP approach also integrates individual decision makers' judgments into a composite group model, allowing direct comparisons to be made of individual specific priorities versus the composite judgments of the group. The hierarchical construct of the prioritization process presented a definitive audit trail as how group decisions are reached and the levels of agreement or disagreement among the participants.

APPENDIX C. FINAL DECISION MODELS

Use Scenarios

Fixed Sites: Static installations in well-controlled areas; primary consideration is Air Force bases. Time between likely modifications of JWARN system configuration is on the order of months to years. This is a mixed deployment environment including stationary installation locations where the sensor is temporarily deployed for increased threat conditions and where the sensor is permanently installed. Sensors may not be under constant observation.

Garrison/Provisional: Static installations in less well-controlled areas than fixed sites; primary consideration is Army tactical garrisons and Air Force expeditionary provisional wings and forward operating bases. Time between likely modifications of JWARN system configuration is on the order of weeks to months. This is a temporary deployment environment where the sensor net is employed appropriately to meet threat conditions. Sensors may not be under constant observation.

Mobile Dismountable: Primary consideration is Army units and military platforms operating in hostile environment. Time between likely modifications of JWARN system configuration on the order of weeks. This secenario includes mobile installations where the sensor is carried in vehicle under physical control and stationary installations where the sensor is carried from the vehicle. Sensors may not be under constant observation.

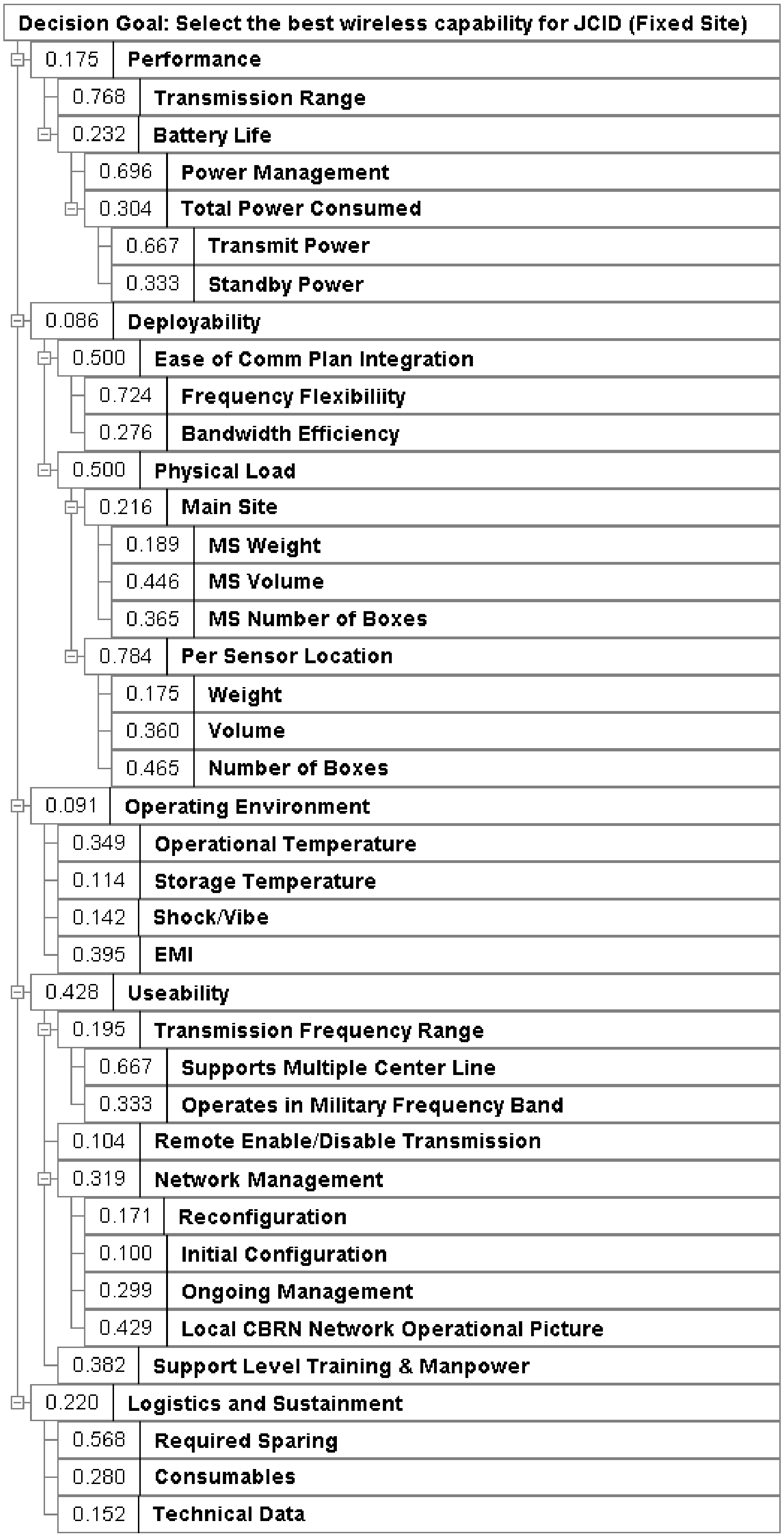
Decision Support Facilitation

The Decision Support and Analysis Team facilitated a conference with the user and combat development community on March 21–23, 2006. During this conference, the models and criteria definitions were presented for refinement and concurrence. The next step was to lead the service representatives through a process to further define the model structure and criteria definitions. Once the model structure was in place, the next step was to use pairwise comparisons of the criteria with respect to each of the three mission scenarios (CONOPS). The warfighters know what they want operationally; however, they do not know whether it is technically feasible and/or the specific performance parameters across the candidate technologies. The AoA Integrated Process Team and the technical team acted as SMEs and advisors to the user and combat development community concerning the feasibility with respect to engineering and physics concerns regarding their requirements. Weighing the criteria by the users helps the technical team better understand their mission requirements, priorities, and preferences so that they can better recognize the military worth of each of the technologies to the warfighter when the evaluation is scored. And the synthesis of the warfighter priorities and technical performance provides a holistic approach toward evaluating candidate approaches and technologies.

Decision Lens Modeling

The modeling in Decision Lens of the agreed-upon evaluation criteria and associated structure is the first step in using the software tool to support the technology evaluation process. A combination of warfighter input and information gathered from the JWARN JCID ORD, P Spec was used to develop a basic decision model or tree. Additional information provided by the technical team concerning core functional criteria and measures of performance provided a comprehensive basis for discussion and set the stage for the evaluation. In the process, the Service representatives determined a set of working definitions and assumptions. Following that, those definitions and assumption were refined into a set of working rules which are used to determining if the technologies do or do not meet minimal user requirements. Next, the users were given an overview of the CONOPS for JCID wireless solution. The associated CONOPS and mission tasks were used as a foundation for discussion and to begin to structure and refine the evaluation criteria in operational terms. Because the users are expected to determine their operational requirements to meet mission objectives and the relative importance of each of these requirements to them, it was essential to decompose the problem in operational objectives. The DS&A Team developed a rough draft of the basic decision model. The users determined three mission models—fixed site, garrison/provisional, and mobile dismounted.

Decision Goal: Select the best wireless capability for JCID (Fixed Site)

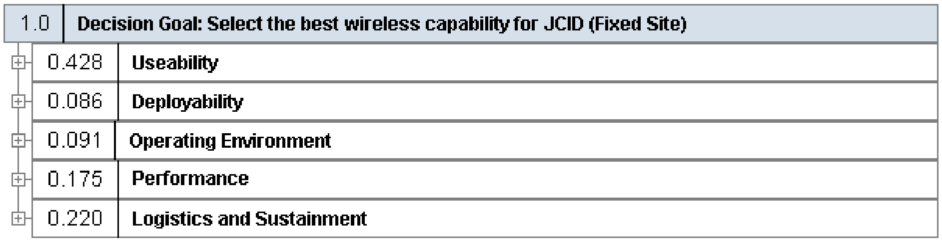


Decision Goal: Select the best wireless capability for JCID (Fixed Site)

- 0.175 **Performance**
  - 0.768 **Transmission Range**
  - 0.232 **Battery Life**
    - 0.696 **Power Management**
    - 0.304 **Total Power Consumed**
      - 0.667 **Transmit Power**
      - 0.333 **Standby Power**
- 0.086 **Deployability**
  - 0.500 **Ease of Comm Plan Integration**
    - 0.724 **Frequency Flexibiliity**
    - 0.276 **Bandwidth Efficiency**
  - 0.500 **Physical Load**
    - 0.216 **Main Site**
      - 0.189 **MS Weight**
      - 0.446 **MS Volume**
      - 0.365 **MS Number of Boxes**
    - 0.784 **Per Sensor Location**
      - 0.175 **Weight**
      - 0.360 **Volume**
      - 0.465 **Number of Boxes**
- 0.091 **Operating Environment**
  - 0.349 **Operational Temperature**
  - 0.114 **Storage Temperature**
  - 0.142 **Shock/Vibe**
  - 0.395 **EMI**
- 0.428 **Useability**
  - 0.195 **Transmission Frequency Range**
    - 0.667 **Supports Multiple Center Line**
    - 0.333 **Operates in Military Frequency Band**
  - 0.104 **Remote Enable/Disable Transmission**
  - 0.319 **Network Management**
    - 0.171 **Reconfiguration**
    - 0.100 **Initial Configuration**
    - 0.299 **Ongoing Management**
    - 0.429 **Local CBRN Network Operational Picture**
  - 0.382 **Support Level Training & Manpower**
- 0.220 **Logistics and Sustainment**
  - 0.568 **Required Sparing**
  - 0.280 **Consumables**
  - 0.152 **Technical Data**

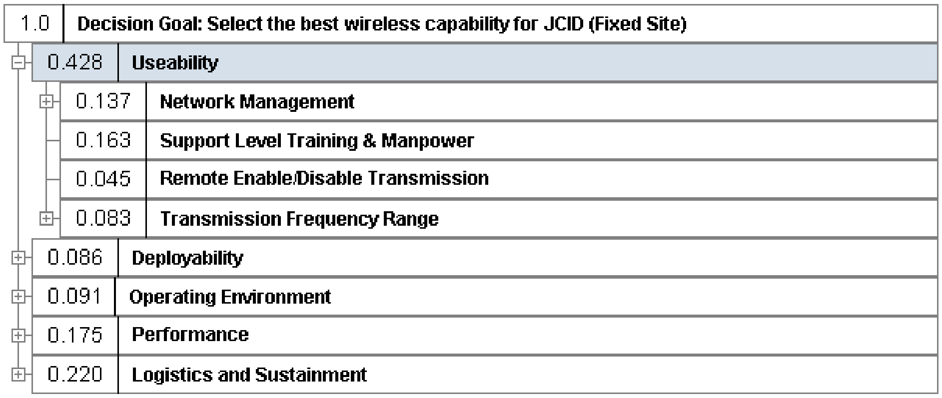
1.0 Decision Goal: Select the best wireless capability for JCID (Fixed Site)

1.1 Top-Level Priorities



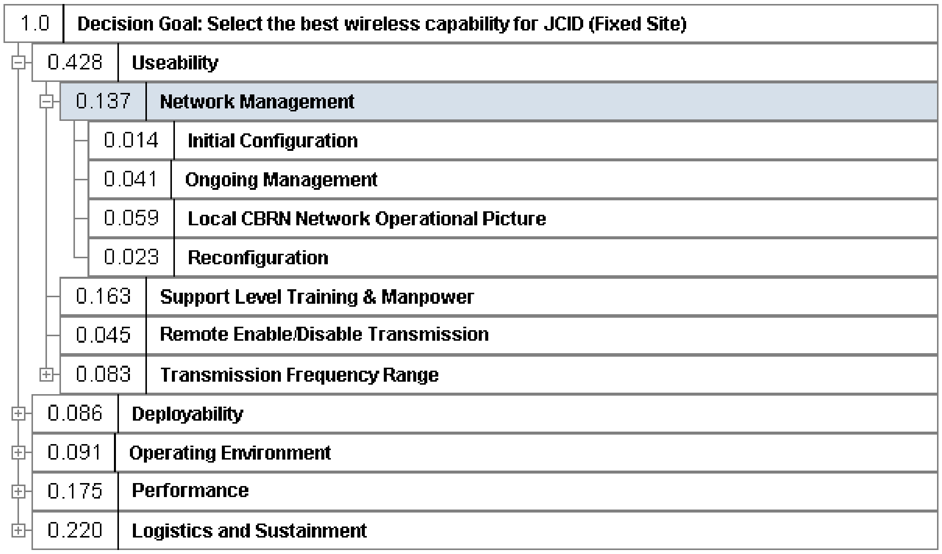
- 1.0 Decision Goal: Select the best wireless capability for JCID (Fixed Site)
  - 0.428 Useability
  - 0.086 Deployability
  - 0.091 Operating Environment
  - 0.175 Performance
  - 0.220 Logistics and Sustainment

1.2 Usability



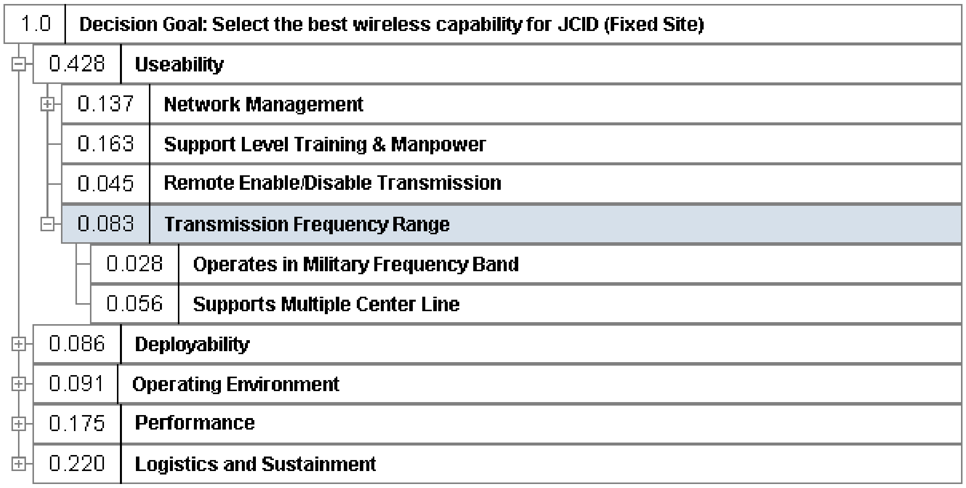
- 1.0 Decision Goal: Select the best wireless capability for JCID (Fixed Site)
  - 0.428 Useability
    - 0.137 Network Management
    - 0.163 Support Level Training & Manpower
    - 0.045 Remote Enable/Disable Transmission
    - 0.083 Transmission Frequency Range
  - 0.086 Deployability
  - 0.091 Operating Environment
  - 0.175 Performance
  - 0.220 Logistics and Sustainment

1.3 Network Management



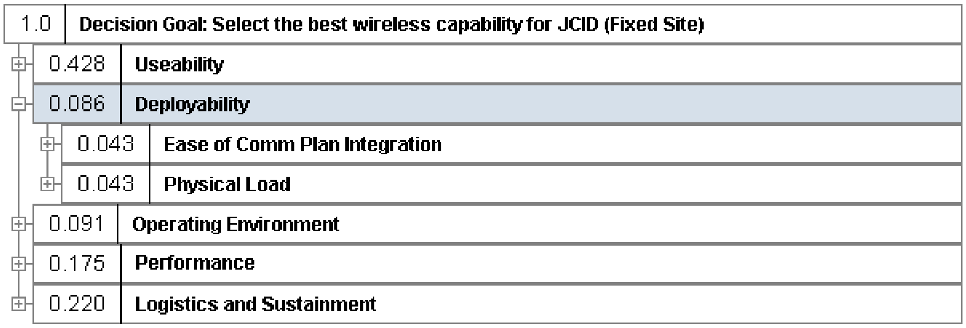
- 1.0 Decision Goal: Select the best wireless capability for JCID (Fixed Site)
  - 0.428 Useability
    - 0.137 Network Management
      - 0.014 Initial Configuration
      - 0.041 Ongoing Management
      - 0.059 Local CBRN Network Operational Picture
      - 0.023 Reconfiguration
    - 0.163 Support Level Training & Manpower
    - 0.045 Remote Enable/Disable Transmission
    - 0.083 Transmission Frequency Range
  - 0.086 Deployability
  - 0.091 Operating Environment
  - 0.175 Performance
  - 0.220 Logistics and Sustainment

1.4 Transmission Frequency Range



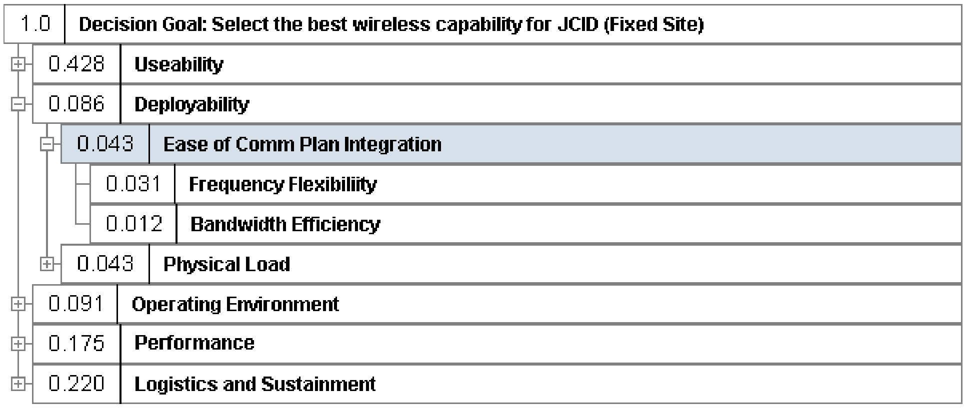
1.0	**Decision Goal: Select the best wireless capability for JCID (Fixed Site)**
0.428	**Useability**
0.137	**Network Management**
0.163	**Support Level Training & Manpower**
0.045	**Remote Enable/Disable Transmission**
0.083	**Transmission Frequency Range**
0.028	**Operates in Military Frequency Band**
0.056	**Supports Multiple Center Line**
0.086	**Deployability**
0.091	**Operating Environment**
0.175	**Performance**
0.220	**Logistics and Sustainment**

1.5 Deployability



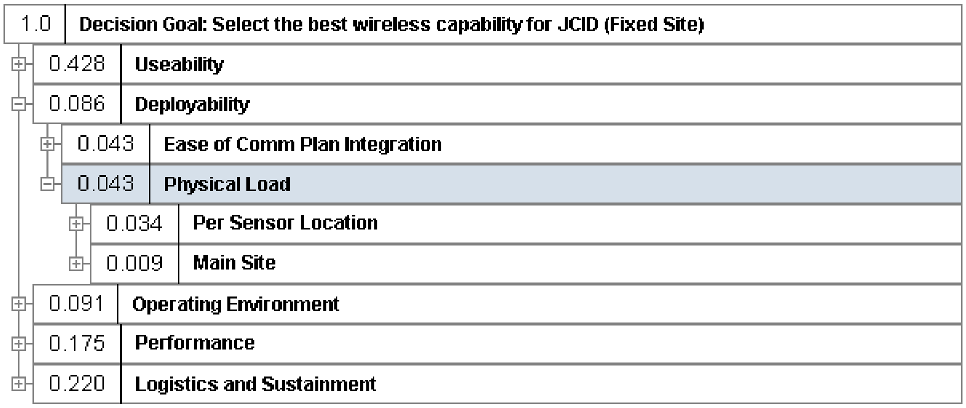
1.0	**Decision Goal: Select the best wireless capability for JCID (Fixed Site)**
0.428	**Useability**
0.086	**Deployability**
0.043	**Ease of Comm Plan Integration**
0.043	**Physical Load**
0.091	**Operating Environment**
0.175	**Performance**
0.220	**Logistics and Sustainment**

1.6 Ease of Communications Plan Integration



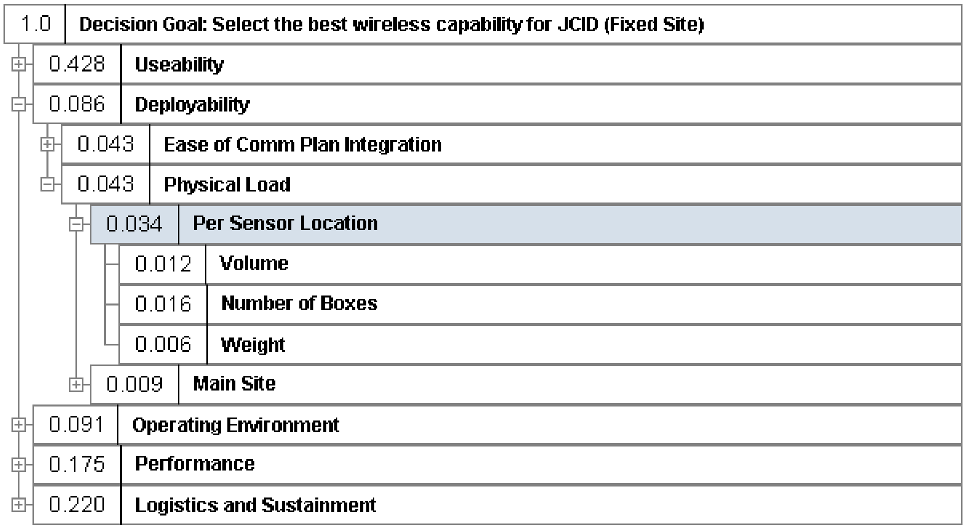
1.0	**Decision Goal: Select the best wireless capability for JCID (Fixed Site)**
0.428	**Useability**
0.086	**Deployability**
0.043	**Ease of Comm Plan Integration**
0.031	**Frequency Flexibiliity**
0.012	**Bandwidth Efficiency**
0.043	**Physical Load**
0.091	**Operating Environment**
0.175	**Performance**
0.220	**Logistics and Sustainment**

1.7 Physical Load



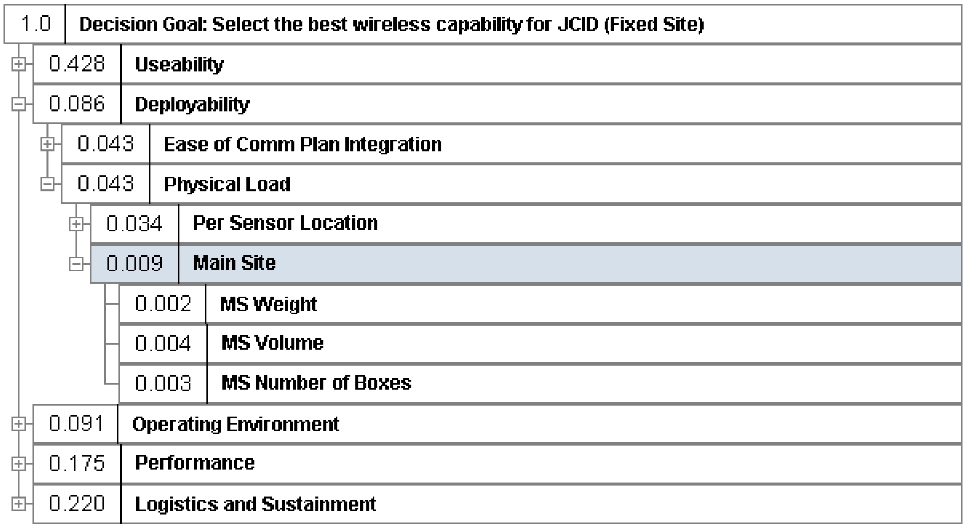
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Fixed Site)**
  - 0.428 **Useability**
  - 0.086 **Deployability**
    - 0.043 **Ease of Comm Plan Integration**
    - 0.043 **Physical Load**
      - 0.034 **Per Sensor Location**
      - 0.009 **Main Site**
  - 0.091 **Operating Environment**
  - 0.175 **Performance**
  - 0.220 **Logistics and Sustainment**

1.8 Per Sensor Location



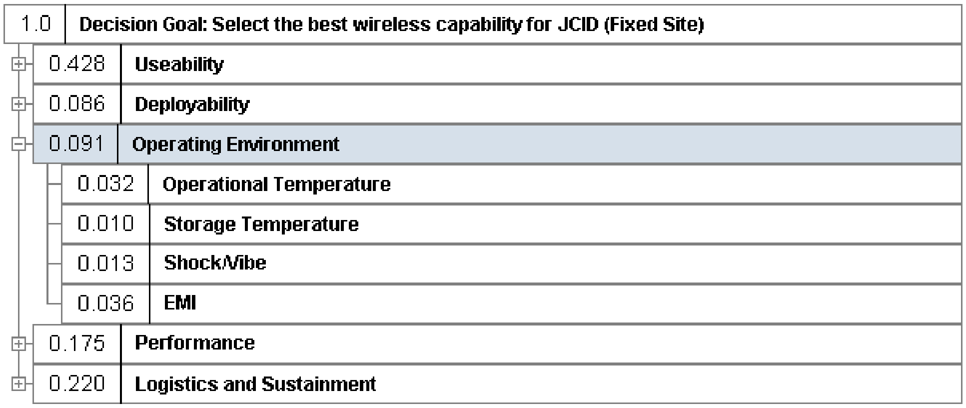
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Fixed Site)**
  - 0.428 **Useability**
  - 0.086 **Deployability**
    - 0.043 **Ease of Comm Plan Integration**
    - 0.043 **Physical Load**
      - 0.034 **Per Sensor Location**
        - 0.012 **Volume**
        - 0.016 **Number of Boxes**
        - 0.006 **Weight**
      - 0.009 **Main Site**
  - 0.091 **Operating Environment**
  - 0.175 **Performance**
  - 0.220 **Logistics and Sustainment**

1.9 Main Site



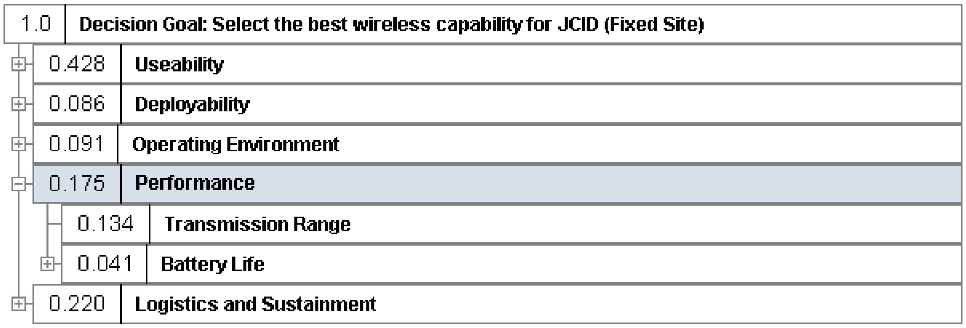
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Fixed Site)**
  - 0.428 **Useability**
  - 0.086 **Deployability**
    - 0.043 **Ease of Comm Plan Integration**
    - 0.043 **Physical Load**
      - 0.034 **Per Sensor Location**
      - 0.009 **Main Site**
        - 0.002 **MS Weight**
        - 0.004 **MS Volume**
        - 0.003 **MS Number of Boxes**
  - 0.091 **Operating Environment**
  - 0.175 **Performance**
  - 0.220 **Logistics and Sustainment**

1.10 Operating Environment



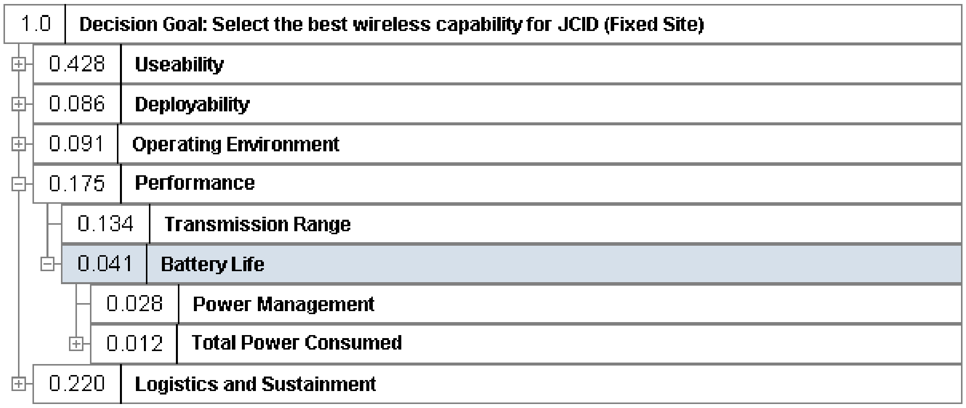
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Fixed Site)**
  - 0.428 **Useability**
  - 0.086 **Deployability**
  - 0.091 **Operating Environment**
    - 0.032 **Operational Temperature**
    - 0.010 **Storage Temperature**
    - 0.013 **Shock/Vibe**
    - 0.036 **EMI**
  - 0.175 **Performance**
  - 0.220 **Logistics and Sustainment**

1.11 Performance



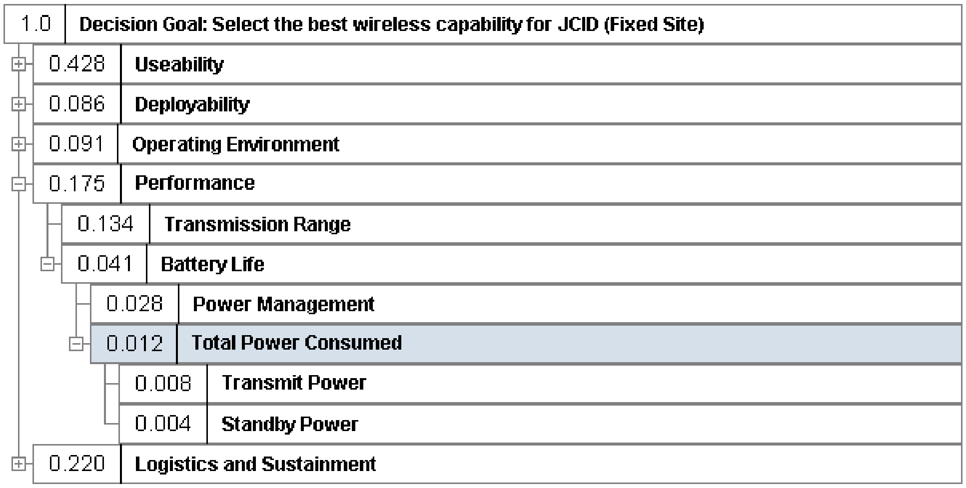
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Fixed Site)**
  - 0.428 **Useability**
  - 0.086 **Deployability**
  - 0.091 **Operating Environment**
  - 0.175 **Performance**
    - 0.134 **Transmission Range**
    - 0.041 **Battery Life**
  - 0.220 **Logistics and Sustainment**

1.12 Battery Life



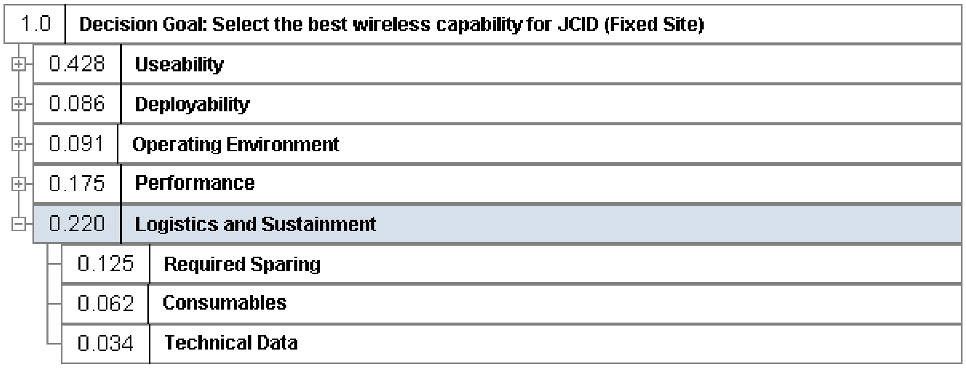
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Fixed Site)**
  - 0.428 **Useability**
  - 0.086 **Deployability**
  - 0.091 **Operating Environment**
  - 0.175 **Performance**
    - 0.134 **Transmission Range**
    - 0.041 **Battery Life**
      - 0.028 **Power Management**
      - 0.012 **Total Power Consumed**
  - 0.220 **Logistics and Sustainment**

1.13 Total Power Consumed



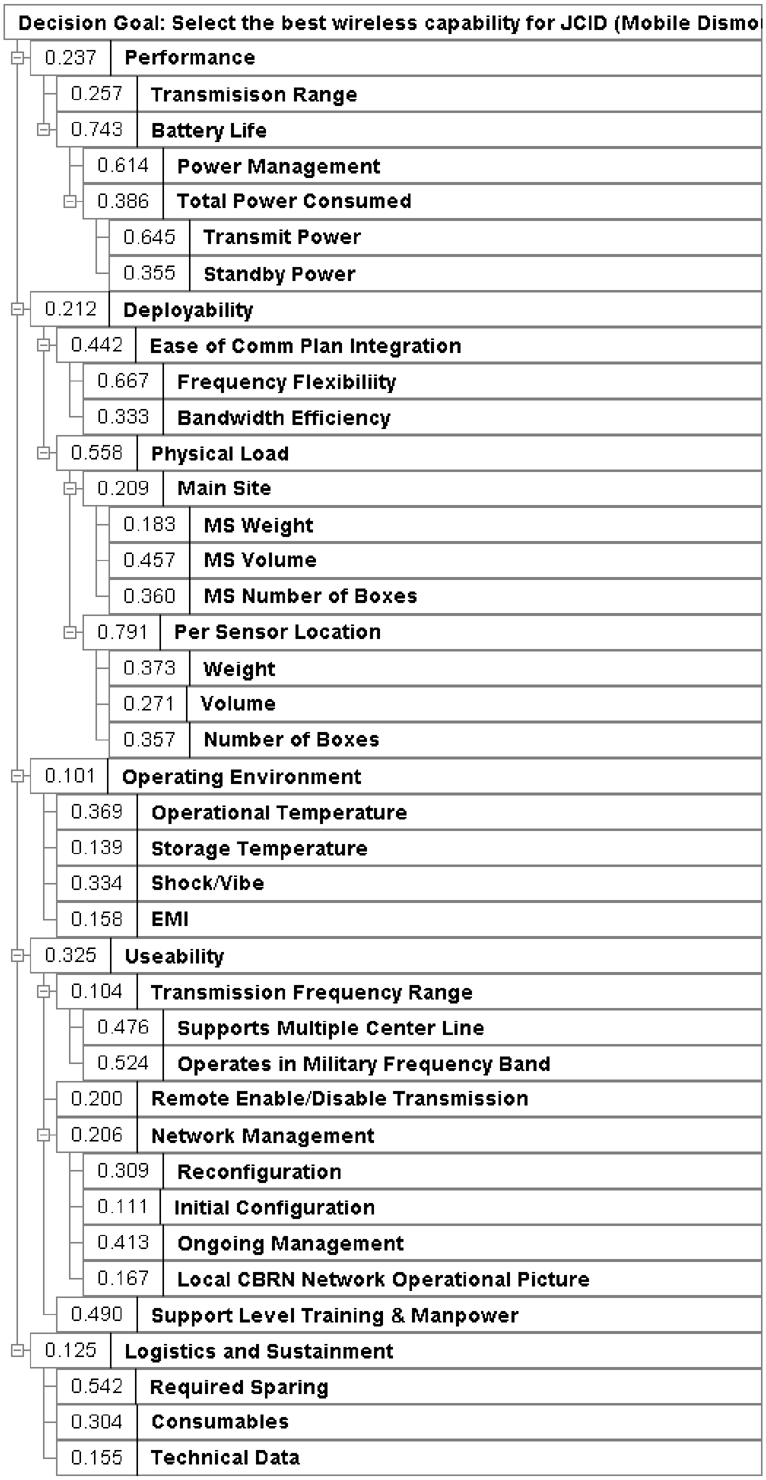
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Fixed Site)**
  - 0.428 **Useability**
  - 0.086 **Deployability**
  - 0.091 **Operating Environment**
  - 0.175 **Performance**
    - 0.134 **Transmission Range**
    - 0.041 **Battery Life**
      - 0.028 **Power Management**
      - 0.012 **Total Power Consumed**
        - 0.008 **Transmit Power**
        - 0.004 **Standby Power**
  - 0.220 **Logistics and Sustainment**

1.14 Logistics and Sustainment



- 1.0 **Decision Goal: Select the best wireless capability for JCID (Fixed Site)**
  - 0.428 **Useability**
  - 0.086 **Deployability**
  - 0.091 **Operating Environment**
  - 0.175 **Performance**
  - 0.220 **Logistics and Sustainment**
    - 0.125 **Required Sparing**
    - 0.062 **Consumables**
    - 0.034 **Technical Data**

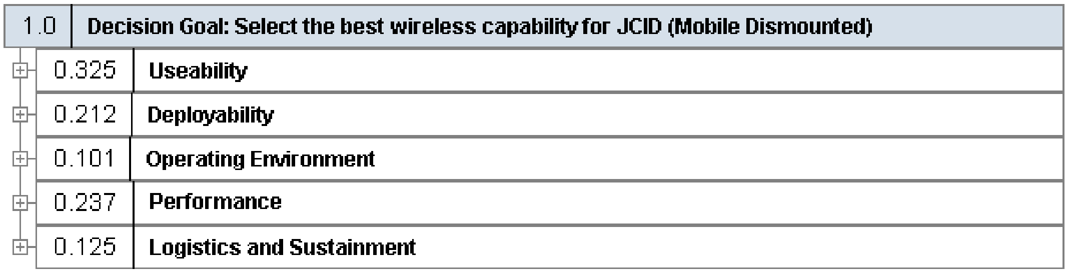
2.0 Decision Goal: Select the best wireless capability for JCID (Mobile Dismounted)



Decision Goal: Select the best wireless capability for JCID (Mobile Dismo

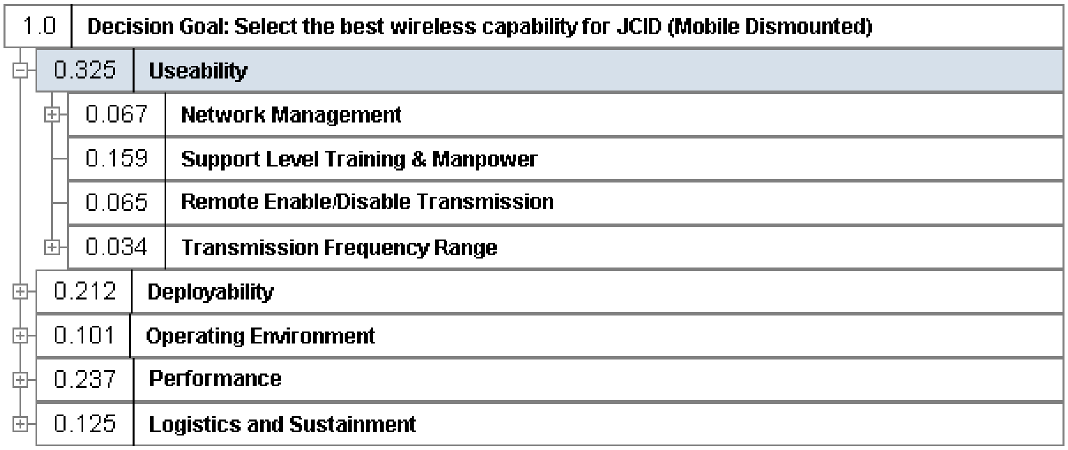
- 0.237 **Performance**
  - 0.257 **Transmisison Range**
  - 0.743 **Battery Life**
    - 0.614 **Power Management**
    - 0.386 **Total Power Consumed**
      - 0.645 **Transmit Power**
      - 0.355 **Standby Power**
- 0.212 **Deployability**
  - 0.442 **Ease of Comm Plan Integration**
    - 0.667 **Frequency Flexibiliity**
    - 0.333 **Bandwidth Efficiency**
  - 0.558 **Physical Load**
    - 0.209 **Main Site**
      - 0.183 **MS Weight**
      - 0.457 **MS Volume**
      - 0.360 **MS Number of Boxes**
    - 0.791 **Per Sensor Location**
      - 0.373 **Weight**
      - 0.271 **Volume**
      - 0.357 **Number of Boxes**
- 0.101 **Operating Environment**
  - 0.369 **Operational Temperature**
  - 0.139 **Storage Temperature**
  - 0.334 **Shock/Vibe**
  - 0.158 **EMI**
- 0.325 **Useability**
  - 0.104 **Transmission Frequency Range**
    - 0.476 **Supports Multiple Center Line**
    - 0.524 **Operates in Military Frequency Band**
  - 0.200 **Remote Enable/Disable Transmission**
  - 0.206 **Network Management**
    - 0.309 **Reconfiguration**
    - 0.111 **Initial Configuration**
    - 0.413 **Ongoing Management**
    - 0.167 **Local CBRN Network Operational Picture**
  - 0.490 **Support Level Training & Manpower**
- 0.125 **Logistics and Sustainment**
  - 0.542 **Required Sparing**
  - 0.304 **Consumables**
  - 0.155 **Technical Data**

2.1 Decision Goal: Select the best wireless capability for JCID (Mobile Dismounted)



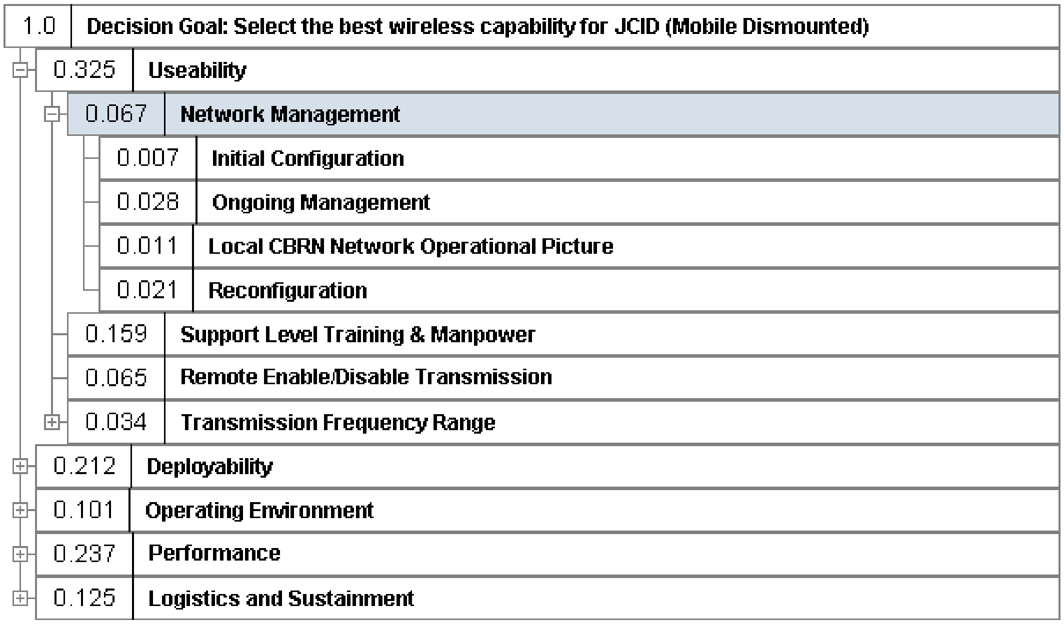
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Mobile Dismounted)**
  - 0.325 **Useability**
  - 0.212 **Deployability**
  - 0.101 **Operating Environment**
  - 0.237 **Performance**
  - 0.125 **Logistics and Sustainment**

2.1 Usability



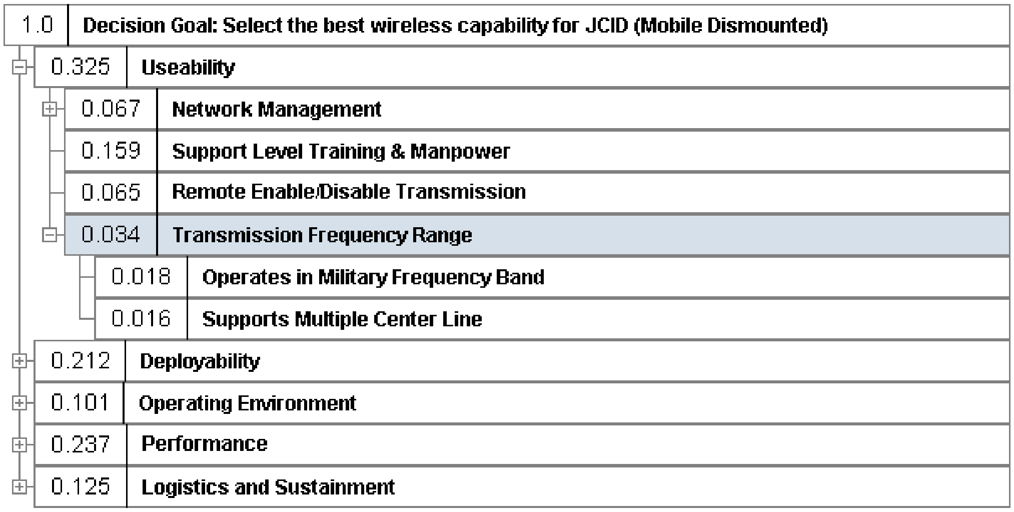
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Mobile Dismounted)**
  - 0.325 **Useability**
    - 0.067 **Network Management**
    - 0.159 **Support Level Training & Manpower**
    - 0.065 **Remote Enable/Disable Transmission**
    - 0.034 **Transmission Frequency Range**
  - 0.212 **Deployability**
  - 0.101 **Operating Environment**
  - 0.237 **Performance**
  - 0.125 **Logistics and Sustainment**

2.3 Network Management



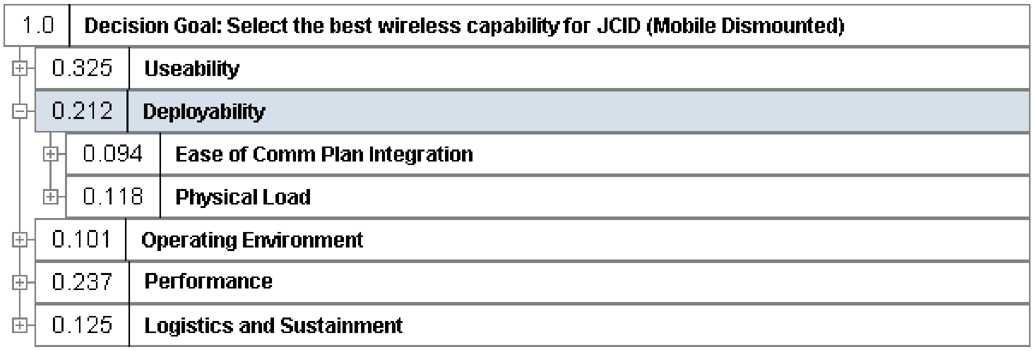
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Mobile Dismounted)**
  - 0.325 **Useability**
    - 0.067 **Network Management**
      - 0.007 **Initial Configuration**
      - 0.028 **Ongoing Management**
      - 0.011 **Local CBRN Network Operational Picture**
      - 0.021 **Reconfiguration**
    - 0.159 **Support Level Training & Manpower**
    - 0.065 **Remote Enable/Disable Transmission**
    - 0.034 **Transmission Frequency Range**
  - 0.212 **Deployability**
  - 0.101 **Operating Environment**
  - 0.237 **Performance**
  - 0.125 **Logistics and Sustainment**

2.4 Transmission Frequency Range



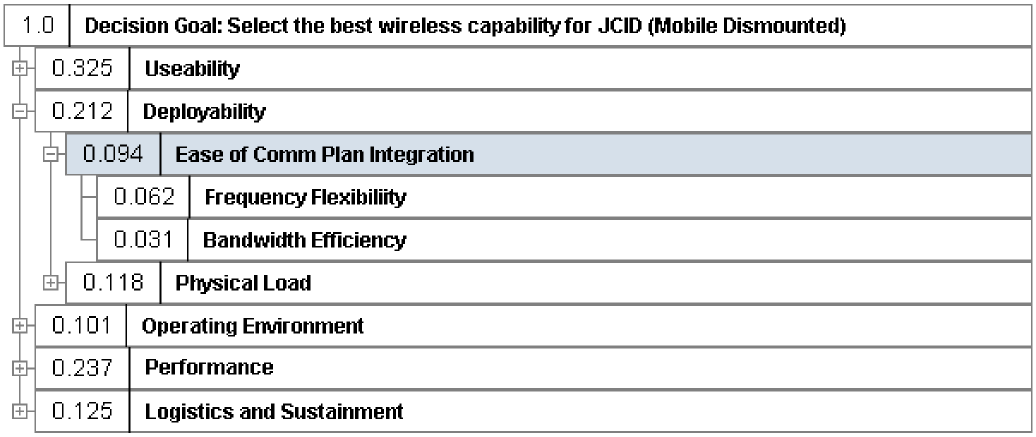
- 1.0 Decision Goal: Select the best wireless capability for JCID (Mobile Dismounted)
  - 0.325 Useability
    - 0.067 Network Management
    - 0.159 Support Level Training & Manpower
    - 0.065 Remote Enable/Disable Transmission
    - 0.034 Transmission Frequency Range
      - 0.018 Operates in Military Frequency Band
      - 0.016 Supports Multiple Center Line
  - 0.212 Deployability
  - 0.101 Operating Environment
  - 0.237 Performance
  - 0.125 Logistics and Sustainment

2.5 Deployability



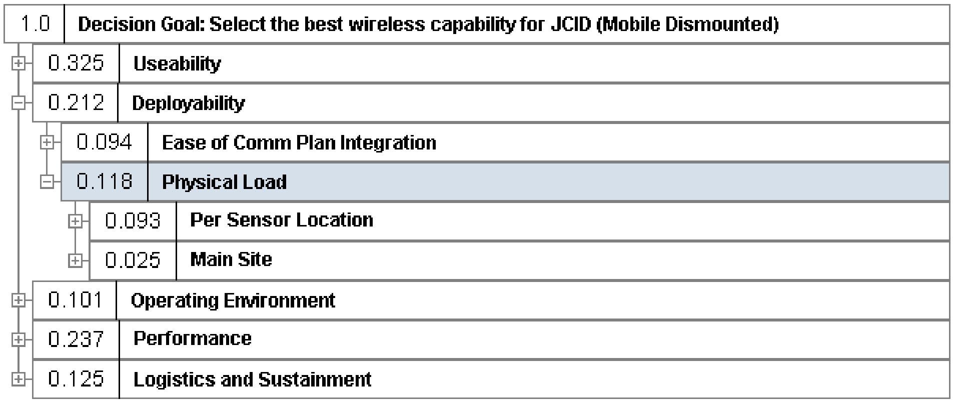
- 1.0 Decision Goal: Select the best wireless capability for JCID (Mobile Dismounted)
  - 0.325 Useability
  - 0.212 Deployability
    - 0.094 Ease of Comm Plan Integration
    - 0.118 Physical Load
  - 0.101 Operating Environment
  - 0.237 Performance
  - 0.125 Logistics and Sustainment

2.6 Comparisons for Ease of Communications Plan Integration



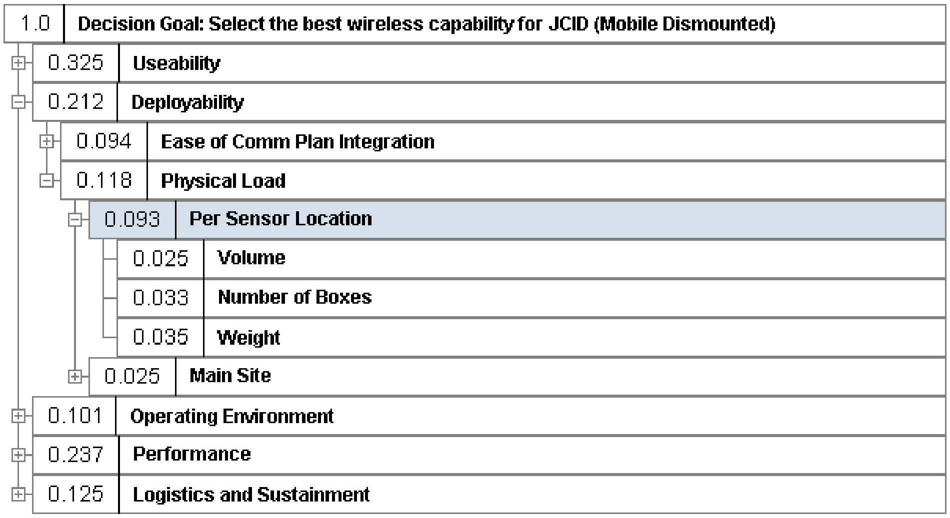
- 1.0 Decision Goal: Select the best wireless capability for JCID (Mobile Dismounted)
  - 0.325 Useability
  - 0.212 Deployability
    - 0.094 Ease of Comm Plan Integration
      - 0.062 Frequency Flexibiliity
      - 0.031 Bandwidth Efficiency
    - 0.118 Physical Load
  - 0.101 Operating Environment
  - 0.237 Performance
  - 0.125 Logistics and Sustainment

2.7 Physical Load



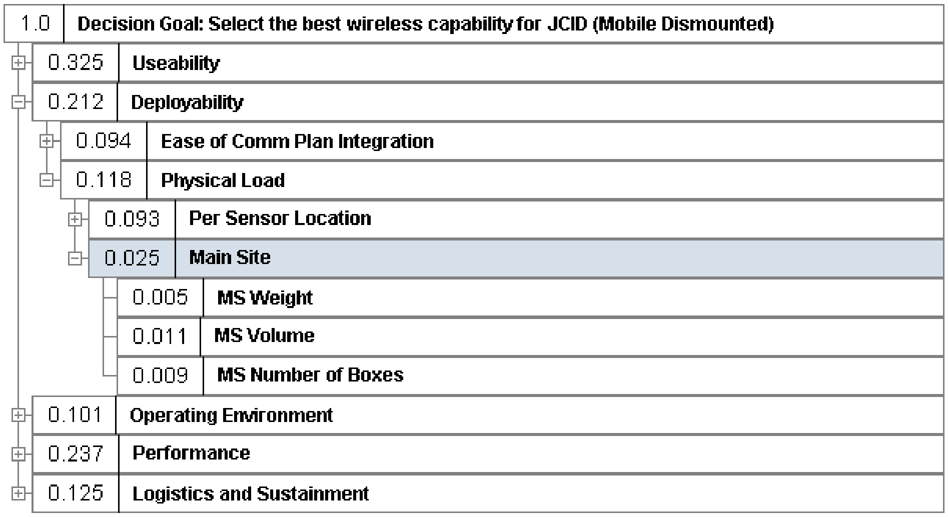
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Mobile Dismounted)**
  - 0.325 **Useability**
  - 0.212 **Deployability**
    - 0.094 **Ease of Comm Plan Integration**
    - 0.118 **Physical Load**
      - 0.093 **Per Sensor Location**
      - 0.025 **Main Site**
  - 0.101 **Operating Environment**
  - 0.237 **Performance**
  - 0.125 **Logistics and Sustainment**

2.8 Per Sensor Location



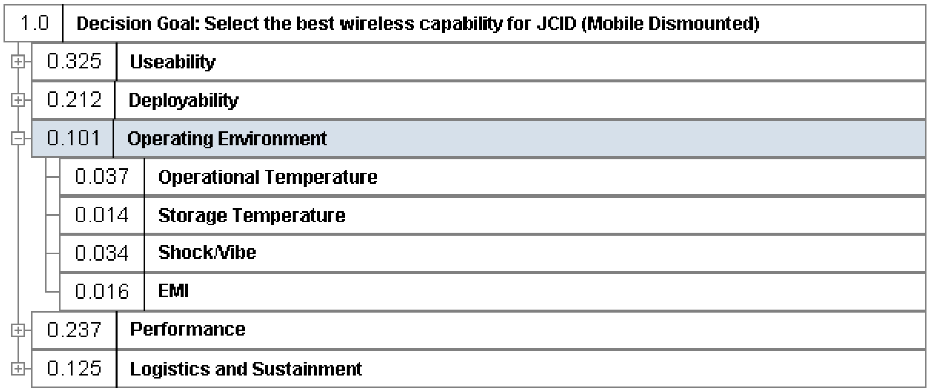
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Mobile Dismounted)**
  - 0.325 **Useability**
  - 0.212 **Deployability**
    - 0.094 **Ease of Comm Plan Integration**
    - 0.118 **Physical Load**
      - 0.093 **Per Sensor Location**
        - 0.025 **Volume**
        - 0.033 **Number of Boxes**
        - 0.035 **Weight**
      - 0.025 **Main Site**
  - 0.101 **Operating Environment**
  - 0.237 **Performance**
  - 0.125 **Logistics and Sustainment**

2.9 Main Site



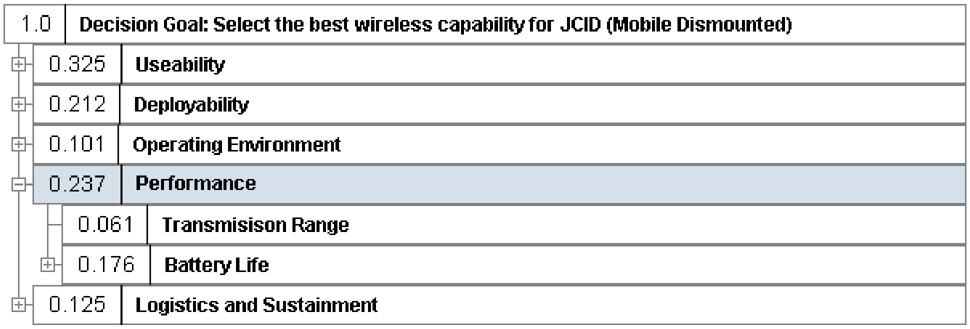
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Mobile Dismounted)**
  - 0.325 **Useability**
  - 0.212 **Deployability**
    - 0.094 **Ease of Comm Plan Integration**
    - 0.118 **Physical Load**
      - 0.093 **Per Sensor Location**
      - 0.025 **Main Site**
        - 0.005 **MS Weight**
        - 0.011 **MS Volume**
        - 0.009 **MS Number of Boxes**
  - 0.101 **Operating Environment**
  - 0.237 **Performance**
  - 0.125 **Logistics and Sustainment**

2.10 Operating Environment



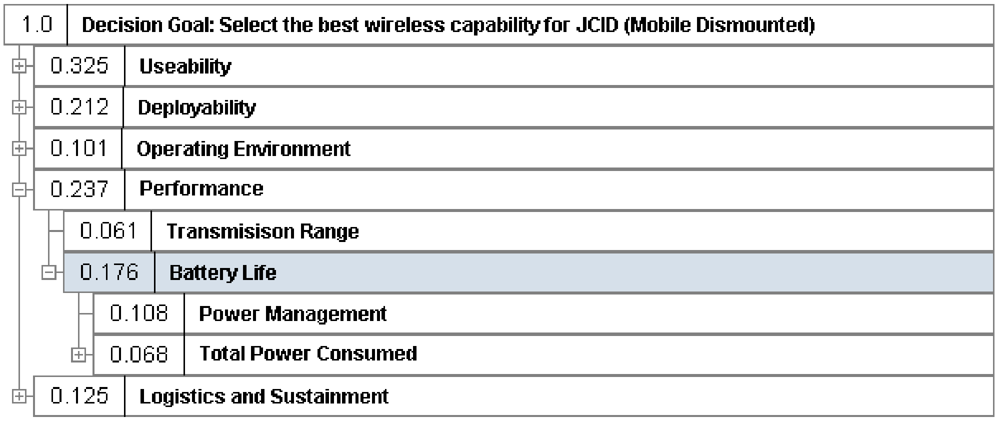
- 1.0 Decision Goal: Select the best wireless capability for JCID (Mobile Dismounted)
  - 0.325 Useability
  - 0.212 Deployability
  - 0.101 Operating Environment
    - 0.037 Operational Temperature
    - 0.014 Storage Temperature
    - 0.034 Shock/Vibe
    - 0.016 EMI
  - 0.237 Performance
  - 0.125 Logistics and Sustainment

2.11 Performance



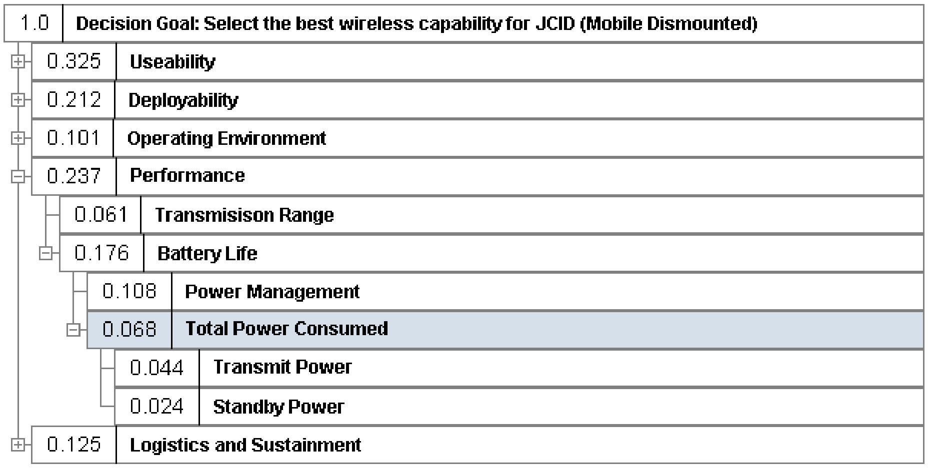
- 1.0 Decision Goal: Select the best wireless capability for JCID (Mobile Dismounted)
  - 0.325 Useability
  - 0.212 Deployability
  - 0.101 Operating Environment
  - 0.237 Performance
    - 0.061 Transmisison Range
    - 0.176 Battery Life
  - 0.125 Logistics and Sustainment

2.12 Battery Life



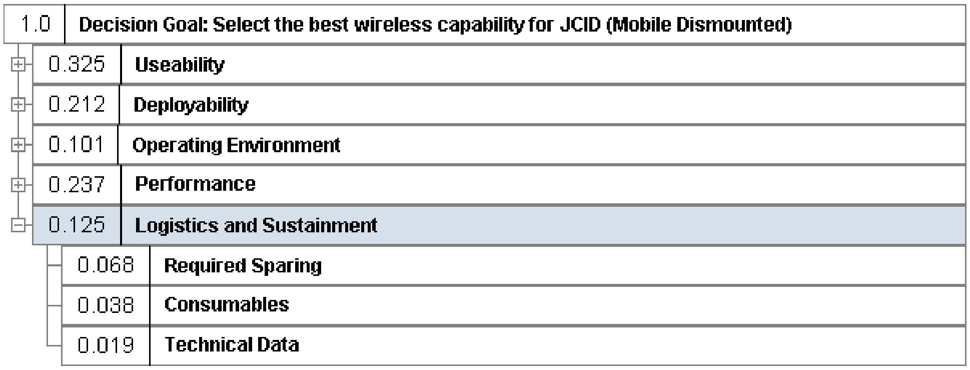
- 1.0 Decision Goal: Select the best wireless capability for JCID (Mobile Dismounted)
  - 0.325 Useability
  - 0.212 Deployability
  - 0.101 Operating Environment
  - 0.237 Performance
    - 0.061 Transmisison Range
    - 0.176 Battery Life
      - 0.108 Power Management
      - 0.068 Total Power Consumed
  - 0.125 Logistics and Sustainment

2.13 Total Power Consumed



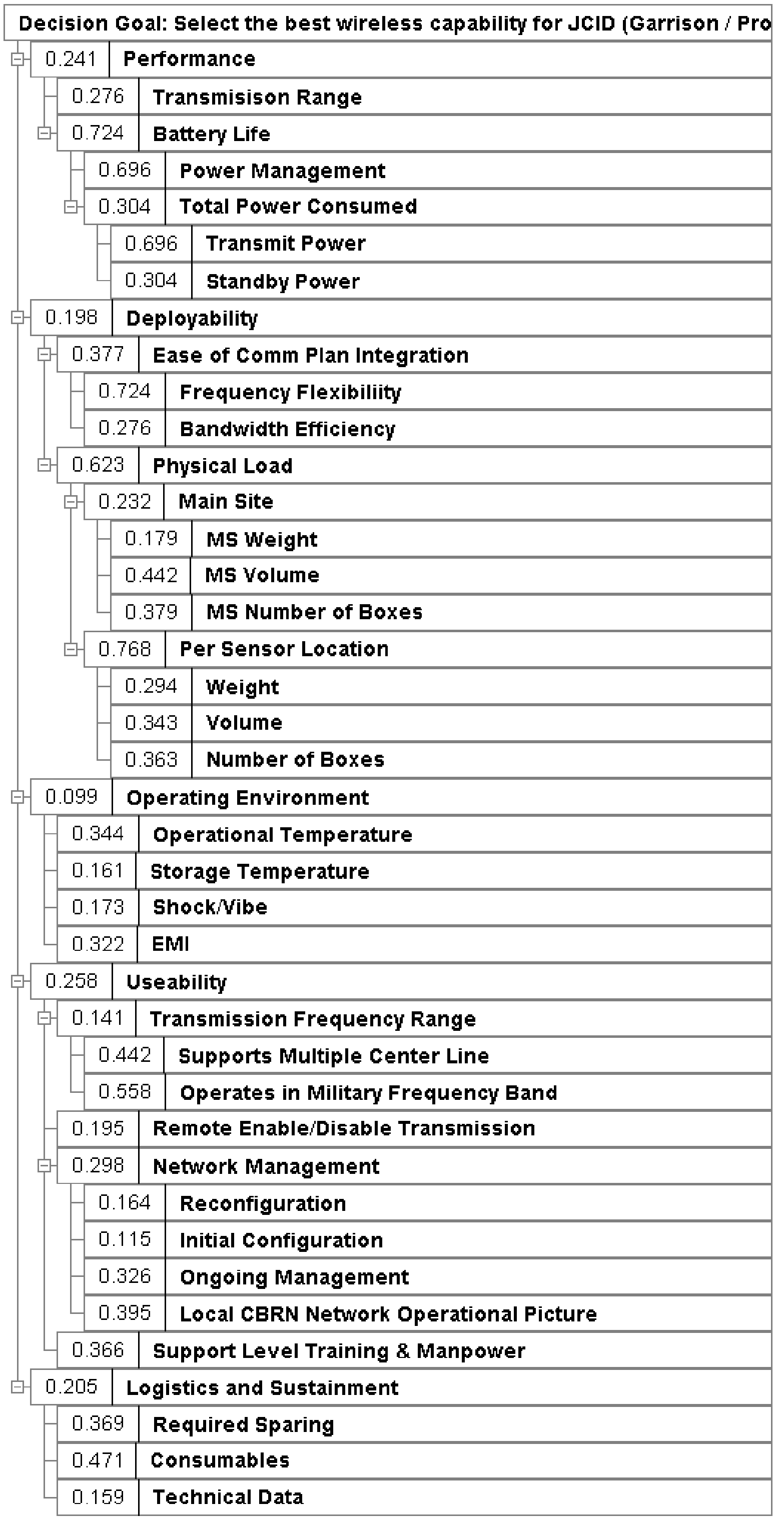
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Mobile Dismounted)**
  - 0.325 **Useability**
  - 0.212 **Deployability**
  - 0.101 **Operating Environment**
  - 0.237 **Performance**
    - 0.061 **Transmisison Range**
    - 0.176 **Battery Life**
      - 0.108 **Power Management**
      - 0.068 **Total Power Consumed**
        - 0.044 **Transmit Power**
        - 0.024 **Standby Power**
  - 0.125 **Logistics and Sustainment**

2.14 Logistics and Sustainment



- 1.0 **Decision Goal: Select the best wireless capability for JCID (Mobile Dismounted)**
  - 0.325 **Useability**
  - 0.212 **Deployability**
  - 0.101 **Operating Environment**
  - 0.237 **Performance**
  - 0.125 **Logistics and Sustainment**
    - 0.068 **Required Sparing**
    - 0.038 **Consumables**
    - 0.019 **Technical Data**

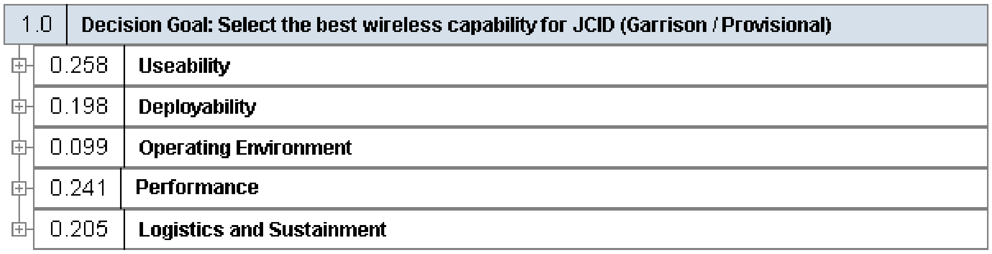
3.0 Decision Goal: Select the best wireless capability for JCID (Garrison/Provisional)



Decision Goal: Select the best wireless capability for JCID (Garrison / Pro

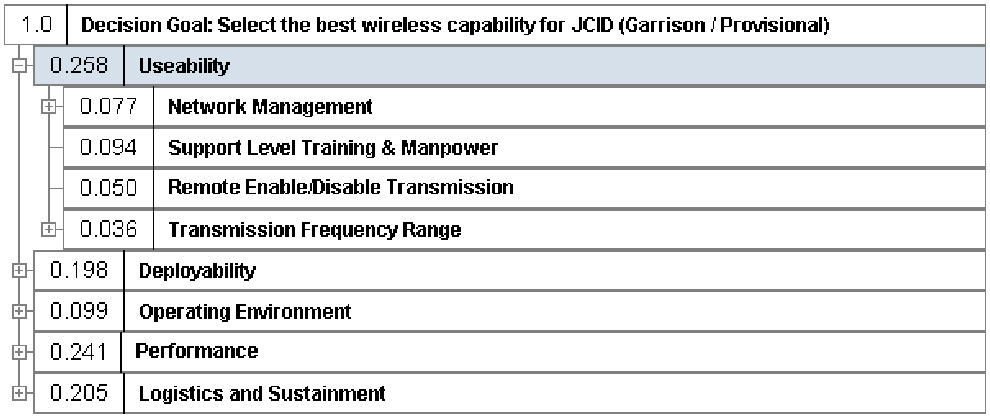
- 0.241 Performance
  - 0.276 Transmisison Range
  - 0.724 Battery Life
    - 0.696 Power Management
    - 0.304 Total Power Consumed
      - 0.696 Transmit Power
      - 0.304 Standby Power
- 0.198 Deployability
  - 0.377 Ease of Comm Plan Integration
    - 0.724 Frequency Flexibiliity
    - 0.276 Bandwidth Efficiency
  - 0.623 Physical Load
    - 0.232 Main Site
      - 0.179 MS Weight
      - 0.442 MS Volume
      - 0.379 MS Number of Boxes
    - 0.768 Per Sensor Location
      - 0.294 Weight
      - 0.343 Volume
      - 0.363 Number of Boxes
- 0.099 Operating Environment
  - 0.344 Operational Temperature
  - 0.161 Storage Temperature
  - 0.173 Shock/Vibe
  - 0.322 EMI
- 0.258 Useability
  - 0.141 Transmission Frequency Range
    - 0.442 Supports Multiple Center Line
    - 0.558 Operates in Military Frequency Band
  - 0.195 Remote Enable/Disable Transmission
  - 0.298 Network Management
    - 0.164 Reconfiguration
    - 0.115 Initial Configuration
    - 0.326 Ongoing Management
    - 0.395 Local CBRN Network Operational Picture
  - 0.366 Support Level Training & Manpower
- 0.205 Logistics and Sustainment
  - 0.369 Required Sparing
  - 0.471 Consumables
  - 0.159 Technical Data

3.1 Decision Goal: Select the best wireless capability for JCID (Garrison/Provisional)



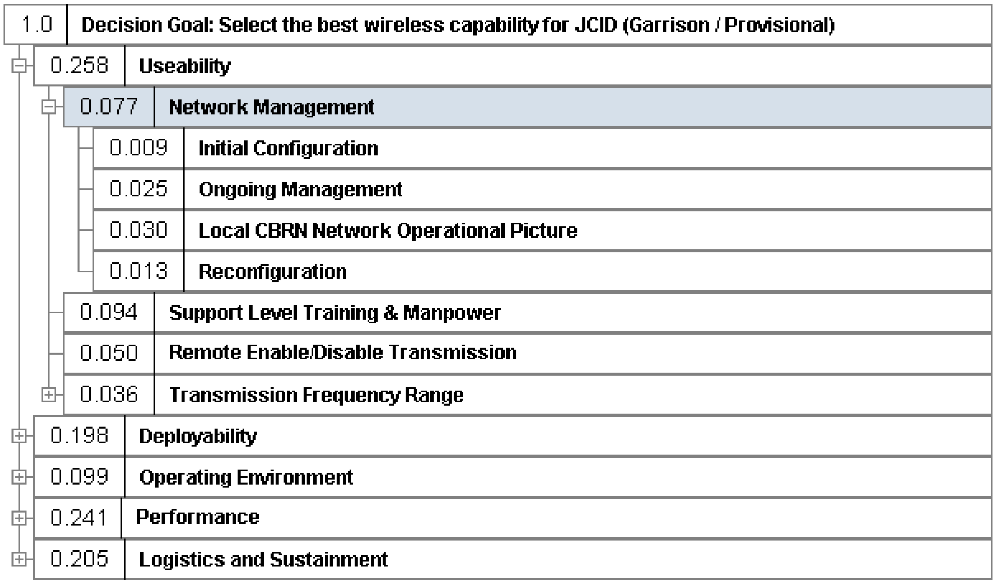
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Garrison / Provisional)**
  - ⊞ 0.258 **Useability**
  - ⊞ 0.198 **Deployability**
  - ⊞ 0.099 **Operating Environment**
  - ⊞ 0.241 **Performance**
  - ⊞ 0.205 **Logistics and Sustainment**

3.2 Usability



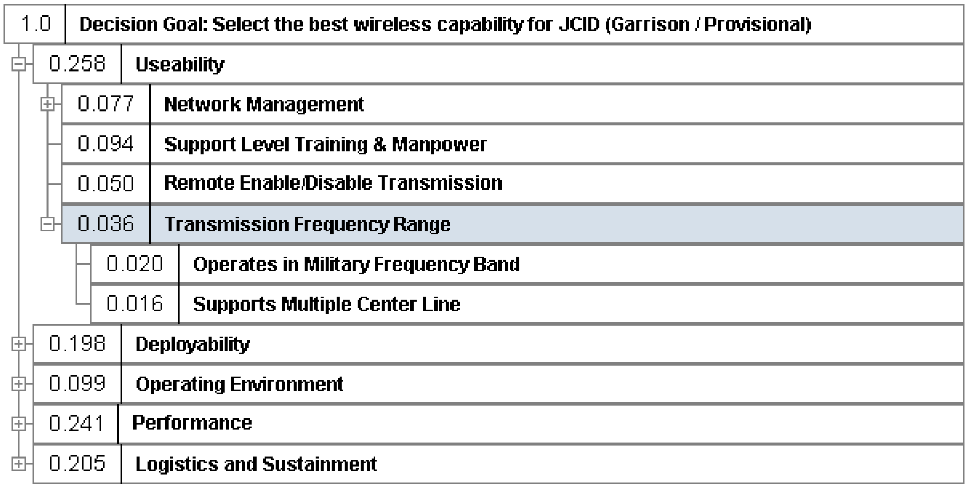
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Garrison / Provisional)**
  - ⊟ 0.258 **Useability**
    - ⊞ 0.077 **Network Management**
    - 0.094 **Support Level Training & Manpower**
    - 0.050 **Remote Enable/Disable Transmission**
    - ⊞ 0.036 **Transmission Frequency Range**
  - ⊞ 0.198 **Deployability**
  - ⊞ 0.099 **Operating Environment**
  - ⊞ 0.241 **Performance**
  - ⊞ 0.205 **Logistics and Sustainment**

3.3 Network Management



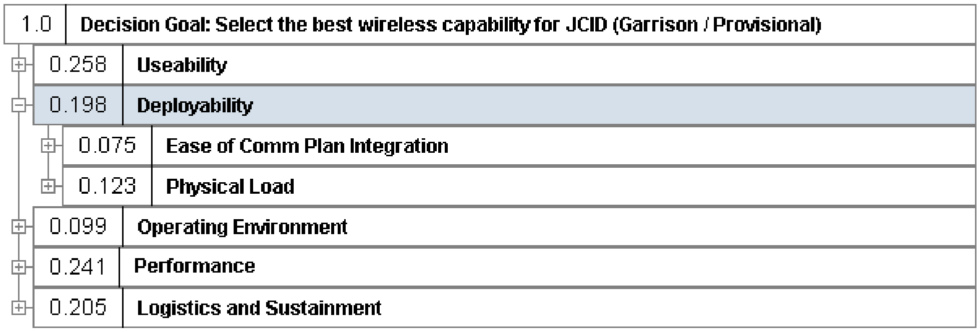
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Garrison / Provisional)**
  - ⊟ 0.258 **Useability**
    - ⊟ 0.077 **Network Management**
      - 0.009 **Initial Configuration**
      - 0.025 **Ongoing Management**
      - 0.030 **Local CBRN Network Operational Picture**
      - 0.013 **Reconfiguration**
    - 0.094 **Support Level Training & Manpower**
    - 0.050 **Remote Enable/Disable Transmission**
    - ⊞ 0.036 **Transmission Frequency Range**
  - ⊞ 0.198 **Deployability**
  - ⊞ 0.099 **Operating Environment**
  - ⊞ 0.241 **Performance**
  - ⊞ 0.205 **Logistics and Sustainment**

3.4 Transmission Frequency Range



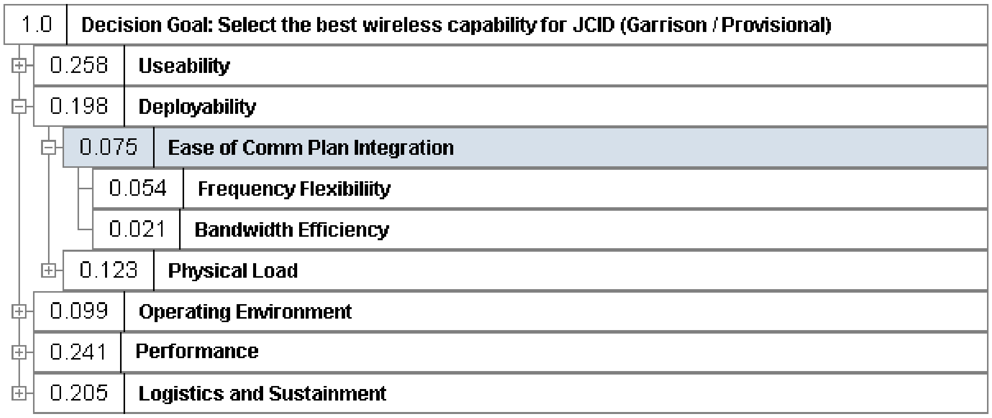
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Garrison / Provisional)**
  - 0.258 **Useability**
    - 0.077 **Network Management**
    - 0.094 **Support Level Training & Manpower**
    - 0.050 **Remote Enable/Disable Transmission**
    - 0.036 **Transmission Frequency Range**
      - 0.020 **Operates in Military Frequency Band**
      - 0.016 **Supports Multiple Center Line**
  - 0.198 **Deployability**
  - 0.099 **Operating Environment**
  - 0.241 **Performance**
  - 0.205 **Logistics and Sustainment**

3.5 Deployability



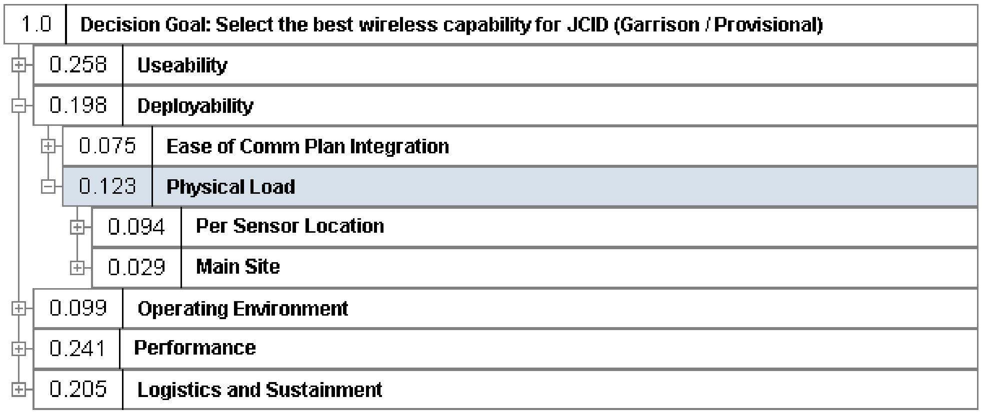
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Garrison / Provisional)**
  - 0.258 **Useability**
  - 0.198 **Deployability**
    - 0.075 **Ease of Comm Plan Integration**
    - 0.123 **Physical Load**
  - 0.099 **Operating Environment**
  - 0.241 **Performance**
  - 0.205 **Logistics and Sustainment**

3.6 Ease of Communications Plan Integration



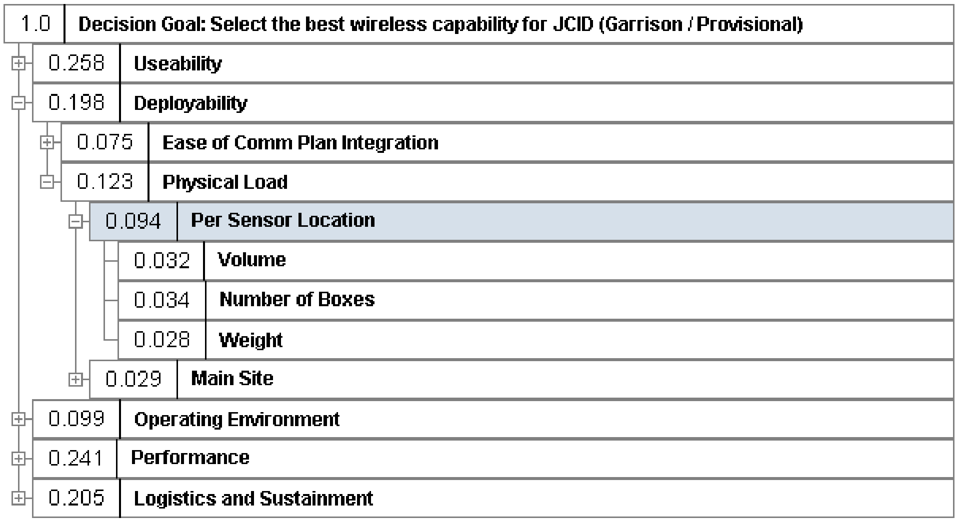
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Garrison / Provisional)**
  - 0.258 **Useability**
  - 0.198 **Deployability**
    - 0.075 **Ease of Comm Plan Integration**
      - 0.054 **Frequency Flexibility**
      - 0.021 **Bandwidth Efficiency**
    - 0.123 **Physical Load**
  - 0.099 **Operating Environment**
  - 0.241 **Performance**
  - 0.205 **Logistics and Sustainment**

3.7 Physical Load



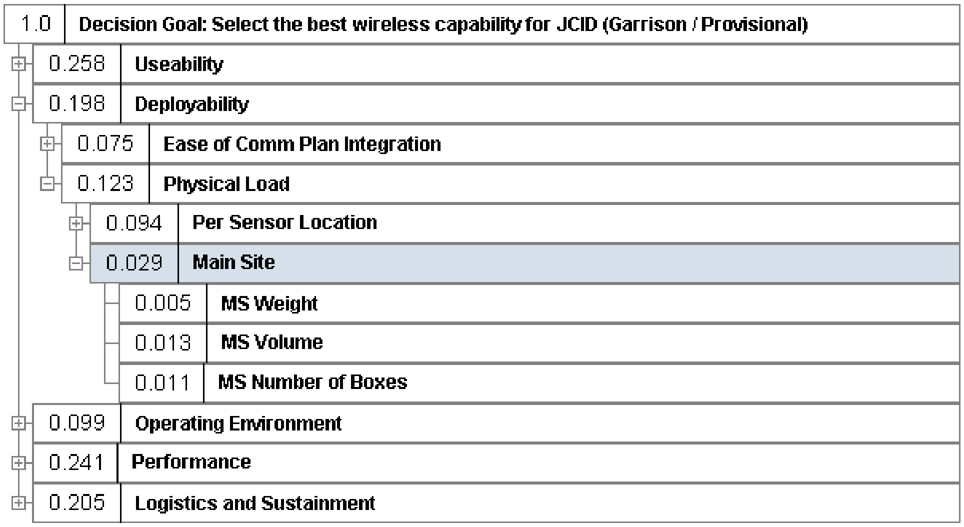
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Garrison / Provisional)**
  - 0.258 **Useability**
  - 0.198 **Deployability**
    - 0.075 **Ease of Comm Plan Integration**
    - 0.123 **Physical Load**
      - 0.094 **Per Sensor Location**
      - 0.029 **Main Site**
  - 0.099 **Operating Environment**
  - 0.241 **Performance**
  - 0.205 **Logistics and Sustainment**

3.8 Per Sensor Location



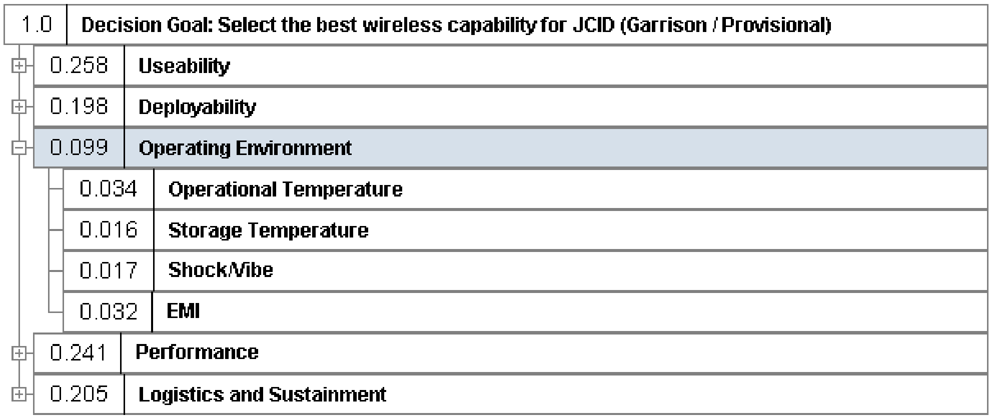
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Garrison / Provisional)**
  - 0.258 **Useability**
  - 0.198 **Deployability**
    - 0.075 **Ease of Comm Plan Integration**
    - 0.123 **Physical Load**
      - 0.094 **Per Sensor Location**
        - 0.032 **Volume**
        - 0.034 **Number of Boxes**
        - 0.028 **Weight**
      - 0.029 **Main Site**
  - 0.099 **Operating Environment**
  - 0.241 **Performance**
  - 0.205 **Logistics and Sustainment**

3.9 Main Site



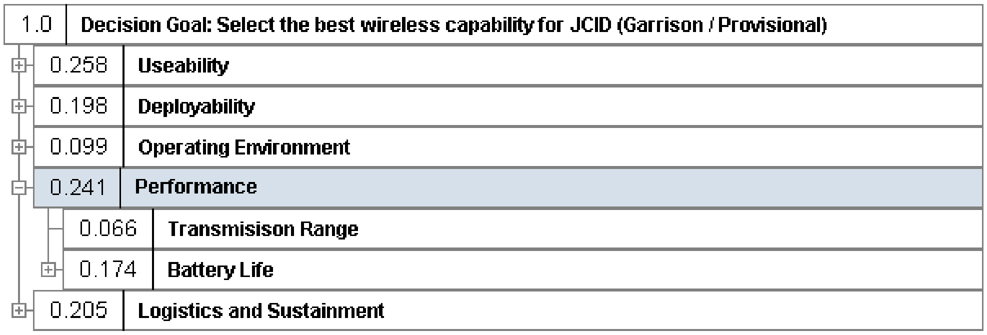
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Garrison / Provisional)**
  - 0.258 **Useability**
  - 0.198 **Deployability**
    - 0.075 **Ease of Comm Plan Integration**
    - 0.123 **Physical Load**
      - 0.094 **Per Sensor Location**
      - 0.029 **Main Site**
        - 0.005 **MS Weight**
        - 0.013 **MS Volume**
        - 0.011 **MS Number of Boxes**
  - 0.099 **Operating Environment**
  - 0.241 **Performance**
  - 0.205 **Logistics and Sustainment**

3.10 Operating Environment



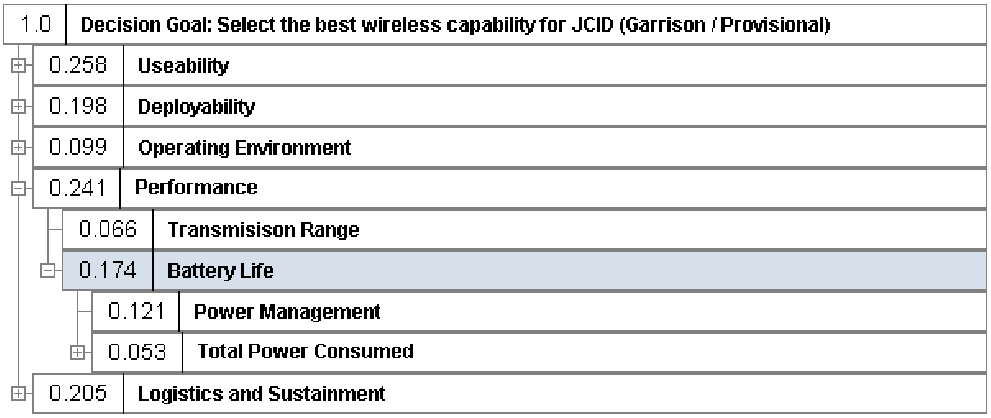
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Garrison / Provisional)**
  - 0.258 **Useability**
  - 0.198 **Deployability**
  - 0.099 **Operating Environment**
    - 0.034 **Operational Temperature**
    - 0.016 **Storage Temperature**
    - 0.017 **Shock/Vibe**
    - 0.032 **EMI**
  - 0.241 **Performance**
  - 0.205 **Logistics and Sustainment**

3.11 Performance



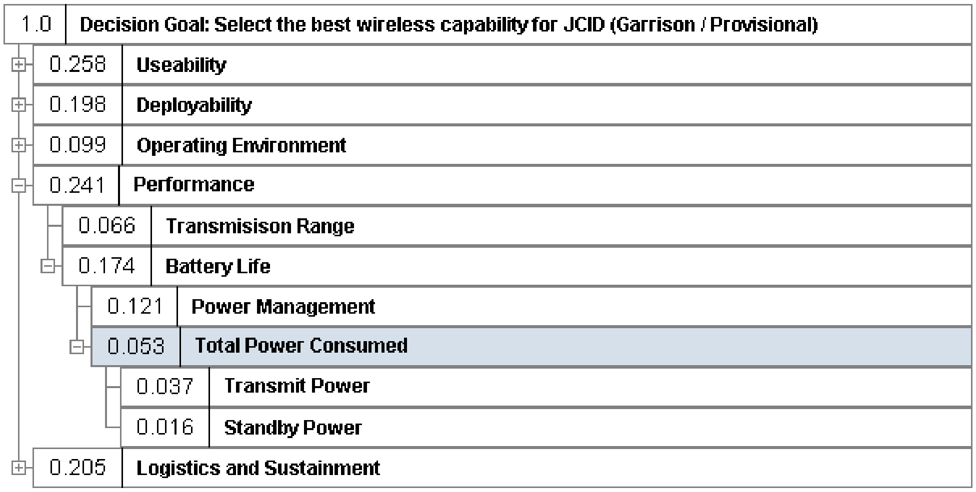
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Garrison / Provisional)**
  - 0.258 **Useability**
  - 0.198 **Deployability**
  - 0.099 **Operating Environment**
  - 0.241 **Performance**
    - 0.066 **Transmisison Range**
    - 0.174 **Battery Life**
  - 0.205 **Logistics and Sustainment**

3.12 Battery Life



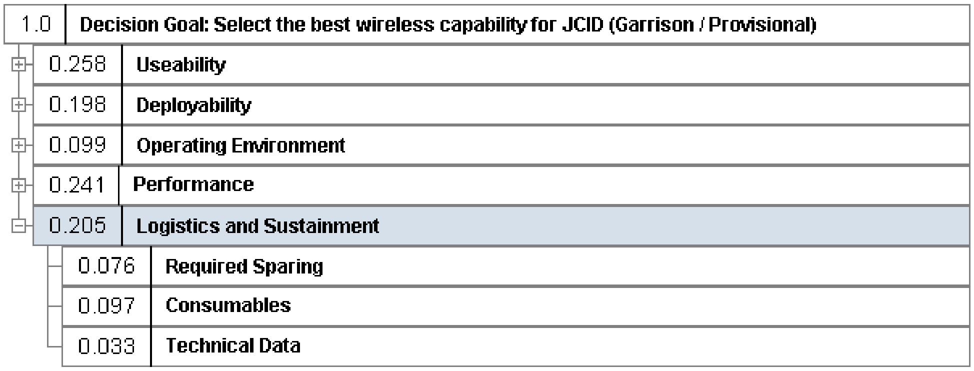
- 1.0 **Decision Goal: Select the best wireless capability for JCID (Garrison / Provisional)**
  - 0.258 **Useability**
  - 0.198 **Deployability**
  - 0.099 **Operating Environment**
  - 0.241 **Performance**
    - 0.066 **Transmisison Range**
    - 0.174 **Battery Life**
      - 0.121 **Power Management**
      - 0.053 **Total Power Consumed**
  - 0.205 **Logistics and Sustainment**

3.13 Total Power Consumed



- 1.0 **Decision Goal: Select the best wireless capability for JCID (Garrison / Provisional)**
  - 0.258 **Useability**
  - 0.198 **Deployability**
  - 0.099 **Operating Environment**
  - 0.241 **Performance**
    - 0.066 **Transmisison Range**
    - 0.174 **Battery Life**
      - 0.121 **Power Management**
      - 0.053 **Total Power Consumed**
        - 0.037 **Transmit Power**
        - 0.016 **Standby Power**
  - 0.205 **Logistics and Sustainment**

3.14 Logistics and Sustainment



- 1.0 **Decision Goal: Select the best wireless capability for JCID (Garrison / Provisional)**
  - 0.258 **Useability**
  - 0.198 **Deployability**
  - 0.099 **Operating Environment**
  - 0.241 **Performance**
  - 0.205 **Logistics and Sustainment**
    - 0.076 **Required Sparing**
    - 0.097 **Consumables**
    - 0.033 **Technical Data**

APPENDIX D. VENDOR LISTS

List of manufacturers that were reviewed that provide PCMCIA cards that are: Wireless modems, Radio modems, 802.x, and for encryption:

2Wire, Inc. (Manufacturer)
3Com® Corporation (Manuf., Distrib. & Service)
3e Technologies International, Inc. (Manufacturer)
3J Tech Co., Ltd. (Manufacturer)
3Sixty Group (Manuf. & Service)
4th Dimension Computer (Manuf. & Distrib.)
A3J Engineering Inc. (Manufacturer)
A3Net Servers, Inc. (Distributor)
AAA Media Inc. (Distributor)
AAEON Electronics, Inc. (Manufacturer)
AB Distributing (Distributor)
ABACOM Technologies (Manufacturer)
ABB Automation Ltd. (Manufacturer)
Abbeon Cal, Inc. (Manufacturer)
ABC Drives (Distrib. & Service)
Able Groups, Inc. (Distrib. & Service)
ACCES I/O Products, Inc. (Manufacturer)
Accton Technology Corporation (Manufacturer)
Accurite Technologies Inc. (Manufacturer)
ACM Computers, Inc. (Manuf., Distrib. & Service)
Acqiris USA (Manufacturer)
Acquisition Technology (Manuf. & Service)
Acqutek Corporation (Manufacturer)
ACTIA USA (Manufacturer)
Actiontec Electronics, Inc. (Manufacturer)
ACTIS Computer Inc. (Manufacturer)
Aculab plc (Manuf. & Distrib.)
Acutec Systems Ltd. (Manufacturer)
ADAC Corporation (Manufacturer)
Adaptec, Inc. (Manufacturer)
Adax, Inc. (Manufacturer)
ADC Telecommunications / ADC Access Products Division (Manufacturer)
ADC Telecommunications, Inc. (Manufacturer)
Adcon Telemetry Inc. (Manufacturer)
Addonics Technologies, Inc. (Manufacturer)
Addtech (Distributor)
ADLINK Technology Inc. (Manuf. & Sole Distrib.)
ADMtek (Manufacturer)
Adtran, Inc. (Manufacturer)
Advanced Cellular Communications Corporation (Manufacturer)
Advanced IC Engineering, Inc. (Manufacturer)
Advanced Micro Devices, Inc. (Manufacturer)
Advanced RF Technologies (Manufacturer)
Advanced Technology Unlimited, Inc. (Distributor)
Advanced Vehicle Technologies, Inc. (Manufacturer)
Advanced World Products (Manufacturer)
Advanet Inc (Manufacturer)
Advantech - Applied Computing Group (Manufacturer)
Advantech Corporation, Industrial Automation Group (Manufacturer)
Advantech Corporation, Network Computing Group (Manufacturer)
Advantra (Manufacturer)
Aero Telemety Corporation (Manufacturer)
AeroComm, Inc. (Manuf. & Service)
AESP, Inc. (Manuf. & Service)
Agilent Technologies, Inc. / Test & Measurement (Manufacturer)
Airgo Networks (Manufacturer)
AirLink Communications, Inc. (Manufacturer)
Alacron, Inc. (Manufacturer)
Alcatel (Manufacturer)
Alcatel Space (Manufacturer)
Allcan Electronic Distributors (Distributor)
Allen Osborne Associates, Inc. (Manufacturer)
Allied Data Technologies (Manufacturer)
Allied Telesyn International Corp. (Manufacturer)
AllSunPlus.com (Distributor)
Alpha and Omega Computer Corporation (Manuf. & Distrib.)
ALPHI Technology Corporation (Manufacturer)
Alps Electric (USA) Inc. (Manufacturer)
Altima Communications, Inc. (Manufacturer)
Amalgamated Instrument Co Pty Ltd. (Manufacturer)
AMASS Data Technologies, Inc. (Manufacturer)
AmbiCom, Inc. (Manufacturer)
AMC Technologies Corporation (Manuf. & Service)
American Best Computing LLC (Manuf. & Distrib.)
American Power Conversion Corp. - APC (Manufacturer)
American Sigma, Inc. (Manufacturer)
Amerilon Products by Surf Networks Inc. (Manufacturer)
Amigo Communication Inc (Manufacturer)
Anacon Systems, Inc. (Manufacturer)
ANADIGICS, Inc. (Manufacturer)
Analog and Digital Peripherals, Inc. (Manufacturer)
Andor Design Corporation (Manufacturer)
Antares Computing, Inc. (Manuf. & Distrib.)
Antec, Incorporated (Manufacturer)
AP Labs, Inc. (Manufacturer)
Aperto Networks (Manufacturer)
Apogee Labs, Inc. (Manufacturer)
Appcon Group, Inc. (Manuf. & Service)
Applicom International (Manufacturer)

Applied Innovation, Inc. (Manufacturer)
Appro International, Inc. (Manufacturer)
Archtek America Corp. (Manuf. & Sole Distrib.)
ARESCOM, Inc. (Manufacturer)
Ark Technology, Inc. (Manufacturer)
Arlotto Technologies, Inc. (Manufacturer)
ArmorLink Corp. (Manufacturer)
Asanté Technologies, Inc. (Manufacturer)
ASCO (Manufacturer)
ASCOR, Inc. (Manufacturer)
ASI Controls, Inc. (Manufacturer)
ASI Corp. (Distributor)
ASIX Electronics Corporation (Manufacturer)
Askey International Corp. (Manufacturer)
Atlanta Attachment Co., Inc. (Manuf. & Service)
Atlaz International Ltd. (Distributor)
Aurora Technologies, Inc., A Carlo Gavazzi Group Company (Manufacturer)
Automationdirect.com (Manuf. & Sole Distrib.)
Avaya Corporate (Manufacturer)
AVM of America, Inc. (Manufacturer)
AVTEC Systems, Inc. (Manufacturer)
Axxcelera Broadband Wireless (Manufacturer)
B&B Electronics (Manuf. & Distrib.)
B&R Industrial Automation Corp. (Manuf. & Service)
Ballard Technology, Inc. (Manufacturer)
Bay Advanced Technologies, LLC (Manuf. & Distrib.)
Beckhoff Automation LLC (Manuf. & Service)
Belkin Components (Manuf. & Service)
Bell Microproducts Inc. (Distributor)
Best Data Products, Inc. (Manufacturer)
Better On-Line Solutions, Inc. (Manufacturer)
Bill West, Inc. (Manuf., Distrib., Sole Distrib. & Service)
Binatone Broadband (Manuf. & Service)
Black Box Corporation (Manuf., Distrib. & Service)
Blue Tree Wireless Data Inc. (Manufacturer)
Bluesocket, Inc. (Manufacturer)
Bothhand USA (Manufacturer)
Broadcom Corporation (Manufacturer)
Bromax Communications, Inc. USA (Manufacturer)
Brooktrout Inc. (Manufacturer)
Buffalo Technology (USA), Inc. (Manufacturer)
ByteRunner Technologies (Manufacturer)
CableFree Solutions Limited (Manufacturer)
CableWholesale.com (Distributor)
Cadmus Micro, Inc. (Manufacturer)
CalAmp Solutions (Manuf. & Service)
CAL-AV Labs, Inc. (Manuf. & Service)
California Microwave, Inc. (Manufacturer)
Campbell Scientific, Inc. (Manufacturer)
Capital Equipment Corp. (Manufacturer)
Captec North America, Inc. (Manuf. & Service)
CARLO GAVAZZI Automation Components (Manufacturer)
Carlo Gavazzi Mupac, Inc. (Manufacturer)
Carrier Access Corp. (Manufacturer)
Catalyst Enterprises, Inc. (Manufacturer)
CeLAN Technology U.S.A. (Manufacturer)
Celite Systems (Manufacturer)
Ceragon Networks, Inc. (Manufacturer)
Chroma Systems Solutions (Manuf. & Distrib.)
Circon Systems Corporation (Manuf. & Service)
Circuit Assembly Corp. (Manuf. & Service)
Circuit Design, Inc. (Manufacturer)
Cirronet, Inc. (Manuf. & Service)
Cirrus Logic, Inc. (Manufacturer)
Cisco Systems, Inc. (Manuf. & Service)
Clarinet Systems, Inc. (Manufacturer)
CML Microcircuits (USA) Inc. (Manufacturer)
CMS Peripherals, Inc. (Manufacturer)
CNet Technology, Inc. (Manufacturer)
Coherent Communications, Inc. (Manufacturer)
Cole-Parmer Instrument Co. (Distributor)
Colubris Networks Inc. (Manufacturer)
Columbia Electronics International, Inc. (Manufacturer)
COM One (Manufacturer)
Commtech, Inc. (Manufacturer)
Communication Automation Corporation (Manufacturer)
Compex, Inc. (Manufacturer)
CompuCable Corporation (Manuf. & Distrib.)
Computer Modules, Inc. (Manuf., Distrib. & Service)
Comstock Telcom (Distributor)
Comtech Complementary Technologies Ltd. (Manufacturer)
Comtech Holdings Ltd. (Manufacturer)
Comtrol Corporation (Manuf. & Service)
Concurrent Technologies, Inc. (Manufacturer)
Condor Engineering, Inc. (Manufacturer)
Conexant Systems, Inc. (Manufacturer)
Connect Tech Inc. (Manufacturer)
Connecticut microComputer, Inc. (Manufacturer)
CONTEC Microelectronics Europe B.V. (Manufacturer)
Contec Microelectronics U.S.A., Inc. (Manufacturer)
Contemporary Controls (Manufacturer)
Control Technology Corporation (Manufacturer)
Copley Controls Corp. (Manufacturer)
Copper Mountain Networks, Inc. (Manufacturer)
CoSystems, Inc. (Manufacturer)
CoWave Networks Inc. (Manufacturer)
CQ Computer Communications, Inc. (Manufacturer)
Creative Electronics Systems (Manufacturer)
Creative Labs, Inc. (Manufacturer)
Crestron Electronics, Inc. (Manufacturer)
Crossbow (Manufacturer)
C-SPEC Corporation (Manufacturer)

CTC Union Technologies Co., Ltd. (Manufacturer)
Cue Technologies Inc (Distributor)
Curtiss Wright Controls - Embedded Computing (Manufacturer)
Cybernetic Micro Systems (Manufacturer)
Cyclades Corporation (Manufacturer)
D.SignT (Manuf. & Service)
Daniel Woodhead Co. (Manufacturer)
Danpex Corporation (Manufacturer)
DapTechnology BV (Manufacturer)
Data And Telephone Supply Co. (Manufacturer)
Data Base Access Systems, Inc. (Manufacturer)
Data Comm for Business, Inc. (Manuf. & Distrib.)
Data Device Corporation (DDC) (Manufacturer)
Data Translation, Inc. (Manufacturer)
Datafab USA Inc. (Manufacturer)
Data-Linc Group (Manufacturer)
Dataprobe, Inc. (Manufacturer)
Dataradio Corporation (Manufacturer)
DataRemote Inc. (Manufacturer)
dataTaker (Manufacturer)
Datron World Communications, Inc. (Manufacturer)
Davicom Semiconductor. Inc. (Manufacturer)
Delkin Devices, Inc. (Manufacturer)
Dell Computer Corp. (Manuf. & Service)
Delphi Communication Systems, Inc. (Manuf. & Service)
Delta Electronics, Inc. (Manufacturer)
Diamond Traffic Products (Manufacturer)
Digi International, Inc. (Manufacturer)
digicom s.p.a. Digicom (Manufacturer)
digicom s.p.a. Digicom (Manufacturer)
Digi-Key Corporation (Distributor)
Digital Dynamics, Inc. (Manufacturer)
D-Link Systems, Inc. (Manuf. & Service)
Drive Solutions, Inc. (Manufacturer)
DSS Networks, Inc. (Manufacturer)
Duel Systems Inc. (Manufacturer)
DY 4 Systems, Inc. (Manufacturer)
Dynalink (UK) Ltd. (Manufacturer)
Dynatem, Inc. (Manufacturer)
Eastern Research, Inc. (Manufacturer)
Echelon Corporation (Manufacturer)
Echo Communications, Inc. (Manufacturer)
E-COMMS, Inc. (Manufacturer)
Eicon Technology, Inc. (Manufacturer)
EKF Elektronik GmbH (Manufacturer)
Electronic Hook-Up (Distributor)
ELPRO Technologies (Manufacturer)
Emerson Electric Co. (Manufacturer)
Emicros (Manufacturer)
Emulex Corporation (Manufacturer)
Enterasys Networks (Manufacturer)
Envoy Data Corporation (Distributor)
Epson Electronics America, Inc. (Manufacturer)
Equinox Systems, Inc. (Manufacturer)
esd electronic system design (Manufacturer)
Excalibur Systems, Inc. (Manufacturer)
Excel Distributing, Inc. - Ohio (Distributor)
Excess Solutions (Distributor)
EXP Computer, Inc. (Manufacturer)
FastComm Communications Corp. (Manufacturer)
FieldServer Technologies (Manufacturer)
Firebit Ltd. (Manufacturer)
FreeWave Technologies, Inc. (Manufacturer)
Fujitsu Microelectronics America, Inc. (Manufacturer)
Gaintech Peripherals Co., Ltd. (Manufacturer)
Galazar Networks Inc. (Manufacturer)
GarrettCom, Inc. (Manufacturer)
Gauging Systems Inc. (Manufacturer)
GE Industrial Systems (Manuf. & Service)
General Standards Corporation (Manufacturer)
GENROCO, Inc. (Manufacturer)
Geomation, Inc. (Manufacturer)
Gespac, Inc. (Manufacturer)
Global American, Inc. (Manufacturer)
GMW Associates (Manuf. & Sole Distrib.)
GoCables (Manuf. & Service)
Grayhill, Inc. (Manuf. & Service)
Grid Connect (Manufacturer)
HACKER-DatenTechnik (Distributor)
Handlink Technologies, Inc. (Manufacturer)
Harris Microwave Communications Division (Manuf. & Service)
HARWIN (Manufacturer)
Hawke International USA (Manuf. & Distrib.)
Hawking Technologies, Inc. (Manufacturer)
Hewlett-Packard (Manuf. & Service)
Hirschmann Electronics, Inc. (Manufacturer)
Horner APG (Manuf., Distrib. & Service)
Hubbell Industrial Controls, Inc. (Manuf. & Distrib.)
Huntron, Inc. (Manufacturer)
HyperLink Technologies, Inc. (Manuf. & Distrib.)
IC INTRACOM (Manufacturer)
IMO Precision Controls Limited (Manufacturer)
Industrial Logic Corporation (Manufacturer)
Industrial PC, Inc. (Manufacturer)
ines GmbH (Manufacturer)
INRANGE Technologies (Manufacturer)
Insight (Manuf. & Distrib.)
Instant InfoSystems (Distributor)
Instrumentation Technology Systems (Manufacturer)
Integrated Circuit Solution, Inc. (Manufacturer)
Interface Amita Corporation (Manufacturer)
INTERFACE CONCEPT (Manufacturer)
InterlinkBT LLC (Manuf. & Distrib.)
Intermec Technologies Corporation (Manufacturer)
Intersil Corporation (Manuf. & Service)
Intrepid Control Systems (Manufacturer)
IPWireless, Inc. (Manufacturer)
ISDN*tek (Manufacturer)

J & S Instruments, Inc. (Manuf. & Distrib.)
JA Electronics Mfg. Co., Inc. (Manufacturer)
Janz Automation Systems (Manufacturer)
Jekyll Electronic Technology (Manufacturer)
JM Fiber Optics, Inc. (Manuf. & Distrib.)
JNI Corporation (Manufacturer)
Juniper Networks Inc. (Manufacturer)
Kantronics Co., Inc. (Manufacturer)
Keithley Instruments, Inc. (Manufacturer)
Kern Engineering & Mfg Corp. (Manufacturer)
Keyspan (Manufacturer)
KINGMAX Semiconductor, Inc. (Manufacturer)
Kingston Technology (Manuf. & Distrib.)
Kontron Canada (Manufacturer)
Kontron USA (Manufacturer)
Koutech Systems Inc. (Manuf. & Distrib.)
KVH Industries, Inc. (Manufacturer)
L-3 Communications / Telemetry West (Manufacturer)
Lava Computer MFG Inc. (Manufacturer)
L-com, Inc. (Manuf., Distrib. & Service)
Leadertech Systems Of Chicago, Inc. (Manufacturer)
Lenord, Bauer & Co. GmbH (Manuf. & Sole Distrib.)
Leviton Voice & Data Division (Manufacturer)
Liberatas
Locus, Inc. (Manufacturer)
Logical Co. (The) (Manufacturer)
Lumberg, Inc. (Manufacturer)
Luminous Networks, Inc. (Manufacturer)
Lynn Products, Inc. (Manuf. & Service)
M S I Computer Corp. (Manufacturer)
Mace Group, Inc. (Manufacturer)
Mackay Communications, Inc. (Distributor)
Macsense Connectivity, Inc. (Manufacturer)
MagicRAM, Inc. (Manufacturer)
Marconi Communications / Outside Plant Products (Manufacturer)
Marvell Semiconductor, Inc. (Manufacturer)
Matric (Manuf. & Service)
Maxima Technologies - Datcon Instruments (Manufacturer)
Measurement Computing (Manufacturer)
Measurement Systems International (Manuf. & Service)
Meglab électronique inc. (Manuf. & Distrib.)
Meilhaus Electronic GmbH (Manuf. & Distrib.)
Mercury Computer Systems, Inc. (Manufacturer)
Mesa Electronics (Manufacturer)
Methode Electronics, Inc. (Manufacturer)
Metric Systems Corporation (Manufacturer)
Metrodata Limited (Manufacturer)
MicroImage Technology Consultants Inc. (Distributor)
Microwave Networks (Manufacturer)
Mid-State Communications & Electronics, Inc. (Manufacturer)
Mighty Micro Inc. (Manuf. & Distrib.)
Mindready Solutions (Manuf. & Service)
Mitsumi Electronics Corporation (Manufacturer)
Monicor Electronic Corp. (Manufacturer)
MSE - Tetragenics (Manufacturer)
Multi-Tech Systems, Inc. (Manufacturer)
Murrelektronik, Inc. (Manufacturer)
Myricom, Inc. (Manufacturer)
Narda East (Manufacturer)
National Instruments (Manufacturer)
Nayna Networks, Inc. (Manufacturer)
Nematron Corporation (Manufacturer)
Netgate (Distributor)
Network Controls International, Inc. (Manufacturer)
New England Digital Computers, Inc. (Manuf., Distrib. & Service)
New England Technology, Inc. (Manufacturer)
New Wave PDG (Manufacturer)
Newark InOne (Distributor)
NEXCOM (Manufacturer)
Niobrara Research & Development Corporation (Manufacturer)
Nippon Pulse America, Inc. (Manufacturer)
Noran Tel Communications Ltd. (Manufacturer)
North Atlantic Industries, Inc. (Manufacturer)
NovaTech Process Solutions, LLC (Manuf. & Service)
Novatel Wireless
Novatel Wireless, Inc. (Manufacturer)
O2Micro, Inc. (Manufacturer)
Oasis SiliconSystems AG (Manufacturer)
Octagon Systems Corporation (Manufacturer)
OMEGA Engineering, Inc. (Manufacturer)
OneAccess Networks (Manufacturer)
OnSpec Electronic, Inc. (Manufacturer)
Optical Scientific, Inc. / Mobile Telesystems, Inc. (Manufacturer)
Opto 22 (Manufacturer)
Ositech Communications Inc. (Manufacturer)
OTC Wireless, Inc. (Manufacturer)
Pacific CommWare, Inc. (Manufacturer)
Pacific Crest Corporation (Manufacturer)
Pacific Parts & Controls, Inc. (Distributor)
PACSCOM Ltd. (Manufacturer)
Panasonic Industrial Co., ECG (Manuf. & Service)
Parvus Corporation (Manuf. & Service)
PATTON Electronics, Co. (Manufacturer)
PC Wholesale (Manufacturer)
PCI Embedded Computer Systems (Manufacturer)
Performance Technologies, Inc. (Manufacturer)
Peripheral Enhancements Corp. (Manufacturer)
Perle Systems, Inc. (Manufacturer)
Prairie Digital, Inc. (Manufacturer)
Pressure System, Inc. (Manufacturer)

Pretec Electronics Corporation (Manufacturer)
Primary Simulation, Inc. (PSI) (Distributor)
Proxim
Quanser Consulting, Inc. (Manuf. & Service)
Quatech (Manufacturer)
Quest Technology International, Inc. (Manufacturer)
Racal Instruments, Inc. (Manufacturer)
Racore Technology Corporation (Manufacturer)
RAD Data Communications, Inc. (Manufacturer)
Radicom Research, Inc. (Manufacturer)
Radio-Tech Ltd. (Manufacturer)
Raylink, Inc. (Manufacturer)
Red Lion Controls, Inc. (Manuf. & Sole Distrib.)
Red Rock Technologies, Inc. (Manufacturer)
Renasis (Manufacturer)
RF Digital Corporation (Distrib. & Service)
RF Micro Devices, Inc. (Manufacturer)
RF Power Components, Inc. (Manufacturer)
RFL Electronics Inc. (Manufacturer)
ROHDE & SCHWARZ, Inc. (Manufacturer)
Ronan Engineering Co. (Manufacturer)
Rose Electronics (Manufacturer)
Rosemount, Inc. (Manufacturer)
Samsung Electro-Mechanics (Manuf. & Service)
SanDisk Corp. (Manufacturer)
Satel-West (Sole Distributor)
SBE, Inc. (Manufacturer)
SBS Technologies, Inc. (Manufacturer)
ScanData, Inc. (Manufacturer)
Sciemetric (Manuf. & Service)
Sealevel Systems, Inc. (Manufacturer)
Semtech Corp. (Manufacturer)
Semtron, Inc. (Manuf. & Distrib.)
Seneca Data, Inc. (Manufacturer)
Sensoray Company, Inc. (Manufacturer)
Sensor-Technik UK (Manufacturer)
Shenzhen Founder Cyber Technology Co., Ltd. (Manufacturer)
Siemens Energy & Automation, Inc. (Manufacturer)
Sierra Wireless, Inc. (Manufacturer)
Signalcrafters Tech, Inc. (Manuf. & Service)
SIIG, Inc. (Manufacturer)
Silicom Connectivity Solutions, Inc. (Manufacturer)
Silicon Wave, Inc. (Manuf. & Distrib.)
Siliconrax-Sliger (Manufacturer)
SMART Modular Technologies, Inc. (Manufacturer)
Smart Technologies, Inc. (Manufacturer)
SMC Electric Supply (Distributor)
SMSC - Standard Microsystems Corporation (Manufacturer)
Socket Communications, Inc. (Manufacturer)
Solar Systems & Peripherals, Inc. (Manufacturer)
Solutions-II, Inc. (Manuf. & Service)
Spectrum Signal Processing (Manufacturer)
SST, Inc. (Manuf. & Service)
Statmon Technologies Corp. (Manufacturer)
SuperLogics, Inc. (Manufacturer)
Support Systems International Corporation (Manufacturer)
SW Controls, Inc. (Distributor)
SWS Electronics (Distrib. & Service)
SYBA Multimedia, Inc. (Manufacturer)
Synchrotech (Manuf. & Distrib.)
Syndetix, Inc. (Manuf. & Service)
SysKonnect Inc. (Manufacturer)
Tahoma Technology (Manufacturer)
Targa Systems Division (Manufacturer)
Team 1 Systems, Inc. (Manufacturer)
Team Solutions, Inc. (Manuf. & Distrib.)
Technisonic Industries Ltd. (Manufacturer)
Technobox, Inc. (Manufacturer)
TELCO Intercontinental Corp. (Manuf. & Service)
Telenetics Corporation (Manufacturer)
Teletronics International, Inc. (Manufacturer)
TERN, Inc. (Manuf. & Service)
Test Systems, Inc. (Manuf. & Service)
The MOXA Group (Manufacturer)
Thermo Electron Corporation, Process Instruments Division (Manufacturer)
Think Computer Products (Manuf., Distrib. & Service)
Third-Rail Americas (Manufacturer)
Tima Digital Technologies, Inc. (Distributor)
Toko America, Inc. (Manufacturer)
Total Technologies, Ltd. (Manuf. & Service)
Transition Networks, Inc. (Manufacturer)
Tranzeo Wireless Technologies (Manufacturer)
Traquair Data Systems, Inc. (Manuf. & Sole Distrib.)
TRENDware International, Inc. (Manufacturer)
TreNew Electronic GmbH (Manufacturer)
Triangle Digital Services LTD. (Manufacturer)
Trimble (Manufacturer)
Trio Motion Technology (Manufacturer)
U.S. Digital Corporation (Manufacturer)
U.S. Robotics Corporation (Manufacturer)
Unex Tech. (Manufacturer)
Uniden America Corporation (Manufacturer)
V. G. Controls, Inc. (Manuf. & Service)
Vector CANtech, Inc. (Manufacturer)
Vector Electronics & Technology, Inc. (Manufacturer)
Veriplus International Inc. (Manuf. & Service)
VersaLogic Corporation (Manufacturer)
VIA Technologies, Inc. (Manufacturer)
Via West Interface, Inc. (Manufacturer)
Viewpoint Systems, Inc. (Manuf. & Service)
Voiceboard Corporation (Manufacturer)
VXI Technology, Inc. (Manufacturer)
Vyyo, Inc. (Manufacturer)
WDL Systems (Distributor)
Wegener Corp. (Manufacturer)
Wi-LAN Inc. (Manufacturer)

Winchester Computers (Distributor)
Wind Wireless Inc. (Manuf. & Service)
Winstation Systems Corporation (Manufacturer)
Wintriss Engineering Corp. (Manufacturer)
Wireless Interactive Comm., Inc. (Manufacturer)
WNI Global, Inc. (Distributor)
Woven Electronics (Manuf. & Service)
Wrenchman, Inc. (Manuf. & Service)
Xecom, Inc. (Manufacturer)
Xerxes Computer Corporation (Manufacturer)
Xsilogy, Inc. (Manufacturer)
Zendex Corp. (Manufacturer)
ZNYX Networks, Inc. (Manufacturer)

List of manufacturers that have FIPS 140-2 certified products that were reviewed:

3Com Corporation
3e Technologies International, Inc.
3S Group Incorporated
ActivCard, Inc.
ActivCard, Inc., Atmel, Inc. and MartSoft, Inc.
Admiral Secure Products, Ltd.
AEP Networks
Airespace, Inc.
AirMagnet, Inc.
AKCode, LLC.
Aladdin Knowledge Systems, Ltd.
Alcatel
Algorithmic Research, Ltd.
Altarus Corporation
Aruba Wireless Networks Inc.
Atalla Security Products of Hewlett Packard Corporation
Attachmate Corporation
Avaya, Inc. (Formerly VPNet Technologies, Inc.)
Axalto
Backbone Security.com, Inc.
Blue Ridge Networks
Bluefire Security Technologies
Bluesocket, Inc.
Bodacion Technologies
C4 Technology, Inc.
Carrier Access Corporation and TeamF1
Caymas Systems Inc.
Certicom Corp.
Check Point Software Technologies Ltd.
Chunghwa Telecom Co., Ltd. Telecommunication Labs
CipherOptics Inc.
Cisco Systems, Inc.
Colubris Networks, Inc.
Communication Devices, Inc.
Control Break International Corporation
Corsec Security, Inc.
Cranite Systems, Inc.
Credant Technologies Corporation
Cryptek, Inc.
CTAM, Inc.
CyberGuard Corporation
D’Crypt Pte Ltd.
Dallas Semiconductor, Inc.
Decru, Inc.
Dreifus Associates Limited, Inc.
E.F. Johnson Co.
ECI Systems & Engineering
Encotone Ltd.
Enterasys Networks
Entrust CygnaCom
Entrust, Inc.
Eracom Technologies Group, Eracom Technologies Australia, Pty. Ltd.
Fortinet, Inc.
Fortress Technologies, Inc.
Forum Systems, Inc.
Francotyp-Postalia
F-Secure Corporation
Funk Software, Inc.
Gemplus Corp.
Gemplus Corp. and ActivCard Inc.
General Dynamics Decision Systems
Giesecke & Devrient
Good Technology
GTE Internetworking
Hasler, Inc.
High Density Devices AS
IBM® Corporation
iDirect Technologies
IMAG Technologies, Inc.
Information Security Corporation
Intel Network Systems, Inc.
IP Dynamics, Inc.
ITServ Inc.
ITT
JP Mobile, Inc.
Juniper Networks, Inc.
Kasten Chase Applied Research, Ltd.
L-3 Communication Systems
Lipman Electronic Engineering Ltd.
Litronic, Inc.
Lucent Technologies
M/A-COM, Inc.
Meganet Corporation
Microsoft Corporation
Mitsubishi Electric Corporation

Mobile Armor, LLC
Motorola, Inc.
Mykotronx, Inc.
National Semiconductor Corporation
nCipher Corporation Ltd.
Neopost
Neopost Industrie
Neopost Ltd.
Neopost Online
NeoScale Systems, Inc.
Netscape Communications Corp.
NetScreen Technologies, Inc.
Network Security Technology (NST) Co.
Nokia Enterprise Mobility Systems
Nortel
Novell, Inc.
Oberthur Card Systems
Oceana Sensor Technologies, Inc.
Oracle Corporation
Palm Solutions Group
PalmSource, Inc.
PC Guardian Technologies, Inc.
PGP Corporation
Phaos Technology Corporation
Pitney Bowes, Inc.
Pointsec Mobile Technologies
Prism Payment Technologies (Pty) Ltd
Priva Technologies, Inc.
PrivyLink Pte Ltd
PSI Systems, Inc.
Real Time Logic, Inc.
Realia Technologies S.L.
RedCannon Security
RedCreek Communications
ReefEdge, Inc.
RELM Wireless Corporation
Research In Motion
Rockwell Collins, Inc.
RSA Security, Inc.
SafeNet, Inc.
SafeNet, Inc. and Cavium Networks
SchlumbergerSema
Schweitzer Engineering Laboratories, Inc.
Secure Systems Limited
Securit-e-Doc, Inc.
Sigaba Corporation
Simple Access Inc.
SkyTel Corp.
Snapshield, Ltd.
SonicWALL, Inc.
SPYRUS, Inc.
SSH Communications Security Corp.
Stamps.com
Standard Networks, Inc.
StoneSoft Corporation
Sun Microsystems, Inc.
Symantec Corporation
Symbol (Columbitech)
Technical Communications Corp.
Telkonet Communications, Inc.
Thales e-Security
TimeStep Corporation
Transcrypt International
Tricipher, Inc.
Trust Digital, LLC
Tumbleweed Communications Corp.
Utimaco Safeware AG
Voltage Security, Inc.
V-ONE Corporation, Inc.
Vormetric, Inc.
Wei Dai
WinMagic Incorporated
WRQ, Inc.

Companies that have technologies that were used for the final analysis:

3Com
3e Technologies International
Argon Electronics
B & B Electronics
Buffalo
Cisco Systems
Colubris Networks
Dust Networks
EFJohnson
Electronic Systems Technology Inc.
Ember
Ericsson Government Solutions
Esteem
FreeWave
FreeScale
Hughes Network Systems
Intuicon
Mesh Dynamics
Microhard systems Inc.
Motorola
NAL Research Corporation
Nanjing Z-Com Wireless Co,. Ltd.
Newberry
Novatel Wireless
Radius
RAJANT
Redline Communications
Reliawave

Relm Wireless
RTI
Sentel RDR
Sentrus
Sierra Wireless
Strix Systems
Teledesign Systems Inc.
Wavesat Inc.
Wireless Interactive Communications Inc.