

# ONR BAA 06-007 System Requirements Specification

Version 1.1

**Mercury Data Systems**

10 April 2007

## *Abstract*

*This System Requirements Specification contains all system level requirements for the **ONR BAA 06-007 - Navigation in a GPS Denied Environment** phase I project activities. The contents of this document were derived from the original BAA content, FAQs, review of USMC field manuals and analysis of available commercial off the shelf products. This content will be utilized to design and construct the prototype systems that will be delivered as part of the Phase II effort.*

**Copy To:** John Taylor, Nathan Smith

**Created By:** Clayton Kane, Sid Winslow, Adam Abdelhamied, Stefan Goetz

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Owner Details	
<b>Name</b>	Clayton Kane
<b>Office/Region</b>	Greensboro NC
<b>Contact Number</b>	336.553.0689
<b>E-mail Address</b>	<a href="mailto:clayton.kane@mercdatasys.com">clayton.kane@mercdatasys.com</a>

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Document Approvals		
Name / Signature	Company / Role	Contact Info.
John Taylor /	Mercury Data Systems, CEO	336.294.2828 x103 jtaylor@mercdatasys.com
Sid Winslow /	Mercury Data Systems, Quality Assurance Mgr.	336.553.0688 swinslow@mercdatasys.com

## Confidentiality Statement

The information contained herein is approved for Public Release; distribution is considered Unlimited/Unclassified.

## Preface

The purpose of this document is to effectively communicate the system level requirements of the Navigation in a GPS Denied Environment (NAVGPSDE) system that is under analysis / development as part of the ONR BAA06-007 contract. The information within this document was generated by the Mercury Data Systems development team and is based on data found in the BAA solicitation / SOW, the MDS proposal to the solicitation and descriptions of the proposed solution analysis and design activities. The information within this document will be utilized in conjunction with the Concept of Operations Document to provide an overall functional picture of the proposed system. This document will be provided to the ONR project management resources and end user community to ensure the documented system requirements meet the needs of the users and to ensure that the development team fully understands the functionality of the targeted system. To that end this document will be continually updated throughout the life cycle of the project during Phase I Analysis and Phase II Design / Construction efforts to allow for changes in direction as new requirements or system limitations are identified. The content of this document is based on the end user view of the system, if any content is found to be inaccurate, misleading, erroneous or incomplete please notify the document owner as soon as possible. See the document control section for contact information.

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# 1 Introduction

## 1.1 System Purpose

The system to be developed under the initiative for the ONR BAA 06-007 will improve the way that ground forces track, locate and report their physical position to both their immediate neighbors and to higher headquarters in order to reduce fratricide. Furthermore, the system will improve ground force position location information in GPS denied / limited GPS environments.

## 1.2 System Scope

A position and location prototype system will be developed as a result of the requirements definition herein and the subsequent development phase. The positioning system will attempt to reduce the occurrence of fratricide during ground force operations by increasing the spatial awareness of personnel location across the battlefield.

## 1.3 Definitions, Acronyms, and Abbreviations

This section includes a bulleted list of all applicable definitions, acronyms and abbreviations utilized within the document.

- A-GPS – Assisted GPS
- AO – Area of Operation
- BAA – Broad Agency Announcement
- C2 – Command and Control
- CMR – Clique Member Radio
- DGPS – Differential GPS
- DOP – Dilution of Precision
- EGNOS – European Geostationary Navigation Overlay Service
- FBCB2 – Force Battle Command Brigade and Below
- FOM – Figure of Merit
- GPS – Global Positioning System
- GUI – Graphical User Interface
- HDOP – Horizontal Dilution of Precision
- HUD – Heads Up Display
- I<sup>2</sup>C – Inter-Integrated Circuit
- INS – Inertial Navigation System
- JTRS – Joint Tactical Radio System
- JVMF – Joint Variable Message Format
- LOS – Line of Sight
- LSE – Least Squared Error
- MANET – Mobile Ad-hoc Network
- MSAS – Multi-functional Satellite Augmentation System
- MSE – Minimum Squared Error
- NMEA-0183 – National Marine Electronics Association 0183 Interface Standard. Defines electrical signal requirements, data transmission protocol and time, and specific sentence formats for a 4800-baud serial data bus.
- ONR – Office of Naval Research
- PDOP – Position Dilution of Precision
- PPP – Point-to-Point Protocol
- PPS – Precise Positioning Service
- RF – Radio Frequency
- SAASM – Selective Availability Anti-Spoofing Module



- SEP – Spherical Error Probability
- SINCGARS – Single Channel Ground and Airborne Radio System
- SMS – Short Message Service
- SPI – Serial Peripheral Interface
- TDS – TOA-based Data Screening
- TOA – Time-of-Arrival Radio Frequency Ranging
- TOC – Tactical Operations Center
- TRPS – TOA-based Ranging Partner Selection
- TTFF – Time to First Fix
- TTL – Time-to-Live
- USB – Universal Serial Bus
- VDOP – Vertical Dilution of Precision
- VGA – Video Graphics Array. A standard for graphics displays, implying a resolution of 640x480 pixels, defined by IBM.
- WAAS – Wide Area Augmentation System

## 1.4 References

The following documents were utilized as references to generate content for this document:

- External System Interface Documentation/Specifications (Military/SINCGARS radio, JTRS, JVMF, FBCB2, etc.)
- IEEE Std 1233-1998 Guide for Developing System Requirements Specifications
- ONR BAA Announcement # BAA 06-007
- ONRP\_ConOps\_ONRBAA06-007.pdf, ONR BAA06-007 Concept of Operations Document, v 1.0, 3/12/2007, source – Mercury Data Systems, Inc.
- ONRP\_TechReport\_ONRBAA06-007.pdf, ONR BAA06-007 Final Technical Report, v 1.0, 3/12/2007, source Mercury Data Systems, Inc.
- Solicitation No. HDTRA1-05-R-0005 titled Global Positioning System - Denied Navigation and Mapping

## 1.5 System Overview

In the current battlefield environment, our ground forces are often deployed in environments where GPS is either partially or completely unavailable. An example of partial denial includes operations in urban terrain where buildings limit satellite visibility. Operations either underground or inside of buildings prevent all satellite visibility, as well as affecting general Radio Frequency (RF) propagation. Therefore, an accurate position and location system is required that will operate in these environments.

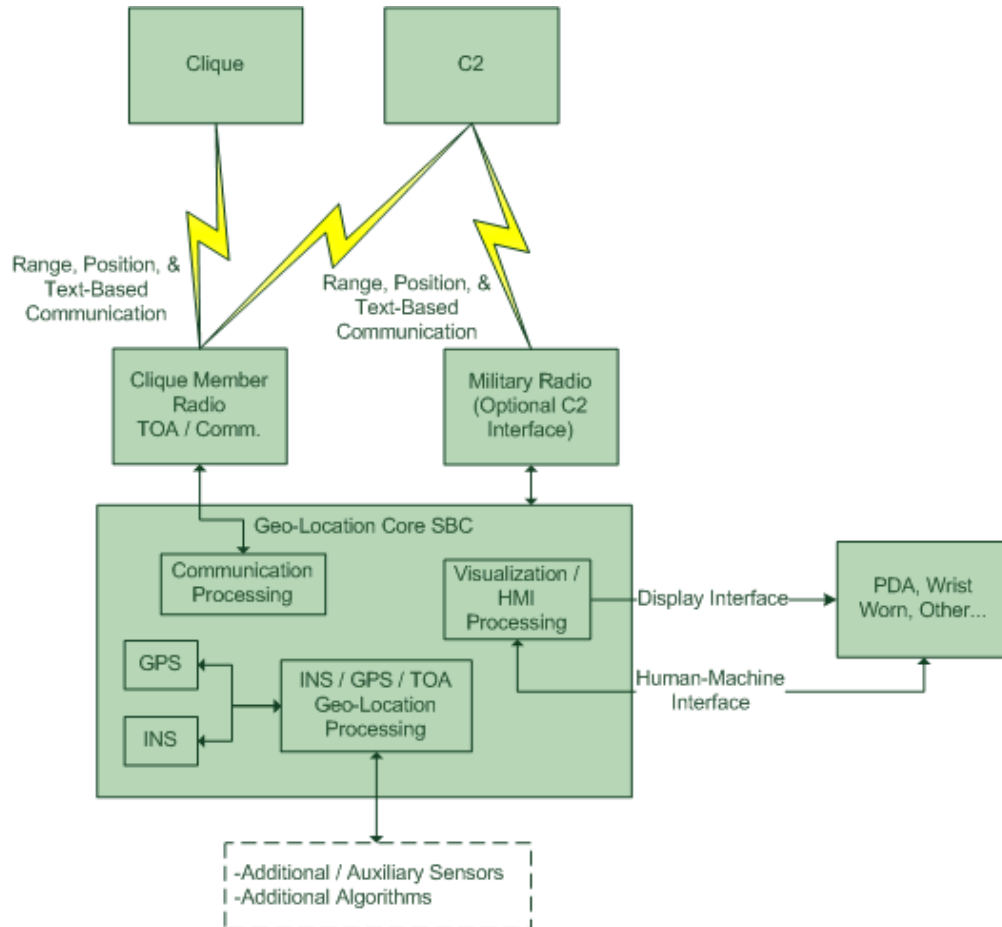
Nominally, each Marine will carry a lightweight device capable of reporting its own location, as well as reporting the location of the other members of its clique (where a clique is defined as a group of devices/Marines that are operating together). These devices shall cooperate with each other in order to provide a position estimate.

Often, knowledge of the relative positions of the other members of the clique is more important than their absolute position. An example of this would be the knowledge that a fire team is in position on the other side of a building prior to a forced entry. There shall be a method of determining one's own position and of associating devices into a clique. In order to permit higher headquarters to have knowledge of personnel location, at least one device shall have a standard military radio interface in order to transmit position/location data. Information presentation/display shall be minimal, preferably graphical and shall note when position location is degraded. A complete windowing environment is discouraged due to its unnecessary complexity for a fixed function device.

## 2 Description, Capabilities, Goals, Assumptions and Dependencies

### 2.1 System Description

A primary requirement of the position and location system to be developed under the ONR BAA 06-007 initiative will be to fuse position estimates from a variety of sources. The primary position sensors include Global Position System (GPS), Terrestrial Time-of-Arrival (TOA), and Inertial Navigation System (INS). Figure 1 depicts the significant interfaces that will be required across the system's boundaries. Items enclosed by dashed lines are considered additional/optional components that may improve/extend the core functionality of the system in the future.



**Figure 1:** Geo-location Core and Significant System Interfaces.

Minimally, each soldier will be equipped with a positioning system that is composed of a GPS component, an INS component, an RF Communication and TOA Ranging component, a GEO-Location Core Processing Unit, and a Display Interface. The GEO-Location Core shall provide I/O access to the various local position sensors and shall implement advanced fusion algorithms in order to produce an enhanced local position estimate based upon the data available from the various position sensors. The fused position estimate produced by the GEO-Location Core shall be viewable by each soldier on a simple graphical display. The fused position estimate shall also be encrypted with NSA Suite B compatible data security before it is eventually shared amongst clique members and the Command and Control (C2) center via the RF communication component. Furthermore, each individual's local positioning system shall receive the position estimates of other members in the clique as well as those from additional data sources (i.e. beacons and/or relays), decrypt the data, and if the received position information is determined to be reliable, fuse the data with the local position estimate to further enhance position accuracy at the individual and/or group level. Each individual in the clique, including C2, shall receive available position data of other clique members/data sources that will also be presented via each individual's graphical display unit, enabling shared situational awareness throughout the operating clique as well as at the command level. Finally, limited, text-based data transfer will be supported by each system in order to provide a Short Message Service within the clique.

## 2.2 System Modes and States

The personnel tracking system should operate in 3 navigation modes and provide a status indicator for the current mode to the user. The modes that shall be supported include:

- **GPS Enabled mode** – GPS signal strength and VDOP/HDOP are low enough to allow continuous personnel navigation and tracking by GPS
- **GPS Restricted mode** – GPS signal strength and/or VDOP/HDOP vary and do not allow continuous personnel navigation and tracking by GPS alone
- **GPS Denied mode** – GPS signal strength and/or VDOP/HDOP are too high to allow continuous personnel navigation and tracking by GPS at all

Status indicators should also be made available to the user relative to these navigation modes. They are the following:

- The state of the position sensors currently being used for navigation (GPS, INS, TOA, degraded/unreliable)
- The state of the network link (Connected, Degraded, Disconnected)

## 2.3 Major System Capabilities

The major system capabilities are organized by technical challenge areas (major/minor) based upon the perception of their relevance to the program and upon the level of effort that will be required for each area.

### 2.3.1 Accurate Personnel Tracking (Major Technical Challenge)

The accuracy of personnel tracking systems is often expressed as position error relative to distance traveled, i.e. 2% of distance traveled. The personnel tracking accuracy requirement for this project is 25m Spherical Error Probable (SEP). At first glance, this requirement appears to require only moderate performance, but when considered as a percentage of distance traveled, the desired accuracy translates into a very high performance requirement – 0.25% of distance traveled (25m SEP/10Km). An absolute positioning source, such as GPS, may only be available at mission initiation, so periodic synchronization with an absolute reference may not be possible. To achieve such high level of absolute accuracy, a multi-sensor positioning system initialized by an absolute source and aided by advanced sensor fusion algorithms, shall be designed and developed.

### **2.3.2 Collaborative Personnel Tracking (Major Technical Challenge)**

If GPS is denied at mission initiation, due to jamming or even mission location, the clique will establish, and operate under, an alternate referential coordinate system. If the starting coordinates for clique personnel are established via GPS; an independent referential coordinate system relative to the starting coordinates shall be established and maintained throughout the mission operation.

At all times, each clique member must be able to self localize their own position and to visualize the positions of all members of the clique. Over time, the accuracy of these self/remotely localized position estimates may deteriorate, which will result in divergences among the individual perspectives of the coordinate system. Even when self localized positions are maintained within the desired SEP, a very divergent group perspective of the coordinate system and the positions of clique members may evolve.

An overarching alternate coordinate system shall be maintained, across the clique, which can supersede the inevitable divergences among position estimates that will result as clique members navigate between the different types of environments. A consistent understanding of the relative positions of all clique personnel shall be established and distributed – both to effectively organize mission operations and to minimize divergences among individually localized position estimates.

To establish and maintain the alternate referential coordinate system, methods to implement a mobile ad hoc network that incorporates two-way TOA ranging techniques shall be designed. Additionally, a distributed voting algorithm process will be provided to maintain the integrity of the referential coordinate system; to reconcile divergences among clique position estimates; and to disseminate a converged clique position estimate.

The alternate coordinate system must be able to survive any single point of failure, which requires design and development of methods to support cross network data replication and automated failover support among focal nodes for the coordinate system.

### **2.3.3 Visualization (Minor Technical Challenge)**

The prototype positioning system shall include a lightweight, graphical user interface (GUI) – a complete windowing system is discouraged due to its unnecessary complexity for a fixed function device. At all times, each Marine must be able to visualize the relative positions of other clique personnel via the GUI – even if their individually localized position relative to a starting point has been lost. Each Marine shall also be able to visualize other clique personnel and locate the distance and orientation to each. As well, each Marine shall be able to visualize parameters for position estimate precision, network connectivity, and beacon locations. The ability to interact with Short Message Services (SMS) shall also be provided by this interface. Lastly, the boundaries between cliques may intersect and each Marine shall be able to visually identify members of other cliques as they approach, this ability will be provided as a future system enhancement.

### **2.3.4 Communications (Minor Technical Challenge)**

Mobile Ad-Hoc communications/network capabilities shall be designed and developed to support autonomous sharing of personnel positioning information. The Communications component shall include five additional capabilities:

#### **2.3.4.1 Locating Beacons**

The system nodes will be able to function as mobile/portable beacons to augment accurate positioning and to extend communication range for Non-Line-of-Sight (NLOS) environments. Simple methods to initialize and display beacon ID's and coordinates, as well as communicate and range with such beacons shall be developed.

#### **2.3.4.2 Data Transfer Security**

All cryptographic operations to secure both data at rest and in transit shall meet Suite B security requirements (see Section 3.3.1 for more info).

#### **2.3.4.3 Text Messaging / Short Message Service (SMS)**

Limited text-based messaging / Short Message Service (SMS) shall be supported between clique personnel, and clique groups.

#### **2.3.4.4 Assimilation**

During navigation, the boundaries between cliques may intersect; the positions of Marines within the intersecting areas must be recognized and disseminated across the intersecting cliques. Since the coordinate reference systems of the intersecting cliques may differ, the position estimates of the Marines within the intersecting area may also differ – perhaps, even to the point that the position estimates of physically separated Marines display that they are both at the same coordinates.

When cliques intersect, the Marines within the intersecting area must be assimilated within the coordinate reference system of the destination clique. The destination clique must also acknowledge the hierarchy and the identity of the Marine, and the Marine's relative position must be disseminated throughout the destination clique. If the Marine must be permanently assimilated, a process must be initiated to transform the coordinate reference system of the Marine to that of the destination clique.

To avoid friendly fire incidents during these intersections, autonomous and manual processes shall be developed to assimilate Marines within intersecting AO's.

**Note:** Clique Assimilation will not be addressed as part of the prototype system, but shall be incorporated into the system as an enhancement post completion of field trials prior to creation of the production hardware / software.

#### **2.3.4.5 Military Radio Interface**

The system must provide a standard military radio interface (mechanical, electrical, data).

#### **2.3.5 Ease of Use (Minor Technical Challenge)**

The prototype positioning system shall require minimal-to-no user training; hence, a human-machine interface that supports minimal user interaction shall be incorporated into the system design. The system initialization processes should be automated so that they execute and establish the user's position when the user turns the system on. The GUI and SMS service shall be easy to use and shall not distract the clique personnel from their mission duties. Lastly, automated processes shall facilitate geo-location of beacons based upon the user's coordinates and the TOA measurements between the user's system and the placement of the beacon.

### **2.4 Major System Goals**

It is not anticipated that the prototype system will meet all the major system goals of this project, nor is such a requirement. Meeting the personnel tracking capabilities through the development of an integrated system that achieves an unobtrusive form factor is the major objective and technical challenge of this program and the efforts towards these challenges shall take precedence over these goals. However, the goals should be targeted as closely as possible and are included to serve as guidelines during the design and development phase(s).

#### **2.4.1 GPS-denied Position Accuracy**

Position accuracy in a GPS-denied environment shall be 25m SEP (Spherical Error Probability) or better after eight hours of operation.

#### **2.4.2 Size, Weight and Power (SWAP)**

##### **2.4.2.1 Size**

Volume of each unit shall be 400 cm<sup>3</sup> (24.4 inches<sup>3</sup>) or less.

##### **2.4.2.2 Weight**

Unit mass shall be 1kg or less, not including battery.

##### **2.4.2.3 Power**

Each unit shall operate for 8 hours (or more) upon recharge from a single BA5590 battery (170 WH) capacity.

#### **2.4.3 Cost**

Projected production cost per unit in quantity of 1000 shall be \$2K or less.

#### **2.4.4 Prototype Delivery**

A minimum of five (5) positioning units are to be produced and delivered in Phase II. If beacons and/or relays are required to meet the system capabilities defined herein, a maximum of three (3) shall be produced and delivered in Phase II.

### **2.5 User Characteristics / Roles**

The system will require establishing distinct user types and roles. The roles are based on functional responsibilities for the system end user; there shall be no restricted access to the UI features based on role. The Logistics support resources shall utilize a wireless network connection to access/download the system data to support system pre-mission configuration; he will not require access to the UI unless he is testing the unit post maintenance or repair activities.

- **Logistics user** – this user will be a technical resource similar to the radio technician who will be responsible for establishing clique node identification, ranging partner tables, communications channels / partners for text messaging, selection and calibration of mission maps for the clique, setup for each system to be deployed with the dismounted resources. They will also provide pre-configuration and setup for the location beacons if used by the system and Assisted GPS data for the Area of Operation. This resource will have to be a part of the unit and will need to have access to all mission parameters / plans in order to accurately setup the system prior to team deployment.
- **Team Lead** – this user will be the lead resource associated with the various USMC unit levels. Fire Team Lead – Fire Team Level, Squad, Platoon, etc. These users will be primarily responsible for configuration / deployment of fixed position beacons if used, assimilation of new clique members and communication with the command center or next higher level team leader. This user will also make decisions on when/where to enable the remote system zeroize feature.
- **Soldier** – this user will be the basic system user, they will have access to all system features. When directed they will support the decisions of the team lead. All users will also have access to the map user options (map selection, measuring distance/angle, system zeroize local and remote, etc...)

## 2.6 Assumptions and Dependencies

### 2.6.1 General

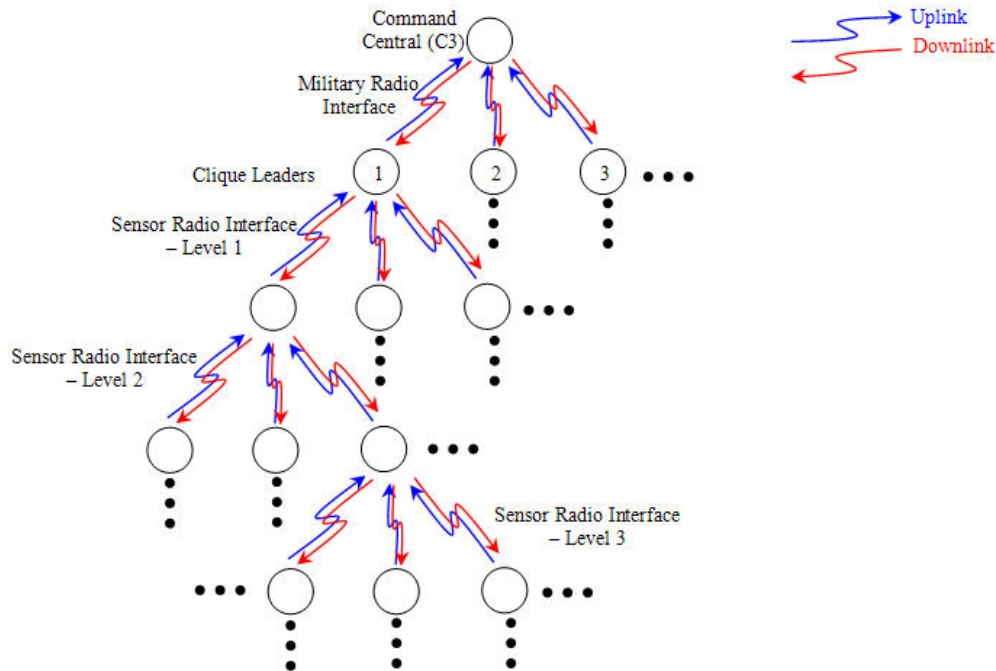
1. Assumed that one- or two-way transfer of textual information is used.
2. Assumed that an accuracy of 25m is desired (95% SEP).
3. Assumed that a simple 2D graphical display is sufficient.
4. Assumed that the communication links (for data transfer) between nodes incorporates the NSA Suite B security standard.
5. Assumed that the device will be employed and is required to operate in a wide variety of environments (see terrain list).
6. Assumed that we are not concerned with GPS-jamming.
7. The reduction of fratricide and the ability to maneuver in a coordinated fashion without explicit communications via sharing of accurate position data with all clique members is the main premise of the system.
8. Assumed that a military radio will be available to at least one member in the clique.
9. Assumed that access to the military radio is provided in case node/clique positions are to be transmitted to higher headquarters – the platoon leader will send data to higher headquarters.
10. Assumed that preference will be given to three dimensional (3D) positioning with fallback to a two dimensional (2D) position location.
11. Assumed that the maximum potential distance traveled by the intended user within the 8 hrs of operation is 10km radial area (10 km linear distance - straight line or random walk).
12. Uninterrupted operation, over duration of 8 hours without the need for preventive maintenance or system calibration, except at system startup, shall be supported by the system.

### 2.6.2 Initialization and Coordinate System Requirements

Initialization and maintenance of a referential coordinate system will require that:

1. The Marine Corp Units utilizing the system are following the “Rule of Three” structure (Figure 2).  
Assumptions
  - Three men to a fire team commanded by a Corporal (so there are actually a total of four on the team, when you count the team leader). Three fire teams to a rifle squad commanded by a sergeant. Three rifle squads to a platoon commanded by a Lt. Three rifle platoons to a company commanded by a Capt. Three companies to a battalion commanded by a Lt Col., etc.





**Figure 2: Network and Clique Structure**

- **Team (Fire Team):** Four individual Marines assigned to a specific team (Three team members, plus the team leader). 4
  - **Squad:** Three Teams are assigned to a specific squad. 13
  - **Platoon:** Three squads are usually assigned to a specific platoon. 40
  - **Company (or Battery):** Three platoons are assigned to a Company (sometimes called a battery). The Company/battery is the lowest level of command with a headquarters element (example, a Company Commander, or Company First Sergeant). 121
  - **Battalion:** Three companies/batteries are assigned to form a battery a battalion.
  - **Regiment:** Three battalions form a Regiment (Sometimes called a Brigade).
  - **Division:** Three Regiments (Brigades) are assigned to make up a Division.
  - **Marine Corps:** Three or more divisions make up the Marine Corps.
2. A minimum of 3 resources will be required to establish a 2D relative coordinate system.
  3. A minimum of 4 resources will be required to establish a 3D relative coordinate position.
  4. The maximum clique size will be 50 resources or a platoon.
  5. The recon or rifle platoons will plan a mission prior to committing resources to the field, the plans will include a starting position for each unit and the area of operation will be defined on a common map. Landmarks and waypoints will be defined and provided during mission planning, and these shall be used to enhance the system position accuracy.
  6. It is possible that no GPS signal will be available during system initialization and the system will have to be initialized using a relative coordinate system. The relative coordinate system will be maintained via fusion of position data from RF Multi-lateration and INS; the relative values will be utilized until an absolute coordinate reference can be used.
  7. If GPS is available and 4-12 satellites are viewable, the system can be initialized using the GPS position (known lat/long coordinate starting position). The absolute coordinate structure will be maintained via fusion of position data from GPS, INS and RF Multi-Lateration sources.



8. All systems within a given clique or operating environment utilize a common time mark or UTC time value. The systems will not need to be calibrated or synchronized in the field due to availability of network timing clocks and communication algorithms.
9. Logistics Processing Required prior to fielding the system:
  - Each system will have a unique ID, Mac Address, and/or IP Address that can be used to identify and communicate with that system.
  - Each node user will be assigned an ID when they arrive within the theatre of operations. This ID will also be utilized in the visualization component to identify a particular resource on the GUI map.
  - A table of “neighbors” or ranging partners will be setup via the logistics network interface / processes prior to deploying the system to the field. Maximum number of ranging partners will be 10, and minimum number will be 3 partners.

### **2.6.3 Relative Position Accuracy Assumptions**

In order to achieve/maintain the relative position accuracy requirement, it is assumed that:

1. At least three (3) members of the clique will operate within the RF position sensor's range.
2. Only legged motion (e.g. walking, running, climbing, etc.) is exercised when the system is relying on the INS / RF TOA Ranging fused position data for tracking (infers that GPS is unavailable/unreliable and RF Non-LOS conditions exist).

### **2.6.4 Absolute Position Accuracy Assumptions**

In order to achieve/maintain absolute position accuracy, it is assumed that:

1. GPS will be available at least during mission start/device initialization; or
2. A Landmark-based, calibrated map with position metadata will be available at least during mission start/device initialization.

## **3 Conditions and Constraints**

### **3.1 Environmental Conditions**

No environmental conditions have been explicitly expressed in the ONR BAA; hence, following conditions are not system requirements. However, the following list was taken from Solicitation No. HDTRA1-05-R-0005 entitled Global Positioning System - Denied Navigation and Mapping due to its relevance to the solution defined herein. These conditions should be targeted as closely as possible and are included here to serve as a guideline during the design and development of the system final form factor, for phase 1 they should be viewed as future system enhancements.

1. Operating Temperature Range = 0 to 120 degrees F.
2. Storage Temperature Range = -10 to 130 degrees F.
3. Waterproof and submersible to 3 feet for 10 minutes.
4. Operational reliability not less than (NLT) 95% following exposure to an 8 hour MIL-STD 810E Salt/Fog and Sand/Dust test or industry equivalent standard.
5. No parts breakage or system degradation following NLT 3 drops from different orientations in accordance with MIL-STD-33 1B Five Foot Drop Test or equivalent industry standard.
6. Operational reliability NLT 95% following exposure to a 30 minute MIL-STD 810E Loose Cargo Vibration Test or equivalent industry standard.

## 3.2 Constraints

The following constraints are based on statements found in the BAA, responses to BAA FAQs and physical constraints of the proposed system components:

- The system must operate over an 8 hour period with a single charge of a BA-5590 battery.
- The system must maintain a 25 meter Spherical Error Probability (SEP) over the 8 hour period and over a range of 10km.
- The entire clique will be operating within a 2km area over the 10km range.
- The entire system shall weigh 1kg (2.2 lb) or less, not including battery.
- The system size shall be 400 cm<sup>3</sup> (24.4 in<sup>3</sup>) or less, not including battery.
- If required no more than 3 relays can be utilized to support operation in underground or cave like environments.
- The system shall not have access to GPS during the 8 hour period.
- The system shall be worn on the users torso and remain in a fixed position (especially during system initialization and auto calibration) throughout the 8 hour operation period.

## 4 Functional / Performance Requirements

### 4.1 RF Communications and TOA GEO-Location

#### 4.1.1 Mobile Ad-Hoc Network (MANET)

##### (a) Transceiver architecture

- Transceivers must fulfill two functions – provide range/position of ranging partners and maintain network connectivity.
- Transceivers must perform the function of position references (beacons) and communications data relays (multi-hop network connectivity):
  - Transceivers used as references/data relays must be tamper and spoof proof.
  - Transceivers used as references/data relays must be expendable.
  - Transceivers used as references/data relays must support a data interface that allows simple/autonomous position (absolute/relative) initialization.
  - Transceivers used as beacons/references/data relays must support ranging functionality amongst clique personnel within 25 meters (100m cave-like environment potential worst-case / 3 relays allowed = approx. 25m).
- Transceivers must have capability of ranging over minimum 3 meter and maximum 2Km range.
- Transceivers must maintain network connectivity over 2Km range.

##### (b) Bandwidth requirements for network communications

- Mobile system nodes shall transmit three data types –
  - Range data – Data generated while ranging with closest references containing –
    - ID of ranging partner – including personnel and clique ID.
    - Range of ranging partner and range accuracy.
  - Position information –
    - ID of personnel including clique ID.
    - Position information generated by each position sensor – INS, TOA and GPS.
    - This information is transmitted to personnel at higher level.

- Other communication data including text messages.

**(c) Multi-hop localization requirements**

- Network must support multi-hop localization.
- Multi-hop localization must provide network connectivity for data sharing and text messaging.

#### **4.1.2 Data Exchange**

**(a) Position information format requirements**

- Position information must be displayed as Latitude/Longitude/Altitude.
- Position information format must stay consistent among all position sensors.

**(b) Data requirements**

- Position information data shall be stored in all local nodes memory, in a database table format.
- Database of *range* and associated accuracy with several ranging partners must be maintained.
- Database of *position* and associated accuracy must be maintained at every level of clique.
- Database must differentiate between members of own clique and other cliques.
- Position information format and transmit data packet size must not burden network during network updates.

#### **4.1.3 Time-of-Arrival (TOA)**

**(a) TOA algorithm performance requirements**

- TOA algorithms must be capable of ranging in open and underground and/or cave-like environments.
- Network connectivity must not interfere with ranging activity (and vice-versa).
- TOA range data accuracy errors must be small enough to allow the overall system to maintain or beat the required 25 m SEP accuracy.
- The TOA algorithms shall provide a minimum 3 range references to support 2D ranging/positioning.
- The TOA algorithms shall provide a minimum 4 range references to support 3D ranging/positioning.
- The TOA algorithms shall automatically select and provide 3-10 range references for each system request for range information.
- The TOA algorithms shall automatically identify / select ranging reference nodes based on a set of criteria which provides the most accurate / consistent ranges possible.
- The TOA algorithms shall automatically review and discard range data that does not meet the criteria required to support system position accuracy requirements.

**(b) TOA algorithm computational requirements**

- The TOA ranging algorithm and associated waveform must be able to resolve multi-path errors present in enclosed environments.
- Multi-path resolution must not be resource intensive –
  - Computations must not exceed sampling rate (sampling rate < 5 seconds) to ensure real time operation.

- Computations must not require additional processing resources outside of the RF signal processing component of the system.
- Multi-path resolution must not interfere with network connectivity.

**(c) TOA algorithm hardware design requirements**

- The TOA component hardware volume shall be small enough to allow the overall system to be 400 cm<sup>3</sup> or less.

#### **4.1.4 Multi-lateration**

**(a) Multi-lateration requirements**

- Multi-lateration processing is required to generate a position estimate when provided with TOA range data.
- For 2D ranging/positioning, the multi-lateration must use minimum of 3 references.
- For 3D ranging/positioning, multi-lateration must use 4 references.

**(b) Multi-lateration performance requirements**

- Multi-lateration algorithms must perform with at least threshold accuracy of 25m SEP or better.
- Multi-lateration algorithms must be capable of threshold accuracy in outdoor, indoor, underground/cave-like environments.

#### **4.1.5 Transmission Security**

- All RF data transmission must be encrypted; NSA Suite B compliance is required.

### **4.2 INS GEO-Location**

- The INS shall support all forms of legged motion (walking, running, climbing, etc.) in all directions (forward, backward, sideways, up/down, etc.) in a 3D GPS denied environment.
- The INS threshold tracking accuracy shall be 25 m SEP or better for use between the absolute position update intervals.
- The INS component shall provide 3D position information in Latitude, Longitude, Altitude (meters) at a minimum frequency of 1 Hz.
- The INS component shall include an RS232 data interface that provides position and system status data as well as supports 3D position updates from external position sensors.
- The INS component shall automatically initialize to the relative co-ordinates of (0, 0, 0) within 5 seconds after the appropriate power source is connected to the system and the system is switched on.
- The INS component hardware volume shall be small enough to allow the overall system to be 400 cm<sup>3</sup> or less.
- The placement of the INS component on the navigating personnel shall not inhibit the user from performing their operational / tactical responsibilities during mission activity.

### **4.3 Single Board Computer (SBC)**

- The SBC component shall automatically initialize (complete the OS boot-loading process and be ready for local position initialization) within 15 seconds after the appropriate power source is connected to the system and the system is switched on.
- The SBC component hardware volume shall be small enough to allow the overall system to be 400 cm<sup>3</sup> or less.

- The placement of the SBC component on the navigating personnel shall not inhibit the user from performing their operational / tactical responsibilities during mission activity.
- The SBC component shall support data interfaces to the GPS/INS (RS232), TOA/Communication (RS232/Ethernet) and Military Radio (Ethernet) components.
- The SBC component shall be able to capture data from the GPS, INS and TOA components in near real-time (data should be captured with in less than 1 second for each component).
- The SBC component shall support a standard data / video interface for host control / display.
- The SBC component shall provide processing capability that allows for the completion of the sensor data fusion in near real-time (fusion process must complete within 5 seconds).
- The SBC component shall support 8 hours of continuous on-board data logging/storage during mission activity.
- The SBC component shall produce system logs of the following mission data:
  - Local User's Position Data
  - Text Messages (sent/received)
  - System Errors / Alerts

#### 4.4 GPS

- The placement of the GPS Receiver component shall not inhibit users from performing their operational / tactical responsibilities during mission activity.
- In order to ensure tight package integration / small form factor, the GPS receiver shall be enclosed along with the other system components.
- The placement of the GPS Antenna component on navigating personnel shall not inhibit users from performing their operational / tactical responsibilities during mission activity while ensuring the highest possible reception of the GPS signal transmissions.
- The GPS shall support reception of the L1 frequency, C/A code (SPS), provide 12 independent tracking channels, and a separate search & acquisition engine.
- The GPS receiver shall provide support for WAAS, EGNOS, and MSAS.
- The GPS component shall provide A-GPS and D-GPS support.
- GPS component accuracy will be 3m CEP (50%) to 5m CEP (95%) at velocity of 0.1 m/s, and time of 20 ns RMS.
- The GPS shall be able to perform signal reacquisition at 100ms typical.
- The GPS Time to First Fix (TTFF) for an out of the box start shall be 40s typical; for a cold start shall be 35s; and for a hot start shall be 4.5s minimum.
- GPS sensitivity acquisition (cold) shall be at -141.5 dBm; acquisition (hot, warm) shall be -149 dBm; tracking (hot, warm) shall be -156 dBm; and navigation (hot, warm) shall be -155.5 dBm.
- The GPS hardware shall work on an operating voltage range of 2.7V - 3.3VDC.
- The GPS shall be able to operate at temperatures -40C to +85C.
- The GPS shall work with an external, passive or active antenna, with an input of LGA pad, 50ohm.
- The GPS power consumption rate shall be 95mW @ 2.7V (Continuous Mode), 15mW @ 2.7V (Idle Mode), and 20μW @ 2.7V (Sleep Mode).
- The GPS component shall provide a serial data interface (RS232) that supports the output of position information @ minimum 1 Hz to a host computer.
- The GPS data output format shall be in line with the NMEA-0183 protocol.
- The GPS shall have an onboard 16MB flash memory, minimum.

- The GPS unit dimensions shall be 22 x 23 x 2.9 mm or less including RF shield.
- The GPS unit mass shall be 3 g or less.

## 4.5 Fusion Algorithm

The position fusion algorithm is a critical component of the proposed solution. The fusion algorithm fuses position information received from different positioning systems – INS, Velocimeter, GPS, TOA, Pseudolites, LORAN, etc. positioning systems. Afore-mentioned positioning systems are composed of one or more sensors (see Figure 3) that have inherent inaccuracies over distance traveled, time or area of operation. The fusion algorithm must provide the best estimate of position in presence of these inaccuracies. The fusion algorithm is a statistical tool that reduces noise (inaccuracy) of the position information acquired from the position sensors and provides the best position estimate.

- The fusion algorithm shall utilize a Kalman Filter, which includes *system state estimation* and *Kalman gain estimation* processes.
- Mobility models of each position sensor must be generated and verified.
- Models will be expressed as either regression (uni/multi-variate) or as polynomials.
- Mobility model determines linearization process of mobility model of each position sensor.
  - Polynomials can be linearized by smoothing, or other forms of low pass filtering of process data.
  - Regression variates can be linearized by differentiation of the process data.
- Variables critical to position estimation other than position information such as velocity, acceleration, etc. must be identified, placed and updated in the system state matrix.
- Standard deviation ( $\sigma$ ) of position estimates must have an SEP of 25m or less.
- Round off errors during computation of Kalman filter gain must be reduced by matrix factorization.
- Use of Reset/Reinitialize feedback loop design parameters must be defined
  - Time of operation –
    - INS systems drift with time and will be reset with the fused position (Reset/Reinitialize Loop)
    - The time of reset will be obtained after testing of the INS systems
  - RF range/position estimate data shall include an accuracy estimate. If accuracy does not conform to the SEP requirements, fusion algorithm will reset the TOA ranging component using available fused position.

## 4.6 Mobility Estimation

### 4.6.1 Mobility Estimation Requirements – INS GEO-Location

- Mobility model must represent position information with the least error (minimum squared error (MSE) or least squared error (LSE)).
- Mobility model must model process noise and measurement noise.

### 4.6.2 Mobility Estimation Requirements – TOA GEO-Location

- To calculate a 2D position estimate the RF Positioning system requires a minimum of 3 reference nodes.
- To calculate a 3D position estimate the RF Positioning system requires a minimum of 4 reference nodes.
- The Mobility model must represent position information with least error (minimum squared error (MSE) or least squared error (LSE)).



- Mobility model must model process noise and measurement noise.
- Modeling of the RF Positioning variables will be required in order to provide the most accurate position calculation processing.

## 4.7 Referential Coordinate System

- Initialization process must be autonomous requiring minimal human intervention.
- Initialization must commence on power on.
- Preference must be given to GPS/global coordinate system.
- If neither coordinates are available then setting up local coordinate system must commence.
- Local coordinate system origin must be the highest ranked personnel in ranging distance.
- Minimum 3 personnel required for 2D positioning, 4 personnel for 3D positioning.
- Neighbor table must be initiated while forming the local coordinate system.
- Coordinate system transformations must be recorded in coordinate transformation table.
- Upon arriving in ranging distance of higher ranked personnel, local coordinate system must be transformed to higher ranked personnel's coordinate system.
- Coordinate transformation must be made backward compatible – i.e. position information in the older coordinate system must be transformed to newer coordinate system to permit personnel to track back to original path if necessary.
- As a future enhancement the system shall be capable of identifying clique members from visitors.
- The assimilation process shall have a manual interface to allow verification of the assimilation task prior to adding a visitor to the local system neighbor table.

## 4.8 Visualization

### 4.8.1 *Auto-calibration / System initialization Status Display requirements*

During the auto-calibration / system initialization process the status bar indicator and text fields will be utilized to indicate current system status. The indicator area / field will be red during Start-up, Initialization, or Coordinate System Initialization. Text values will be displayed in the status text field. The status indicator field will turn green after the coordinate system initialization process has completed, the status text field will provide details on the status of the system including – INS only, INS/TOA, TOA Only or GPS.

### 4.8.2 *Network Health display requirements*

The Network Connectivity field in the Status Bar will be utilized to display the RF IP Based Tactical Internet Link network connectivity based on data provided by the CMR.

### 4.8.3 *Position Accuracy display requirements*

The Accuracy indicator / Figure of Merit (FOM) field will be used to display position accuracy. The Spherical Error Probability (SEP) shall be used to populate this field. The displayed value will be in meters and will correspond to the calculated value from the position fusion process.

### 4.8.4 *Pre-mission configuration requirements*

A list of clique members who will support each mission shall be identified and their node information shall be added to the system configuration file and installed into the system nodes by the logistics user. The configuration file data will be utilized to populate the neighbor table. The

neighbor table shall be utilized by the system to identify ranging partners for each node within the clique, identify group hierarchy for each node within the clique and role of node (end user or beacon). The data will be entered into a comma delimited text files and the data will be downloaded into the node memory location. The configuration files will be specific to each mission plan and shall include a list of clique members, their assigned node ID, pre-canned text message content, a list of map files, clique structure and A-GPS data. This configuration file will then be loaded into each system node where the data will be added to the local copy of the neighbor table. The following fields will be available for population:

- SID
- UID
- Resource Type
- Text Messages (canned)
- Maps (location)

The remainder of the data in the memory location will be loaded into the UI via the system startup/initialization, local coordinate initialization and position fusion processes. Please review the appropriate area of this document for further details on those processes.

#### **4.8.5 Minimum / Optimal Visualization Requirements**

- The user interface shall include an auto-calibration / system initialization status in the status bar section of the display.
- The user interface shall include a network connectivity status in the status bar section of the display.
- The user interface shall include a position accuracy value in the status bar section of the display.
- The user interface shall provide a page to support the text messaging feature.
- The user interface main page shall be the map display screen and shall provide a means to change the map displayed on the screen.
- The user interface shall provide a means to manually set user position by selection of a point on the map displayed on the main UI screen.

The list below indicates features or functions that are not necessary for the basic functionality of the system but will be targeted as system enhancements to improve the user's capabilities or provide additional functionality beyond that originally requested by the ONR project definition. These items will be targeted for inclusion in Phase 2 deliverables based on feedback from the user community and time available for development of the associated functionality.

- The user interface End User Task bar features, shall include the following features as a future system enhancement; Measure Distance, and Bearing To functions.
- The user interface shall be upgraded in the future to provide a Logistic / Configuration user interface enhancement. For phase 2 prototype the project the configuration file can be produced and loaded manually.

### **4.9 Ease of Use**

#### **4.9.1 Auto – calibration / System initialization requirements**

The TrakPoint application / system software will be updated to include an auto-calibration and system initialization procedure. The procedure will allow the system end user to just power-on the system node and the system will visually display when it is ready for resource tracking / end user navigation. Previously the system would require user interface with data entry prior to the system



being ready for navigation. Specific system requirements for the auto-calibration / system initialization procedures can be found in the Initialize and Maintain a Referential Coordinate system section of this document.

#### **4.9.2 *Clique/Group auto assignment process requirements***

As part of the pre-deployment mission configuration file setup, the hierarchy of each clique shall be defined and entered in to the local version of the neighbor table in every node that will be deployed with a dismounted rifleman. This table shall automatically allow the individual system nodes to identify the other nodes within their range that are a part of their clique or group. See the Visualization section of this document for more details on the neighbor table, configuration file and clique assignment processes. For the process requirements associated with the transition from one clique to another see the Clique Assimilation section of this document.

#### **4.9.3 *Startup requirements for identifying relative remote user positioning***

See the Referential Coordinate System section of this document for a description of the processes and related requirements for identification of relative remote user positioning. This section will provide details on how each user node position is identified and how that data is shared with the other members of the clique or remote users. Post identification of each node's (user's) position, the data shall be stored in a neighbor table which shall be stored locally on each node and shared with other nodes within range. This information shall be updated as new information is received from other resources. The local neighbor table data shall be used to display the position of all nodes / resources on the local Map UI. All position data shall be forwarded to C2 for a Situational Awareness display that can be utilized by supervisory resources.

### **4.10 Communications Processes**

#### **4.10.1 *Multi-hop Localization***

The communication system shall support shared position awareness of all clique personnel by "hopping" through intermediary/relay nodes, when direct communication links are unavailable and Non-LOS conditions exist.

#### **4.10.2 *Locating Beacons***

##### **(a) Deployment Requirements**

- The system nodes shall provide a dual role; they shall support the mobile users and shall provide a hardware component that can be utilized as a stationary beacon.
- The Beacon configuration shall be supported by the use of the set position UI feature. See the Visualization section of this document for details on the UI features.
- When in the beacon mode the system nodes must meet all network functionality requirements including data connectivity and TOA ranging.
- The system nodes hardware configuration will be the same whether used as a mobile tracking device or as a system location beacon, on/off switch, zeroize button, external connections, etc...
- The system nodes shall support standard operations including auto-initialize (OS, communication / ranging processes) within 1 minute of being turned on, when functioning in the beacon mode.
- The system nodes while in beacon mode shall automatically join the communication network and assimilate into the local coordinate system (show up accurately on the clique members' map) of the clique to which it has been assigned.

**(b) Spoof-Proofing Requirements**

The beacon operating mode shall provide a method to ensure authenticity / data and position validity during mission operation.

**(c) Position Reference / Initialization**

After power is supplied to the beacons, they shall automatically establish communication with the clique and assimilate into the local coordinate system. In addition to the ad-hoc method of initialization, a logistics resource shall be able to establish the initialization parameters via the system pre-mission configuration process by editing the configuration file on a local command and control computer and transferring it via a USB memory device or wireless network to the system node. The configuration file shall specify that the device is to initialize based upon the provided values rather than by the default auto-initialization process. An additional method shall be available wherein any clique member can initialize the beacon manually in the field. After placing the beacon in the desired location, turning it on, and establishing communications, the clique member shall be able to mark the beacon location via the set position UI feature.

### **4.10.3 Text Messaging**

**(a) Interface Requirements**

- The UI component shall provide a messaging interface that allows the clique personnel to send short text-based pre-canned messages to other clique members through the MANET.
- At minimum, text messages shall consist of the following fields:
  - Sender ID
  - Sender Name
  - Send Time
  - Message Data
- Maximum Data packet size shall be 1500 bytes.
- A log of sent and received messages shall be stored on each personnel member's local computer unit; the log shall be accessible for review by clique personnel through the UI
- The UI shall provide a means for the message recipient to acknowledge the message.
- At minimum, the log shall consist of the following fields:
  - Sender ID
  - Sender Name
  - Send Time
  - Received Time
  - Message Data

**(b) Canned Message Requirements**

- The pre-mission configuration file shall support a method of defining, editing and downloading predefined messages to all system nodes prior to deployment in order to save data entry time for common communication tasks.

### **4.10.4 Clique Assimilation**

Blue force tracking capability is necessary to prevent fratricide. To provide blue force tracking, systems must be capable of tracking members within the clique as well as members from other cliques. In extreme cases where a member of another clique is lost or out of range of his own clique after deployment, another clique shall possess the capability to assimilate the lost personnel.

A technique to ensure that this process of assimilating new members into the clique remains spoof-proof shall be devised. The assimilation technique shall ensure that only valid members of other cliques are assimilated by using a form of key exchange. Since all personnel will be equipped with encrypted communications channels, personnel may be equipped with special keys for clique assimilation. The clique member who is not associated with a given clique shall automatically exchange these special keys when within range of the target wireless network island. The key exchange shall alert clique members of presence of member of another clique in the vicinity. When key exchange is completed successfully, the non aligned resource shall be assimilated into the clique.

#### **4.10.5 Military Radio**

The primary purpose of the military radio component is to provide clique position information and mission status updates to a TOC over a long-haul wireless connection. Currently, one military radio is deployed per platoon/clique (40 men) and is normally utilized by the platoon leader. All position information applicable to the platoon/clique shall be funneled through this link in order to be visualized, analyzed, and reviewed at the TOC / C2 level.

A table that reflects the platoon's operational status and situational awareness shall be maintained by the system nodes and platoon leader hardware. Periodic updates to this table (at least 1 update every 5 minutes) shall be received from the squad and fire-team levels, when connectivity is available. Whenever an update has been made to the table that results in an overall change of the table state, an exchange process shall be initiated and executed between the platoon leader's system (via the military radio connection) to the TOC / C2.

The connection to the military radio component is either Ethernet or Serial. For additional information, please refer to "WSRT Quick Reference Guide 6-9-06.pdf" and the MDS-SR Interface Control Documentation for the mechanical, electrical, and data interface requirements for the Military Radio component.

### **4.11 Performance and Cost Requirements**

#### **4.11.1 Requirements for evaluation of cost vs. performance based on system configuration**

Based on the system requirements, data will need to be captured to enable evaluation of cost verses performance.

When multiple components or processes are identified the engineers will need to capture technical requirements and cost information from the component vendor to determine which product will best suit the needs of the project. The information captured during these efforts will be utilized to develop the Cost verses Performance matrix.

To ensure the data is meaningful the difference between component or procedures will have to be classified, the difference may be cost, performance, speed, capacity, volume, processing power, time required to develop / implement, etc. See the next section for data that should be gathered for generation of a Cost verses Performance Matrix.

#### **4.11.2 Requirements for a Cost vs. Performance Matrix**

The following data shall be collected to populate the Cost verses Performance Matrix. External data including component technical specification sheets and back up documentation should also be captured to ensure there is enough material to evaluate the best solution for the cost. See the spreadsheet named "Cost2Performance.xls"; this document template will be utilized to generate the matrix.

- **Item #** – this field is the item number from 1 to  $\infty$ , this is just a place holder for tracking a given item.

- **System Feature / Component** – this field should be used to identify the system feature or component that is impacted by the item(s) that will be described on this line. Allows the reader to determine priority for implementation.
- **Description of Item** – provide a brief description of the hardware / software component, process, procedure or algorithm. If this is a COTS item the manufacturer and part number should also be provided.
- **Item Cost** – the cost of the item for a single item and for volumes of 100, 500, and 1000. If this is a process, procedure or algorithm that must be created / constructed internally this should be a cost estimate based on limited requirements / design definition. The cost estimate approach used, calculations along with high level design definition should be included in the associated documentation.
- **Performance Category** – this field should be a drop down list of values like, cost, performance, speed, capacity, volume, processing power, time required to develop / implement, etc... The complete list will be developed as data is collected.
- **Explanation of Performance Improvement** – provide a brief description of how the component can improve the performance of the system and why you feel this is a valid improvement, tech specs, prior exposure or utilization of the item, etc...
- **Notes** – provide any additional notes that can be beneficial in determining implementation priority.
- **Location of Associated Documentation** – provide a full UNC defined path to the location of any supporting documentation along with a name of the document.

#### 4.11.3 Minimum/Optimal Performance and Cost Requirements

The minimal Performance vs. Cost requirements will be the generated and shall be accompanied by delivery of the cost to performance matrix at the end of phase 2. The delivery of the matrix will be followed by a review and recommendation of next steps with the ONR program management team and system end users. The matrix shall identify opportunities for improvements in system functionality, based on cost, to target future system enhancements. These items shall be prioritized for inclusion in future releases of the production units as a means to provide continual improvement of product functionality.

### 4.12 System Security

#### 4.12.1 Communication Security

All cryptographic operations to secure both data at rest and in transit shall meet all Suite B security requirements.

Elements of SUITE B include –

- Encryption: Advanced Encryption Standard (AES) - FIPS 197 (with keys sizes of 128 and 256 bits) – <http://csrc.nist.gov/publications/fips/fips197/fips-197.pdf>,
- Digital Signature: Elliptic Curve Digital Signature Algorithm - FIPS 186-2 (using the curves with 256 and 384-bit prime moduli) – <http://csrc.nist.gov/publications/fips/fips186-2/fips186-2-change1.pdf>,
- Key Exchange: Elliptic Curve Diffie-Hellman or Elliptic Curve MQV Draft NIST Special Publication 800-56 (using the curves with 256 and 384-bit prime moduli) – <http://csrc.nist.gov/CryptoToolkit/kms/keyexchange-Jan03.pdf>,
- Hashing: Secure Hash Algorithm - FIPS 180-2 (using SHA-256 and SHA-384) – <http://csrc.nist.gov/publications/fips/fips180-2/fips180-2withchangenotice.pdf>.

For more information on Suite B: [http://www.nsa.gov/ia/industry/crypto\\_suite\\_b.cfm?MenuID=10.2.7](http://www.nsa.gov/ia/industry/crypto_suite_b.cfm?MenuID=10.2.7).

#### **4.12.2 Physical Security**

The physical enclosure for each system component shall implement measures that deter immediate access to, tampering with, or destruction of internal hardware components by unauthorized personnel.

#### **4.12.3 Data Access / Storage Security**

A zeroize function shall be available to erase all volatile and non-volatile data for each system component in order to disable / prevent unauthorized access to confidential mission information. As a future enhancement a user verification procedure shall be employed at system start-up in order to ensure access to authorized personnel.

### **4.13 Information Management**

#### **4.13.1 Mission Data**

The following data shall be stored on each user's system in a secure directory (encryption may be necessary) in order to accurately initialize for a mission as well as to reproduce and replay a mission in its entirety:

- Scenario File
- Position Log
- Message Log
- Error Log
- Map(s)
- AGPS Data File

## **5 Interface Requirements**

This clause contains the specification of requirements for interfaces among different components. Any interdependencies or constraints associated with the interfaces are identified (e.g., communication protocols, special devices, standards, fixed formats). Each interface may represent a bidirectional flow of information. A graphic representation of the interfaces is used (Figure 3).

### **5.1 IMU-GPS/INS Interface**

The IMU and INS mechanical and electrical interface will be SPI compliant.

#### **5.1.1 IMU Input**

The IMU component shall provide the GPS/INS fusion pre-processor with the following data, at minimum:

- Raw Magnetometer Data
  - X-axis component
  - Y-axis component
  - Z-axis component
- Raw Accelerometer Data
  - X-axis component
  - Y-axis component
  - Z-axis component
- Raw Angular Rate Data
  - X-axis component
  - Y-axis component

- Z-axis component
- Temperature of the interior of the IMU (if an IMU enclosure is used)

## 5.2 Barometer-GPS/INS Interface

The Pressure sensor and GPS/INS mechanical and electrical interface will be SPI compliant.

### 5.2.1 Barometer Input

The Barometer component shall provide the GPS/INS fusion pre-processor with the following data, at minimum:

- Pressure
- Temperature

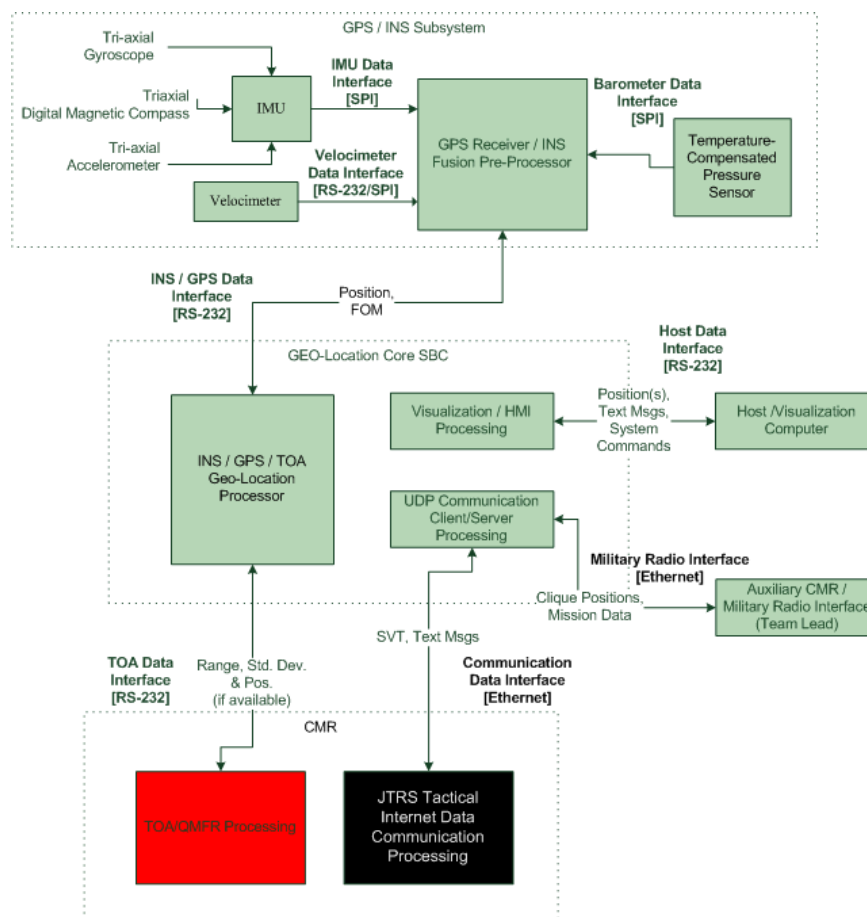
## 5.3 Velocimeter-GPS/INS Interface

The Velocimeter and INS mechanical and electrical interface will be SPI or RS232 compliant.

### 5.3.1 Velocimeter Input

The Velocimeter shall provide the GPS/INS fusion pre-processor with the following data, at minimum:

- Velocity



**Figure 3: System Interfaces.**

## 5.4 GPS/INS-SBC Interface

The GPS and SBC mechanical and electrical interface will be RS232 compliant. The NMEA-0183 data interface standard will be followed. Proprietary message formats that meet the NMEA-0183 standard are acceptable.

### 5.4.1 GPS/INS Input

The GPS/INS component shall provide the SBC with the following RMC, GGA, GSA, and GSV sentence data, at minimum:

- UTC Fix Time
- Position Information
  - Latitude
  - Longitude
  - HDOP/VDOP/PDOP
  - Altitude (meters above sea level)
  - Height of geoid (mean sea level) above WGS-84 ellipsoid
- Speed over ground (m/s)
- Magnetic Variation
- Satellite Information
  - Number of satellites in view
  - Satellite PRN number
  - Elevation (degrees)
  - Azimuth (degrees)
  - Signal strength
  - Fix Quality (0 – Invalid, 1 – GPS Fix, 2 – DGPS Fix)
- System related status / error messages
- System parameter configurability (baud rate, etc.)

### 5.4.2 GPS/INS Output

The GPS/INS component shall accept the following data from the SBC, at minimum:

- Position Update / Override Information
  - Latitude
  - Longitude
  - HDOP/VDOP/PDOP
  - Altitude (meters above sea level)

## 5.5 TOA-SBC Interface

The TOA and SBC mechanical and electrical interface will be RS232 compliant. The message structure and their protocols follow ICD-GPS-150. Refer to “ICD\_v7 4\_modified for MDS\_SR.doc” for additional information.

### 5.5.1 TOA Input

The TOA component shall provide the SBC with the following data, at minimum:

- TOA Ranging Data (Ranging Partner Specific)
  - ID



- Range
- Figure of Merit (FOM)
- Position Information (WGS-84)
- Time Tag
- PVT Time
- TOA Time Reference

### 5.5.2 TOA Output

The TOA component shall accept the following data from the SBC, at minimum:

- System Status
  - Status of GPS and INS
  - Navigation FOM
- Navigation Solution and Guidance Data
  - Position Information (WGS-84)
    - Latitude
    - Longitude
    - Altitude
  - ENU Velocity (Velocity in East, North, and Up coordinates)
  - Position and Velocity Variances
  - PVT Time

## 5.6 Communication-SBC Interface

The Communication and SBC mechanical and electrical interface will be either Ethernet or RS232 compliant. The radio shall support Ethernet or PPP interface for data. Using a serial connection shall require configuration of the SBC for Point-to-Point Protocol (PPP). For additional information, please refer to “WSRT Quick Reference Guide 6-9-06.pdf”. The following data will be shared over this interface:

- Clique-wide SVT updates
- Clique Text Messages
- Mission Data

## 5.7 Military Radio/Auxiliary CMR-SBC Interface

The Military Radio/Auxiliary CMR and SBC mechanical and electrical and data interface will be Ethernet compliant. The following data will be shared over this interface:

- Clique and C2 Text Messages
- Clique Positions to C2
- Mission Data to/from C2



## 6 Appendices

### 6.1 References

- [1] Capkun, Hamdi, Hubaux, “GPS-free positioning in mobile ad-hoc networks”, 34<sup>th</sup> *Hawaii International Conference on Systems and Sciences*, Jan 2001, HICSS-34.
- [2] Z. R. Zaidi, B. L. Mark, “A Distributed Kalman Filter-based Mobility Tracking Scheme for Ad-hoc Networks”, Unpublished.
- [3] D. Niculescu, B. Nath, “Localized Positioning in Ad Hoc Networks”, *Proceedings of IEEE INFOCOM 2003*, pp. 1734–1743, March 2003.
- [4] J. Buetel, “Design and Deployment of Wireless Networked Embedded Systems”, Master’s Thesis.

## 6.2 Verification Requirements

The table below provides the verification objectives that will be utilized to verify the requirements within this document. These objectives will be used as a basis for development of unit, integration, system and acceptance test cases that will be executed during the product test cycles. Content may be added or removed based on changes to the requirements, design and/or testing activities. Where differences exist between the content below and the content of the Test Plans, Designs, and Cases (all phase 2 deliverables), the test documentation will take precedence. The requirements coverage matrix will ensure that all system requirements / functionality have test coverage. The Requirement ID is associated with hidden text tags within the body of the document that are present at the beginning of each associated requirement statement.

**Table 1 - Verification Objectives Table**

Requirement ID	Verification Requirement
SyRS1	Verify that the system mobile nodes include a GPS component, an INS component, an RF Communication and TOA Ranging component, a GEO-Location Core Processing Unit, and a Display Interface.
SyRS2	Verify that the position estimation system GEO-Location Core provides I/O access to the various local position sensors and shall implement advanced fusion algorithms in order to produce an enhanced local position estimate based upon the data available from the various position sensors.
SyRS3	Verify that the mobile system node fused position estimate is viewable by all mobile users via a simple graphical display.
SyRS4	Verify that position data is encrypted with NSA Suite B compatible data security before it is transmitted to the clique network or C2.
SyRS5	Verify that the system mobile nodes can receive position data from members on the clique network or from beacons.
SyRS5	Verify upon receipt of position data the system nodes will decrypt the data, determine data reliability, and fuse reliable data with the local position estimate to improve local position accuracy.
SyRS6	Verify that system nodes can transmit/share position data between clique resources and C2.
SyRS6	Verify that all user position data is present on the system display unit.
SyRS7	Verify that text-based data transfer is provided by the mobile system nodes to provide Short Message Service within the clique.
SyRS8	Verify that the mobile tracking system nodes provide an indication of current mode of operation in the visual display.
SyRS8a	Verify that the system nodes can operate providing accurate position estimates when in GPS Enabled mode and that the proper mode is displayed on the UI.
SyRS8b	Verify that the system nodes can operate providing accurate position estimates when in GPS Restricted mode and that the proper mode is displayed on the UI.
SyRS8c	Verify that the system nodes can operate providing accurate position estimates when in GPS Denied mode and that the proper mode is displayed on the UI.
SyRS9	Verify that the system UI provides sensor and network status.
SyRS9a	Verify that the system UI displays the appropriate position sensors status when the following sensors are in use for providing position estimates: GPS, INS, TOA, and degraded/unreliable.
SyRS9b	Verify that the system UI displays state of the network link and provides accurate status when the network is: Connected, Degraded, or Disconnected
SyRS10	Verify that personnel tracking system nodes can maintain a position accuracy of 25m SEP over 8 hours an a distance of 10Km.
SyRS11	Verify that the system nodes utilize a multi-sensor positioning system which is initialized by an absolute source and aided by advanced sensor fusion algorithms.
SyRS12	Verify that when GPS is denied to the system nodes at mission initiation, the system will

Requirement ID	Verification Requirement
	establish an alternate referential coordinate system for use in clique position tracking.
SyRS13	Verify when the system node starting coordinates are established via GPS; that an independent referential coordinate system relative to the starting coordinates shall be established and maintained throughout the mission operation.
SyRS14	Verify that throughout the 8 hour mission period every clique member is able to self localize their own position and to visualize the positions of all team members.
SyRS15	Verify that the system nodes can maintain an alternate coordinate system that can supersede divergences among position estimates.
SyRS16	Verify that the system can establish and distribute relative positions of all clique personnel that minimizes divergences among individually localized position estimates.
SyRS17	Verify that the system utilizes two-way TOA ranging techniques to establish / maintain the alternate referential coordinate system and provide a mobile ad hoc network.
SyRS18	Verify that the system incorporates the use of a distributed voting algorithm process to maintain the integrity of the referential coordinate system; to reconcile divergences among clique position estimates; and to disseminate a converged clique position estimate.
SyRS19	Verify that post creation of the alternate coordinate system the tracking device are able to survive any single point of failure, including support for cross network data replication and automated failover support among focal nodes.
SyRS20	Verify that the system nodes include a lightweight, easy to use graphical user interface.
SyRS21	Verify that the system nodes provide every system user a UI that provides visualization of the relative positions of other clique personnel even if their individually localized position relative to a starting point has been lost.
SyRS22	Verify that the system nodes provide every system user the ability to visualize other clique personnel and locate the distance and orientation to each.
SyRS23	Verify that the system nodes provide every system user has the ability to visualize parameters for position estimate precision, network connectivity, and beacon locations.
SyRS24	Verify that the system node UI provides every system user the ability to interact with Short Message Service.
SyRS25	Verify that the system node UI enables the system user to visually identify members of other cliques as they approach and are within range of the local mobile adhoc network.
SyRS26	Verify that system provides mobile adhoc network capabilities that support autonomous sharing of personnel positioning information.
SyRS27	Verify that system nodes can be utilized as beacons to augment accurate positioning and to extend communication range for NLOS conditions.
SyRS28	Verify that the system provides a simple method to initialize nodes operating as beacons / display beacon ID / coordinates; and that these nodes can be used to support RF TOA ranging.
SyRS29	Verify that the system nodes incorporate cryptographic logic which provides security for data at rest and in transit while meeting Suite B security requirements.
SyRS30	Verify that the system nodes support limited text-based messaging / Short Message Service between clique personnel, and clique groups.
SyRS31	Verify that the system provides a method to identify / share user position data when the boundaries between cliques intersect and that the positions of Marines within the intersecting area, from both cliques, are displayed to all system users within range.
SyRS32	Verify that the system provides a means to assimilate Marines within the intersecting clique area into the coordinate reference system of the destination clique.
SyRS33	Verify that system provides a means for the destination clique to acknowledge the hierarchy / identity of the Marine, and the Marine's relative position is disseminated throughout the destination clique.
SyRS34	Verify that the system provides a method to permanently assimilate the Marine into the destination clique.

Requirement ID	Verification Requirement
SyRS35	Verify that when clique intersection incidents occur the system provides a means to avoid friendly fire by making the position data distribution and assimilation processes simple to implement.
SyRS36	Verify that the system provides a functional standard military radio interface.
SyRS37	Verify that the prototype system nodes require minimal-to-no user training and that the system UI requires minimal user interaction for operation.
SyRS38	Verify that the system initialization processes is automated, executing to establish the user's position when the node is powered on.
SyRS39	Verify that system node GUI features are easy to use and that they do not distract the mobile user from their mission duties.
SyRS40	Verify that the automated processes facilitate geo-location of beacons based upon the user's coordinates and the TOA measurements between the user's system and the placement of the beacon.
SyRS41	Verify that system node position accuracy in a GPS-denied environments is be 25m SEP or better after eight hours of operation.
SyRS42	Verify that the system node volume is 400 cm <sup>3</sup> (24.4 inches <sup>3</sup> ) or less.
SyRS43	Verify that the system node components total mass is 1kg or less, not including battery.
SyRS44	Verify that the system nodes operate for 8 hours (or more) upon recharge from a single BA5590 battery (170 WH) capacity.
SyRS45	Verify that the individual system node estimated production cost in quantity of 1000 is \$2000 USD or less.
SyRS46	Verify that MDS produces and delivers a minimum of five (5) positioning system nodes at the end of Phase II.
SyRS47	Verify that if the system utilizes relays to meet the system capabilities a maximum of three (3) additional nodes will be produced and delivered at the end of Phase II.
SyRS48	Verify that system user roles are based on functional responsibilities for the system end user and that there is no restricted access to the UI features based on role.
SyRS49	Verify that the Logistics support resources can utilize a wireless network connection to access/download the system data to support system pre-mission configuration, ensure the logistics user does not require access to the UI unless he is testing the unit post maintenance or repair activities.
SyRS50	Verify that the Logistics user can establish clique node identification, create data for ranging partner tables, communications channels / partners for text messaging, select mission maps for the clique, and setup each system node prior to node mission deployment.
SyRS51	Verify that the system provides a means for the Logistics user to provide pre-configuration data, setup the location beacons, and Assisted GPS data for the Area of Operation.
SyRS52	Verify that the system provides users the means to configuration / deploy fixed position beacons, assimilate of new clique members and send position data to C2 via the military radio interface.
SyRS53	Verify that system provides the user will the ability to enable the remote system zeroize feature.
SyRS54	Verify that system provides the user access to all system features and that all features present function as designed.
SyRS55	Verify that all system users have access to the map user options including: map selection, measuring distance/angle, system zeroize local and remote.
SyRS56	Verify that the system can generate a 2D relative coordinate system with a minimum of 3 system nodes.
SyRS57	Verify that the system can generate a 3D relative coordinate system with a minimum of 4 system nodes.
SyRS58	Verify that system can provide network connectivity and position tracking for a maximum of 50 clique resources or an entire platoon.

Requirement ID	Verification Requirement
SyRS59	Verify that the system provides a means for mission operations landmarks and waypoints to be added to maps and that these items can be utilized by the system user to update their position to provide an accurate position estimate.
SyRS60	Verify that the system can be initialized on a relative coordinate structure when no GPS signal is available.
SyRS61	Verify that the system use a process called position fusion to maintain the relative coordinate structure using data from RF Multi-lateration and INS; ensure the system overrides the relative values when an absolute position data can be received by the system node.
SyRS62	Verify that the system fusion process can maintain absolute coordinate structure using data from GPS, INS and RF Multi-Lateration sources.
SyRS63	Verify that the system nodes overcome the need for calibration / synchronization in the field via the use of network timing clocks and communication algorithms.
SyRS64	Verify that each system node has a unique ID, Mac Address, and/or IP Address that can be used to identify and communicate with that system.
SyRS65	Verify that every node users ID is utilized in the visualization component to identify a particular resource on the GUI map.
SyRS66	Verify that the system table of "neighbors" or ranging partners can be setup via the logistics network interface / processes prior to deploying the system to the field; ensure the system supports the use of a minimum of 3 and a maximum of 10 ranging partners.
SyRS67	Verify that the system requires a minimum of 3 clique members operating within the RF position sensor's range to calculate a position estimate via trilateration.
SyRS68	Verify that the system can produce an accurate INS / RF TOA Ranging fused position estimate for all legged motion (e.g. walking, running, climbing, etc.).
SyRS69	Verify that the system nodes are functional over an operating temperature range of 0 to 120 degrees F.
SyRS70	Verify that the system nodes can withstand a storage temperature range of -10 to 130 degrees F, without negative impact on system operation.
SyRS71	Verify that the system nodes are waterproof and submersible to 3 feet for 10 minutes.
SyRS72	Verify that system node operational reliability is not less than 95% following exposure to an 8 hour MIL-STD 810E Salt/Fog and Sand/Dust or industry equivalent standard test.
SyRS73	Verify that the system nodes experience no parts breakage or system degradation following NLT 3 drops from different orientations in accordance with MIL-STD-33 1B Five Foot Drop or equivalent industry standard test.
SyRS74	Verify that system nodes maintain or exceed an operational reliability NLT 95% following exposure to a 30 minute MIL-STD 810E Loose Cargo Vibration or equivalent industry standard test.
SyRS75	Verify that the system nodes support operation over an 8 hour period with a single charge of a BA-5590 battery.
SyRS76	Verify that the system nodes are capable of maintaining a 25 meter SEP over the 8 hour period and over a range of 10km.
SyRS77	Verify that all system components weigh 1kg (2.2 lb) or less, not including battery.
SyRS78	Verify that the volume of all system components are 400 cm <sup>3</sup> (24.4 in <sup>3</sup> ) or less, not including battery.
SyRS79	Verify that they system requires no more than 3 relays to support operation in underground or cave like environments for a range of up to 100 meters.
SyRS80	Verify that the system can provide accurate position estimates without access to GPS over an 8 hour period.
SyRS81	Verify that the system CMR component provides range/position of ranging partners and network connectivity.
SyRS82	Verify that the system CMR component can function as position references (beacons) and

Requirement ID	Verification Requirement
	communications data relays to provide multi-hop network connectivity.
SyRS83	Verify that when the system CMR component is used as references/data relays they are tamper and spoof proof.
SyRS84	Verify that when the system CMR component is used as references/data relays that they are expendable.
SyRS85	Verify that when the system CMR component is used as references/data relays the GUI provides an interface that allows simple/autonomous position (absolute/relative) initialization.
SyRS86	Verify that when the system CMR component is used as beacons/references/data relays they provide ranging functionality amongst clique personnel within 25 meters minimum, verify that longer and shorter ranges between nodes to not inhibit system capabilities.
SyRS87	Verify that the system CMR components are capable of ranging over minimum 3 meter and maximum 2Km range.
SyRS88	Verify that the system CMR component can maintain network connectivity over 2Km range.
SyRS89	Verify that mobile system nodes can transmit three data types – range data, position information and text messages.
SyRS89a	Verify that the system range data includes the ID of ranging partner (personnel and clique ID), range of ranging partner(s), and range accuracy.
SyRS89b	Verify that the system position information includes the ID of personnel including clique ID, position data from the INS, TOA and GPS sensors and that this information is transmitted to the entire clique.
SyRS89c	Verify that the system can support communication of text messages.
SyRS90	Verify that the system network component supports multi-hop localization.
SyRS91	Verify that the system network multi-hop localization processes provide network connectivity for data sharing and text messaging.
SyRS92	Verify that the system position estimate is displayed in the UI as Latitude/Longitude/Altitude.
SyRS93	Verify that the system position estimate format is consistent among all position sensors.
SyRS94	Verify that the system position estimate is stored in all local nodes memory, in a database table format.
SyRS95	Verify that the system position database includes range and associated accuracy of all clique members and that the data is updated / maintained over the entire 8 hour operational period.
SyRS96	Verify that the system position database is maintained within every clique node.
SyRS97	Verify that the system position database can differentiate between members of own clique and other cliques.
SyRS98	Verify that the system position data format and transmit data packet size do not burden the network during data distribution activities.
SyRS99	Verify that the system TOA algorithms are capable of ranging in open and underground and/or cave-like environments.
SyRS100	Verify that the system network connectivity does not interfere with ranging activity (and vice-versa).
SyRS101	Verify that the system nodes TOA range data accuracy errors are small enough to allow the overall system to maintain or beat the required 25 m SEP accuracy.
SyRS102	Verify that they system TOA algorithms can generate a 2D position estimate from a minimum of 3 range references.
SyRS103	Verify that they system TOA algorithms can generate a 3D position estimate from a minimum of 4 range references.
SyRS104	Verify that the system TOA algorithms automatically select and provide 3-10 range references for each system node request for range information.



Requirement ID	Verification Requirement
SyRS105	Verify that the system TOA algorithms automatically identify and select ranging reference nodes based on a set of criteria which provides the most accurate / consistent ranges possible.
SyRS106	Verify that the system TOA algorithms automatically review and discard range data that does not meet the defined selection criteria.
SyRS107	Verify that the system TOA ranging algorithm and associated waveform are able to resolve multi-path errors present in enclosed environments.
SyRS108	Verify that the system Multi-path resolution processes are resource intensive – ensure the computations do not exceed sampling rate (sampling rate < 5 seconds) for real time operation and that computations do not require additional processing resources outside of the CMR RF signal processing component of the system.
SyRS109	Verify that the system Multi-path resolution processes do not interfere with network connectivity.
SyRS110	Verify that the TOA component hardware volume enables the overall system volume to be 400 cm <sup>3</sup> or less.
SyRS111	Verify that the system utilizes Multi-lateration processing to generate a position estimate when provided with TOA range data.
SyRS112	Verify that the system multi-lateration processes can support 2D ranging/positioning with a minimum of 3 references.
SyRS113	Verify that the system multi-lateration processes can support 3D ranging/positioning with a minimum of 4 references.
SyRS114	Verify that the system Multi-lateration algorithms can maintain a threshold accuracy of 25m SEP or better.
SyRS115	Verify that the system Multi-lateration algorithms are capable of maintaining the threshold accuracy in outdoor, indoor, underground/cave-like environments.
SyRS116	Verify that all system RF data transmission is encrypted and compliant with NSA Suite B.
SyRS117	Verify that the system INS component supports all forms of legged motion (walking, running, climbing, etc.) in all directions (forward, backward, sideways, up/down, etc.) in a 3D GPS denied environment.
SyRS118	Verify that the system INS component threshold tracking accuracy is 25 m SEP or better and is used to track mobile users between absolute position update intervals.
SyRS119	Verify that the system INS component provides 3D position information in Latitude, Longitude, Altitude (meters) at a minimum frequency of 1 Hz.
SyRS120	Verify that the system INS component includes an RS232 data interface that provides position and system status data as well as supports 3D position updates from external position sensors.
SyRS121	Verify that the system INS component automatically initializes the relative co-ordinates of (0, 0, 0) within 5 seconds after power is enabled.
SyRS122	Verify that the system INS component hardware volume is small enough to allow the overall system volume to be 400 cm <sup>3</sup> or less.
SyRS123	Verify that the system INS component on the mobile personnel does not inhibit the user from performing their operational / tactical responsibilities.
SyRS124	The associated requirement was removed from the SyRS content.
SyRS125	Verify that the system SBC component automatically initializes (complete the OS boot-loading process and be ready for local position initialization) within 15 seconds after the power is enabled.
SyRS126	Verify that the system SBC component hardware volume is small enough to allow the overall system volume to be 400 cm <sup>3</sup> or less.
SyRS127	Verify that the system SBC component does not inhibit the user from performing their operational / tactical responsibilities.
SyRS128	Verify that the system SBC component provides data interfaces to the GPS/INS (RS232),

Requirement ID	Verification Requirement
	TOA/Communication (RS232/Ethernet) and Military Radio (Ethernet) components.
SyRS129	Verify that the system SBC component is able to capture data from the GPS, INS and TOA components in near real-time and the data is captured with in less than 1 second for each component.
SyRS130	Verify that the system SBC component provides a standard data / video interface for host control / display.
SyRS131	Verify that the system SBC component provides processing capability that allows for the completion of the sensor data fusion in near real-time and the fusion process completes within 5 seconds.
SyRS132	Verify that the system SBC component supports 8 hours of continuous on-board data logging/storage during mission activity.
SyRS133	Verify that the system SBC component generates system logs with the following mission data: Local User's Position Data, Text Messages (sent/received), System Errors / Alerts
SyRS134	Verify that the system GPS Receiver component does not inhibit users from performing their operational / tactical responsibilities.
SyRS135	Verify that the system GPS receiver is enclosed along with the other system components.
SyRS136	Verify that the system GPS Antenna does not inhibit users from performing their operational / tactical responsibilities and that the antenna ensures reception of available GPS signal transmissions.
SyRS137	Verify that the system GPS supports reception of the L1 frequency, C/A code (SPS), provides 12 independent tracking channels, and a separate search & acquisition engine.
SyRS138	Verify that the system GPS receiver supports WAAS, EGNOS, and MSAS.
SyRS139	Verify that the system GPS component provides A-GPS and D-GPS support.
SyRS140	<b>The associated requirement was removed from the SyRS content.</b>
SyRS141	Verify that the system GPS component accuracy is 3m CEP (50%) to 5m CEP (95%) at velocity of 0.1 m/s, and time of 20 ns RMS.
SyRS142	Verify that the system GPS is able to perform signal reacquisition at 100ms typical.
SyRS143	Verify that the system GPS Time to First Fix (TTFF) for an out of the box start is 40s typical; for a cold start is 35s; and for a hot start is 4.5s minimum.
SyRS144	Verify that the system GPS sensitivity acquisition (cold) is -141.5 dBm; acquisition (hot, warm) is -149 dBm; tracking (hot, warm) is -156 dBm; and navigation (hot, warm) is -155.5 dBm.
SyRS145	Verify that the system GPS hardware works on an operating voltage range of 2.7V - 3.3VDC.
SyRS146	Verify that the system GPS can operate at temperatures -40C to +85C.
SyRS147	Verify that the system GPS works with an external, passive or active antenna, with an input of LGA pad, 50ohm.
SyRS148	Verify that the system GPS power consumption rate is 95mW @ 2.7V (Continuous Mode), 15mW @ 2.7V (Idle Mode), and 20μW @ 2.7V (Sleep Mode).
SyRS149	Verify that the system GPS component provides a serial data interface (RS232) that supports the output of position information @ 1 Hz minimum to a host computer.
SyRS150	Verify that the system GPS data output format shall be in line with the NMEA-0183 protocol.
SyRS151	Verify that the system GPS has an onboard 16MB flash memory.
SyRS152	Verify that the system GPS unit dimensions are 22 x 23 x 2.9 mm or less including RF shield.
SyRS153	Verify that the system GPS unit mass is 3 g or less.
SyRS154	Verify that the system fusion algorithm fuses position information received from different positioning systems - INS, Velocimeter, GPS, TOA, Pseudolites, LORAN, etc. positioning systems.
SyRS155	Verify that the system fusion algorithm provides the best estimate of position in presence



Requirement ID	Verification Requirement
	of component inaccuracies.
SyRS156	Verify that the system fusion algorithm utilizes a Kalman Filter, including system state estimation and Kalman gain estimation processes.
SyRS157	Verify that the system Position fusion mobility models are generated for each position sensor.
SyRS158	Verify that the system Position fusion mobility models are expressed as either regression (unimulti-variate) or as polynomials.
SyRS159	Verify that the system Position fusion mobility model is capable of determining the linearization process of mobility model of each position sensor.
SyRS160	Verify that the system variables critical to position estimation are identified, placed and updated in the system state matrix.
SyRS161	Verify that the system Position fusion algorithm position estimate standard deviation have an SEP of 25m or less.
SyRS162	Verify that the system Position fusion algorithm rounds off errors created during computation of Kalman filter gain are reduced by matrix factorization.
SyRS163	Verify that the system Position fusion algorithm INS bias drift is reset by the fused position reset/reinitialize loop.
SyRS164	Verify that the system Position fusion algorithm RF range/position estimate data includes an accuracy estimate and that when the accuracy does not conform to the SEP requirements, the system fusion algorithm will reset the TOA ranging component using available fused position.
SyRS165	Verify that the system INS Geolocation mobility model represents position information with the least minimum squared error (MSE) or least squared error (LSE).
SyRS166	Verify that the system INS Geolocation mobility model includes modeling of process noise and measurement noise.
SyRS167	Verify that TOA Geolocation RF Positioning system requires a minimum of 3 reference nodes to calculate a 2D position estimate.
SyRS168	Verify that TOA Geolocation RF Positioning system requires a minimum of 4 reference nodes to calculate a 3D position estimate.
SyRS169	Verify that the system TOA Geolocation mobility model represents position information with the least minimum squared error (MSE) or least squared error (LSE).
SyRS170	Verify that the system TOA Geolocation mobility model provides for process noise and measurement noise.
SyRS171	Verify that TOA Geolocation modeling of the RF Positioning variables are performed to provide the most accurate position calculation processing.
SyRS172	Verify that the system initialization process is autonomous requiring minimal human intervention.
SyRS173	Verify that the system initialization commences at the node power on.
SyRS174	Verify that the system give preference to GPS/global coordinate system, when that data is available.
SyRS175	Verify that when no absolute coordinate references are available to the system, it automatically establishes and maintains a local referential coordinate system.
SyRS176	Verify that the local coordinate system origin must be the highest ranked personnel within ranging distance.
SyRS177	Verify that the system can create a 2D position estimate with a minimum of 3 resources or 4 resources for 3D positioning.
SyRS178	Verify that the system neighbor table is initiated while forming the local coordinate system.
SyRS179	Verify that the system coordinate transformations are recorded in coordinate transformation table.
SyRS180	Verify that upon arriving in ranging distance of higher ranked personnel, the system local coordinates are transformed to higher ranked personnel's coordinate system.

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SyRS180a	Verify that the system coordinate transformation is backward compatible - i.e. position information in the older coordinate system is transformed to the newer coordinate system to permit personnel to track back to original path.
SyRS181	Verify that the system is capable of identifying clique members from visitors.
SyRS182	Verify that the system assimilation process has a manual component for verification of the transaction prior to completion.
SyRS183	Verify that during the auto-calibration / system initialization process the system node UI status bar indicator and text fields indicate current system status.
SyRS184	Verify that the system UI system mode indicator area / field is red during Start-up, Initialization, or Coordinate System Initialization.
SyRS185	Verify that system processing status field displays text values indicating which components are in use by the system.
SyRS186	Verify that the system UI status indicator field will turn green after the coordinate system initialization process has completed, and that the status text field will provide details on the status of the system including - INS only, INS/TOA, TOA Only or GPS.
SyRS187	Verify that the system UI network connectivity field in the Status Bar displays the RF IP Based Tactical Internet Link network connectivity based on data provided by the CMR.
SyRS188	Verify that the system UI accuracy indicator / FOM field displays position accuracy or SEP.
SyRS189	Verify that the system UI SEP value is displayed in meters and corresponds to the calculated value from the position fusion process.
SyRS190	Verify that the system UI pre-mission configuration process includes a method to list clique members who support the mission along with their node information and that this data can be added to the system configuration file / installed into the system nodes by the logistics user.
SyRS191	Verify that the system pre-mission configuration file data is utilized to populate the neighbor table.
SyRS191	Verify that the system neighbor table is utilized by the system to identify ranging partners for each node within the clique, identify group hierarchy for each node within the clique and role of node (end user or beacon).
SyRS192	Verify that the system configuration file data can be entered into a comma delimited text files and downloaded into the node(s) memory location.
SyRS193	Verify that the system configuration files are specific to each mission plan and include a list of clique members, their assigned node ID, pre-canned text message content, a list of map files, clique structure and A-GPS data.
SyRS194	Verify that the system configuration file can be loaded into each system node and the data is then added to the local copy of the neighbor table at system start-up.
SyRS195	Verify that the system provides the following fields for population of the neighbor table: SID, UID, Resource Type, Text Messages (canned), and Maps (location).
SyRS196	Verify that the system uses the remainder of the data in the memory location are present in the UI post system startup/ initialization, local coordinate initialization and position fusion processes.
SyRS197	Verify that the system user interface includes an auto-calibration / system initialization status in the status bar section of the display.
SyRS198	Verify that the system user interface includes a network connectivity status in the status bar section of the display.
SyRS199	Verify that the system user interface includes a position accuracy value in the status bar section of the display.
SyRS200	Verify that the system user interface provides a page to support the text messaging feature.
SyRS201	Verify that the system user interface main page is the map display screen which provides a means to change the map displayed on the screen.

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SyRS202	Verify that the system user interface provides a means to manually set user position by selection of a point on the map displayed on the main UI screen.
SyRS203	Verify that the system user interface End User Task bar features, include the following features as a future system enhancement; Measure Distance, and Bearing To functions.
SyRS204	Verify that the system user interface structure provides for the inclusion of a Logistic / Configuration user interface enhancement.
SyRS205	Verify that the phase 2 prototype system nodes support a manual process for creation and installation of the project the configuration file.
SyRS206	Verify that the system application software is updated to include an auto-calibration and system initialization procedure.
SyRS207	Verify that as part of the pre-deployment mission configuration file setup, the system provides a means to distribute the clique hierarchy definition to the local node neighbor table for all nodes that will be deployed with mission resources.
SyRS208	Verify that the system neighbor table automatically provides each node with the ability to identify other nodes within RF range that are a part of their clique or group.
SyRS209	Verify that the system, post identification of each node's (user's) position, stores the position data in a neighbor table and that the data is shared with other nodes within range.
SyRS210	Verify that the system neighbor table position information is updated as new information is received from other resources.
SyRS211	Verify that the system nodes local neighbor table data is used to display the position of all nodes / resources on the local Map UI.
SyRS212	Verify that the system is capable of forwarding position data is to C2 via a Military Radio Interface.
SyRS213	Verify that the system communication network supports shared position awareness of all clique personnel by "hopping" through intermediary/relay nodes, when direct communication links are unavailable and Non-LOS conditions exist.
SyRS214	Verify that the system node hardware can be utilized by mobile users or as a stationary beacon.
SyRS215	Verify that the system beacon configuration process is supported by the use of the set position UI feature.
SyRS216	Verify that when operating in the beacon mode the system nodes provide data connectivity and TOA ranging.
SyRS217	Verify that when operating in the beacon mode the system node hardware configuration is the same whether used as a mobile tracking device or as a system location beacon, on/off switch, zeroize button, external connections, etc...
SyRS218	Verify that when operating in the beacon mode the system node supports standard operations including auto-initialize (OS, communication / ranging processes) within 1 minute of being turned on, when functioning in the beacon mode.
SyRS219	Verify that when operating in the beacon mode the system nodes automatically join the communication network and assimilate into the local coordinate system (show up accurately on the clique members' map) of the clique to which it has been assigned.
SyRS220	Verify that the beacon operating mode provides a method to ensure authenticity / data and position validity during mission operation.
SyRS221	Verify that when power is supplied to the beacons, they automatically establish communication with the clique and assimilate into the local coordinate system.
SyRS222	Verify that in addition to the ad-hoc method of initialization, a logistics resource is able to establish the initialization parameters via the system pre-mission configuration process.
SyRS223	Verify that the system configuration file specifies that a beacon device with pre-configuration data will initialize based upon the provided values rather than by the default auto-initialization process.
SyRS224	Verify that after placing the beacon in the desired location, turning it on, and establishing

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	communications, the clique member is able to mark the beacon location via the set position UI feature.
SyRS225	Verify that the system UI component provides a messaging interface that allows the clique personnel to send short text-based pre-canned messages to other clique members through the MANET.
SyRS226	Verify that the system text messages data consist of the following fields: Sender ID, Sender Name, Send Time, and Message Data.
SyRS227	Verify that maximum data packet size for message text transmitted by the system be 1500 bytes or less.
SyRS228	Verify that the system generates a log of sent and received messages, stored on each personnel member's local computer unit; ensure the log is accessible for review by clique personnel through the UI.
SyRS229	Verify that the system UI provides a means for the message recipient to acknowledge the message.
SyRS230	Verify that the system text message log contains the following fields: Sender ID, Sender Name, Send Time, Received Time, and Message Data.
SyRS231	Verify that the system pre-mission configuration file supports a method of defining, editing and downloading predefined messages to all system nodes prior to deployment.
SyRS232	Verify that the system provides the capability to track members within the clique as well as members from other cliques.
SyRS233	Verify that the system assimilation process provides the capability to assimilate lost or unattached clique personnel.
SyRS234	Verify that the system provides a technique to ensure that the process of assimilating new members into the clique remains spoof-proof.
SyRS235	Verify that the system assimilation technique ensures that only valid members of other cliques are assimilated by using a form of key exchange.
SyRS236	Verify that the system assimilation provides a means to ensure the clique member who is not associated with a given clique automatically exchanges special keys when within range of the target wireless network island.
SyRS237	Verify that the system assimilation key exchange alerts clique members of presence of member of another clique in the vicinity.
SyRS238	Verify that when the system assimilation key exchange is completed successfully, the non aligned resource shall be assimilated into the clique.
SyRS239	Verify that the system military radio component can provide clique position information and mission status updates to a TOC over a long-haul wireless connection.
SyRS240	Verify that the system funnels all platoon/clique position information through the military radio link for transmission to TOC / C2 level.
SyRS241	Verify that the system includes a database table that reflects the platoon's operational status and situational awareness and is maintained by the system nodes/ platoon leader hardware.
SyRS242	Verify that the system periodically updates to the position information data table at least once every 5 minutes as updates are received from the squad and fire-team levels.
SyRS243	Verify that when the system updates the position data table generating an overall change of the table state, an exchange process is initiated and data is transmitted to TOC/C2 by platoon leader's node military radio connection.
SyRS244	Verify that the system connection to the military radio component is either Ethernet or Serial.
SyRS245	Verify that when multiple components or processes are identified for use in the system, technical data and cost information are captured and entered into the Cost verses Performance matrix for use in determination of which option will best suit the needs of the project.
SyRS246	Verify that the Cost verses Performance matrix provides fields to identify classification on

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	the difference between component or procedures such as, cost, performance, speed, capacity, volume, processing power, time required to develop / implement, etc.
SyRS247	Verify that the Cost versus Performance matrix includes the following data fields: Item #, System Feature / Component, Description of Item, Item Cost, Performance Category, Explanation of Performance Improvement, Notes, and Location of Associated Documentation.
SyRS248	Verify that the Cost versus Performance matrix is delivered to ONR at the end of phase 2 to identify opportunities for improvements in system functionality, based on cost, to target future system enhancements.
SyRS249	Verify that the Cost versus Performance matrix items are prioritized for inclusion in future releases of the production units as a means to provide continual improvement of product functionality.
SyRS250	Verify that all system cryptographic operations for data at rest and in transit meet all Suite B security requirements.
SyRS251	Verify that the system node physical enclosure implements measures that deter immediate access to, tampering with, or destruction of internal hardware components.
SyRS252	Verify that the system provides a zeroize function to erase all volatile and non-volatile data for each system component in order to disable / prevent unauthorized access to confidential mission information.
SyRS253	Verify that as a future enhancement, the system incorporates a user verification procedure employed at system start-up in order to ensure access to authorized personnel.
SyRS254	Verify that the following data is stored on each user's system in a secure directory for use in system initialization and to provide a means to replay a mission in its entirety: Scenario File, Position Log, Message Log, Error Log, Map(s), and AGPS Data File.
SyRS255	Verify that the system IMU and INS mechanical and electrical interfaces are SPI compliant.
SyRS256	Verify that the system IMU component provides the GPS/INS fusion pre-processor with the following data: Raw Magnetometer Data (X, Y, and Z-axis), Raw Accelerometer Data (X, Y, and Z-axis), and Angular Rate, (X, Y, and Z-axis), and Temperature of IMU interior.
SyRS257	Verify that the system pressure sensor and GPS/INS mechanical and electrical interfaces are SPI compliant.
SyRS258	Verify that the system barometer component provides the GPS/INS fusion pre-processor with the following data: Pressure and Temperature.
SyRS259	Verify that the system Velocimeter and INS mechanical and electrical interfaces are SPI or RS232 compliant.
SyRS259a	The system velocimeter component provides the GPS/INS fusion pre-processor with the following data: Velocity
SyRS260	Verify that the system GPS and SBC mechanical and electrical interface is RS232 compliant, the NMEA-0183 data interface standard is followed and that proprietary message formats that meet the NMEA-0183 standard are acceptable.
SyRS261	Verify that the system GPS/INS component provide the SBC with RMC, GGA, GSA, and GSV sentence data including: UTC Fix Time, Position Information (Latitude, Longitude, HDOP/VDOP/PDOP, Altitude (meters above sea level), and Height of geoid (mean sea level) above WGS-84 ellipsoid); Speed over ground (m/s); Magnetic Variation; Satellite Information (Number of satellites in view, Satellite PRN number, Elevation (degrees), Azimuth (degrees), Signal strength, Fix Quality (0 - Invalid, 1 - GPS Fix, 2 - DGPS Fix)); System related status / error messages; and System parameter configurability (baud rate, etc...).
SyRS262	Verify that the system GPS/INS component accepts the data from the SBC including: Position Update / Override Information (Latitude, Longitude, HDOP /VDOP /PDOP, and



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	Altitude (meters above sea level).
SyRS263	Verify that the system TOA and SBC mechanical and electrical interfaces are RS232 compliant and that the message structure / their protocols follow ICD-GPS-150.
SyRS264	Verify that the system TOA component provides the SBC with the following data: TOA Ranging Data / Ranging Partner Specific (ID, Range, Figure of Merit (FOM), Position Information (WGS-84), Time Tag, and PVT Time); and TOA Time Reference.
SyRS265	Verify that the system TOA component accepts the following data from the SBC: System Status (Status of GPS and INS, and Navigation FOM); Navigation Solution and Guidance Data - WGS-84 Position Information (Latitude, Longitude, and Altitude); ENU Velocity (Velocity in East, North, and Up coordinates); Position and Velocity Variances; and PVT Time.
SyRS266	Verify that the system Communication and SBC mechanical and electrical interfaces are either Ethernet or RS232 compliant supporting Ethernet or PPP interface for data.
SyRS266	Verify that the system communication and SBC interface provides the following data: Clique-wide SVT updates, Clique Text Messages, and Mission Data.
SyRS267	Verify that the system Military Radio/Auxiliary CMR and SBC mechanical and electrical and data interface is Ethernet compliant and the following data is shared over this interface: Clique and C2 Text Messages, Clique Positions to C2, and Mission Data to/from C2.