MERCURY
DATA SYSTEMS
4214 Beechwood Drive, Suite 105 • Greensboro, N.C. 27410
Toll-Free 800-557-6374
www.mercdatasys.com

ONR BAA06-007 Concept of Operations Document

Version 1.1

Mercury Data Systems

April 10, 2007

Abstract

This Concept of Operations Document provides an overview of the current system operation, changes necessary to meet the needs and a description of the proposed system operation 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 design modifications of the current TrakPoint application. 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: Sid Winslow, Clayton Kane, Adam Abdelhameid

Report Documentation Page						*Form Approved* *OMB No. 0704-0188*
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.						
1. REPORT DATE **10 APR 2007**		2. REPORT TYPE **N/A**				3. DATES COVERED **-**
4. TITLE AND SUBTITLE **ONR BAA 06-007 Concept of Operations Document**						5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)						5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Mercury Data Systems 4214 Beechwood Drive Suite 105 Greensboro, NC 27410**						8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)						10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**						
13. SUPPLEMENTARY NOTES **The original document contains color images.**						
14. ABSTRACT						
15. SUBJECT TERMS						
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON	
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**79**		

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Document Control

This is a controlled document produced by Mercury Data Systems Inc. (Mercury). The control and release of this document is the responsibility of the Mercury document owner. This includes any amendment(s) that may be required.

Issue Control			
Document Reference	ONRP_ConOps_ONRBAA06-007_Final.doc	**Project Number**	ONR BAA 06-007
Issue	1.0	**Date**	April 10, 2007
Classification	Unlimited/Unclassified	**Author(s)**	Sid Winslow, Clayton Kane, Adam Abdelhameid
Document Title	ONR BAA06-007 Concept of Operations Document		
Approved by	ONR Project Team Resources		
Released by	Sid Winslow		

Owner Details	
Name	Sid Winslow
Office/Region	Greensboro
Contact Number	336.553.0688
E-mail Address	swinslow@mercdatasys.com

Document Version History			
Issue	**Date**	**Author(s)**	**Description**
1.0	12 March 2007	Sid Winslow, Clayton Kane, Adam Abdelhameid	Initial Release of the document.
1.1	10 April 2007	Sid Winslow	Updated Classification.

Revision Table			
Paragraph	**Page**	**Identifier -Description of Change/Reason for Release**	**Release**
n/a	ii	Confidentiality Statement was modified to ensure document could be distributed for review.	1.1
Footer / properties	all	Properties classification was changed from MDS proprietary to Unlimited/Unclassified.	1.1

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 concept of operations of the Navigation in a GPS Denied Environment (NAVGPSDE) system that is under analysis / development as part of the ONR BAA06-007 contract and to explain the analysis / development activities that will be undertaken as part of the project effort. 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 System Level Requirement Specifications 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 defined operational concept meets the needs of the users and to ensure that the development team fully understands the operational needs of the user community. 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.

Table of Contents

List of Figures

List of Tables

1. Scope

This Concept of Operations document applies to the system(s) that are under analysis and development in conjunction with the ONR BAA06-007 Navigation in a GPS-Denied Environment Research and Development project. The scope of the document includes project team tasks / activities, system components, elements, and/or sub-systems which will compose the final product(s) required to support resource tracking in a GPS denied and/or GPS limited environments.

1.1 Identification

This document is named ConOps_ONRBAA06_007.doc, and is referred to as the Concept of Operations Document or ConOps. No other concept of operations documents will be generated to describe this system and project activities.

1.2 Document overview

The purpose of this ConOps document is:

- To communicate the tasks to be completed for this project in the analysis and design activities required to define the system operations and to construct a system prototype; and
- To communicate the proposed system’s capabilities and user expectations, from the development group to the ONR program management team and system end users; and
- To provide a documented set of text that can be reviewed and approved by the end user community, systems testing entities and/or ONR program management resources; and
- To build consensus between MDS and its subcontractor (ITT), and among the MDS development resources; and
- To communicate that the development team understands the users’ needs and how the system shall operate to fulfill those needs.

The audience for this ConOps document includes the following:

- The System End Users and/or System Test Community will use it to determine whether their needs, desires, and operational requirements have been correctly specified and to verify the developer understands of the system needs; and
- The Development team (MDS, and ITT) will use the ConOps document as a basis for system development activities, and to familiarize new team members with the problem domain and the system to which the ConOps applies; and
- The ONR program management team will use this content to help determine if the MDS proposal will be selected for continuation of the development efforts into Phase2 of the project.

This document is divided into sections that describe the current, proposed and future systems operations. Partitioning of the document is as follows:

Section	Topic
2.0	Referenced Documents
3.0	Current System or Situation
4.0	Justification for and Nature of Changes
5.0	Concepts for the Proposed System
6.0	Operational Scenarios
7.0	Summary of Impacts
8.0	Analysis of Proposed System
9.0	Notes

1.3 System Overview

The purpose of the proposed system is to provide situational awareness (SA) and dismounted resource tracking capabilities to system users when they are located in GPS limited or GPS denied areas such as caves, urban canyons, buildings, heavily forested or jungle environments where GPS access is restricted.

The project sponsor is the Office of Naval Research (ONR) in support of the US Marine Corps (USMC). All products and deliverables created as part of this effort will be generated in support of the Office of Naval Research (ONR) contract number N00014-06-C-0488

The system that will be enhanced by this analysis, design and development effort is currently called the TrakPoint system. TrakPoint includes hardware and software required to track dismounted resources in a GPS denied and/or limited environment. The current system utilizes an Inertial Navigation System (INS) only to accomplish this task. This system was developed as part of the Accurate Tactical Navigation System (ATNS) program, Penn State EOC subcontract # 0046-4-0111.

2. Referenced documents

This section lists the document number/name, title, revision, and date of all documents referenced in the ConOps document. This clause also identifies the source for all documents not available through normal channels.

- Accurate Tactical Navigation System Operations Manual, v1.8, Jan. 2006, source - Mercury Data Systems, Inc.
- Afghanistan Cave Complexes 1979-2004 Mountain strongholds of the Mujahideen, Taliban & Al Qaeda, Copyright 2004, source – http://www.ospreypublishing.com
- ATNS Final Technical Report.pdf, Accurate Tactical Navigation System Final Technical Report, v2.0, 4/11/2006, source – Mercury Data Systems, Inc.
- baa_06_007.pdf, BAA 06-007, Navigation in a GPS-Denied Environment, 2/13/2006, source - http://www.onr.navy.mil/02/baa/expired.asp
- baa_06_007_amend_01.pdf, Amendment No. 0001 to BAA 06-007 "Navigation in a GPS-Denied Environment", 2/21/2006, source - http://www.onr.navy.mil/02/baa/expired.asp
- baa_06_007_faq.pdf, Frequently Asked Questions (FAQ's) for BAA 06-007 "Navigation in a GPS-denied environment", 3/7/2006, source - http://www.onr.navy.mil/02/baa/expired.asp
- baa_06_007_faq2.pdf, Frequently Asked Questions (FAQ's) #2 for BAA 06-007 "Navigation in a GPS-denied environment", 3/16/2006, source - http://www.onr.navy.mil/02/baa/expired.asp
- baa_06_007_faq3.pdf, Frequently Asked Questions (FAQ's) #3 for BAA 06-007 "Navigation in a GPS-denied environment", 3/27/2006, source - http://www.onr.navy.mil/02/baa/expired.asp
- Graphics / Images included in this document were downloaded from the following sources - http://www.defenselink.mil/multimedia/, http://www.fotosearch.com/clip-art/marine-corps_2.html and http://sill-ww.army.mil/Graphics/clipart_library.htm
- IEEE Std 1362-1998, IEEE Guide for System Definition – Concept of Operations Document, source - http://standards.ieee.org
- Innovation: GPS + LORAN-C, Performance Analysis of an Integrated Tracking System, Jul 1, 2006, By: James Carroll, GPS World, source – http://www.gpsworld.com
- Integrated GPS, LORAN-C and INS for Land Navigation Applications, C. Hide, C. Hill, T. Moore, C. Noakes, D. Park, University of Nottingham, U.K., source - http://www.ion.org/meetings/gnss2006
- Iraqi Facilities Maps, November 2003 Force Laydown Facilities Map, source - http://www.globalsecurity.org/military/facility/iraq-maps.htm

- ONR Code 30 TTA: FNT-FY04-01-C4-01, Technology Transition Agreement Navigation in a GPS-Denied Environment for the Marine Air Ground Task Force Between the Program Manager, Sea Strike FNC/Urban Asymmetric Expeditionary Operations and the Program Manager Reconnaissance and Amphibious Raids, source – Office of Naval Research
- OpshaugIONGPS02.pdf, Leapfrog Navigation System, v5, Guttorm R. Opshaug, Presented at Institute of Navigation's GPS Meeting, Portland, OR, September 2002, source - http://waas.stanford.edu/~wwu/papers/gps/PDF/OpshaugIONGPS02.pdf
- Lessons Learned: Infantry Squad Tactics in Military Operations in Urban Terrain During Operation Phantom Fury in Fallujah, Iraq, Sep. 2005, Sgt. Catagnus, Jr. Earl. J., Cpl. Edison, Brad. Z., LCpl. Keeling, James. D., and LCpl. Moon, David. A., 3rd Battalion, 5th Marines, Scout/Sniper Platoon, Section 1, Fallujah, Iraq, source – http://www.marinecorpstimes.com/content/editorial/pdf/mc.**infantry_squad_lessons**418.pdf
- Marine Special Warfare & Elite Unit Tactics by Bob Newman, Copyright 1995, source – Paladin Press, P.O. Box 1307, Boulder CO, 80306, USA.
- ONRP_SyRS_BAA06-007.pdf, ONR BAA 06-007 System Requirements Specification, v1.0, 3/12/2007, source – Mercury Data Systems, Inc.
- Operation Enduring Freedom Tactics, Techniques and Procedures Handbook No. 02-8, source - http://www.globalsecurity.org/military/library/report/call/call_02-8_toc.htm
- reelektronika_LORADD_Manual_v1.01.pdf, Reelektronika LORADD Series Integrated GPS/eLORAN Receiver Installation and Operation Manual, source - http://www.reelektronika.nl
- TrakPoint_User_Manual.pdf, Accurate Tactical Navigation System Operations Manual, version 1.8, source – Mercury Data Systems, Inc.
- Trident_2006121.pdf, Wearable Display Systems by Jimmy O'Looney, program manger and Will Coffey, Military Analyst, source – http://www.tridsys.com/C4I/WD.php
- USMC 3-36.3 Military Operations on Urbanized Terrain (MOUT), source – Pentagon Publishing, http://www.pentagonpublishing.com/mamacd.html
- USMC Fleet Marine Force Manual FMFM 6 Ground Combat Operations Operational Handbook, source – Pentagon Publishing http://www.pentagonpublishing.com/mamacd.html
- USMC Fleet Marine Force Manual FMFM 6-4 Marine Rifle Company/Platoon, source – Pentagon Publishing http://www.pentagonpublishing.com/mamacd.html
- USMC Fleet Marine Force Manual FMFM 6-7 Scouting and Patrolling, source – Pentagon Publishing http://www.pentagonpublishing.com/mamacd.html

3. Current System or Situation

This section describes the TrakPoint system as it currently exists; we will also describe the situation that motivates development of the proposed system.

3.1 ONR Project Problem Domain

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 determine their relative positions.

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 present position/location information. 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.

3.2 TrakPoint Background, objectives, and scope

The ATNS Project problem domain was similar to the current ONR project effort. The scope of the ATNS program subcontract included the design, development, test, and demonstration of a proof of concept mobile position location reporting system. Mercury Data Systems was responsible for the design and integration of a Wireless Network Module (WNM) with the Personal Navigation Module (PNM) and Mobile Computer Module (MCM) for accurate tactical navigation. To augment the PNM an RF signal based location tracking process or RF Ranging Module (RFRM) was also integrated – the RFRM was to be a functional component of the WNM and/or Ultra Wide Band (UWB) radio systems.

On April 11, 2005, Mercury began work on a subcontract by the Penn State Electro-Optics Center (EOC) for the Special Operations Command (SOCOM) funded Accurate Tactical Navigation System (ATNS) Program. Under this program, and working with NPS, Mercury developed the TrakPoint application to provide real-time Situational Spatial Awareness (SSA) for GPS Enabled and GPS Denied environments.

Mercury Data Systems (MDS) was responsible for conducting a needs assessment to define and document requirements. MDS entered into a Cooperative Research and Development Agreement (CRADA) with the Naval Post-Graduate School (NPS) in Monterey California, consulted with the Naval Research Labs (NRL) and worked with resources within the Special Operations Command community (SOCOM) Joint Special Operations Command (JSOC) out of Ft. Bragg, North Carolina to help define system requirements from the 13 technical capabilities defined in the SOW.

Post completion of the technical design and construction activities MDS was responsible for testing the system and demonstration of the system capabilities**.**

3.3 Operational policies and constraints

The ATNS SOW lists 13 technical capabilities for the mobile position location reporting system. The list includes the following items:

- Lightweight, wearable design for extended, mobile use.
- Accurate navigation in both GPS Enabled and GPS Denied areas.
- Track and display the absolute 3D coordinates of mission personnel.
- Track and display the differential 3D coordinates of mission personnel.
- Systematically resolve and minimize mission personnel position errors.
- Systematically resynchronize the absolute and relative 3D positions of mission personnel.
- Increase navigation and location tracking accuracy as the number of mission personnel increases.
- Increase navigation and location tracking accuracy as the mobility of mission personnel increases.
- Support ad hoc, synthesis and synchronization of information.
- Support ad hoc, shared access to information acquired via mission personnel.
- Support ad hoc, location based communication and information routing.
- Enable mission personnel to quickly acquire spatial awareness in unmapped environs.
- Allow mission personnel to roam and seamlessly inter-operate with different mission units.

3.4 Description of the current system or situation

This section provides a technical description of the current system.

3.4.1 System Overview

The ATNS system was designed to provide portable, PDA based SSA for mobile users – a Tacticomp Ruggedized PDA was one of several MCM platforms used for system validation. The system also included a C2 component whereby mobile personnel, vehicles and other assets, such as sensors could be tracked.

The system was designed to use any TCP/IP based wireless mobile network to support transmission of personnel positions and collaboration among personnel. Figures 1 through 11 identify the existing functional capabilities of the TrakPoint system.

For the Naval Research Laboratories, remote positioning support was also developed that enabled an interface with small, disposable active beacons. Content could be uploaded to the beacons – location (lat, long, altitude), alerts, etc. – and automatically transmitted to users navigating within range.

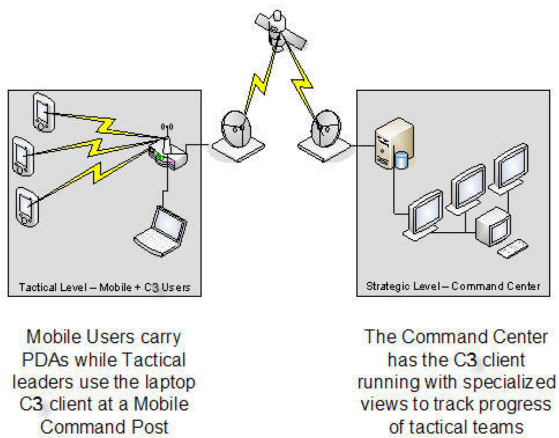

Figure 1 - Mobile Ad Hoc Network Support

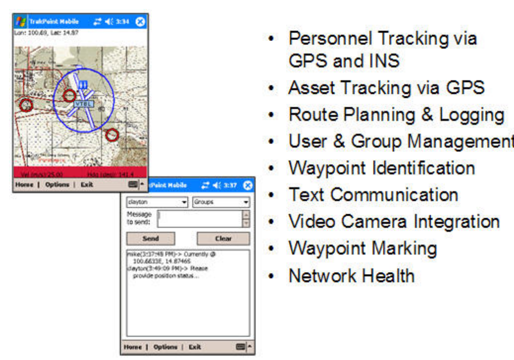

Figure 2 - Mobile Interface for PDAs

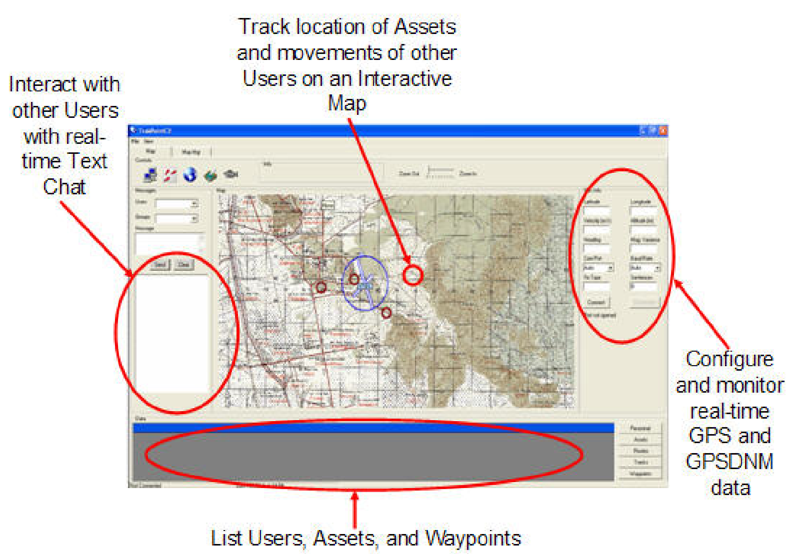

Figure 3 - C2 Interface for Laptops/Workstations

In order to meet the technical capabilities documented in the subcontract SOW, an application was required to provide an integration platform for all of the ATNS system sub components. MDS developed an application called TrakPoint that provides a 3 tiered, distributed personnel management system with a UI that displays spatial situational awareness (SSA) to military or first responders, in a near real-time fashion.

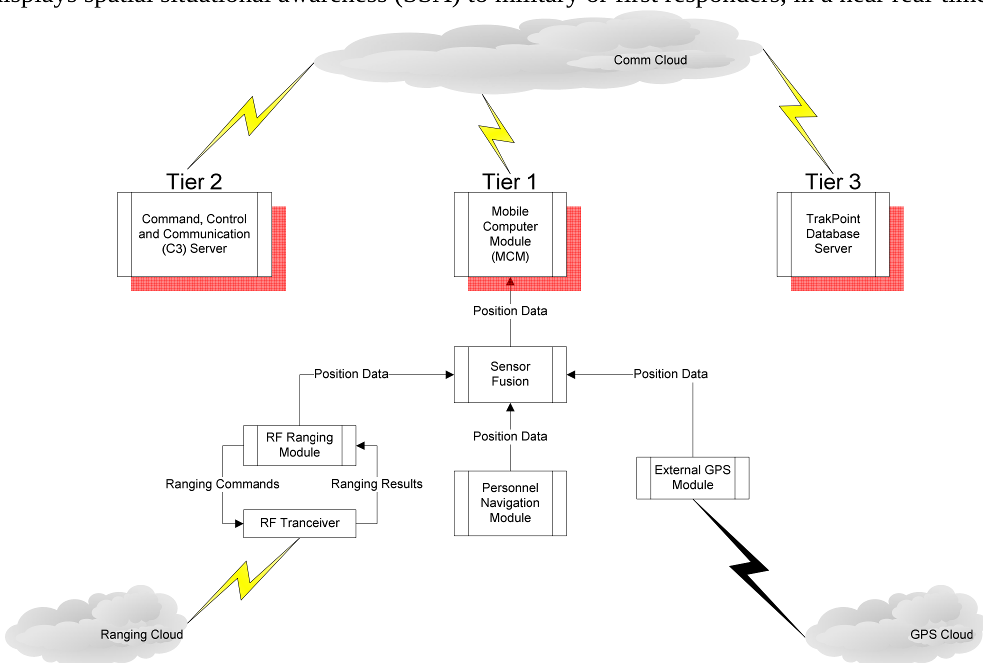

Figure 4 - TrakPoint System Diagram

3.4.1.1 Tier 1 – Mobile Client Application

The first tier is a client application that can be deployed on a mobile computer or handheld PDA. This tier provides GPS enabled and GPS denied location tracking capability for mobile users in a distributed environment. Each team member's handheld device provides them with their current position and the positions of their team members (Blue Forces) in a peer-to-peer wireless network environment. The location data is aggregated from several position sensors (GPS, RF Beacons, PNM, RFRM etc.), whose data is filtered and rated for highest reliability/precision. This tier is also capable of displaying messages to/from the group of responders as well as providing them with spatial data (the locations) and descriptions of available resources and assets, such as mesh sensors and networked cameras.

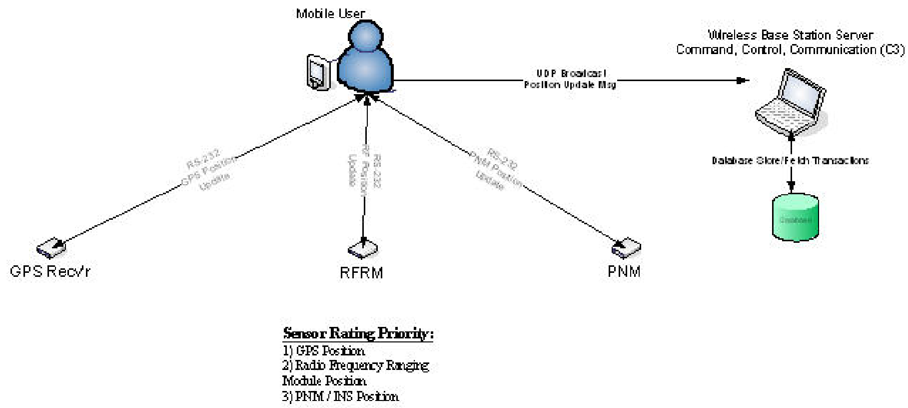

Figure 5 - Mobile Client Tier

3.4.1.2 Tier 2 – Command, and Control (C2) Base Station Application

The second tier is comprised of a base station monitoring platform that performs similarly to the first tier (mobile client application); however, since this portion of the system is designed to be used by blue force command post resources, it has some additional features for such deployment. One feature that is critical to this tier's implementation is the ability to monitor and control available network cameras. This tier hosts a robust spatial database for high-speed exchanges of tactical information.

3.4.1.3 Tier3 – Robust, Redundant, High-Speed Database Server

The third tier in the SA distributed system incorporates a high-performance, redundant server running a Relational Database Management System (RDBMS) that will store spatial data and respond to spatial queries from the 1st and 2nd tiers. This tier is optional as the 2nd tier can host the RDBMS, if desired

Three iterations of design / development activities were conducted during the ATNS program based period project. The following design model represents the current TrakPoint software structure.

Beyond the design and construction of the integration software / application the design effort focused on defining the following system components / functionality.

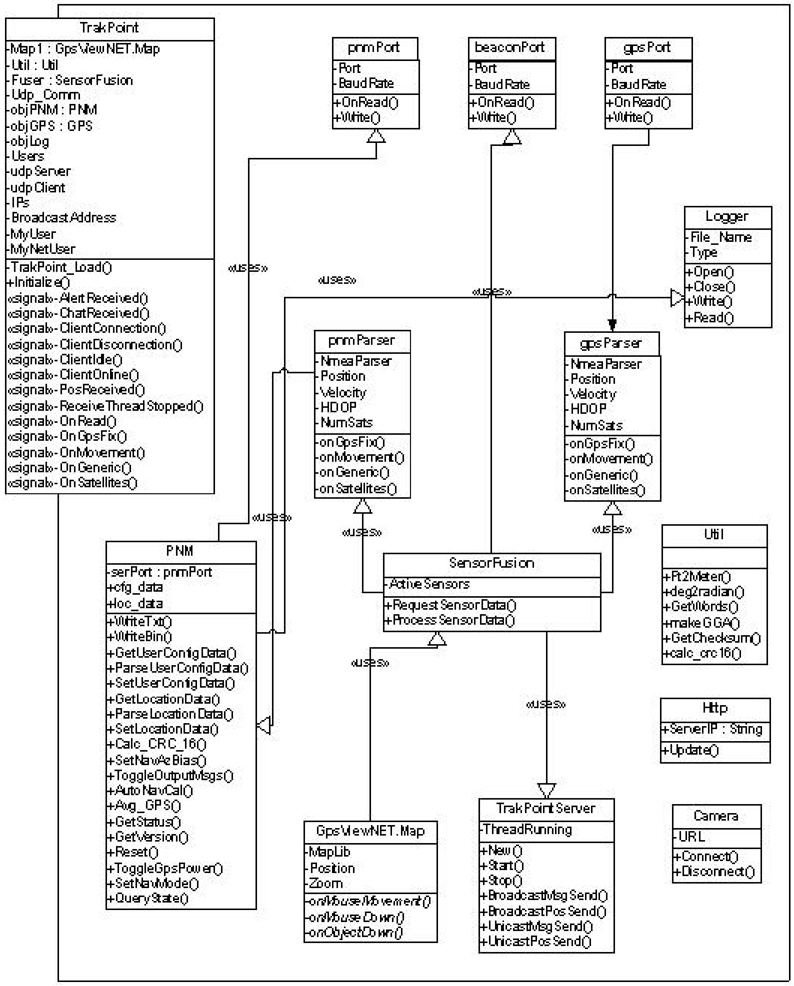

Figure 6 - UML Class Diagram

3.4.2 Client Server Architecture

The Client/Server architecture is required to support communications and data sharing between the mobile system users and with the C2 command post resources. The architecture is an Occasionally Connected Computing (OCC) environment with User Datagram Protocol (UDP) socket connections and a web service layer. Chat messages, position updates and alerts are transmitted and received over UDP socket connections, while authentication and incident data updates (i.e. – Assets, Tracks, Waypoints and Personnel) are available via the TrakPoint Web Service layer. The UDP service can operate in broadcast or multicast mode – this is an important functionality as some network hardware does not support broadcast messages. Once a user authenticates via the Web Service layer, activates the UDP service and begins to transmit chat messages and/or position updates, the TrakPoint UDP service will auto-detect any available users on the network and allow data exchange to occur amongst them. The following diagram indicates the final client server architecture.

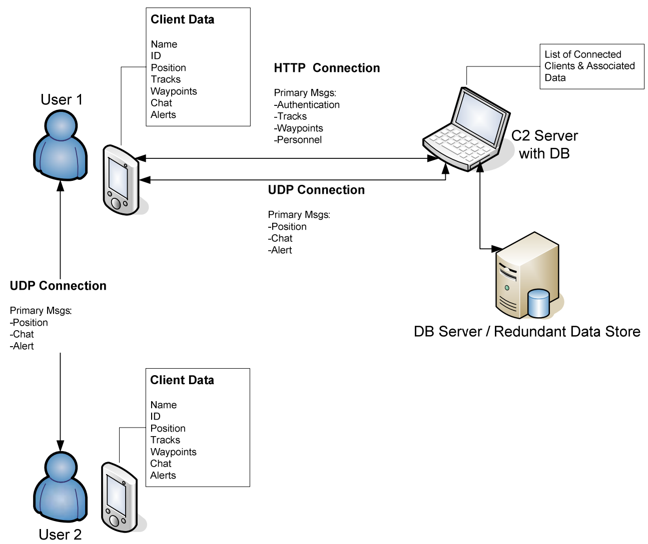

Figure 7 - ATNS /TrakPoint UDP Network Topology

3.4.3 Data Logging

In order to save and replay navigation data a logging mechanism was designed and integrated into the TrakPoint application and database server. The design allows the user to designate which data elements will be captured for record and playback activities via the TrakPoint UI. In addition the system automatically stores each location data point for a given user track in the database for use in playback activities. The user can also elect to save a given completed navigation track as an ESRI Shapefile for retrieval / display on a given map. The data that can be captured includes the following data elements:

- GPS NMEA-0183 GGA and RMC sentences
- PNM Compass Data
- PNM Gyroscope Data
- PNM Pressure Data

3.4.4 Map Specifications

In order to display mobile user navigation tracks in absolute or relative coordinates a common map needs to be used by all resources on the ATNS system. To that end TrakPoint was designed to support both Vector and Raster maps. The Vector maps allow the user to draw of polygons or poly-lines and supports loading, displaying, saving and managing ESRI Shapefiles. The Raster map support allows the user to draw and display icons, shapes, ellipses, and text on the map using geographic coordinates.

3.4.4.1 Map Configuration

Maps created in Graphics Interchange Format files (.GIF) or Bitmap (.BMP) file formats can be loaded into TrakPoint post calibration. Three (3) known GPS positions are required to calibrate the map files. The Franson GPS Tools Studio application, a map configuration tool, is currently being utilized to calibrate maps for use by TrakPoint. The resulting, calibrated map file is saved as a Map Library with the .MapLib extension. Multiple image files can be saved in a single Map Library, for instance the system user can have various views of a single facility, varied zoom level images and all will be accessible from a single Map Lib file.

3.4.4.2 Supported Map Grids

As part of the calibration activities the TrakPoint application can support all of the following map projections: AUSTRIAN_GRID_M28, AUSTRIAN_GRID_M31, AUSTRIAN_GRID_M34, BELGIUM_GRID, BRITISH_GRID, DHDN, DUTCH_GRID, FINNISH_GRID_ZONE_1, FINNISH_GRID_ZONE_2, FINNISH_GRID_ZONE_3, FINNISH_GRID_ZONE_4, FRENCH_GRID_RGF_93, FRENCH_GRID_ZONE_1, FRENCH_GRID_ZONE_2, FRENCH_GRID_ZONE_3, FRENCH_GRID_ZONE_4, FRENCH_GRID_ZONE_2_ETENDU, FRENCH_GRID_GRAND_CHAMP , IRISH_GRID, ITALIAN_GRID_ZONE_1, ITALIAN_GRID_ZONE_2, LUXEMBOURG_GRID, NORWEGIAN_GRID_ZONE_1, NORWEGIAN_GRID_ZONE_2, NORWEGIAN_GRID_ZONE_3, NORWEGIAN_GRID_ZONE_4, NORWEGIAN_GRID_ZONE_5, NORWEGIAN_GRID_ZONE_6, NORWEGIAN_GRID_ZONE_7, NORWEGIAN_GRID_ZONE_8, NZMG, NZTM, SPCS_27, SPCS_83, SWEDISH_GRID, SWISS_GRID, SWISS_GRID_LV95, SYSTEM_34, SYSTEM_45 , UTM, UTM_AMG_84, UTM_ED_50, UTM_ED_50, UTM_ED_50, UTM_ED_50, UTM_ED_50, UTM_ED_50, UTM_ED_50_DENMARK, UTM_ETRS_89, UTM_ETRS_89, UTM_ETRS_89, UTM_ETRS_89, UTM_ETRS_89, UTM_MGA_94, UTM_NAD_27, UTM_NAD_83, UTM_NORTH, UTM_NORTH, UTM_NORTH, UTM_NORTH, and UTM_SOUTH.

3.4.4.3 Map Features

The following map features were also designed for the TrakPoint UI, these features allow ATNS system users the capability to change the way information is displayed on the Map region of the UI.

- **Pan** - the user can pan the map in any direction via the available controls.
- **Zoom** - the user can the map magnification zoom in and out via the available controls.
- **Add Item** – the user can add Assets and Waypoints to the map. If the user is an Admin running the C2 application, they are also able to add Personnel.
- **Measure Distance** – the user can continuously measure distances by clicking several locations on the map.
- **Send Message** – the user can click on a personnel icon and load their user name in the chat "Send To" drop-down box to facilitate transmission of messages.
- **Get Info** – the user can click on a map icon and get name and ID information for the selected item.
- **Set Start Position** – the user can click on a location on the map and the position information for that location will be loaded into the PNM start position fields.
- **Correct Position** – the user can click on a location on the map while in PNM navigation mode to update the PNM's position to the selected location.
- **Bearing To** - the user can click on two map icons and get the bearing from the first item selected to the second item selected.
- **Go To Location** - the user can enter the coordinates of a particular location and the map will center on that location.
- Map Layers (Drawing, Personnel, My Track, Personnel Tracks, Assets, Waypoints, and Imported Tracks).
  - **Toggle** – the user can toggle on/off a particular shape layer on the display interface.
  - **Clear** – the user can clear a particular shape layer from the display interface.

3.4.5 ESRI Shapefiles

TrakPoint was designed to support importing and exporting ESRI shapefiles. A Shapefile object can be used for many purposes:

- As a container for GPS coordinates. For example, when saving a track.
- To draw polygons, poly-lines and multi-points on a map.
- To act as a map.
- To make GIS calculations such as distance measurements, bearing calculations, etc...

3.4.6 Development Tools and Platform Deployment Considerations

The development tools implemented along with all the components utilized in the ATNS Program result in a Spatial Situational Awareness system that can be easily adapted to almost any operating system or environment, especially those related to PDA's.

The 1st tier (Mobile Client Application) and 2nd tier (C2 Base Station Application) were developed using the Visual Basic.NET language available within the Visual Studio 2003 and Visual Studio 2005 Integrated Development Environment (IDE). This was mainly due to the "code once, deploy anywhere" functionality of the associated .NET 1.1 and 2.0 frameworks. These frameworks also met the necessary demands of rapid application development, near real-time performance, and low memory consumption.

A simple, small, open-source, database component (MySQL 4.1.13), web service component (Apache 2.0.54) and database web management component (phpMyAdmin 2.6.3-pl1) packaged within the XAMPP 1.4.15 distribution/control panel, were the chosen tools to cover the performance and scalability demands associated with the various database/management tiers.

3.4.7 ATNS Component Breakdown

The ATNS program included the evaluation of various system components. Therefore the construction of the TrakPoint integration software open architecture Application Interface (API) had to be robust enough to all integration with various system components.

The diagram below indicates the various system components that were integrated into or which are targeted for future evaluation / integration.

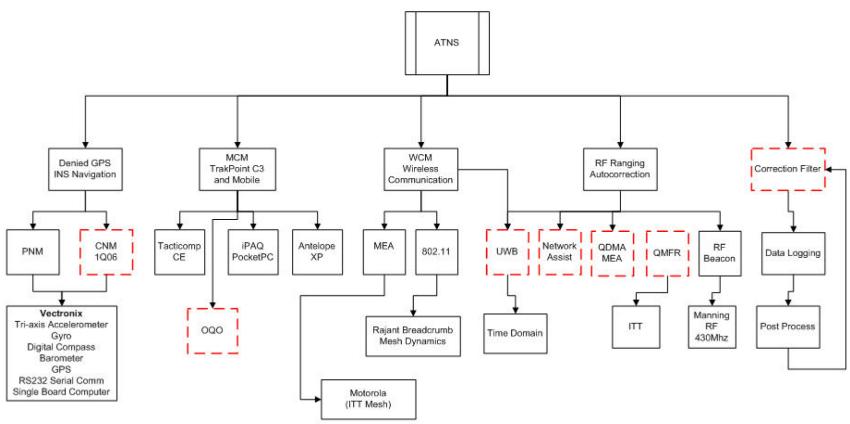

Figure 8 - ATNS Component Breakdown

3.4.8 System Topology Overview

The final system architecture is represented in the diagram below. The diagram includes the use of RF Beacons in lieu of a functional RF ranging module / remote position location tracking device.

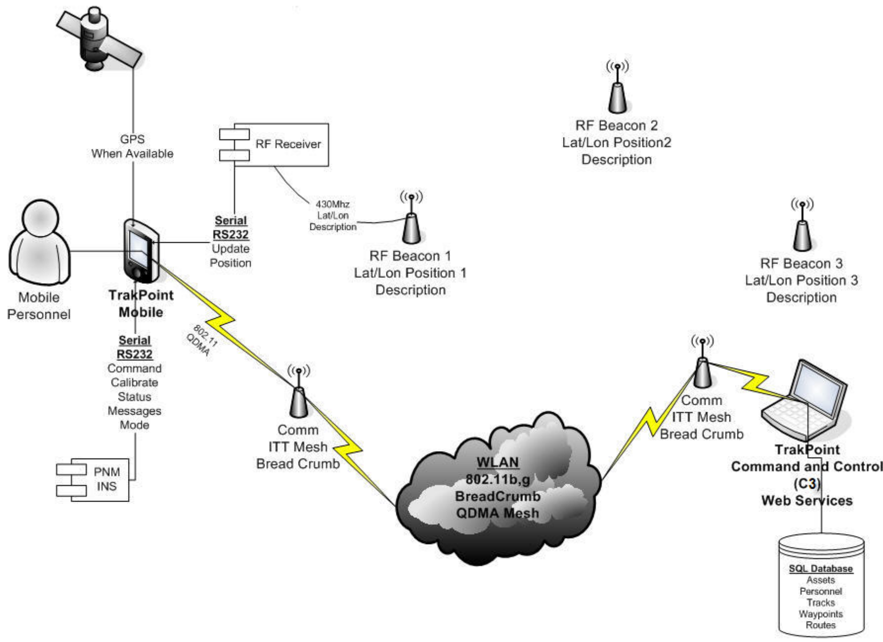

Figure 9: ATNS System Topology

3.4.9 TrakPoint Pocket PC / PDA User Interface

A version of the TrakPoint application was developed and deployed to an HP iPAQ PDA. This activity was initiated to reduce the size and processing power of the MCM required to support the ATNS program. See the images in Figure 2 for a view of the PDA UI. The minimum OS requirements for use of the TrakPoint on a PDA platform are WinCE 4.21 with Compact Framework 2.0 or newer / equivalent OS.

3.4.10 TrakPoint XP / C2 User Interface

Additional functionality is present on the XP version of TrakPoint for the C2 user as shown below. The C2 user has administrative access to the database server and associated data. The system user administration functionality has to be conducted at the database interface level using the Apache XAMPP user interface. See the Figure below for a current view of the TrakPoint XP UI. The Figure provides a view with a global map, user specified waypoints, and assets on the map. The message and mission data / configuration segments of the UI are also displayed. Across the top of the map area you can see the map options listed in section 3.4.4.3. There is a "Cameras" tab at the top of the UI that can be utilized to toggle between the map and video UI panels. MDS successfully integrated the use of web based cameras for viewing operating areas, when they are available.

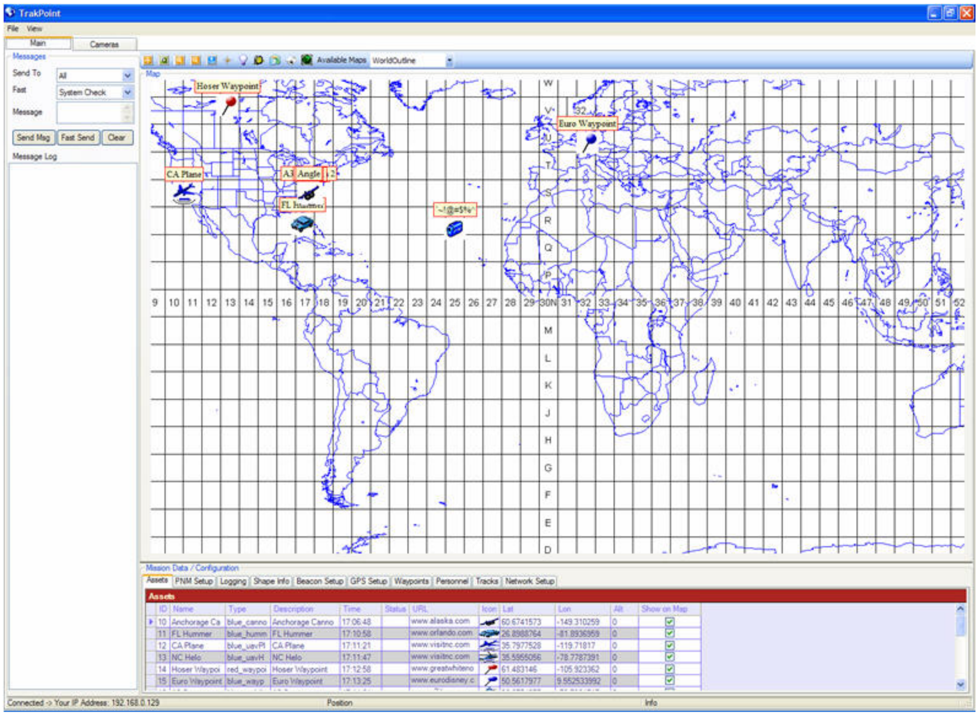

Figure 10 - TrakPointXP Main Screen

3.5 Physiological Status Monitor Interface

The TrakPoint application was modified post completion of the ATNS project to support functionality required by the first responder / fire fighter community. A physiological status monitor called the LifeShirt 300S from Vivometrics Government Sciences Division was integrated with the TrakPoint user interface to display user status including:

- Respiration
- Heart Rate
- Activity
- Posture (Vertical or Horizontal position)
- Skin Temperature

The system is supported by a lightweight (215 grams) chest strap with embedded sensors , the output of these sensors were ported to the TrakPoint system processor and the individual user physiological data is displayed in directory format in the lower left hand corner of the main screen below the Message Log (see Figure 11). This technology is currently under evaluation by the US Air Force FLARE program and Walter Reed Army Institute of Research for use in military applications.

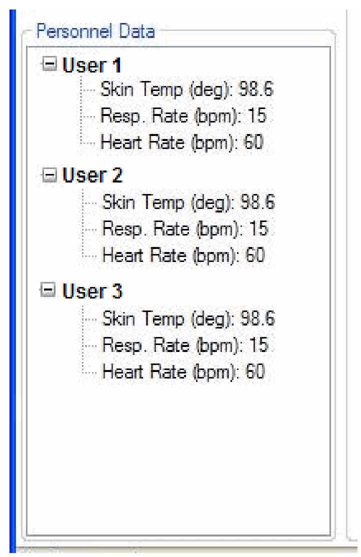

Figure 11 - Physiological Data Display

3.6 Modes of operation for the current system or situation

There are two basic modes of operation for the TrakPoint / ATNS system, calibration mode and navigation mode.

3.6.1 Calibration Mode

A) The Calibration mode is utilized to ensure the PNM accuracy based on several factors including:
- User starting / current position.
- User step length, based on a standard mobility model correlated to user height.
- Azimuth (Dead Reckoning) or alignment of the sensor to the user's spine relative to the location of the unit on the user's body. This calibration is used to determine the offset between the direction a person is facing and the direction the PNM is pointing.
- Area of operation magnetic declination, this calibration is used to determine the offset between magnetic north and true north based on the current user's geospatial location.

B) The PNM Setup UI Panel allows the user to manually enter data required to calibrate the INS/PNM prior to using the unit to track their navigation path. The data entry required for calibration includes:
- Starting position Latitude, Longitude and Altitude, note these fields can be populated manually or via selection of the correct position map option and then touching the map on your current coordinates. When the GPS Receiver is connected and the user is in an area with GPS reception this data is automatically populated.
- User height, in meters, once entered this data remains in place until the application is stopped or restarted.
- AZ or azimuth bias – this value can be entered manually if the value is known from prior calibration tasks, if not the user can utilize the "DR Calibration" PNM command.
- Declination – if the declination of the area of operation is known the user can manually enter this data, if it is not known the user can auto-calibrate their unit by using a compass, facing north and enabling the GPS Calibration PNM command. This calibration is required when using the INS only; if a GPS with active reception is available and that unit has a build in declination adjustment the correction will not be required.

3.6.2 Navigation Mode

The navigation mode can be supported by either the INS only, the GPS receiver only or a combination of both sensors. After the user has calibrated the unit it can be switched into Navigation mode by enabling the "Go" PNM command. Once enable the user position will be updated on the mobile PDA interface and the C2 user interface once every second. Position errors can be corrected and other tasks can be completed via the use of the various map features previously described.

3.7 User classes and other involved personnel

There are two user classes in conjunction with the TrakPoint system, C2 admin, personnel and a technical support or logistics super user.

3.7.1 Profiles of user classes

A) Personnel User Class – this user class has permissions for all system functionality with the exception of adding system users on the mobile user interface. Further these users have access to the add item feature for adding assets and / or waypoints to the map locally, this data is not shared with rest of the mobile users.

If the user is operating using a PDA or CE version of the application the functionality is reduced slightly from that available on the XP version of the application. The XP version can be run on mobile computer modules with the appropriate operating system. The privileges are listed below by device.

The full list of Personnel User Class privileges includes access to:

- Navigation / Map Features – Pan, Go To, Zoom In/Out, Add Item (with previously described limitations), Set Position, Correct Position, Message Distance, Text Messaging, Get Info and Bearing To.

- Mission Data/Configuration Data; Assets, Logging, Shape Info, Waypoints, Personnel, and Tracks.
- Mission Data/Configuration Setup; PNM Setup, Beacon Setup, GPS Setup, and Network Setup.
- Menu Options – File-> Connect / Disconnect Server, Load, Import and Export files; View-> Moving Map, Layers-> Toggle On/Off and Clear, Position As, and Add-Ins.

B) C2 Admin User Class – this user class has the same permission set as the Personnel user with the addition of the ability to add system users/userids and access to the system database and corresponding data sets. The C2 admin user class can utilize their permission set to administer the userids and to specify user privileges / class specification.

3.7.2 Interactions among user classes

The C2 Admin users and the mobile personnel can interact in a variety of ways. The C2 user can add waypoint and assets data which can then be shared will all mobile users on the same network that are connected to the TrakPoint database.

Both user classes can interact via the use of the text messaging feature, with the ability to send canned or typed text messages to the entire group or to a given individual.

3.7.3 Other involved personnel

Logistics Support / Super User – These are technical support resources that deploy and maintain the TrakPoint application on the various computer / PDA user modules. They are responsible for installation of the system software, setup, administration, and maintenance of the PHP database.

4. Justification for and nature of changes

This section of the ConOps document describes issues with the current system and requirements from the NAVGPSDE project that motivates development of the new / proposed system.

4.1 Justification for changes

The needs specified in the ONR BAA differ slightly from those in the ATNS project scope; this is the primary justification for the proposed system changes. In addition to ONR project needs the system that was produced by the ATNS project had limitations that were not overcome during the project. Feedback from our NPS end user test group identified improvement opportunities as well. These changes / limitations / improvements include but are not limited to the following:

- The ATNS system design utilizes QDMA Mesh network gear which operates within the 802.11 (2.4 MHz) space for communications / transfer of data to the C2 workstation. The ONR project requires the system to provide an interface with a Military Radio that provides connectivity for data transfer to the C2 location.
- The current ATNS system does not provide for security / encryption of data, the ONR project requires that the data communication equipment meet the NSA Suite B security requirements.
- Human Factors –
    - ATNS Hardware - multiple components were utilized with wired connections between each, system was bulky and cumbersome to use; the ONR project requires the components be housed in a single unit that does not burden the deployed forces.
    - The ATNS User Interface (UI) was based on a PDA with a full operating system and multiple functions; the system also requires user input for calibration and for system maintenance; The ONR project requires a simplified display device that requires little to no user interaction and/or training.

- The ATNS system UI requires the use of a stylus/touch screen for data entry, or menu option selection, when gloves are worn by the user the current design interface is cumbersome. The ONR project specifies the controls should be operable by a user wearing gloves.
- The ATNS UI hardware display was not adjustable for viewing in direct sunlight and not viewable with Night Vision Goggles (NVG). The ONR project components should be compatible with both based on BAA FAQs.

- The ATNS system operational battery life does not meet minimum operation duration requirements of the ONR project.
- The ATNS system INS accuracy drift over time / distance traveled does not meet ONR project requirements for position accuracy over the 8 hours of operation and the 10 km navigation range.
- The ATNS system utilized the INS as the primary component for tracking user movement and to provide position data in the absence of GPS, the ONR project requires that the new system be able to fuse multiple references and utilize auxiliary data sources to generate position information.
- The RFRM hardware components analyzed for the ATNS project were unable to provide accurate range data, the RFRM component is required to enable the INS accuracy drift to be overcome and therefore a reliable RF Ranging component is required for application in the ONR project.
- The hardware selected for the ATNS project is only operational in scenarios where the user is walking, the proposed system for the ONR project will have to be able to handle all types of human mobility (running, crawling, jogging, etc…)
- The network communications gear selected to support the ATNS project did not provide the necessary data communications range (2km) required by ONR.
- The system topology required a client server network configuration supported by a database to provide voice and data communications between mobile users. The ONR project requires a more robust and mobile approach including the use of peer to peer networking for position data and text communications.

4.2 Description of desired changes

This section summarizes new or modified capabilities, functions, processes, interfaces, and other changes needed to respond to the factors identified in section 4.1.

4.2.1 Capability Changes

The proposed design for the ONR system includes the addition or modification of the following capabilities:

- **Fusion of multiple sensor data output** – via the use of principle component analysis, the data output by each component in the INS/IMU can be interpreted, verified or complimented by data from the Velocimeter and TOA Ranging system sensors. This fused data will allow the system to overcome the limitations of the individual components, when supported by Kalman Filtering and Predictive Modeling the system output provides a more accurate position estimate which can be sustained over a longer period of time or distance traveled. “PosiFusion” is the term MDS uses to describe this process.
- **RF Time of Arrival (TOA) Ranging** – this capability will enable the proposed system to overcome the distance accuracy issues inherent in all INS/IMU components; the data from this component will also support principle component data analysis to ensure the data utilized generates the most accurate position estimates possible.
- **Velocimeter –** this sensor will enable the new system to utilize secondary data to verify and compliment the output of the INS/IMU accelerometer to support the principle component analysis calculations.

- **Communications Security** – the proposed system will be operating in environments where non-friendly forces will make every attempt to capture and decipher intelligence transmitted via RF signals. With the addition of TRANSEC capabilities the threats present on the battlefield can be mitigated.
- **Kalman Filtering** – this capability will be a part of the PosiFusion processing to aid in correction of erroneous data spikes that can occur in situations where magnetic fields or environmental anomalies generate false sensor readings. The filtering provides a predictive model based on historical user movement data to help identify and override these anomalous events.
- **Assisted GPS & Differential GPS** – this functionality is present on the GPS & INS pre-processor component of the proposed system; it enables the system to reduce GPS signal errors and acquisition time in environments where GPS data is available and overcome the limitations to GPS signal acquisition in environments where GPS data access is limited.
- **User interface type and features** – the existing system interface provides too many options / features and requires too much user input to support the hands free operation of the system. The proposed system will reduce the interface features to the bare minimum required to support the system end user while providing the data specified in the BAA.
- **Accurate tracking on varied mobility modes –** the majority of the INS/IMU sensors on the market have an inherent issue with accuracy over varied mobility modes due to the fact that the calibrations are performed or modeled on walking motion only. The addition of the new system sensors, principle component analysis, helmert calibration, predictive modeling/filtering and the fusion of data from these sensors will enable the system to overcome the mobility limitations inherent within the INS/IMU products.
- **Support for use of auxiliary data sources including Pseudolites and LORADD** – the auxiliary data sources can aid the system accuracy by providing access to absolute data or reference points into the area of operations where and when GPS signals are not normally accessible.

4.2.2 System Processing Changes

The system processing changes include the movement of processing from a laptop PC or micro computer device such as a PDA to a Single Board Computer (SBC). The SBC will be responsible for merging data from the system sensor devices, and generation of data output to a visual display unit and for transmission of data to C2 via a standard military radio interface.

Previously the ATNS system integration software was built as an application that operated on the Windows XP and CE operating systems. The ONR project integration software will be Linux based and will operate at the processor level as firmware with embedded processing algorithms required for this system.

4.2.3 Interface Changes

For the proposed system design, the number of external interfaces required will be reduced due to the single component housing design. The system interfaces will include internal data processing and sensor component control by a single board computer, the external interfaces will include a connection to the UI display component and a port for use by a military radio for transmission of data from the clique to C2 and for admin user configuration. See the next section for details on the system interface design.

4.2.4 Personnel Changes

For the ONR proposed system there will be a single user class, the user system nodes will all contain the same functionality and will therefore be interoperable for each member of the clique. The State Vector Table will be utilized to configure the mode of operation for each unit during the mission based on which clique member will be wearing the unit and what function the unit will support. The hierarchy (rank) of the personnel within the clique will be used as a way to determine localization logic and in some cases to determine or identify the ranging partners or nodes that will support the TOA ranging capability.

4.2.5 Environment Changes

There will be no changes to the operational environment for this product. The BAA project system will function in areas where GPS is partially or completely unavailable including; urban terrain, thick forests, or jungles where buildings and trees limit satellite visibility; operations underground or inside buildings prevent all satellite visibility and hamper RF signals.

4.2.6 Operational Changes

Operational changes include the reduction in the user interaction required to calibrate the system, to enable the system to just work when the dismounted soldiers are deployed in the area of operation. There are no operational changes required from the user community; rather, this system will support the standard operating procedures / practices currently in use the by the USMC resources.

4.2.7 Support Changes

No support changes are required by the proposed system as far as support resources are concerned. Additional system position identification and navigation support will be provided by signals of opportunity as auxiliary position data sources.

4.3 Priorities among changes

This section provides a list of the changes required by the ONR BAA description and their associated priority levels.

4.3.1 Desired Capabilities

The following capabilities are essential to the system operation / performance. Each one of the following items will be addressed within the concept of operations as well as the requirements and technical specifications. These capabilities will be the primary focus of the Phase1 Analysis and Design efforts.

1) The system should not burden the deployed forces in either volume or mass.
2) The system should "just work" requiring minimal-to-no training for operation.
3) The system should be prepared to operate in a GPS-limited or GPS-denied environment.
4) The system should operate in open spaces as well as underground or cave-like settings.
5) The system should provide for the fusion of multiple references in order to provide location information.
6) The system should provide for auxiliary data sources/beacons for location information.
7) The system should provide for auxiliary data relays when in an underground or cave like setting.
8) The system should provide for information security during data transfer consistent with the NSA Suite B (http://www.nsa.gov/ia/industry/crypto_suite_b.cfm).
9) The system should acknowledge when it is operating in a degraded information mode.
10) The system should provide for a limited/text-based data transfer from tracked/remote nodes.
11) The system shall provide for operation of 100m into underground or cave-like environments (use of up to three relays is permissible).
12) The system must provide a standard military radio interface (mechanical, electrical, data).

13) If relays are used as part of the system solution, said relays should be disposable and spoofing and tamper resistant.

4.3.2 Goals

The following features are desired in order to make the system wearable, and cost effective. The primary concern of these features are for size, weight and price (SWAP). These items are defined as criteria for the system's final form factor that will have to be realized as part of the Phase II prototype product development efforts and the system productization. These features will be finalized as part of the Phase II detailed design description and each item will be addressed in the concept of operations as well as the requirements and technical specifications. The final form factor productization plan will provide details on how these items will be accomplished longer term. These goals will be a secondary focus of the Phase1 Analysis and Design efforts; achievement of the goals will be based on the SWAP available COTS technology / products and a cost verses performance analysis for the available components.

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

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

3) Projected production cost per unit in quantity of 1000 shall be $2k or less.

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

5) Volume of each unit shall be 400 cm^3 or less.

6) A minimum of five units are to be produced and delivered in Phase 2.

4.3.3 Optional Capabilities

There are no optional capabilities specified in the BAA.

4.4 Changes considered but not included

The following sensors are considered to be devices that support state of the art solutions for Pedestrian Navigation or GPS denied tracking systems, the use of these components were considered for inclusion in the proposed system but were not incorporated due to the issue(s) listed.

- Gait Recognition Aids (Pedometry)
  - Scale factor change from variation in terrain, load, body size, fatigue
- Optical Navigation Aids (range finder, optical flow, object/landmark recognition & tracking)
  - Visual clutter or lack of features
  - Low light / smoke visibility
  - Clothing / body interference
  - Cost

4.5 Assumptions and constraints

The following assumptions and/or constraints were utilized in development of the proposed system design.

4.5.1 Assumptions

The assumptions listed below include items derived from the BAA, responses to the BAA FAQs and items identified during the analysis and design efforts of the proposed system:

- The Marine Corp Units utilizing the system are following the "Rule of Three" structure. In a nutshell, the rule is this: each Marine has three things to consider:

    - 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 Lieutenant. Three rifle platoons to a company commanded by a Captain. Three companies to a battalion commanded by a Lt Colonel, etcetera.
- The USMC Recon and Marine Expeditionary Rifle Squad units 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.
- As part of the mission planning activity, the dismounted soldiers will be assigned mission roles to include security, assault and support or reserve roles. These roles will be assigned at the Platoon, Squad or Fire Team level based on the number and type of resources required to support each role.
- The dismounted soldiers will follow the procedures listed in the Field Manuals that define the operational tactics in the Military Operations on Urbanized Terrain (MOUT), Ground Combat Operations, Marine Rifle Company/Platoon, Scouting and Patrolling arenas.
- The absolute position is determined through some method at the beginning of the 8 hour operational period.
- The absolute coordinate structure will be maintained throughout the 8 hour operation timeframe.
- All systems within a given clique or operating environment utilize a common time mark or UTC time value, systems will need to be calibrated or synchronized in the field.
- The area of coverage in which the clique operates is assumed to be one kilometer radius.
- The relays are assumed to be within RF range of the clique members.
- The operation of 100m into underground or cave-like environments requirement means 100m linear distance into a cave, or similar environments.
- The standard military radio Ethernet interface will be sufficient.
- The dismounted soldiers will move by human locomotion (walking, running, jogging, crawling, etc…) only during the entire 8 hour period within a 10km radius with a 50%-moving/50%-static mode during navigation.
- The soldier may be transported to the area of operations via land, sea, or air transport.
- The maximum number of relays used is three (3), if said relays are necessary.
- Bi-directional transfer of textual information will be utilized for transmission of data between members of the clique or from clique leaders to all of or a subset of the clique.
- The SEP accuracy of 25m is desired at the 95% probability level.
- A simple 2D graphical display is sufficient as long as altitude data is available for the node positions.
- The communication links (for data transfer) between nodes incorporates the NSA Suite B security standard.
- The system components will be employed and is required to operate in a wide variety of environments including:
    - Urban areas
    - Heavily forested areas
    - Jungles
    - Underground
    - Cave-like structures
    - Inside Buildings
- The communications system will not be concerned with GPS-jamming.

- 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.
- A military radio will be available to at least one member in the clique; the CMR will be utilized to provide the military radio interface for our proposed solution.
- Access to the military radio is provided so that node/clique positions can be transmitted to higher headquarters (C2) – the platoon leader will send data to the C2 location.
- Preference will be given to three dimensional (3D) position locations with fallback to a two dimensional (2D) position location.
- 50 will be the maximum number of nodes in a single clique (includes warfighters, beacons, relays, etc.).
- 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).
- Admin processing will be required prior to fielding the system for a given mission:
    - Each system will have a unique ID that can be used to identify and communicate with that system.
    - A table of "neighbors" or ranging partners (p/o the SVT table) will be setup via an admin interface / processes prior to deploying the system to the field. Max number of ranging partners will be 10, min number = 3.
    - A Relative Coordinate System focal node will have to be established for each ranging partner group, lowest level is the Fire Team lead resource. The focal node selection will be based on the position accuracy and/or signal strength.
- In order to achieve/maintain the relative position accuracy requirement:
    - At least three (3) members of the clique will operate within the RF position sensor's range.
    - Only legged motion (e.g. walking, running, climbing, etc.) is exercised when the system is relying on the INS sensor alone for position tracking (infers that GPS is unavailable/unreliable and RF Non-LOS conditions exist).
    - Auxiliary data sources may be utilized.
    - The user will be able to manually reset their position via the use of visual landmarks and the system map interface.
- Visualization Design Assumptions:
    - The primary user interface will be based on the RBCI UI design; the RBCI UI entails displaying user position on a blank or map layer background with 3 concentric circles, the outer circle indicating 1.5 times the maximum effective range of the end user's weapon systems. The maximum effective range that will be displayed is 3,000 meters based on the M2 weapon range. The UI will also provide a map scale to support distance estimates.
    - ADRG/CADRG and Satellite maps will be used for mission planning and these maps will provide accurate localization of landmarks and other points of interest during mission operation.
    - Personnel will be able to localize their positions using manual methods to pinpoint their location relative to landmarks and points of interest on the maps
    - Figure of Merit is a standard way to display or track system accuracy, FOM will be utilized along with an associated value to display the accuracy of the system position data along with the network health/connectivity status.

4.5.2 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^3 (24.4 in^3) or less, not including battery;
- If required no more than 3 relays can be utilized to support operation in underground or cave like environments; and
- The system may not have access to GPS during the 8 hour period.

4.6 Concepts for the Proposed System

The ONR project phase 1 efforts primarily addressed the analysis of available technologies, commercial off the shelf (COTS) products, and studies on algorithms required to merge data from various sensors to enable the system to overcome the limitations of the INS component. The analysis effort was accomplished to identify which components would meet the technical requirements stated in the BAA and provided a high level design of the software algorithms / processing required to integrate data from each sensor generating an accurate position value. To that end the proposed system will be comprised of:

- A simplified user interface.
- Minimum set of hardware / software required to produce an accurate position data set for the local system user(s).
- A self-generating, self-healing, ad-hoc network for distribution of the position data to the other members of the clique.
- An interface to a military radio for distribution of the position data for all clique members to the C2 location to aid in battlefield situational awareness.
- All sensors required to provide accurate position data.
- Microcomputer hardware and software to merge the sensor data, generate a visual display for the user, and output data for transfer across the network for communications between clique members or the C2 location.

4.7 Background, objectives, and scope

The ONR project is specifically targeted to significantly improve the ability of Expeditionary Forces to navigate in areas where signals from GPS are weak or blocked. GPS denial may occur in urban terrain, thick forests or jungles where buildings and trees limit satellite visibility. Operations within buildings or underground prevent the ability to access GPS satellites and hamper RF communications.

The objective of the proposed system should enable the dismounted soldier to locate their position without the use of GPS, provide a means to show relative position data to other team members, provide all team members with the ability to share this information among networked forces including other teams, adjacent units or headquarters personnel.

The scope of the Phase 1 effort of this project is to analyze the current capabilities of COTS products, determine what is required to integrate these products; and define enhancements that improve system performance and operational capabilities to produce a system that is reliable and that meets the requirements stated in the BAA. The Phase 1 effort is 7 months in duration and the deliverables include system requirements, operational requirements, and a high level design. Post review of the Phase 1 deliverables the ONR project office will down select vendors to participate in Phase 2, detailed design and prototype construction efforts. The final system should be ready for use by the USMC during FY08.

4.8 Operational policies and constraints

There following operational policies or constraints are based on the proposed system design, or hardware limitations;

- The maximum number of clique members supported by a single network island is 50;
- The maximum number of cliques that can be supported by the network is 50 or a total of 2500 nodes;
- The maximum range between TOA Ranging partners will be based on the height of the system antenna, signal HDOP value, depth of foliage in the Area of Operation (AO) and the CMR output power (see Figure 12 for details on system accuracy); and
- The system shall will take 30 - 60 seconds to initialize in the absence of absolute position data, when absolute data is available the system will take less than 30 seconds to initialize.

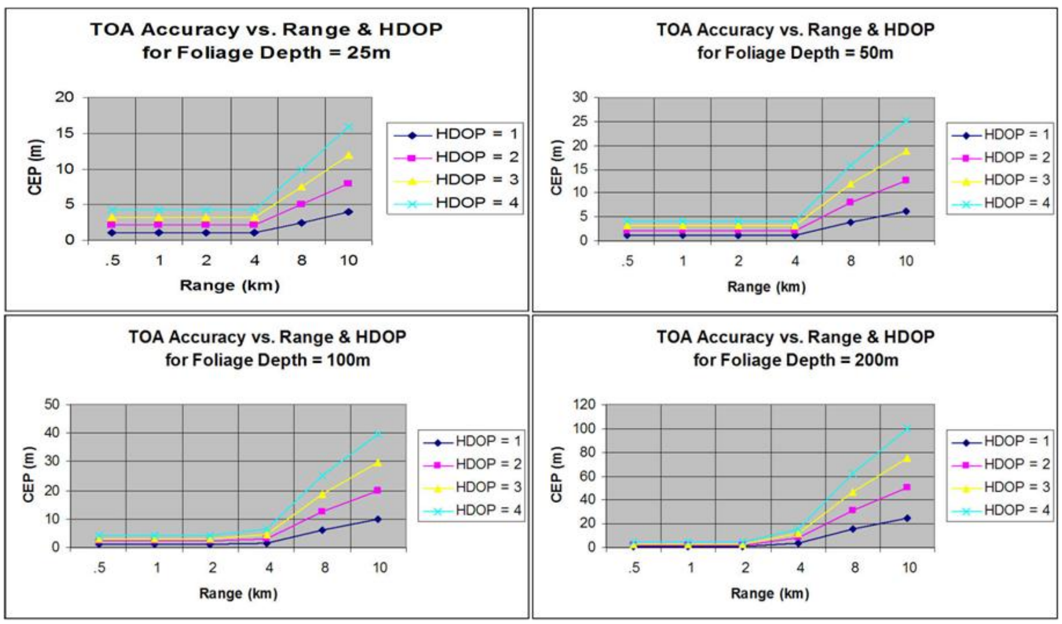

Figure 12 - TOA Range Accuracy vs. HDOP and Foliage Depth

Note: The plots show TOA location accuracy versus range, HDOP, and foliage depth. The TOA application is used to determine horizontal position by performing RF ranging, with TOA measurement, to two (2) references with an associated HDOP (assumed here to be from 1 – 4). Foliage attenuates the signal as a function of depth and the foliage isn't necessarily contiguous, for example, 100m of foliage could be spread over a 2km range. Note that best achievable TOA accuracy of approximately 1.5ns (estimated) limits CEP at the closest ranges, for example ≤ 4km range in the first chart (Foliage Depth = 25m).

4.9 Description of the proposed system

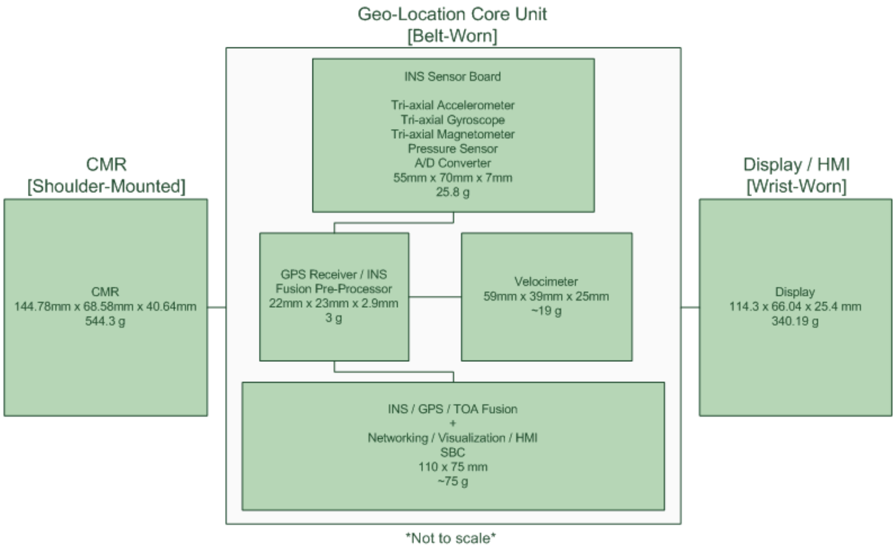

Figure 13 - Proposed System Components

The basic NAVGPSDE System design will integrate the following components:

- Geo-Location Core Unit or Inertial Navigation System (INS) including:
    - Inertial Navigation System (INS) Sensor Board including the following components;
        - → Tri-axial Accelerometer;
        - → Tri-axial Gyroscope;
        - → Tri-axial Magnetometer;
        - → Pressure Sensor / Barometer; and
        - → Analog to Digital Converter.
    - High Performance Commercial GPS Receiver / INS Fusion pre-processor;
    - Velocimeter;
    - General Purpose Processor and Peripheral Single Board Computer (SBC) to fuse INS, GPS, RF TOA and auxiliary data based position estimates; provide networking support; and a Human Machine Interface (HMI) for the visual display unit;
    - External GPS antenna and CMR connections;
    - External Battery connection;
    - External Visual Display Unit connection;
    - External Military Radio Interface connection; and
    - System On/Off and Kill switches.
- Clique Member Radio (CMR) – a Multi-band Software Defined Radio (SDR) to:
    - Enable network formation, connectivity and transmission; and
    - Provide RF range based position estimates (TOA/QMFR).
- Visual Display Unit with Integrated Operator Controls.

When GPS is available and accurate, the NAVGPSDE System will primarily identify the GPS signal as the most accurate position estimate, and the system will automatically calibrate the INS and TOA based position estimates. When the availability or accuracy of the GPS signal declines, the system will automatically switch to a fused position estimate inferred from the INS and RF components – the INS will be automatically calibrated when the TOA based position estimate is within the required Spherical Error

Probable (SEP). The auxiliary data acquisition / transmission components can be mobile or stationary, perhaps placed in GPS enabled vehicles.

Primary position estimation will be performed by the INS when GPS is either inaccurate or unavailable and the RF based position estimate is unreliable. To maintain RF based position estimates in high multipath environments, the RF ranging packets will incorporate, Quadrature Multi Frequency Ranging (QMFR), which uses novel frequency hopping and leading edge curve fitting techniques to determine the frequency at which the multipath impact is minimized. The NAVGPSDE system will automatically intersperse RF ranging packets during network operation. The accuracy goal for the NAVGPSDE system is 3m SEP in all environments.

The NAVGPSDE System will provide communications in multiple bands from 1.2MHz to 4.8MHz bandwidths and will operate up to 2km in the open field and up to 1km in urban areas. With data transfer capabilities of up to 2.6Mbps, the NAVGPSDE System will support various field data needs, including inter-clique position data and text messaging. The NAVGPSDE System will automatically form ad hoc networks; can be controlled via an integrated Human Machine Interface (HMI); and can also provide full function control via external HMI with a PDA/CDA or computer.

Our concept for the NAVGPSDE System is that it may be used with or without a user interface. When used without a user interface, the user will simply press the On/Off Button to start tracking and to conclude tracking. When the system is started, it will perform initialization and calibration processes including GPS acquisition, and initialization of the INS settings. As well, the embedded SDR will automatically establish network communications and determine its position relative to other mobile and/or fixed network systems, using TOA and QMFR techniques. The system will continuously fuse the independent position estimates and continuously/periodically transmit the fused 3D position estimate across the mobile network, where it will be parsed and displayed on a C2 console or any other authorized mobile computer. In this case, configuration of the NAVGPSDE System parameters, such as transmit rate, can be set via an administrative console. Remote configuration will be a future system enhancement; this functionality will not be present in the prototype systems.

When used with a user interface, the system will execute the same power on, initialization and calibration processes. The user can also manually set/reset their location at any time. In addition, the user will be able to integrate local maps, display other mobile personnel (id, location, group, etc…). Additionally, the user will be able to place/calibrate the 3D coordinates of beacons/repeaters and communicate with other mobile personnel. As a future enhancement the system will enable encrypted text/data communications using the IP based network. System configuration values, such as transmit rate and local maps can be set locally or via an administrative console.

The system will utilize auxiliary data sources to provide the ability to acquire absolute position reference data within the area of operation, these sources include:

- CMR Reference Data Points / Nodes
- Pseudolites
- Loran

Reference data points will be provided for use by the TOA ranging system from mission support vehicles and personnel that are within line of sight communication. These references will utilize the same hardware that is present on other clique members to provide a least mobile reference point or position data value for use in position triangulation / trilateration within the area of operations for mobile clique members.

4.9.1 Operational Environment

The system will be functional in open or forested terrain, urban areas, inside buildings and underground or cave like environments. The following images depict the operational environment(s) for the proposed system. The system will utilize the INS as the core navigation / position estimate data sources which will be supported by additional sensors. The sensor data will be analyzed and fused to provide the optimal position estimate accuracy. Further, the individual sensor device outputs will be used to calibrate the system when certain accuracy thresholds have been exceeded. The system will utilize signals of opportunity from supported auxiliary data source(s) accessible within the area of operation.

Figure 14 - Operational Environment

4.9.2 Major System Components

The components displayed in Figure 13 will form the core functionality of the NAVGPSDE system.

4.9.2.1 Geo-Location Core Unit

The Geo-Location Core Unit contains the core processing capability of the system with the following components housed in a single enclosure:

- INS Sensor Board / Vectronix DRC;
- GPS Receiver / INS Fusion Pre-Processor;
- Sonic Instruments RSS Radar Velocimeter; and
- INS / TOA / GPS Fusion, Networking, Visualization, and Human Machine Interface (HMI) Single Board Computer (SBC).

4.9.2.1.1 INS Sensor Board / Vectronix DRC

The INS Sensor Board is small (55mm x 70mm x 7mm) and costs less than $200. In addition, the board is highly adaptable to advancements in sensor technology. As higher performance MEMS become available, old components can be replaced without significant changes in the system design. The onboard sensors include a tri-axial accelerometer, tri-axial gyro, and tri-axial magnetometer sensor suite that form a 6-degree of freedom (DOF) Inertial Measurement Unit (IMU). The IMU will measure changes in mobility and orientation and will consist of high-performance sensors in order to reduce measurement drift. The sensor board also includes a pressure sensor (barometer), for determining relative altitude, and an analog-to-digital converter that will quantize the IMU sensor information. The bias drift errors which are common to all INS sensors will be addressed via sensor fusion algorithms managed by the iTrax03 GPS receiver / INS pre-processor and SBC components of the system. Although low-level I/O drivers have been developed for the Sensor Board to communicate with the GPS receiver / INS pre-processor, the device requires further integration efforts that will exceed the ONR phase II timeframe. For this reason, we will use the Vectronix Dead-Reckoning Computer (DRC) for the phase II prototype.

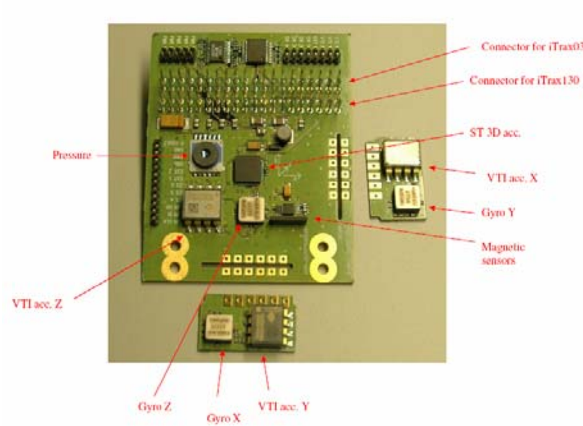

Figure 15 - INS Sensor Board

The DRC is small (49mm x 33mm x 13.5mm) and is currently in production and available for purchase. Several DRC units have been acquired, integrated and tested by our Mercury system engineers. From preliminary test results, the error over distance traveled during navigation in a 2-Dimensional GPS-Denied environment with arbitrary magnetic interference sources was approximately 3%-5%. Additional work is being done by Vectronix to further improve the accelerometer sensor performance of the DRC in order to more accurately detect a variety of motions beyond forward walking, including sideways and backward motions. For example, an autonomous step-scale and misalignment calibration (Helmert Calibration) has been developed. Additional Enhancements/improvements in the machine-machine interface are also underway such as a function to increase the reliability of data exchange between the DRC and host computer is under consideration. The DRC consists of a tri-axis accelerometer, a tri-axis magnetometer and a micro-controller capable of providing fused position estimates in NMEA-0183 compatible and proprietary Vectronix sentence formats. With the current sensor configuration only 2-D navigation is attainable and heading errors will accumulate quickly in the presence of long-term magnetic disturbances. The step-model is also a limitation of the DRC, as it is currently a static model that averages the step length of the navigating personnel. A function to detect whether the sensor is in a prone orientation is included and an accurate azimuth reading is still produced while in this mode; however, no change in position can be detected while the sensor is operating in this fashion. Significant advantages of the DRC solution are relative to its ability to be mounted practically anywhere on a user's belt or torso area as well as the fact that it is a completely self-contained INS system in a small package that already meets the SWAP requirements of the ONR project.

Figure 16 - Vectronix DRC

For the DRC to meet the full ONR system requirements, a barometer and gyroscope must be integrated. The barometer will enable 3D positioning and the gyro will augment the DRC's magnetic compass for more accurate heading determination. Utilizing the DRC, we can focus on the barometer and gyro efforts and develop the position fusion and mobility estimation algorithms discussed earlier. Due to the fact that the DRC does not currently meet the system cost goal for productization, the Sensor Board will eventually replace the DRC and the phase II algorithms will be ported to the new device. This process will require minimal additional effort, mostly centered on tuning the position fusion algorithm to the Sensor Board characteristics.

4.9.2.1.2 GPS Receiver / Inertial Navigation System (INS) Pre-Processor

Mercury has researched the Fastrax iTRAX03 GPS receiver component and has selected this component to provide support for GPS data as well as providing INS processing/fusion capability in a single device roughly the size of a stamp (22mm x 23mm x 2.9mm). The iTRAX03 unit utilizes 40% of its processing capability toward GPS functionality which leaves 60% for the INS fusion processing. The device supports Assisted GPS; a feature that will reduce TTFF and minimize localization/calibration time of the clique. Access to raw pseudo range measurements will enable optimization processing for enhanced GPS accuracy. Differential GPS support allows the system to compensate for localized errors due to atmospheric delays - effectively reducing GPS SEP. Another major advantage of this component is the built-in Kalman Filter library that can be leveraged for the INS/GPS pre-processing.

Figure 17 - iTrax03 GPS Receiver / INS Fusion Pre-Processor

Additional rationale for using this component include the presence of a high sensitivity GPS receiver; the ability to derive GPS data from Pseudolites; low power consumption; and a Software Developers Kit (SDK) which includes a Kalman Filter library; direct connectivity with INS Sensor Board and embedded processor; and the capability to tightly couple GPS, INS and Pseudolites via SDK configuration.

4.9.2.1.3 Sonic Instruments RSS Radar Velocimeter

Mercury Data Systems is currently testing the Sonic Instruments RSS radar velocimeter prototype. The sensor measures the Doppler Effect – change in frequency and wavelength perceived by an observer moving toward the wave while it is being received – to calculate the ground speed of a person. The velocimeter consists of a DSP and IO controller, along with supporting chipsets.

The system integration of the velocimeter data is focused on complimenting the INS accelerometer component. The output will be used to validate and compliment the INS data providing a means for the system to overcome any step length errors introduced by the INS step model by supporting all mobility modes. The velocimeter can be used to increase the accuracy of the INS and itself has an estimated accuracy of ±1% of distance traveled, based on MDS testing results.

4.9.2.1.4 INS / TOA / GPS Fusion, Networking, Visualization, and Human Machine Interface (HMI) Single Board Computer (SBC)

Mercury has researched various processor modules and commercial-of-the-shelf (COTS) single board computers (SBC's). The advantage of using a device similar to a SBC is that all processing and peripheral support is integrated on one small printed circuit board (PCB). Although several SBC's are available that meet the system performance goals, none have been identified that meet the desired size and cost goals for productization. As a result, Mercury will develop a custom SBC solution for productization utilizing Freescale Semiconductor's ColdFire embedded microprocessor for sensor fusion and integrated peripheral connections for visualization and HMI support. The ColdFire processor features multiple connectivity peripherals including two Ethernet, USB 2.0, I^2C, and Serial (RS-232/SPI) interfaces required for the Visualization, INS/GPS, CMR, Military Radio and power subsystems. The ColdFire core also provides a Memory Management Unit (MMU), dual precision hardware Floating Point Unit (FPU) and up to 410 (Dhrystone 2.1) MIPS at 266 MHz – all of which ensure the sensor fusion algorithm will operate as fast and accurate as possible. In addition, the device offers an encryption accelerator for secure network communications to augment the security features provided by the CMR.

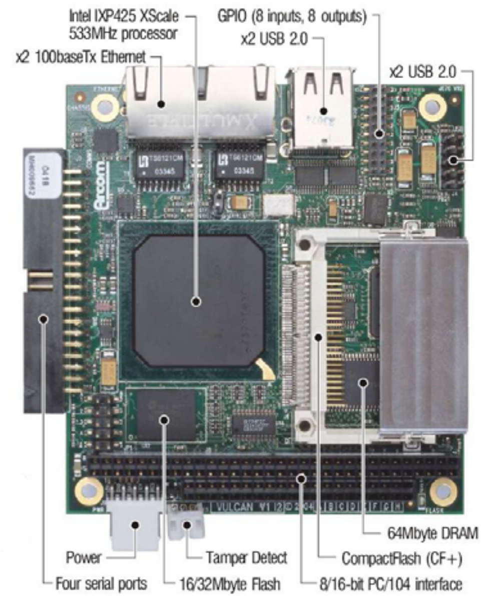

Figure 18 - Arcom Vulcan SBC

The custom SBC development efforts will exceed the ONR phase II timeframe; hence, Arcom's Vulcan SBC (Figure 18) will be implemented for the phase II prototype. The Vulcan SBC is a low-power PC104 format (96mm x 91mm) based on Intel's 533MHz IXP425 XScale network processor. The features include dual 10/100baseTx Ethernet ports with hardware accelerated encryption (DES, 3DES, AES) and authentication (SHA-1 and MD5), four (4) serial ports, four USB 2.0, digital I/O, real time clock (RTC) with 5 day+ backup, tamper switch input, onboard and CompactFlash (CF+) expansion. The device averages 3.5W power consumption and can operate within a range of -40 degrees Celsius to +85 degrees Celsius (extended range version). The IXP425 supports software emulation of floating point arithmetic which will require performance validation to meet ONR system requirements.

4.9.2.2 Clique Member Radio (CMR)

The Clique Member Radio is based on the field proven Soldier Radio Waveform (SRW). The functionality provided by the CMR includes the following.

- Intra-Clique communication both data and text messaging.
- Military Standard Radio interoperability for reach-back to headquarters.
- RF Ranging/TOA
- JTRS Cluster 5 compliance


Figure 19 - CMR / WSRT on Harness

The RF Ranging / TOA Position Accuracy is time-independent. The relative positioning capability is also independent of GPS availability and the systems can maintain accurate location for well over 8 hours as defined by the BAA specification. These radios can operate up to 24 hours based on the battery life for standard military batteries.

The radio is a proven military-grade radio with field experience from AAEF and C4ISR OTM with the following advantages:

- Multi-hopping, ad-hoc networking capability provided with no pre-existing infrastructure.
- Anti-Jam, LPI/LPD waveform.
- COMSEC/TRANSEC (Type3 AES with path to Type1 Crypto), the current configuration is compatible with and can be upgraded to NSA suite B requirements.
- No user set up required to form the network or to provide the RF TOA Ranging location data.

The radio is tunable within the UHF Band for RF transmissions (compared to 802.xx frequencies) and provides optimum building penetration and maximum communication range. The radio incorporates an expandable / scalable system that can easily accommodate the integration of additional sensors.

The system will be available in first quarter 2008 in the form of an RF/Digital ASIC based on the current miniaturization (SWAP and cost) plans in place at ITT. This miniaturization effort will enable MDS to meet the SWAP goals for the final form factor of the integrated system and to reduce the number of system components to the single enclosure and the display unit.

4.9.2.3 Display Unit

Several components were evaluated for the visualization component of the ONR system. At this point the Kent Displays, Inc. Cholesteric Liquid Crystal Display (ChLCD) Module appears to be the most cost-effective component. As a result, the device is targeted for the productization phase. Kent has experience working with DARPA to produce ChLCD technologies for military applications. The Kent devices are general-purpose monochrome or full color graphic display modules suited for battery powered portable devices and display applications. The modules include a wide viewing angle and are sunlight readable. The display is a reflective cholesteric liquid crystal display that takes full advantage of the technology's unique "No Power" image retention attribute. The embedded display controller generates the unique ChLCD drive waveforms and provides automatic temperature compensation. The SPI-compatible interface to the embedded controller simplifies system integration using a minimal number of I/O resources and controls all display operations, from downloading image data to triggering display updates. These units can also be made readable for use at night or in limited light environs via the addition of a light source layer. Kent also produces an Infrared display which is readable at night via the use of night vision goggles as well as a flexible display system. These displays will need to be mounted in an enclosure with controls to provide the display unit for this system. MDS plans on placing these units into an enclosure similar to that used by the Trident WD unit as shown below.

Figure 20 – A) Kent Infrared Display; B) Kent Flexible Display; and C) Trident Enclosure w/ Controls

The development efforts necessary to produce an enclosure and operator controls for the Kent display exceed the ONR phase II timeframe. As a result, the Trident Wearable Display (WD) will be used for the ONR phase II prototype. Although the WD does not meet the cost requirements for productization, it will provide a great platform to prove the visualization concepts of the ONR project. The WD is both small in size (114mm x 66mm x 25mm) and rugged (designed for MIL-STD- 810F and MIL-STD-461E compliance). Using a 2.8" QVGA (320x240) LCD with an LED backlight, the WD provides sunlight-readability and night vision goggle (NVG) friendly operation. As an added feature, specifically designed for operation in hostile environments, the display includes a recessed LCD "kill switch" for instantaneous zero light emissions.

The operator interface consists of a 4-way joystick with integral press-to-select capability and two additional function buttons. All buttons provide tactile feedback, and are fully programmable for control of any host computer application. In addition to monitoring and control functionality, the WD has a programmable vibration capability, providing operator-defined alerts with adjustable cadences for further hands-free operation. Mounting the WD is normally done on the operator's forearm, but the straps are Modular Lightweight Load-carrying equipment (MOLLE)-compatible, allowing easy interfacing with standard military gear. Using a small-diameter USB cable, the WD draws power from and communicates with the host computer. This cable can be routed up the arm for easy connection with a back-mounted host computer.

To provide the system user with the interface they desire at various price points we recommend one of the options:

Table 1 - Display Unit Component Options

Display Description	Price per unit @ 1000 pieces
Kent $^{1}/_{8}$ VGA ChLCD – with addition of system lighting source and heat strip; Resolution 240 x 160; DPI 100; Viewing Area (W x H x Diag.) 41 x 61 x 73.5 mm; and Volume 43 cm^3	$77
Kent ¼ VGA ChLCD – with addition of system lighting source and heat strip; Resolution 320 x 240; DPI 72; Viewing Area (W x H x Diag.) 87 x 114 x 143 mm; and Volume 138 cm^3	$77
Full color version of the Kent ¼ VGA model.	$200
Kent Infrared – in either size listed above with the same features, viewing area, and volume.	$120
Kent Flexible Display – with addition of system lighting source and heat strip; size can be custom orders to meet application / user needs, production volumes not available until 4Q08.	$80
Trident Display – QVGA high resolution AMLCD (Active Matrix) display; night-vision goggle friendly; operator controlled ultra-high dynamic range LED backlight; MIL-STD-810F and MIL-STD-461E compliant; 2.8" diagonal display; and volume 192 cm^3	$859

Note: Prices are approximate values based on feedback from Kent sales contact, an actual quote was not provided. The Trident Display price listed is for reseller cost at 1000 units.

4.9.3 *Optional Components - Auxiliary Data Sources*

- **LORAN/LORADD** – LORAN technology has been used since World War II. In recent years, the capabilities of LORAN have been tremendously enhanced. eLORAN, as the new version is called, can provide accuracy within 20 meters of true position. As well, many new LORAN transmitters have been installed: today LORAN covers all of North America, Europe, the Middle East, and most of Asia.

  LORAN position estimates are not as accurate as GPS, but they are more precise; a LORAN determined position will always define the same point, whereas a GPS determined position will vary based upon the geometry of the GPS constellation. When LORAN is combined with GPS or calibrated by GPS, LORAN is able to maintain accurate positioning during GPS outages. When LORAN and GPS are combined with an odometry system, vehicles are able to maintain accurate positioning throughout GPS Denied environments.

  The Loradd integrated GPS/LORAN receiver from Reelectronika is designed to combine the signals from GPS, LORAN, and their associated augmentation systems, to improve accuracy, availability and continuity of the navigation function. The integration of these signals is used to overcome the dissimilar failure modes of the individual navigation systems and provide a complementary system designed to inhibit a single point of failure. Differential corrections compensate for satellite timing errors, the effects of different ionispheric delays are reduced, the resulting Differential GPS (DGPS) solution can then be used to calibrate the Loradd receiver; once calibrated the system benefits from the repeatable accuracy characteristics of Loradd. This system allows the GPS and LORAN signals to be utilized independently or the signals can be combined with the augmentation data to produce a combined position estimate. The system supports the use of the following augmentation signals: Satellite Based Augmentation System (SBAS); Eurofix Local Area Augmentation System (ELAAS); Eurofix Regional Area Augmentation System (ERAAS); Radiobeacon differential corrections; Differential LORAN or Additional Secondary Factor (ASF) data; and UTC broadcast service.

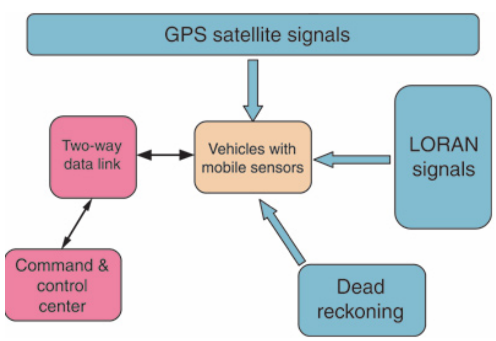

Figure 21 – Tracking with GPS/LORAN

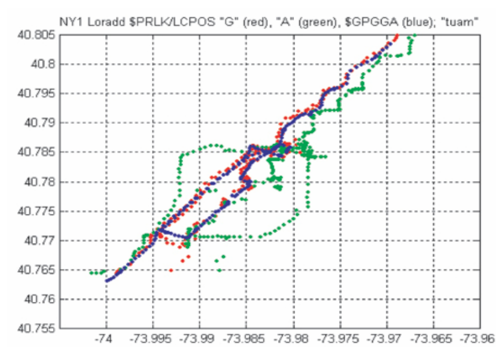

Figure 22 – Loradd GPS (blue), LORAN (green), and GPS-conditioned LORAN (red). Latitude vs. longitude plot, West Side (degrees)

Performance Analysis of an Integrated Tracking System, James Carroll,GPS World, 7/1/2006

Successful results have been have been achieved by an integrated GPS/LORAN/DR when tested in urban applications in the lower Manhattan financial district of New York City. By sampling the covariance between GPS and LORAN, the LORAN signal can be conditioned to provide accurate GPS Denied navigation. The results of the tests show that LORAN can effectively provide a backup data source in areas where GPS does not reach, including urban canyons and open tunnels.

- **Psuedolites** – Pseudolites are able to generate the same L1 signal that GPS satellites generate; therefore a properly configured GPS receiver can acquire positioning information from both GPS satellites and pseudolites. Pseudolite signals can be broadcast from known locations using various military and commercial radio and various frequencies. In Iraq, there are over 100 bases in which pseudolites can be placed to transmit L1 signals. The signals will be acquired by the standard antennas on the remote vehicles. Once the signals are acquired, an application can then transfer them directly to the iTRAX03 (if L1 is broadcast at GPS frequency or via a frequency converter if L1 is broadcast at an alternate frequency), which will process them as though they were received directly from a GPS satellite or pseudolite.

The accuracy of both personnel vehicle position can be further augmented by use of pseudolites. As vehicles transport Marines to areas of operation, their position estimates can be augmented by the L1 broadcasts from Pseudolites. In GPS Denied areas, pseudolites can be used to provide position information to GPS receivers even when the signal from GPS satellites cannot be acquired.

Normally, pseudolites signals are generated at the same frequency as GPS satellites, so their use is regulated by international laws, but if the pseudolite signal is broadcast at a different frequency, these regulations can be avoided. By transmitting the L1 signal at a different frequency, we can also ensure that the signals will not be jammed or spoofed. However, most hardware based GPS receivers will not be able to pick up the GPS signals at a different frequency. Our solution is to use a GPS receiver, the iTRAX03, which provides on-board support for pseudolite transmissions.

We have reviewed two pseudolite systems – from the Center for Remote Sensing (CRS) and Space Systems of Finland (SSF). The SSF GSG-L1 pseudolite systems provide an economical solution in a small package size and have a tunable oscillator, which enables L1 broadcasts at various frequencies. In addition, SSF provides software for the iTRAX03 that supports GSG-L1 broadcasts.

- **APRS –** The Automatic Position Reporting System (APRS) is a system which has been developed by Capt Evangelos Foutzitzis at NPS. Essentially, the system uses the Red Bee radio (433MHz), to maintain 2 way data communications at over 70 miles distance (LOS). The communication packages are encrypted / compressed to transmit ID/GPS data. Captain Foutzitzis is currently working with MDS to enhance his system to support pseudolite data transmission, adapting APRS to transmit PL L1 at 433MHz. The APRS program is currently supported / funded by DARPA.
- **Synopsis –** Using a combination of GPS, LORAN, odometry and pseudolites, mobile vehicles can accurately determine their position anywhere and in any environment.

  If pseudolites are also placed within the mobile vehicles, then they too can serve as absolute position references for dismounted soldiers. The essential application architecture will be the same. The frequency of the vehicle mounted pseudolites will be converted to the LAN frequency that connects the vehicles and the dismounted soldiers. Then, the dismounted soldiers can receive the L1 signals using their standard radios. The L1 signal can be transferred to their individual software GPS receivers, which can be installed on their mobile system controllers. If three or more pseudolite signals can be received, the dismounted soldiers can determine their position without any GPS. If the soldiers also have GPS receivers, the pseudolite and GPS based position estimates can be combined.

  We are discussing collaboration with NPS to develop an auxiliary data source solution that combines the GSG-L1 pseudolites and the APRS radios. We plan to develop this solution during 2007.

  As an example - if GSG-L1 Psuedolite transceivers were positioned on existing radio towers in 18 of the camps within the Iraq theatre of operations, the auxiliary systems could cover 75-80% of the entire country with absolute data via use of LOS RF transmission equipment. Estimated LOS range of the APRS transceivers is 70 miles. By interspersing mobile/portable pseudolite systems that can trilaterate their position using GPS and/or other pseudolites at known locations, absolute position coverage of provinces, even the entire country, can be economically achieved. The mobile pseudolite placement will not require high accuracy surveys - if placed within 5 meters of ground truth, the GSG-L1 can maintain 25m absolute position accuracy within an area of operation (10Km x 2Km). See figure below for projected coverage from 18 systems.

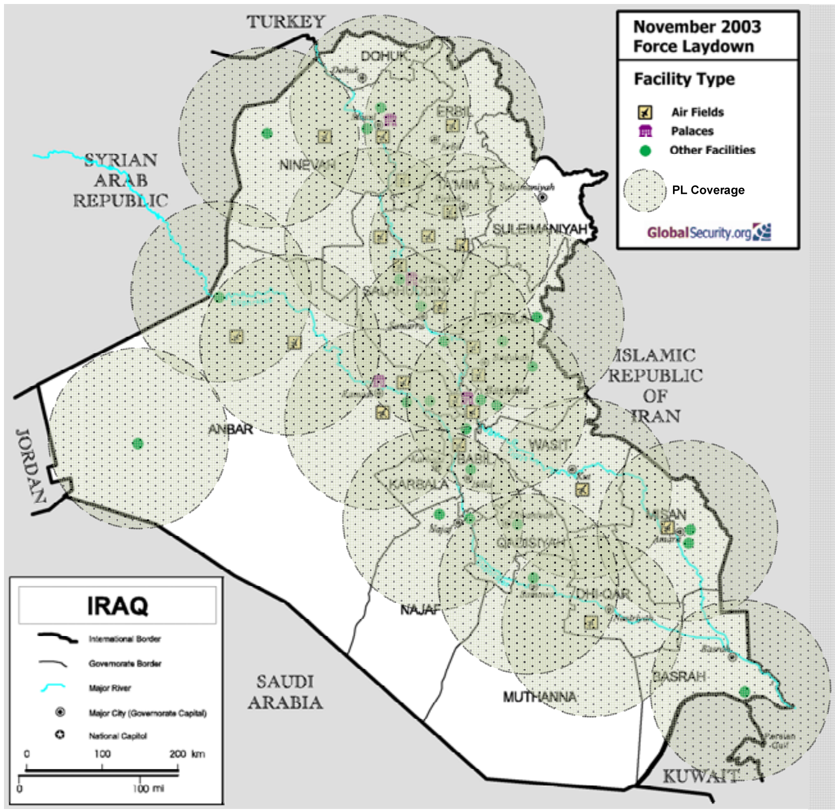

Figure 23 - Projected Psuedolite Coverage of Iraq

- **CMR Beacons** – Similar results as those described above for Pseudolites can be provided by the CMR radio component to provide range references to absolute position estimate in the area of operation when the AO is within a 10km range of the base of operation or the CMRs have access to GPS, PLs or calibrated Loran. Unlike the pseudolites, the CMR beacons are portable and they will additionally support mesh networking and communications for the clique.

  The concept for determining absolute position while navigating in urban areas is shown in figure 23. As shown, two CMR references would have to be positioned at the base of operations or the mission start location for use during absolute horizontal positioning when RF ranging. The position data for the CMR reference beacons will have to be entered into the CMR memory to provide the reference position data; a barometer will be used for absolute vertical positioning to achieve a reasonable VDOP for RF ranging. The two fixed references would have to be mounted at a minimum elevation of 14m and use 3dBi directional antennas facing the mission area with a minimum separation of 2km. The clique members will be able to reach back to these references throughout a10km area.

  This approach can be utilized when mission parameters meet the operational limitations described. This concept would not require the purchase and installation of additional hardware, any one of the system nodes could be utilized to provide this functionality and existing antenna towers could be used to mount the directional antennas. This option should only be considered in conditions where missions within a 10km range of the base are prevalent or an absolute positioning source is available at the area of operations boundary.

CMR beacons, when equipped to receive pseudolite and/or e-Loran signals, can extend absolute positioning into an AO if GPS is denied at the AO boundaries. Similarly equipped CMR beacons, placed in vehicles, can further extend accurate clique navigation within and beyond the AO.

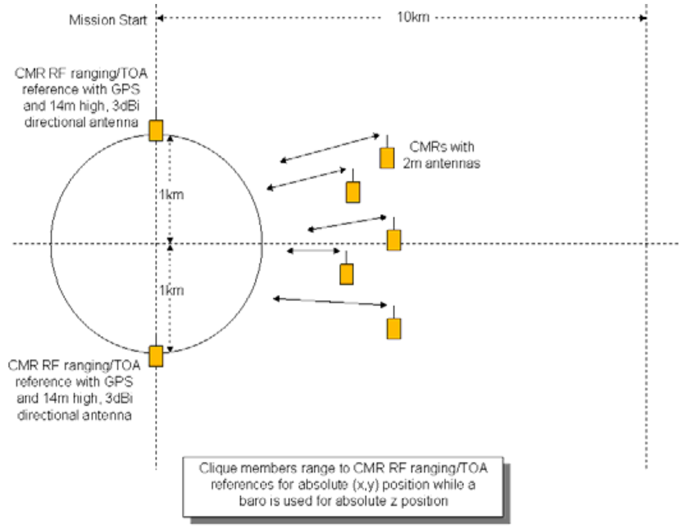

Figure 24 - Absolute Positioning Concept Using CMRs

- **Radio Based Combat Id Integration -** The Radio Based Combat Id (RBCI) ACTD system has been developed by ITT, and provides automated interrogation/response for Blue Force tracking of Marine Corps, Army and NATO forces. The RBCI teams from the Marine Corps and Army have requested integration of our proposed NAVGPSDE system with the RBCI system – this request is unfunded. The timeframe requested for RBCI field evaluation coincides with the expected NAVGPSDE field evaluation timeframe.

RBCI functionality includes:

→ GPS coordinate based Q&A Combat Identification Capability

→ SW-Only Upgrade to Combat Net Radios & Interface Systems

→ Software Waveform upgrade for SINCGARS ASIP, Air SIP and Exportable Spearhead radios

→ Probability of ID (Pid) > 95%

→ Time to ID (Tid) ~ 2.0 sec

→ Variable size footprint for target or area clearance interrogation

→ Provides danger close (minimum safe distance) for nearby friendly forces

With NAVGPSDE integration, RBCI will be able to support soldier tracking in GPS Denied environments. RBCI integration will extend the capabilities of NAVGPSDE to support and be used by other systems and platforms. Integration of the two systems will also increase probability that the NAVGPSDE cost objective can be reached – since probable production volume will increase due to Army procurements via the Combat Id POM, which will begin in 2008. Integration of the two programs will entail the adaptation of the RBCI messaging software for the CMR waveform and the adaptation of the RBCI user interface to support NAVGPSDE requirements. See Figure 25 for a visual description of the RBCI system components.

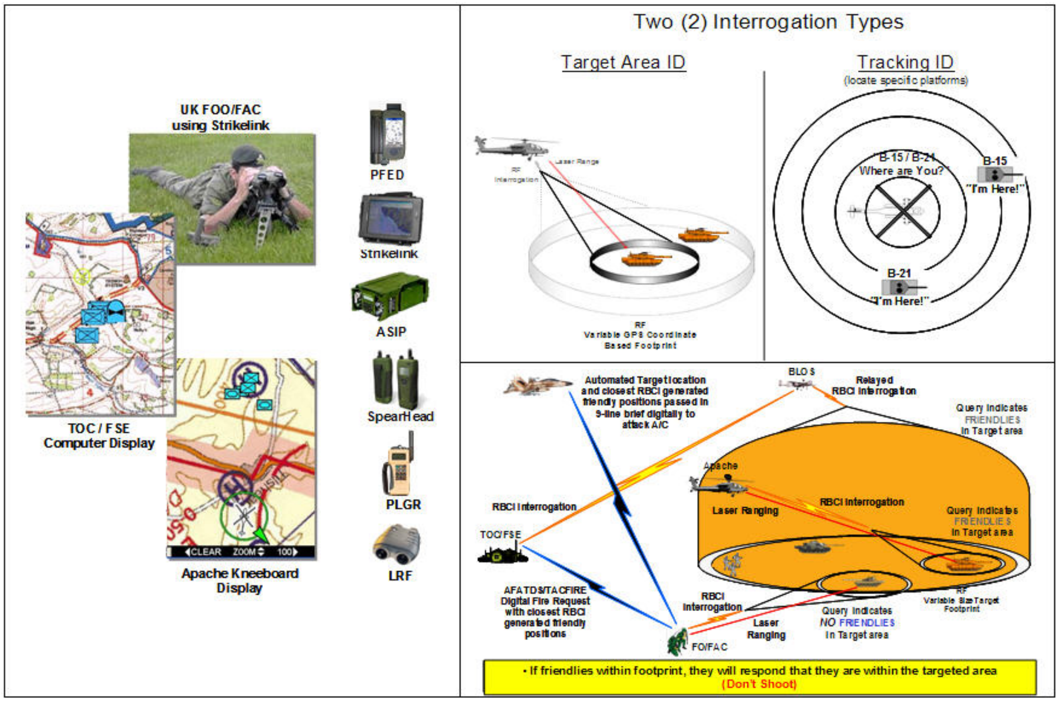

Figure 25 - RBCI Option Description

4.9.4 Interfaces

The following diagram shows the system interfaces – a description of each interface is provided below:

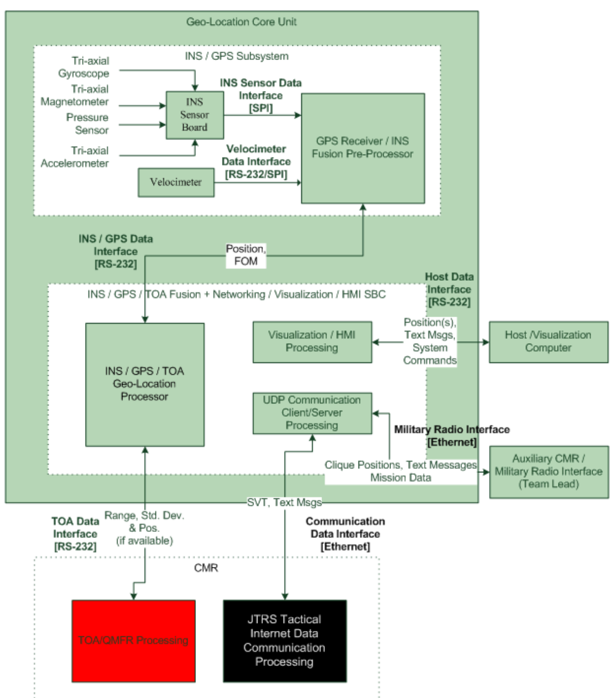

Figure 26 - System Interfaces

4.9.4.1 Internal Interfaces

- **INS Sensor Board Data Interface** – provides relative 3D (x,y,z axis) position and heading information of navigating personnel via SPI connection.
- **Velocimeter Data Interface** – provides velocity of the navigating personnel via RS-232 connection.
- **INS/GPS Data Interface** – provides pre-processed INS/GPS position information along with a Figure-of-Merit (accuracy indicator) to the INS/GPS/TOA Geo-Location fusion processor via RS-232 connection.

4.9.4.2 External Interfaces

- **Host Data Interface** – provides spatial awareness and operator input via RS-232 connection, or similar.
- **Military Radio Interface** – provides clique team leaders with C2 updates including text messaging and mission data, and C2 with clique-wide position updates via standard Ethernet connection.
- **TOA Data Interface –** provides TOA ranging data, TOA reliability indicator, and position information for ranging partners / auxiliary reference CMR's within the clique via RS-232 connection.
- **Communications Data Interface** – provides clique-wide position and mobility updates as well as text messaging via standard Ethernet connection.

4.9.5 Capabilities

The capabilities included in the proposed system include:

4.9.5.1 General Capabilities

- A self-generating, self-healing, ad-hoc network.
- System acquisition of absolute position data when available, automatic shift to referential coordinate system when absolute data is not available.
- The RF TOA component will be utilized to perform intermittent calibrations for the INS to compensate for the bias drift and increase position accuracy over distance traveled.
- 3D position estimation processing, data output for each user will include Latitude, Longitude and Altitude.

4.9.5.2 Project Specific Capabilities

1) **The system should not burden the deployed forces in either volume or mass.**

   The estimated weight and volume of the prototype system is displayed in the table below. The final form factor system estimates are also provided, these values are estimated based on activities required to complete the detailed design and system productization efforts that are described in this document (see Productization section). The prices provided below are based on quantities of 1000 units.

Table 2 - System Estimated Size, Weight, Price

Component	Volume	Mass	Price
Phase 2 Prototype			
Geo-Location Core Unit in a Single Enclosure (Otterbox) w/	~600 cm^3	40g	$40
• INS Sensor Board – 55 x 70 x 7mm	27 cm^3	26 g	$200
• GPS Receiver / INS Fusion Pre-processor – 22 x 23 x 2.9 mm	1.5 cm^3	3 g	$25
• Velocimeter – 59 x 39 x 25mm	57.5 cm^3	19 g	$170
• INS/TOA/GPS Fusion, Networking, Visualization and HMI SBC. – 110 x 75 x 2 mm	16.5 cm^3	75 g	$100
Core Unit Subtotal	N/A	163 g	$535
CMR – 144.8 x 68.6 x 40.6mm	403 cm^3	544 g	$500
Visual Display Unit (Kent Infrared $^1/_8$ VGA) w/ enclosure and controls – 114.3 x 66 x 25.4mm	138 cm^3	340 g	$120
3 separate components for a total	1141 cm^3	1.05 kg	$1155
Final Form Factor			
Two components, Single Enclosure w/ all sensor and processing components and visual display unit.	Less than or equal to 400 cm^3	Less than or equal to 1kg	Less than or equal to $2,000 USD

Note: The costs listed above are component costs only. The product manufacturing costs for custom backplane, unit assembly, enclosure, logic / development and testing; are not known at this point and will be based on the final form factor design. We estimate the production cost to be at or near the target price point.

The CMR cost listed is for the target price of the ASIC chip which will be available for inclusion in this application / system 1Q08; the size listed for the CMR is for the current handheld radio; the total volume of the system post addition of the CMR ASIC to the single enclosure is estimated to be less than 400 $cm^{3.}$ The larger volume enclosure will be required for the prototype systems to enable connection using existing component I/O ports. For the final product these connections will be made via use of a custom PCB.

2) **The system should "just work" requiring minimal-to-no training for operation.**

After a minimal calibration activity when the hardware is issued to the user, and configuration efforts required by logistics personnel previously described, the only effort required by the end user will be to power on the unit at the beginning of the mission. The estimated training time for system end users is less than 2 hours, for systems support / logistics resources 1 day or less.

3) **The system should be prepared to operate in a GPS-limited or GPS-denied environment.**

The proposed system is designed to function completely in the absence of absolute data references. When available, the GPS or Auxiliary absolute data reference will be utilized but the core of the system utilizes the INS, Velocimeter, and RF TOA Ranging to maintain accurate position estimates. See the operational scenarios and the component sections for a full description.

The proposed system will support four methods for generating a position estimate:

- Absolute Positioning – using GPS or auxiliary data;
- Range based relative positioning – via the use of the RF TOA ranging capability;
- Range free relative positioning – via use of the INS components; and
- Manual positioning – using the map interface set position feature.

4) **The system should operate in open spaces as well as underground or cave-like settings.**

   The system has the capability to provide position estimates wherever / whenever the INS can access and utilize the additional system sensors and networking components, the system will operate in the same mode whether in open spaces, in buildings, in urban terrain or in under ground tunnels or caves. The INS can work in any environment as a stand alone unit and maintain the required accuracy over a 500 meter range. The CMR TOA Ranging component can maintain accuracy within the required SEP for up to a range of 2km or less, the networking functionality provided by the CMR can work over multiple hops to provide connectivity for NLOS resources. The system also supports the use of calibrated maps to denote landmarks or navigation starting locations that could be utilized to calibrate INS and TOA position data prior to the user entering the cave.

5) **The system should provide for the fusion of multiple references in order to provide location information.**

   The proposed system utilizes the data output from multiple sensors along with data fusion an Kalman filtering algorithms to provide the greatest accuracy and to create predictive route models in an effort to constantly maintain the position estimate within the required 25 meter SEP.

6) **The system should provide for auxiliary data sources/beacons for location information.**

   The system can utilize signals of opportunity to provide absolute data references including Loran, Psuedolites, and CMR Radio beacons. The system can also use the Assisted / Differential GPS processes to overcome GPS-Limited access scenarios.

7) **The system should provide for auxiliary data relays when in an underground or cave like setting.**

   Each network node can be used to provide multi-hop links for communication in NLOS situations which may be encountered in underground or cave like settings. Separate relays units will not be required, see the operational scenario section for more details.

8) **The system should provide for information security during data transfer consistent with the NSA Suite B (http://www.nsa.gov/ia/industry/crypto_suite_b.cfm).**

   The CMR is designed with an SCA compliant, flexible architecture ready for embedment of NSA Suite B cryptography algorithms; in addition transmission security (TRANSEC) is applied to several of the CMR waveform parameters. The TRANSEC capabilities aid in prevention of standard network attacks including Wormhole, Sybil and reference point compromise / Meaconing.

   The CMR RF ranging/TOA location technology is based on a direct sequence spread spectrum (DSSS) waveform with embedded TRANSEC. The RF ranging/TOA location technology uses the same carrier sense multiple access/collision avoidance (CSMA/CA) protocol for channel access as used when communicating. The DSSS waveform, the layers of the CSMA/CA protocol and the protocol for two-way RF ranging/TOA are not vulnerable to Wormhole, Sybil or Meaconing attacks. The network will not recognize the spurious packets generated by the Wormhole, Sybil or Meaconing attacks because they will not have the latest DSSS code provided by TRANSEC. If unfriendly forces do determine a current DSSS code from TRANSEC, the network will not recognize the spurious packets generated by these attacks because various network timeouts will occur if proper packets are not received in proper sequence, causing the protocol to continue normal network maintenance, communications, or ranging. In addition, because the RF ranging protocol employs a 5-way handshake mechanism, an enemy would require detailed knowledge of the ranging algorithm in order to produce a packet that would not be summarily discarded.

   Our approach is to use ITT's SRW-based DSSS waveform and network for the intra-clique and headquarters "standard military radio" communications as well as for the RF ranging/TOA, incorporating all three functions into the CMR. Communication of the clique member locations will have the same resistance to Wormhole, Sybil or Meaconing attacks as mentioned above for RF ranging in addition to information security provided by NSA Suite B algorithm software.

9) **The system should acknowledge when it is operating in a degraded information mode.**

   The wearable display unit will have an indication of system mode and sensor status a position estimate degradation reading (Figure-of-Merit or SEP value) and network status; this information is displayed to the user on each UI page. See the user interface page descriptions in the Functions and Features section for a full description of this capability.

10) **The system should provide for a limited/text-based data transfer from tracked/remote nodes.**

    The system will provide the means for clique members to send and receive pre-canned short text messages and will provide the ability to transmit data files over the CMR ad-hoc network. See the Text Message Page UI section in the Functions and Features section for a full description of this capability.

11) **The system shall provide for operation of 100m into underground or cave-like environments (use of up to three relays is permissible).**

    The ad-hoc network created by the CMR has a node to node range that meets or exceeds the requirement for 100 meter access into cave like, subsurface and/or underground environments. See the Functions and Features section for a full description of this capability. See item 4 above for a description of the INS and RF TOA ranging component accuracy and range.

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

    The CMR will provide Military Standard Radio interoperability for reach-back to headquarters. The system will also provide an external Ethernet port with data outputs formatted for transmission of clique data via a standard Military Radio interface, if an external radio other than the CMR will be utilized.

13) **If relays are used as part of the system solution, said relays should be disposable and spoofing and tamper resistant.**

    Relays will not be required by the proposed system due to the range and multi-hop network communication and RF TOA Ranging accuracy capabilities of the CMR. The spoofing and tamper resistance capability are provided by the system zeroize feature and the security capabilities of the system. See items 7 and 8 above for additional information.

4.9.5.3 Project Specific Goals

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

   Based on the power requirement of the components selected for the prototype system the estimated power consumption is approximately 158 WH out of the available 170 WH, see the table below for the worst case system / component power consumption breakdown.

Table 3 - System Power Budget

Component	Consumption watts per hour	8 hour consumption value
Phase 2 Prototype		
Geo-Location Core Unit		
• INS Sensor Board	1 W	8 W
• GPS Receiver / INS Fusion Pre-processor	.25 W	2 W
• Velocimeter	.25 W	2 W
• INS/TOA/GPS Fusion, Networking, Visualization and HMI SBC	12 W	96 W
Subtotal	13.5 W	108 W
CMR	5 W	40 W
Visual Display Unit	1.25 W	10 W
Total	19.75 W	158 W
Final Form Factor		
Core Enclosure and Visual Display	15 W	120 W

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

The proposed system will support accurate tracking by fusing the output of complimentary motion sensors through use of proven algorithms. The system will utilize off the shelf components including an INS, TOA RF Ranging, Velocimeter, and a system processor to produce a position estimate that overcomes the limitations of the individual sensors.

The most critical capability of this system is the design of the fusion algorithm – the ability to fuse position information generated by various position sensors. Our approach for position fusion called the PosiFusion™ algorithm will model the position information generated by several position sensors and will apply a Kalman filter to integrate the position information. The system assumes the availability of absolute data at the beginning of the mission and shall utilize this data to generate absolute position estimates for each mobile user / node.

The absolute position information will be extended throughout the area of operation via a distributed protocol referred to as, extended Leapfrog Navigation System (eLNS). The process is an extension of the Leapfrog Navigation System (LNS) processing algorithm that exploits mobility to improve the accuracy and precision of localization and to reduce the number of required anchors. eLNS does not impose any restrictions on node topology it employs the concept of "Virtual Anchors" where a new set of anchors are selected for each epoch defined by a leapfrog distance or leapfrog period. The anchor selection is based on node role, mobility, network topology and geometry. eLNS employs "Iterative trilateration" where localized nodes act as virtual anchors for un-localized nodes and employs situational awareness information to adjust epoch size effectively bounding the error accumulation within the 25 meter SEP budget. The epoch size and number are determined based on human locomotion over 10 Km linear distance.

LNS has demonstrated 10m CEP in 15Km navigation; we expect eLNS performance to be marginally worse than that demonstrated by LNS due to additional position error introduced by node mobility. The projected accuracy of the system using PosiFusion and eLNS is 25 meters SEP or better over 8 hours and a distance of 10Km.

3) **Projected production cost per unit in quantity of 1000 shall be $2k or less.**

See table 1 above for estimated cost of the Phase 2 prototype systems and the final form factor product estimates. The productization section of this document provides a description of how the target price goal will be met.

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

See table 1 above for estimated cost of the Phase 2 prototype systems and the final form factor product estimates. The productization section of this document provides a description of how the target mass goal will be met.

5) **Volume of each unit shall be 400 cm^3 or less.**

See table 1 above for estimated cost of the Phase 2 prototype systems and the final form factor product estimates. The prototype systems targeted for delivery at the end of phase 2 will not meet the volume goal due to the currently available component configurations. The productization section of this document provides a description of how the target volume goal will be met prior to generation of the production form factor.

6) **A minimum of five units are to be produced and delivered in Phase 2.**

Five prototype units will be produced for testing and evaluation as part of the phase 2 deliverables.

4.9.6 Functions and Features

The functions and features included in the proposed system include:

4.9.6.1 User Interface Map Page Features

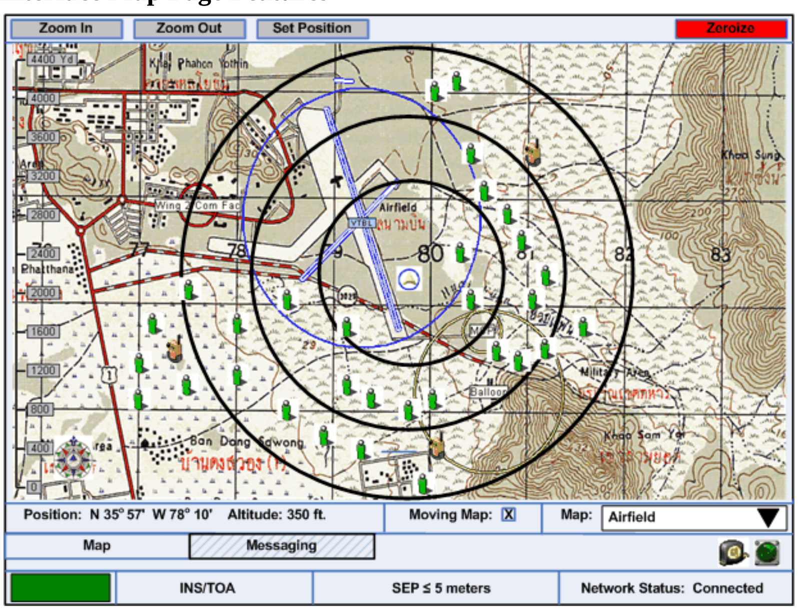

Figure 27 - UI Map Page

The user interface map page will be the primary interface to provide clique member positions to the local user and includes the following features:

- 10x digital zoom capability supported by large **Zoom In/Out pushbuttons** located at the top of the screen.
- A **Set Position pushbutton** also located at the top of the screen; when enabled this will update the user's current position to the next point selected on the map via the cursor, when the interface

button is enabled. This feature will be utilized to localize or correct the user position when no absolute data or referential coordinate system is available to the user.

- A system **Zeroize / Kill pushbutton** top right side of the screen; this feature provides the user the ability to disable the unit when the possibility of capture or position overrun is imminent; when enabled this feature will ask the user to verify the operation before deleting all content in the system memory. Post deletion of system memory the system content, maps, position of troops within the clique will not be available to unintended system users. When this feature is utilized the system functionality will have to be reloaded before the hardware will be functional. The system also provides for a remote zeroize operation that can be performed by other clique members who are on the network, see the text messaging page UI.
- The map will show 2D view of all clique personnel within 1.5 x weapon range.
- **Map Scale**.
- **Compass Rose**.
- The **local user icon** will appear as a blue circle with a notch oriented in the direction of the user's heading.
- The **friendly personnel icon** will be a small figure with a 3-character ID above their icon.
- Local user current position data including **Latitude, Longitude and Altitude**.
- Moving map with north-up and heading-up modes, the moving map capability can be enabled or disabled by selection of the **Moving Map checkbox**.
- Selectable **Map drop down list box** with content based on available maps from those loaded in the pre-mission configuration data.
- **Map and Messaging Tabs** to select which page the user wishes to utilize.
- Two icons are present next to the page tabs that provide the user the ability to measure (**tape measure icon**) the distance or angle (**radar screen icon**) between two points on the map.
- **System mode status**, red indicates the system is in initialization mode, green indicates the system is in user navigation mode.
- **System sensor status** indicating which sensors are currently being used to generate the position estimate.
- **Position estimate degradation reading** - Figure-of-Merit or SEP value.
- **Network Status** with a connected / disconnected value present.

4.9.6.2 User Interface Text Messaging Page Features

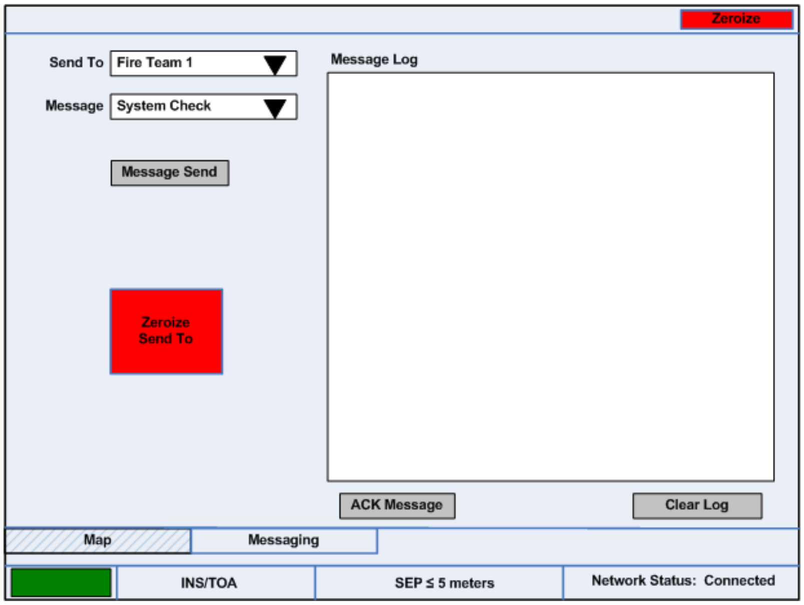

Figure 28 - UI Text Messaging Page

The text messaging interface page supports the transmission or receipt of pre-canned messages via UDP over the ad-hoc network. The messages can be sent to a specific clique member or a group of clique personnel. When messages are sent to the local user a message alert notification (vibration on the wrist worn display unit) will be received. When the user has an opportunity to review the message they will switch to the messaging page of the UI by enabling the "Messaging" tab at the bottom of the UI. The following features will be available on that page:

- A system **Zeroize / Kill pushbutton** top right side of the screen; this feature provides the user the ability to disable the unit when the possibility of capture or position overrun is imminent; when enabled this feature will ask the user to verify the operation before deleting all content in the system memory. Post deletion of system memory the system content, maps, software algorithms and position of troops within the clique will not be available to unintended system users. When this feature is utilized the system functionality will have to be reloaded before the hardware can be utilized in the field.
- A **Send To drop down list box** will contain the option to send a message to a given clique member as specified by their userid or to a subgroup of clique members (Squad 2, Fire Team 3, etc..) or to the entire clique by selecting the appropriate value.
- The **Message drop down list box** contains a selection of pre-canned messages which are available to the user for sending text messages, the content of the drop down list can be specified / modified for each mission based on mission objectives and communications needs; at this point the following default set of messages will be present in the drop down list:
  - All Clear
  - Clear
  - Coming Down
  - Coming In Left
  - Coming In Right
  - Coming Out
  - Coming Up
  - Frag Out
  - Hold

  - Hold Right
  - Hold Left
  - Grenade
  - Move
  - Next Man In
  - Next Man In Left
  - Next Man in Right
  - Ready
  - System Check
- The **Message Send pushbutton** will transmit the selected message to the specified clique member or group when enabled. A selection will have to be made from each drop down list box before the message will be sent as both fields have a NULL value as the default entry.
- The **Message Log field** will display a list of all messages sent or received along with a designation of the sender / receiver userid. The messages will remain in this field until the Clear Log pushbutton is enabled. All messages will be stored in a system log file for playback after completion of the mission, including those cleared from this field.
- The local user can acknowledge the receipt of the message by enabling the A**CK Message pushbutton**. Upon confirmation, an ACK data packet will be transmitted to message sender. This will ensure the sender that the message was received and read.
- The **Zeroize Send To pushbutton** performs the same function as the Zeroize pushbutton for the user(s) selected in the Send To field. This provides a remote user the ability to disable the system remotely for those resources unable to perform this task themselves. When enabled this feature will ask the user to verify the operation before deleting the content from the remote system memory.

  Note: A future enhancement could include the integration of the LifeShirt Physiological Monitor to display remote user data to support the decision making process prior to implementation of the Zeroize feature. See section 3.5 for a description of the LifeShirt functionality.
- **Map and Messaging Tabs** to select which page the user wishes to utilize.
- **System mode status**, red indicates the system is in initialization mode, green indicates the system is in user navigation mode.
- **System sensor status** indicating which sensors are currently being used to generate the position estimate.
- **Position estimate degradation reading** - Figure-of-Merit or SEP value.
- **Network Status** with a connected / disconnected value present.

4.9.6.3 External Features

The following controls and connections will be present on the exterior of the system module:

- **On/Off Switch** – for operation of the system, the system should be switched on at the start of the mission 8 hour period to ensure the BA-5590 battery life is not exceeded.
- **Antenna/Cable Connector –** this connection allows the user to mount the antenna directly onto the unit or if the unit is to be used in a standalone mode / configuration to connect an antenna via cable to the unit for remote antenna positioning.
- **Power Cable Connector** – this connector will be used to attach the power cord from the BA-5590 battery to the module. The BA-5590 will be utilized to power the NAVGSPDE system module, the CMR (Phase 2 prototype only) and the wrist worn display unit.
- **Ethernet Port Connector** – this port will be utilized only when an external military radio is connected to the system module.

- **Visual Display Cable Connector –** this is for a quick disconnect locking cable that attaches the visual display unit to the system module. The connector can be rewired / modified to meet the needs of any interface unit selected.
- **Manual Kill Switch –** this provide a mechanical means for the local user to perform the system zeroize process. The switch will be covered to prevent unintended use and should only be used as a means of last resort to disable the system.

4.9.7 Production Form Factor

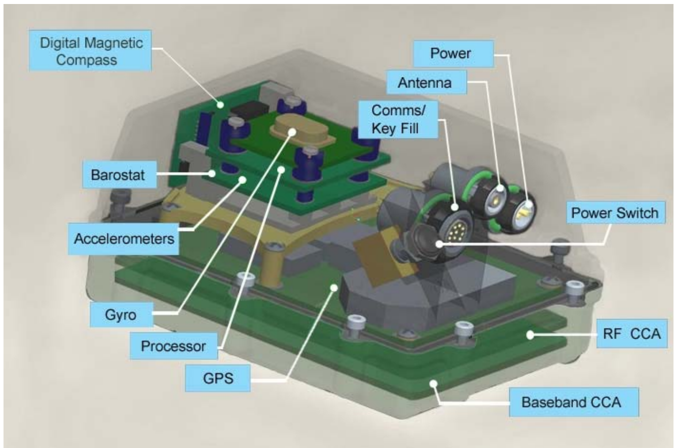

Figure 29 - System Final Form Factor Concept

The prototype systems that will be produced for the Phase 2 effort will include 3 components: the core system processor and sensor components in a single enclosure; the CMR radio; and the system display component. This configuration should be adequate to allow the necessary field testing without burdening the dismounted soldiers with too much mass or volume.

The phase 2 prototype design is not what is intended for the final form factor or production model. The CMR radio is currently in the process of undergoing a migration from the current WRST platform to inclusion of all system capabilities into an ASIC. The ASIC is targeted for production in 1Q08 and the cost target is $500 USD. The ASIC design will allow MDS to complete the construction of production units that are based on a single enclosure with the exception of the display component which will be either a wrist worn or heads up display module. At that point the system final form factor can be realized and all SWAP requirements specified in the BAA can be met. See figure above for the proposed final form factor for this system.

MDS will work with other component vendors to acquire and populate a custom system board configuration which can reduce the overall system module volume to provide an interconnection for all component electronic components / sub-boards. Reduction in overall size will be accomplished by combining the power management and signal processing components of the various off the shelf Printed Circuit Boards (PCBs) onto a single backplane which will also provide the necessary interconnection between PCBs, a memory management module and external interface connectors.

The module enclosure will be constructed out of a molded heat, moisture and shock resistant composite material with an estimated cost of $80.

4.10 Modes of operation

There are 3 basic modes of operation including the calibration, configuration and navigation modes.

4.10.1 Calibration Mode

This mode will be used at the point in time the system is assigned to a given user. The user will be asked to position the system on their LBV/LCE harness when in the Fighting Load/Light configuration worn items plus the assault pack. The unit will need to be located and fixed in a single position prior to the calibration activity. The user under direction by the logistics support resource(s) will calibrate the system:

- User step length. GPS access will be required and the user will have to walk between two known points while being tracked by GPS. The system will automatically update the local system to utilize the collected data to provide a more accurate step length model for the specific user.

  Note: The Velocimeter sensor component of the system will also be utilized to overcome the limitations of the INS step model by providing an alternative data source for distance traveled and to augment the INS output. This calibration is just meant to ensure the output of the INS is as accurate as possible.
- Azimuth (Dead Reckoning) or alignment of the sensor to the user's spine relative to the location of the unit on the user's body. This calibration is used to determine the offset between the direction a person is facing and the direction the INS is pointing.

Note: These calibrations are only performed when the hardware is initially issued to a specific resource or when the position of the system is changed on the navigating personnel.

4.10.2 Configuration Mode

This mode is utilized by the logistics support personnel to download content specific to a given mission. The logistics user will collect the maps to be used for a given mission, the list of mission personnel and support resources, any pre-canned text messages that are specific to a given mission type, and will use this data to populate each system node prior to personnel deployment. This data will be utilized to provide a list of maps that are accessible to the system user, the list of pre-canned text message for fast message send/receive and to configure the network by identification of resources that will belong to a given clique. In the future we will add the capabilities for this data to be downloaded from C2 or base locations to the users in route to or within the area of operation.

4.10.3 Navigation Mode

This is the primary mode of operation for the system users. Post calibration and configuration, the system user will only need to turn the system on and conduct their normal activities while the system initializes. During the system initialization phase all system components will be started, the ad-hoc network will be created and a local coordinate system will be established. During this operation a red status indicator will be displayed to the user. When the status indicator changes from red to green the system will be ready to generate position data and communicate this data to other members of the clique / C2.

4.11 User classes and other involved personnel

There will be a single user class supported by the proposed system; however, based on logic and action there will be a distinction between user types. These user types include the Admin, Team Lead, and Soldier users.

4.11.1 Organizational Structure

The basic structure of the ONR project clique organization matches that of the USMC Rifle or Recon Platoon as shown below. The platoon will be the primary set of users or system nodes that are supported by the updated application. The total clique number/size of 50 users will be made up of relays, beacons and

/ or dismounted soldiers assimilated from other cliques. Assimilation of external clique members will have a future system enhancement post completion of a functional prototype. The Admin user class will be resources that are assigned to logistics / technical support of the platoon, the same type of resources that currently support the deployment and maintenance activities for current electronic devices utilized by the USMC.

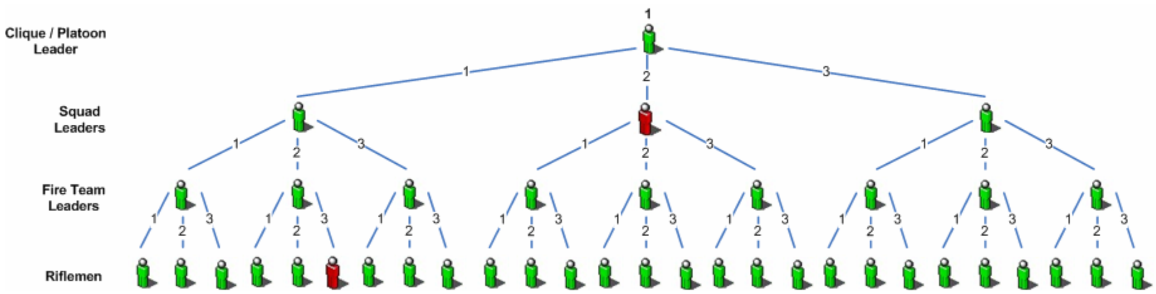

Figure 30 - UID Clique Hierarchy Diagram

4.11.2 Profiles of User Types

A) Team Lead – this user will be the lead resource associated with the various USMC unit levels. Fire Team Lead – Fire Team Level, Squad Leader, Platoon Leader, etc… These users will be responsible for configuration / deployment of fixed position beacons / data relays, coordination of clique communications, assimilation of new clique members and communication with the command center or next higher level team leader.

B) Soldier – this user will be the basic system user, they will be able to view system data and send / receive text messages. They will also have access to the map user options for panning, measuring distance, etc.

Note: These user roles are also associated with security levels that define what actions each user type can perform on the system. The security settings will be associated with a user's system versus an individual end user, therefore anyone who has control of a given system node will have the permissions assigned to that node.

4.11.3 Interactions among User Types

The dismounted soldiers can interact via the use of the text messaging feature, with the ability to send canned or typed text messages to the entire group or to a given individual. All system users will have access to a remote zeroize feature that can disable another clique members system over the data network link. This interaction will allow a system node to be disabled to prevent unintended use by unfriendly forces; the feature is an attempt at keeping clique member position data secure and to prevent reverse engineering of the product or tampering.

4.11.4 Other involved personnel

Admin user – this user will be a logistics technical resource similar to the radio or computer technician who will be responsible for establishing clique node identification, ranging partner tables, communications channels / partners for text messaging, selecting and calibration of mission maps for the clique, setup for each system to be deployed with the dismounted resources. Pre-configuration and setup for the location beacons / data relays, 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.

4.12 Support environment

The admin user will need to have access to all nodes for calibration support as well as pre-mission configuration. This access can be made on a one by one basis or data can be downloaded to all clique nodes that will be utilized for a given mission. To download data to all nodes simultaneously, the admin user will have to have physical access to the individual nodes to power them on, and will require access to the system wireless LAN to enable connection to all mission nodes, this will be accomplished via use of the a standard radio node unit. The configuration file will be populated and uploaded from a laptop or desktop PC. Text editing software will be required to populate the configuration file.

5. Operational Scenarios

The following operational scenarios depict how the proposed system will support operations in real world scenarios. The information provided is based on a review of current operational tactics as described in USMC field manuals. Every attempt has been made to ensure the system can meet the operational requirements, generate and communicate accurate position data, while utilizing current operations techniques to support the system capabilities. There should be no impact on current USMC operations or tactics imposed by this system.

The proposed system will support four methods for generating a position estimate:

- Absolute Positioning – using GPS or auxiliary data;
- Range free relative positioning – via use of the INS components;
- Range based relative positioning – via the use of the RF TOA ranging capability; and
- Manual positioning – using the map interface set position feature.

The Geo-location core navigation system will be supported by fixed (a.k.a. least mobile) reference points, auxiliary absolute position references, and mobile nodes. The fixed or least mobile system nodes are those where the operator has periods of time without movement, such as security / support squads, over-watch, forward observers, or sniper teams. Auxiliary absolute position data references include all mission support vehicles that are outfitted with the auxiliary equipment previously described. The mobile nodes will be the assault force team operators who will have the highest mobility status during the mission execution.

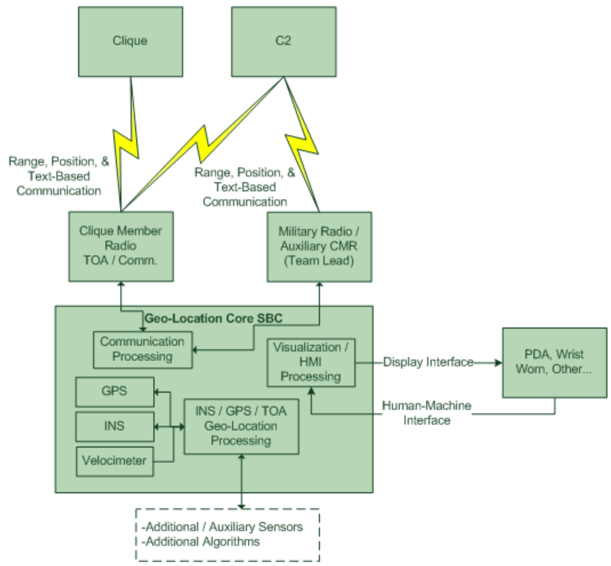

Figure 31 - System Components

5.1 Calibration

As previously discussed, each system node that is worn by a dismounted soldier will require calibration at the time the hardware is issued to the soldier. The soldier will need to evaluate where they can place the unit on their body in order to ensure it does not inhibit freedom of movement or interfere with access to the rest of the gear on their LBV/LCE harness. The system hardware should be mounted to the harness in the fighting load / light configuration, which includes the worn items plus an assault pack.

The optimal unit placement is on the back at or near the base of the spine; however the unit will operate and provide accurate results when placed on the front, side or back of the user. The only requirement is that the unit be worn on the lower portion of the user's torso; above the waist and below the chest.

Once the user has identified the optimal placement of the unit on their harness they will need to calibrate the unit to personalize the step length model and to provide the proper azimuth setting (Helmert Calibration). The calibration will only be required at the initial issue and when the user changes the placement of system hardware on their harness.

5.2 Pre-Mission Configuration

Prior to each system deployment, specific mission data will need to be down-loaded to the units by the admin / logistics support resources. Specific data that will need to be captured from the mission planning session include:

- **Maps specific to the mission area of operations** – these maps will be part of the configuration file that will be loaded in to the node memory to provide a common reference and set of map interfaces for the system users. Military grade maps available from any source(s) can be utilized by this system as long as they are compatible with RBCI/RBSA, Falcon View and FBCB2 application formats (NIMA, VPF, CADRG, and DTED). The maps can be annotated with any supporting mission information such as landmarks, waypoints, ingress / egress routes and other data that will support the mission situational awareness for the dismounted soldiers.
- **List of team / clique members who will be participating in the mission** – this data will be utilized to configure the network communications tables which specify the team members in the field that make up a given clique or networking island. This information is used to ensure all clique members can send or receive data and text messages from / to the other clique members and to provide a level of security / authentication for clique members and their data. This information will also be utilized to determine if a new member within range of the network island should be assimilated into the clique.
- **Structure of the Clique –** this data is required so the userids can be associated with the clique hierarchy / structure. Logic will be embedded in the system software which supports the localization of referential coordinates and sharing of that data based on clique structure. The logic enables the system to initialize as quickly as possible in an organized manner. This information also aids in ensuring the appropriate recipient is addressed when data or text messages are transferred within the clique.
- **Text Messaging pre-canned content –** this data will be utilized by the text messaging feature enabling the users to select a short canned message from a drop down list box. If necessary this data can be modified to meet the needs of the current mission.
- **Assisted GPS (A-GPS) data** – this data is utilized to orient the GPS receiver to the local region by providing satellite orientation information that can reduce the Time to First Fix (TTFF) and enable the system to initialize rapidly in instances where GPS is accessible or limited.

The pre-mission configuration data / files will be loaded into a specific location within each node's memory. At system start-up / initialization the mobile node will check the memory location and use the data present to load the State Vector Table, provide the user access to maps and populate the drop down list box on the text messaging page.

5.3 Deployment

It is assumed that absolute reference data will be available at the mission point of departure (base of operations or forward operating position). The clique members will be transported to the area of operation (AO) by land, air or sea. The vehicles used to transport the users will not be utilized within the mission AO but can be utilized to provide least mobile or fixed reference points for use in the mission. The transport vehicles will be utilized provided they have the appropriate hardware required to generate auxiliary data in support of the system operation.

5.3.1 System Initialization

When the mobile nodes are started the network will be created automatically based on the data loaded in the neighbor table portion of the pre-mission configuration file. This data will ensure that other clique resources which are in range of the newly formed network will not automatically be incorporated into the network island.

Figure 32 - Mission Briefing

In parallel with the networking, effort each node's geolocation processor will also begin searching for access to absolute data via GPS or auxiliary data source; if no absolute data sources are available the system will create its own local referential coordinate system.

5.3.1.1 Network Initialization

The CMR provides a transparent, self-organizing network that hierarchically organizes into two levels (not including the private IP network) as shown in Figure 33. Each level is composed of tiers. Tier 1a islands are composed of individual nodes. One member of the tier 1a island is selected to be the Island Head (IH) administrator. The IH controls island formation and is the primary gateway to tier 1b. Tier 1b is composed of mostly 1a island heads. The tier 1b island also has an IH. Tier 1b islands have members that are gateways to the private IP network. The network required to support 50 clique members will generally be contained within a single tier 1a island. An IH will be selected to be the primary gateway back to headquarters through any relays that are available, when needed; the CMR can also act as the Military Radio interface.

Prior to mission start when the clique members power up their CMRs, neighbors are discovered using Packet Radio Organization Packets (PROPs). PROPs are transparent to the user and are sent periodically after initial power up. The network will be formed and reformed as a result of the information resulting from the periodic PROPs. Once the network is formed, Link State Advertisements (LSAs) periodically send routing information to the network nodes.

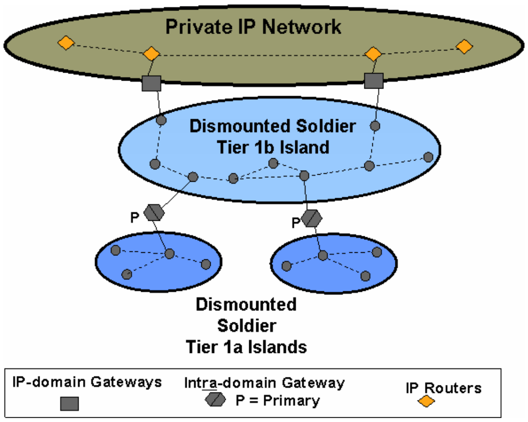

Figure 33 - CMR Network Structure

5.3.1.2 Referential Coordinate System Initialization

The geolocation processor system logic attempts to initialize to WGS-84 (GPS or absolute) coordinates. If absolute position is unavailable, the system establishes a local coordinate system. The local node position value for all clique member nodes initializes to (0, 0, 0), the local coordinate system uses the UTM (Easting, Northing, Altitude) grid. The CMR RF TOA ranging capability is used to compute ranges between neighboring personnel, once range data is available from a minimum of 3 neighboring nodes triangulation is then implemented to establish a referential coordinate system for each fire team. The output from the altimeter component of the INS will be utilized to provide the altitude value.

The highest ranked personnel among ranging partners (assumed to be one hop ranging partners) on the fire team shall be considered the origin of the local coordinate system and relative positions of other personnel shall be computed via a Self Positioning Algorithm. When higher ranked personnel are within RF range, the local coordinate system of lower ranked personnel must align to the higher-ranked personnel's coordinates to provide a common focal node for all fire team members. Once the coordinate structure of the fire team has been established, the process will continue with the fire team leader aligning the fire teams coordinates with the squad leader, this process repeats itself until all fire teams and squads are aligned with the platoon leader's coordinates. This referential or networked coordinate system will then be maintained throughout the duration of the operation. This entire process takes approximately 30 to 60 seconds.

If during the course of the operation absolute data values become present the networked coordinate system will be re-established on the absolute data set. When present, this data can reduce the amount of time required to initialize through the utilization of A-GPS.

If any node(s) within the clique have access to absolute data from GPS or an auxiliary data source, then the overall initialization process duration can be reduced to less than 30 seconds (with A-GPS). The nodes with access to the absolute reference will already have a position value and their position estimate will not have to be calculated. In this case one of the nodes with the absolute data value would act as the coordinate system focal node to provide an absolute coordinate system.

All clique members have the option to manually override the process by enabling the "set position" push button located at the top of the UI Map Page and identifying their location by pointing to a landmark or their position on the calibrated (CADRG) map. If the user has a reliable and accurate position based on map coordinates this will enable the use of absolute data based on the calibrated map metadata values.

5.3.2 Auxiliary Data Sources

One of the absolute data sources / functions listed below can be used to support operations when support vehicles with the appropriate hardware are within range of the area of operations:

- Assisted GPS;
- Differential GPS;
- LORAN/LORADD, Psuedolites / APRS; and
- CMR Beacons.

These sources would be considered signals of opportunity and would be used to support the position estimates generated by the INS and system sensors / software.

5.4 MOUT – Block / Building Clearing Operations

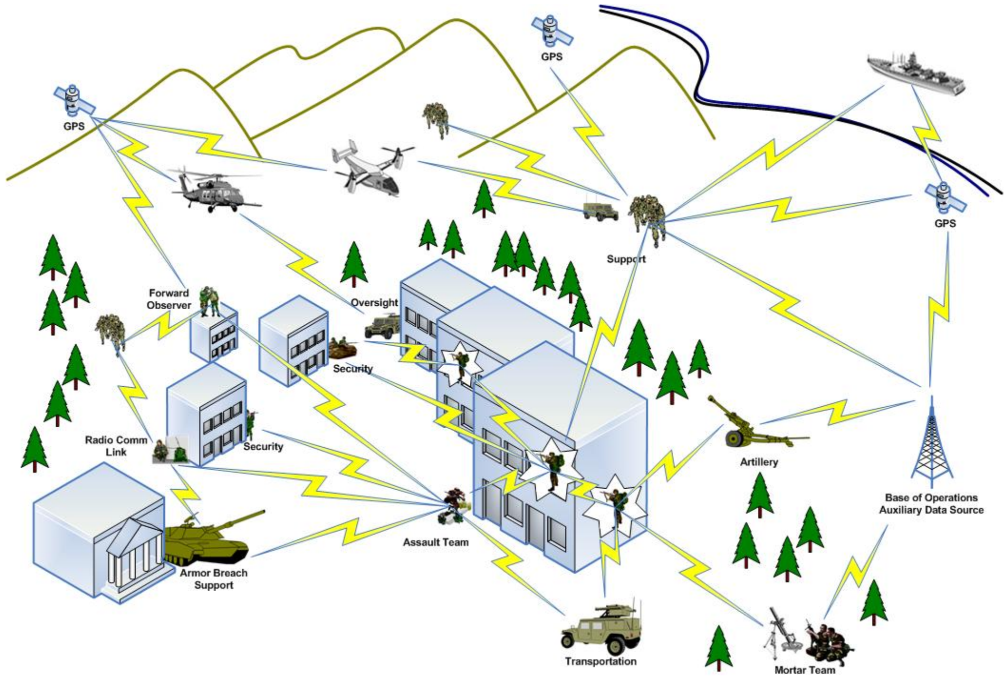

Figure 34 - MOUT Concept of Operations

Based on data in the USMC MOUT field manual, the system can support current operating procedures in the following manner.

Figure 35 - Transportation and Over-watch Support

The clique members will be transported to the area of operations (AO) by helicopter or ground transportation such as a HMMWV (Humvee), Stryker, or other wheeled vehicle. The team may also travel to the AO on foot if the target objective is within close proximity of the base of operations and there is adequate security / over-watch support available.

Once in the AO the soldiers will dismount and based on mission parameters will move to locations as specified in the mission brief to perform their assigned tasks. The security teams will move into positions which provide the fields of fire necessary to provide protection for the assault team. The support forces will take up their positions, forward observers, snipers and over-watch teams will gain access to a position that provides adequate vision for mission observation. In the majority of urban environments these positions will be in the upper floors or on the roofs / tops of buildings to enable the direction of fire support and to ensure the assault team objective can be viewed adequately. Other indirect fire support teams will setup positions within or near the AO; these include mortar teams within close proximity and artillery in locations within weapons range. All dismounted resources within the AO will have a system node mounted on their body to provide text / data communication, position information distribution and a display unit to provide a visual representation of the location of each team member positioned on a map of the AO. When the dismounted resources move, their navigation paths will be tracked by the INS.

Figure 36 - Building Clearing w/ Assault, Security and Support Teams

The INS will be used for short range navigation; when the INS exceeds its position accuracy threshold, the RF TOA ranging capability of the system will be utilized along with other system sensor data to recalculate the user's position and to recalibrate the INS. This position reset function will automatically occur as a result of the PosiFusion processing and sensor feedback loop.

The nodes of those resources that are least mobile (security, support, forward observer, snipers, over-watch etc…) will be more stable and will maintain accurate position data with fewer updates required than the mobile users. Therefore the least mobile node position data will be used to provide the data for trilateration of the mobile user's position. The NAVGPSDE system will identify the least mobile users as the ranging partners or reference nodes for the mobile users. The PosiFusion process will utilize the position data acquired from RF TOA ranging to perform trilateration operations and generate a position estimate. As previously described, this data will be utilized in conjunction with the INS position estimates to provide the most accurate and sustainable position estimate for all mobile resources.

When the assault team performs building clearing activities the system will operate in the normal mode with the INS providing the primary navigation tracking data; the users within RF range outside of the facility will continue to support the RF TOA ranging capability for the soldiers inside the structure via use of the CMR. The CMR is capable of removing multi-path signals normally produced inside of structures via use of the QMFR ranging waveform.

Figure 37 - Building Clearing Foothold

In addition, the assault team members will perform assault, security and support roles within the building structure. While the external security team provides three-dimensional (3D) coverage to ensure all danger areas are covered. The assault team members will provide the same 3D coverage for other members within the stack for those danger areas within the structure that the external security team cannot cover. The assault team will enter the building in stack formation. The supporting resources will perform structure breaching activities and will roll off to the back of the stack. The team will move from foothold to foothold through the structure establishing rally points. Assault team members will peel off of the stack to clear individual rooms and will return to the back of the stack once the rooms have been cleared. When moving between floors security resources will be stationed at rally points / footholds to ensure the structure egress route does not become compromised. The resources that remain at the secured footholds will provide support for eLNS RF TOA Ranging functionality by providing the least mobile reference nodes within the structure.

The assault team, the security team and the support teams should move in between buildings in a tight tactical stack to avoid exposure to possible enemy fire from the street. The system will support these maneuvers with the INS still providing the primary navigation tracking component; the RF TOA ranging capability will bound the INS error accumulation by alternating which nodes are utilized to provide the least mobile ranging partner reference points.

Any available absolute data will be utilized to overcome the limitations of both the INS and RF TOA ranging system capabilities. The vehicles used for transport to the AO will be utilized to provide absolute data references as previously described and can be utilized as stationary ranging partner nodes to support the RF TOA ranging capability of the system.

The estimated accuracy provided by the INS is 25 meters, over a distance traveled of 500 meters. To overcome this limitation the INS will be recalibrated every 50 meters by the combined output of the GPS/INS pre-processor and the GPS/INS/TOA processor hardware / PosiFusion software as previously described in the capabilities section.

At any point in time during the mission operation the system wearer will have the ability to update their location manually by marking their current position on the AO map display unit. This feature will be most useful to the least mobile users to correct their position accuracy to provide better data which provides a more accurate value to the mobile user position estimate trilateration processes.

5.5 Underground / Cave Operations

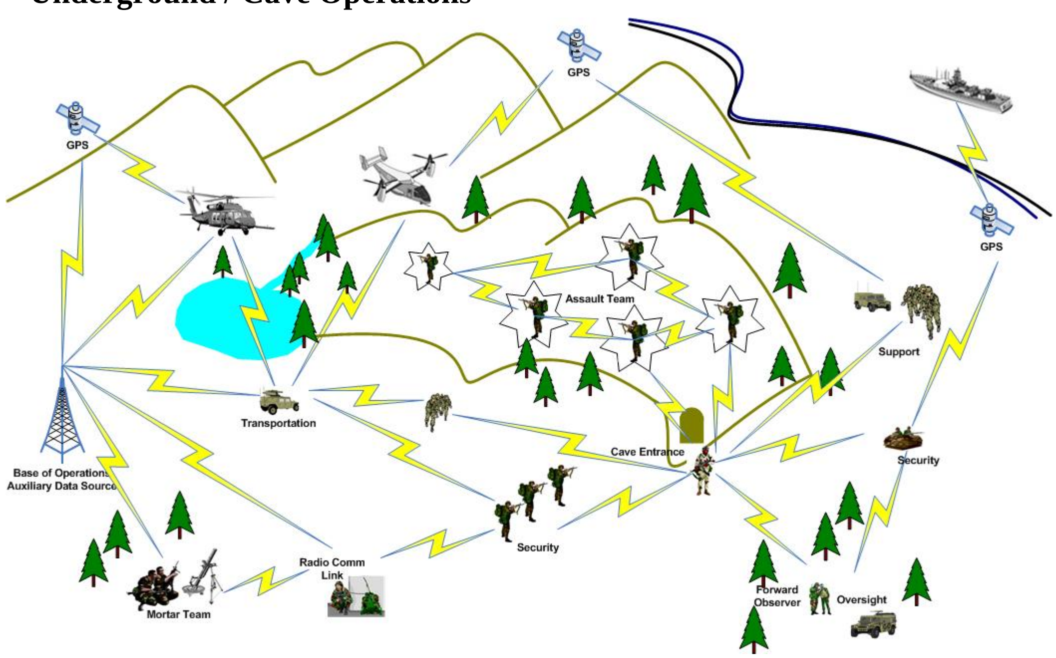

Figure 38 - Cave / Underground Concept of Operations

The transportation process and utilization of support vehicles will be similar to that described for the MOUT scenario. The basic operation for use of least mobile anchors or reference data points will also be used in the Underground / Cave scenario with the exception of the following. The resources entering the cave will need to ensure the accuracy of their position at the mouth of the cave. They can manually update their position based on any landmarks that can be located on the map at or near the cave; if the entrance to the cave can be located on the map it will provide the best landmark. The manual position update operation is not required as long as the team members' position estimate accuracy is 15 meter SEP or less. One resource will need to provide security at the mouth of the cave; this resource will also provide communications reach back to the rest of the clique for the mobile users who enter the cave. The assault team or mobile clique members within the cave will utilize the entry point security resource and the estimated position of other team members within the cave to provide RF TOA Ranging references / partners.

Figure 40 - AO Transportation

The INS component can provide the required accuracy up to 500 meters into the structure without recalibration if the starting position accuracy has been reset; further the INS is capable of maintaining the 25 meter SEP indefinitely as long as RF TOA range data can be acquired from other team members. The system will support position data communication back to the clique network by multi-hop relays from members inside the structure through the cave entrance security resource. Each system node on the mobile users can act as a relay to provide multi-hop network connections and to ensure position data of all clique members either inside the cave or outside of the structure are visible to the entire clique and C2 via the military radio interface.

Figure 39 - Navigation, Target Objective Identification

In this scenario the clique members will enable the NAVGPSDE system using the external power on switch; the system will initialize/localize as previously described. The team will be transported to the AO via helicopter or ground transport.

The team will then proceed to the objective by foot using standard land navigation techniques. The dismounted resources will move in staggered tactical column(s) over various types of terrain to complete the mission.

Figure 41 – Security, Support, Mortar and Over-watch Teams

Once they reach the target area they will establish perimeter security via deployment of over-watch teams, snipers, mortar support, etc… The support team will take up their positions and the assault team will begin the operation by clearing the mouth of the cave to ensure no explosive devices have been hidden to protect the cave entrance. Security resources will cover the mouth of the cave to prevent unfriendly forces from entering behind the assault team who is clearing the cave.

Prior to entering the cave the assault team will check their position estimate accuracy and mark / update their position manually if excess position errors are displayed. One or more security resources will be posted at the mouth of the cave to provide an RF ranging reference point and provide an RF LOS conduit for communications links between system users inside the cave and support resources outside the cave.

The assault team will navigate throughout the cave complex clearing each space while moving in a serpentine or diamond formation. Each team member will have an area of responsibility to provide coverage of danger areas within the area(s) to ensure the team is protected; a lead resource will be covered by flanking and a rear security resource. The flankers will support the lead man via use of probes and grappling hooks to clear the areas of any trip lines or explosive devices and to enable the team to find alternate cave entry / exit points.

Figure 43 - Cave Entry / Position Fix

Figure 42 - Cave Navigation

The team will normally clear the major segments of the cave locate any munitions and/or combatants, neutralize and remove the combatants and then prepare the facility / munitions for detonation. The team may seal the main entrance and employ the use of smoke or tear gas to flush out hidden personnel or to locate alternate cave entrances/exits. The external security forces will ensure that cave inhabitants who attempt to escape from alternate routes are secured.

The system will support the mobile users within the cave by tracking their navigation path via use of the INS component. The system provides a means to generate a local coordinate system for unmapped environments and provide referential position data for these environs. The team members within the structure can localize their positions manually and the system will maintain the local coordinate system while they navigate through the structure. The system will utilize the mobile nodes within the cave to provide support for RF TOA Ranging operations when required to calibrate the INS components throughout the mission duration. Once the users have cleared the structure and exit the enclosure their position information will re-localize to use the same coordinate system as those clique members who remained outside of the structure.

Figure 44 - Cave Clearing

The entire clique will then complete the remainder of their mission and return to the point of embarkation using the predetermined egress routes, check points and rally points. The system will continue to track all clique members throughout the remainder of the mission as previously described.

5.6 Field Operations in Forest / Open Terrain

The system will support operations in open or forested terrain using the same operational procedures as previously described for navigation to the target objective. The dismounted team will be transported to the AO by air or ground transportation, once they begin their mission either reconnaissance or combat patrol they will move throughout the AO on foot. Whether the team utilizes single or double tactical column formation the lead, flank and rear guard segments of the clique will move in a coordinated fashion. They will move from checkpoint to checkpoint over the course of the patrol. Mission rally points will be determined over the course of the patrol and will be communicated to all team members.

Figure 45 – Patrols in Varied Terrain

The system users' will power on their systems as described in the other scenarios per Standard Operating Procedure (SOP) and the system will automatically initialize all system components and establish the local / absolute coordinate system. The primary navigation tracking device supporting this scenario is the system INS component. The coordinated movement of the team and separation between team members will allow the system to identify and utilize mobile system users for RF TOA ranging partners / references when trilateration operations are required to calibrate the INS component. When the team reaches the mission checkpoints they will communicate to C2 to provide mission status. At the checkpoints or rally points the clique members can verify their position accuracy and update manually if required.

In these scenarios the area covered by the clique may be greater than the other scenarios and the terrain may also have increased vegetation / foliage coverage. The increase in area and vegetation will require additional transmission power to ensure communications and RF TOA ranging data can be transmitted between clique members. The CMR has an internal mechanism to support variable power output to ensure communications and ranging functionality in these environments. The system accuracy over the increased range will remain the same.

6. Summary of Impacts

This section describes the operational impacts of the proposed system on the users, the developers, and the support and maintenance organizations. It also describes the temporary impacts on users, buyers, developers, and the support and maintenance organizations during the period of time when the new system is being developed, installed, or trained on.

This information is provided in order to allow all affected organizations to prepare for the changes that will be brought about by the new system and to allow for planning of the impact on the buyer, agency or agencies, user groups, and the support maintenance organizations during the development of, and transition to the new system.

6.1 Operational Impacts

The only operational impact required for use of the proposed system is in the calibration and configuration activities. This impact should be minimal as mission planning efforts are already conducted by the USMC Recon and Rifle squads.

The additional tasks required for calibration will only be required at the point the system is issued to a soldier and when the soldier changes position of the unit on their LBV/LCE harness (azimuth only). The calibration process is called a Helmert Calibration and includes:

- INS Step Length model update (scale factor adjustment); and

- Sensor Misalignment (Azimuth) adjustment.

It is estimated that the calibration procedure will take no longer than 15 minutes after end user resources are trained on the proper procedures.

The additional tasks that will be required for configuration are:

- Acquisition of electronic copies of the mission map(s);
- Calibration of the maps if not already configured for use by existing systems (RBCI, Falcon View or FBCB2);
- Creation of a list of mission personnel and their respective ID, assigned system node;
- Generation of pre-canned messages, only if changes are required from the default list;
- Acquisition of A-GPS isotropic model data for the AO region to reduce the system TTFF; and
- Downloading this information into the appropriate location on all clique member nodes.

It is estimated that this process should take no more than 30 minutes once the logistics resources are trained on the proper procedures.

The logistics resources can extract all logged data from the clique member nodes post mission completion. The mission related data can be utilized in debrief activities by providing a means to review the movements of mission personnel and any text communications between clique members. This data playback will be useful in identification opportunities for improvements or lessons learned.

6.2 Organizational impacts

The system will require the existing logistics resources to take on the responsibility for configuration and maintenance of the system nodes prior to mission deployment. Training for the logistics resources and the system users will also be required. It is expected that the training time for logistics resources will be no more than 1 day, and less than 2 hours for system users.

6.3 Impacts during development

During the phase 2 development efforts MDS will require the support and feedback from the end user community to ensure the system design meets the desired Human Factors Engineering (HFE) / usability standards. The end users should be the resources who specify what type of visual display device is preferred, the best location for placement of that device and the type and location of the interface controls. Access to this community for prototype evaluation will also be of benefit in component of the detailed design for the systems final form factor

7. Analysis of the proposed system

This section provides an analysis of the benefits, limitations, advantages, disadvantages, and alternatives and trade-offs considered for the proposed system.

7.1 Summary of improvements

This sub clause provides a summary of the benefits to be provided by the proposed system.

7.1.1 New Capabilities / Features

- Ad-hoc self forming self healing network;
- Functional RF TOA Ranging w/ QMFR;
- Addition of Velocimeter to verify / compliment INS accelerometer data;
- System zeroize function to prevent tampering;
- Secure transmission and intrusion prevention waveforms / encryption capabilities;

- Fusion of multiple sensor data to provide accurate position estimates;
- Principle Component Analysis, Kalman Filtering and predictive modeling to improve position estimate accuracy;
- Interface via Military Radio for C2 reach back;
- Visual Display contrast adjustable for viewing in direct sunlight and compatible with NVG for use at night;
- Assisted GPS & Differential GPS support to reduce TTFF and enable absolute data access in GPS Limited environments; and
- Support for Auxiliary position data sources.

7.1.2 Enhanced Capabilities / Features

- Automation of the calibration / system initialization processes;
- Set position feature simplified;
- User interface simplified; and
- System accuracy over time and distance traveled.

7.1.3 Deleted Capabilities / Features

- HTTP Service/Communication Layer;
- User Login;
- Manual Network Configuration;
- Manual INS Configuration;
- Manual GPS Configuration; and
- User Input Options/:
  - → Go to a user-entered location on the map
  - → Get info on a selected user/asset icon
  - → Custom text-messages at run-time
  - → All ATNS menu items
  - → Clear / Toggle Map Layers
  - → Add Item (Waypoints, Assets)
  - → Go To Location on the map

7.1.4 Improved Capabilities / Features

- System accuracy improvements based on addition of system sensors and fusion algorithms;
- Single enclosure targeted for product final form factor to reduce system volume and mass;
- Extension of the network communication range;
- Ability to support all types of human mobility (running, crawling, jogging, etc…);
- User controls / UI options capable of operation by a gloved user;
- Power consumption requirements of the system components support operation over an 8 hour period;
- Little to no user interaction required for system operation;
- Ability to accurately track system users over long distances (10Km or more);
- Network data communications range in LOS (2km) and NLOS scenarios;
- Network improvement based on QMFR ability to overcome multipath issues; and
- More robust and mobile approach including the use of peer to peer networking for position data and text communications.

7.2 Disadvantages and Limitations

The following list of limitations are inherent within the proposed system, an attempt has been made to address each of these limitations in the integration of system components and/or logic as previously described:

- All RF system components are limited to LOS connectivity. The network system utilizes multi-hop connections to overcome this limitation and the RF TOA Ranging utilizes QMFR to overcome the LOS and multipath issues encountered inside of structures or caves.
- Maximum number of network nodes that can be handled within a given clique or network island is 50, the network can support up to 2500 total users or 50 cliques.
- Accuracy of TOA ranging values decreases over distance between nodes.

7.3 Alternatives and Trade-offs Considered

This section describes the system hardware components, processing algorithms and logic considered for inclusion in the high level system design. A brief description of the element reviewed and the reason(s) why it was not selected for use in the system is provided.

7.3.1 Hardware Components

The following hardware components were reviewed for possible use in this system but were not chosen for inclusion as a component of the proposed system as previously described.

7.3.1.1 INS/IMU

1) Vectronix Core Navigation Module (CNM)

A beta CNM demonstrator unit has been acquired from Vectronix and has been partially integrated and tested by Mercury system engineers. The CNM can be considered somewhat of an expansion on the DRC system concept, as it extends the DRC's capabilities by providing 3-D navigation data. The CNM consists of a tri-axis accelerometer, a tri-axis magnetometer, a horizontal axis gyroscope, a barometer and a micro-controller capable of providing fused position estimates in NMEA-0183 compatible and proprietary Vectronix sentence formats. The accelerometer and magnetometer sensors are of a lower grade than those utilized in the DRC in order to reduce system cost; however, reduced system performance and tracking accuracy may result from such a configuration. Currently, the most significant limitation is in regard to the CNM gyro and compass sensor integration, as Vectronix engineers have been unable to accurately fuse the data from each. This is causing delay in further product releases as well as further evaluation and implementation of the CNM by Mercury engineers. The step-model is also a limitation of the CNM, as it is currently a static model that averages the step length of the navigating personnel and is projected to produce results similar to the DRC only during forward walking motions. Significant advantages of the CNM solution are relative to its ability to be mounted practically anywhere on a user's belt or torso area as well as the fact that it is a completely self-contained INS system in a small package that already meets the SWAP requirements of the ONR project. As well, Mercury has already developed most of the interface software needed for CNM operation.

This unit will be considered as an alternate INS component, it is not currently considered a component of the proposed system based on an unknown target date for component availability. At this point we are certain that the CNM will not be ready for use in construction of the Phase 2 prototype systems.

3) Techno – Sciences TRX

The TRX system has been partially demonstrated to Mercury personnel; however, unidentified problems encountered during the demonstration have obscured an accurate evaluation of the product's performance capabilities. Review of a public domain white paper documenting the TRX design has presented Mercury engineers with sufficient data to understand the basic operation of the system, specifically in the area of novel signal processing techniques that detect and respond to a dynamic step model via the implementation of a user-defined step library. In the face of challenges to a partnership opportunity between Techno-Sciences and Mercury, efforts to continue researching the prospect of integrating the TRX system have almost entirely ceased. This is not a complete loss as several of the most interesting aspects of the TRX system should be reproducible to a certain degree by Mercury and the other selected INS Partner development teams defined herein.

4) Intersense NavShoe

The NavShoe is another INS solution whose performance capabilities mostly exist on paper. A partner development opportunity has been discussed with the company, and a preliminary agreement has been established that suggests significant support may be available for further development of the NavShoe system. On paper, the NavShoe system quite possibly exhibits the most promising metrics along the lines of satisfying the 3-D position accuracy (approximately 1%-2% SEP over distance traveled) and SWAP requirements for the ONR program. The NavShoe hardware incorporates MEMS sensors that are to be attached to the user's shoe and a wireless link that streams sensor data from the shoe sensor to a receiver module that can be embedded in the vicinity of the core navigation processor. In comparison to the other INS options, the NavShoe development team seems to have the greatest grasp on solving the various sensor integration problems that will be encountered during the ONR project development – namely the difficult gyro and compass integration challenge, GPS transfer alignment (utilization of GPS positions to compensate the gyro bias error), and decentralized filter algorithms that may be necessary to resolve position estimate errors that may arise via the combination of RF range measurements and INS measurements amongst clique members. However, concern definitely exists in regard to the ability of the NavShoe team to be able to develop and deliver a reliable non-paper solution in the timeframe available. Also, no processor requirements have been defined to support the sensor fusion algorithms that would be necessary for the NavShoe system.

5) University of Michigan Personal Dead Reckoning (PDR) System

Along with the DRC, the PDR system is the only other INS system that has been successfully demonstrated before Mercury personnel. The current system is very similar to the NavShoe design as it is also mounted on the foot of the navigating personnel and exhibits excellent tracking performance (approximately 1%-2% SEP over distance traveled) over a variety of legged motion (walking, running, climbing, etc.) in all directions. The limitations of the current system can be attributed to a bulky form factor and the lack of magnetic compass/gyro integration to resolve azimuth errors experienced during navigation timeframes in excess of 20 minutes. The current PDR implementation also requires at least a 133 MHz Pentium-class processor and a Linux OS loaded with real-time extension support.

Mercury has engaged in a development effort with University of Michigan to reduce the PDR SWAP while attempting to maintain the performance achieved by the larger system implementation. The performance of the miniaturized system, as well as its ability to withstand harsh environments, still need to be proven before the device will be considered as a viable component in the system.

6) MicroStrain 3DM-GX1 Inertial Measurement Unit (IMU)

Mercury has acquired and analyzed the functionality of the MicroStrain 3DM-GX1 Attitude Heading and Reference System (AHRS). The 3DM-GX1® module combines three angular rate gyros with three orthogonal DC accelerometers, three orthogonal magnetometers, multiplexer, 16 bit A/D converter, and embedded microcontroller, to output its orientation in dynamic and static environments.

Operating over the full 360 degrees of angular motion on all three axes, 3DM-GX1® provides orientation in matrix, quaternion and Euler formats. The digital serial output can also provide temperature compensated calibrated data from all nine orthogonal sensors at update rates of 350 Hz.

Networks of 3DM-GX1® nodes can be deployed by using the built-in RS-485 network protocol. Embedded microcontrollers relieve the host system from the burden of orientation calculations, allowing deployment of dozens of 3DM-GX1® nodes with no significant decrease in system throughput.

Output modes and software filter parameters are user programmable. Programmed parameters and calibration data are stored in nonvolatile memory.

3DM-GX1® utilizes the triaxial gyros to track dynamic orientation and the triaxial DC accelerometers along with the triaxial magnetometers to track static orientation. The embedded microprocessor contains a unique programmable filter algorithm, which blends these static and dynamic responses in real-time.

This provides a fast response in the face of vibration and quick movements, while eliminating drift. The stabilized output is provided in an easy to use digital format. Analog output voltages proportional to the Euler angles can be ordered as an option.

Full temperature compensation is provided for all nine orthogonal sensors to insure performance over a wide operating temperature range. The price per unit at volumes of 1000 pieces was approximately $900 USD. Even though this product will provide the adequate support for the INS processes and its size meets the volume needs of the BAA, the unit cost is excessive and will not allow the system to meet the price component of the SWAP requirements.

7.3.1.2 Single Board Computer (SBC)

1) Balloon Board – Open Source Development Project

Balloon is an Open hardware development board intended for use as a computing module in embedded devices, development projects or educational settings. Balloon means you can concentrate on the custom development part and add it on to the base Balloon. Balloon has the CPU, RAM, NOR and NAND Flash, serial, USB client/host/OTG, I2C, Compact Flash, IO header, buffered expansion bus, simple 8-bit bus, and a CPLD or FPGA. It is small (113mm x 56mm), lightweight (<30g), and operates on low-power (<1W).

The board is designed so that unneeded parts can be left off and things still work, to keep costs and power consumption down. Small batches of boards (30 or more) can be built to a given spec. Though an attractive option, FPGA development for the Balloon board will most likely take longer than phase II will permit; hence, the device will not be considered for the ONR solution. Cost is also unknown for this device which further discourages its use in the near future. Further information is available at following websites – http://balloonboard.org , and http://www-mdp.eng.cam.ac.uk/.

2) InHand Electronics – FingerTip4

At the size of a credit card, the new Fingertip4 is based on Intel's PXA270 processor and delivers over 500MHz of processing power while consuming less than 0.5 W of power. Fingertip4 incorporates the latest peripherals, including Compact Flash, SDIO, USB host, multiple serial ports, and connects to a wide variety of LCD displays. However, a daughter card interface is necessary to access several of these and other necessary peripherals, such as the Ethernet interface. Fingertip4's power interfaces include support for on-board Li-Ion battery charging and capacity management, with additional support for other batteries and separate power inputs for backup batteries and line voltage.

The PXA270 processor does not provide hardware support for floating point arithmetic which is a significant downfall due to the position fusion (PosiFusion™) algorithm's requirement to perform accurate position estimations in near real-time. The device does, however, provide software emulation for floating point instructions which may make the board feasible for implementation as an alternative if the software FPU can be proven to meet the performance requirements. Cost for the Fingertip4 is in the neighborhood of $300-$400. Further information available at – http://inhand.com/fingertip_4.asp.

3) CompuLab – SBCX270 PC/104+

The SBC-X270 is a standard PC/104+ compliant, single board computer that cost around $100-$200. It is implemented by CM-X270 module providing most of the functions, including an integrated wireless LAN (WiFi) interface. The SB-X270 carrier board provides connectors for four (4) serial interfaces (RS232/RS485/RS422/TTL configurable), dual 100 Mbps Ethernet ports, host / slave USB ports, and several additional functions. The feature set of the SBC-X270 is customizable according to the price /

performance targets of the user's application. The mechanical design of the SBC-X270 allows selecting between two popular form factors: either standard PC/104+ with headers or extended PC/104+ with front panel connectors.

The SBC-X270 contains PC/104+ expansion connectors which open it to the wide range of standard peripheral cards. Furthermore, the SBC-X270 contains an electrical interface and slots for PCMCIA, CardBus and MMC/SDIO extension cards, which may be inserted and secured in the slot with no additional mechanical means, extending the system with capabilities such as a larger solid state disk, GPS or GSM modem.

The device is small (96mm x 91mm without front panel, 111mm x 91mm with front panel connector). Height ranges from 10mm to 22mm (includes the CM-X270 module), depending on the connectors assembled. Power consumption is 2-5W in full activity, below 50mW in sleep mode. Similar to the Fingertip4, the SBC-X270 is based on Intel's XScale PXA270 and lacks hardware floating point arithmetic support but provides software FPU emulation. This means the performance of the device would also have to be proven before being included in the ONR phase II system. Further information available at – http://www.compulab.co.il/x270/html/x270-sb-datasheet.htm .

4) Kontron - EB405

The EB405 SBC is built around the 266MHz AMCC 405EP 32-bit PowerPC reduced instruction set computer (RISC). The device provides onboard Dual Fast Ethernet interfaces, four (4) serial interfaces, I2C as well as several other features. The board is small (115mm x 75mm) and can operate within a range of -40 degrees Celsius to +85 degrees Celsius (extended range version). Weight of the unit is 47 grams. Power consumption is 4W. Peripheral connectors will slightly increase SWAP, but this board is a considerable alternative because it features an on-chip floating point unit (FPU) and can support VxWorks and Linux real-time operating systems (RTOS's). Further information is available at – http://us.kontron.com/downloads/datasheet/eb405.pdf.

7.3.1.3 RF TOA Ranging / Networking

1) Michigan Technical University (MTU) Wireless Local Positioning System (WLPS)

The WLPS was originally the targeted component that would provide the system with the data networking and RF TOA Ranging capability. The WLPS system is still under development at MTU as part of an on-going graduate student project. When this program produces a prototype system capable of supporting our application / system MDS will review and test it's suitability as an alternative to the ITT CMR.

The WLPS consists of (1) a base station in each monitoring mobile, which serves as a non-static or dynamic base station (DBS), and (2) a transponder (TRX) in target mobiles, which acts as an active target. Unique identification (ID) codes are assigned to each target. A DBS transmits an ID request (IDR) signal to all targets located in its vicinity, and targets respond to that signal by transmitting their ID codes back to the DBS. A DBS recognizes each target by its ID code, and then positions, tracks and monitors those targets. In WLPS, each mobile may be equipped with DBS, TRX, or both. For this effort, WLPS transceivers will consist of both DBS and TRX components.

In general, the quality of a positioning system is characterized by two important metrics: one is the probability-of-detection (POD, pd) that represents the ability to detect all targets, and the other is the probability-of-false alarms (pfa) that indicates the probability of falsely treating noise as the desired target. In both vision and radar positioning [1] systems, the target is a passive target, which incurs expensive signal processing. In addition, detecting a passive target always requires tradeoff between pd and pfa: as the former increases, the latter increases as well, resulting in a low overall performance. Because targets in the WLPS system are active and contribute to the process of identification by specific ID codes, the achieved POD is high while the probability-of-false alarm is almost zero.

The program objective is to develop a positioning system suitable for military applications capable of functioning in GPS Denied/Restricted environments, under any weather conditions, with high pd and low pfa. Hence, the system should: (a) not be limited to a static base station; (b) have flexible coverage area; (c) identify and discriminate mobiles; and, (d) need limited power. Various wireless communications technologies will be exploited to establish a paradigm of contiguous, accurate and mobility-aware positioning with non line-of-sight (NLOS) coverage.

This option was not included as part of the proposed system due to several factors including prototype cost and availability within the necessary timeframes required by this project.

2) Motorola Mesh Enabled Architecture (MEA) w/ QDMA

MDS utilized the Motorola MEA gear to support the networking requirements of the ATNS project. The hardware provided exception RF penetration of various RF unfriendly environments and provided a communication range of up to 200 meters with a single network node.

Motorola's Mesh Enabled Architecture (MEA) technology leverages patented and proven routing techniques originally developed for battlefield communications. Motorola's Multi-Hopping technology turns every client device into a router/repeater. As users join the network they improve network coverage and increase network throughput. The MEA network supports simultaneous operation of infrastructure and client meshing while it also allows clients to move seamlessly between infrastructure-based and client-based peer-to-peer networks.

The architecture is a self-forming, self-healing routing system which distributes clients between Access Points. MEA technology also improves network robustness, as clients can hop to alternate Access Points if their current Access Point is congested or fails.

As part of Motorola's exclusive license to the ITT/DARPA mobile ad hoc networking Intellectual Property and patent portfolio, Motorola received the rights to the Quadrature Division Multiple Access (QDMA™) mobile radio platform. The QDMA radio is designed and optimized for mobile ad hoc broadband networking. Its multi-channel MAC and Phy are optimized to meet the scalability and reliability required in mission critical mesh networks. RF challenges encountered in wide area mobile networks such as Doppler shifting, rapid Raleigh fading and Multipath are handled efficiently by the QDMA radio. QDMA solutions have been successfully deployed in Public Safety, transportation and Homeland Security mobile data networks.

Although this product was successful in supporting the ATNS system it does not provide the RF TOA ranging feature present in the ITT CMR and it the network components were not designed for a mobile man-borne system. Further the product design/cost would not allow the system to meet its SWAP goals in weight, volume or price.

7.3.1.4 GPS

1) UBlox GPS Receiver

The LEA-4H module combines high sensitivity (down to -158dBm), low power consumption (105mWH) and USB and serial port support in a small (17mm x 22mm) package. The device also provides A-GPS, DGPS and full SBAS (WAAS, EGNOS) support. The device can operate within a range of -40 degrees Celsius to +85 degrees Celsius. These specifications are similar to the iTrax03 GPS receiver; however, the LEA-4H does not provide the built-in INS pre-processing and Kalman Filter library support that the iTrax03 module provides. As a result, the LEA-4H will be an alternative module for the GPS receiver component. Further information is available at – http://www.u-blox.com/products/lea_4h.html.

7.3.1.5 User Interface

1) Talla-Tech RPDA-57

This is a rugged PDA, currently used as the Pocket-sized Forward Entry Device (PFED) by USMC. It includes an Intel 520 Mhz PXA-270 processor, 400 Mhz processor bus, 128Mb RAM, 64 Mb ROM, with USB host and external battery adapter. Touch sensitive transflective TFT LCD display 320X240 (QVGA). This unit is already in use by several USMC infantry units but it prohibitive for use in this system due to

SWAP requirements, size, weight and price are all outside of the ONR project parameters. Cost at volume of 1000-1500 units is $2,594 each.

2) Zypad WL1000

This unit is a wrist worn PC, AU100 processor @ 400 Hhz, 64Mb nonvolatile flash, 64 Mb RAM, 320X240 (QVGA), with touch screen, automatic contrast adjust via ambient light sensor. A ruggedized military version is available. At $2500 each for the non-ruggedized base model this component will not meet the SWAP targets for the ONR project.

3) MicroOptical SV-6

A Monocular Heads Up display unit for VGA, SVGA, XVGA computer displays. This unit is similar in design to the military version also produced by MicroOptical HMV-M1. The HMV-M1 systems are already in use by the military in conjunction with the Thermal Weapon Sites (TWS) systems available from Raytheon. The display comes with a DB-15 pin VGA connector standard, 640X480, 60 Hz refresh rate, left or right eye configurable with 2 to 15 feet adjustable focus, see the spec sheet for full technical details. Cost for the SV-6 PC $1995 ea. Cost reductions available on order quantities 2 – 49 (25%), 50 – 99 (30%), ≥100 (40%). If MDS becomes an OEM reseller then an additional 30% off retail price is available. This system is still outside of the cost point for the entire system and will not be utilized for the system prototype or final form factor. If a heads up display unit is preferred by the user community a system will be developed using the Kopin component described below.

4) HP IPAQ Pocket PC hx2000 series

Handheld PC w/ Intel PXA270 processor at 520Mhz, 320x240 (QVGA) Transflective TFT 64K color screen, 64Mb RAM, and 192 Mb ROM. A lower cost alternative for the PDA / Hand Held user interface. – Cost is approximately $400.00 each; cost can be drastically reduced if purchased in quantities. This unit could be utilized to replace the SBC and visualization components of the proposed system but would take away from the single housing approach specified in the project requirements.

5) OQO Model 01

Handheld PC, 4.9’ x 3.4’ x 0.9”, 14 ounces. 1 GHz Transmeta Crusoe processor, 512 Mb RAM, 800x480 W-VGA color transflective display for daytime / nighttime use. This unit will allow us to verify operation with a fully functional miniature PC – estimated cost per unit $1699, additional savings can be acquired w/ volume purchase. Cost, volume and weight issues are keeping this unit from being a component of the proposed system.

6) Modular PC Rugged Handheld Computer – MCC DO212

With a rugged housing this unit provides another option to test the system with a fully functional miniature ruggedized pc, the system specifics are 650 nit XGA daylight readable screen, Transmeta Crusoe TM5800 at 1 Ghz, 20 – 30 Gb hard drive, and 512 Mb RAM. – Estimated cost is $3569 per unit. Cost is the primary issue keeping this unit from being a component of the proposed system.

7) Icuiti – M920-CF

The M920 is one of the smallest and lightest head-worn displays in the world, at only 3.5 oz. utilizing a new high brightness no-flicker display, the M920 is easily readable in either daylight or darkness. The display connects directly to any Compact Flash Type II or PCMCIA slot on Pocket PC based PDAs. Our software drivers for Pocket PCs, allow for full VGA screen information (640 x 480 pixels) to be displayed on the hands free M920 display. The M920-VIDEO model connects to virtually any video source, laptops, portable media players, video capable cell phones, test and measurement equipment, and video cameras to name a few. Its industry leading low power electronics drive the display for up to 4 hours on a pair of AA batteries. This is another option for heads up display – cost is $799 per unit, with discounts available for volume purchases. The same company produces a militarized version called TACEYE currently in use by the military. Cost is the primary issue keeping this unit from being a component of the proposed system.

8) Kopin – CyberEVF 230K

This digital electronic viewfinder (EVF), incorporates all the EVF components an OEM requires: a full-color CyberDisplay 230K LV, ultra-thin backlight, optics, and housing with an easy-to-use focusing mechanism. The CyberEVF 230K's tiny size - 17 mm x 23.5 mm x 25 mm, two-thirds the depth and less than half the volume of the competing EVF modules. With 15x image magnification and 22-degree field of view, the viewfinder generates large, vivid color images with virtually no distortion or color aberrations, this unit is the primary component for all of the HUD units listed above, at a cost of $125 per unit with volume discounts, this component will allow MDS to attempt to provide a UI solution that can be placed in various locations of the user's existing equipment to enable the best fit HFE / Usability solution. This unit will be considered an alternative for the interface currently selected for the proposed system. If user feedback indicates the wrist worn system is too cumbersome and/or a heads up display is preferred this component will be utilized to provide the user interface for SA visualization. Trade-offs include additional design effort to develop an enclosure and mounting solution and acclimation of users to small display that covers their vision.

7.3.2 Referential Coordinate System Initialization and Position Maintenance Algorithms

Please see the ONR final technical report for a full description of analysis of the system referential coordinate system initialization processes and position maintenance / data fusion algorithms that will be included in the system. The technical report also provides a listing of the existing industry science on these topics and the materials reviewed to provide the logic that will be implemented.

8. Appendices

This section contains additional information that will aid understanding of the ConOps document.

8.1 Glossary

The glossary includes definitions of terms, acronyms and abbreviations used in the ConOps document. It will be maintained and updated during the processes of concept and analysis and development of the ConOps document. To avoid unnecessary work due to misinterpretations, all definitions have been reviewed and agreed upon by all project resources.

- **A-GPS** – Assisted Global Positioning System. Service that provides aiding information like ephemeris, almanac, rough last position and time and satellite status and an optional time synchronization signal to reduce time to first fix (TTFF) significantly.
- **Anchor** – the fixed or least mobile node(s) used as the primary set of ranging partners for all other nodes in the clique.
- **AO** – Area of Operation
- **AOA** – Angle of Arrival
- **AHRS** – Attitude Heading and Reference System
- **APRS** – Automatic Position Reporting System
- **ASF** – Additional Secondary Factor
- **ATNS** – Accurate Technical Navigation System
- **BAA** – Broad Agency Announcement
- **Beacon** – a stationary CMR/node that is used to mark a specific reference, waypoint or landmark. The Beacon provides constant/static position data when queried by other nodes. It can also act as a relay.
- **C2** – Command and Control
- **C3** – Command, Control and Communications
- **CADRG** – Compressed ARC Digitized Raster Graphics map format
- **CERDEC** - Communications-Electronics Research Development and Engineering Center
- **ChLCD** – Cholesteric Liquid Crystal Display
- **Clique** – a group of dismounted soldiers who operate together on a given mission in the same area of operation, all clique members are within a 1km radius of the clique and will cover an area of 10Km within an 8 hour period. There are up to 50 soldiers/nodes in a clique, basically a platoon of 40+/- USMC infantry with up to 10 additional nodes/members.
- **Cluster Leader** – the focal node or Island Head administrator for the communications network, this function is used to control the network island formation and is the Primary Gateway between Island networks / cliques. The specific node that provides this function can be specified in network setup or will automatically be determined when the network is established.
- **CMR** – Clique Member Radio / node, provides TOA Ranging data and network communication capabilities to all clique members.
- **CNM** – Core Navigation Module
- **COASTS** – Coalition Operating Area Surveillance and Targeting Systems
- **CONOP** – Concept of Operations Document
- **COP** – Common Operation Picture

- **COTS** – Commercial of the Shelf
- **CRADA** – Cooperative Research and Development Agreement
- **DGPS** – Differential Global Positioning System
- **Design Entity** – An element (component) of a design that is structurally and functionally distinct from other elements and that is separately named and referenced.
- **Design View** - A subset of design entity attribute information that is specifically suited to the needs of a software project activity.
- **DOP** – Dilution of Precision. DOP is an indication of the effect of satellite geometry on the accuracy of the fix.
- **DR** – Dead Reckoning
- **DTED** – Digital Terrain Elevation Data map format
- **DTRA** – Defense Threat Reduction Agency
- **EGNOS** – European Geostationary Navigation Overlay Service
- **ELAAS** – Eurofix Local Area Augmentation System
- **eLNS** – Extended Leapfrog Navigation System
- **Entity Attribute** – A named characteristic or property of a design entity. It provides a statement of fact about the entity.
- **EOC** – Penn State Electro-Optical Center
- **ERAAS** – Eurofix Regional Area Augmentation System
- **FBCB2** – Force Battle Command Brigade and Below
- **FOB** – Forward Operating Base Camp
- **FOM** – Figure of Merit, used to provide a reference to the accuracy of the position data from various system sensors.
- **FPU** – Floating Point Unit
- **GPS** – Global Positioning System
- **GPSDNM** - GPS Denied Navigation and for Facility Map Building and Matching
- **GUI** – Graphical User Interface
- **HDOP** – Horizontal Dilution of Precision; DOP is an indication of the effect of satellite geometry on the accuracy of the fix.
- **HMI** – Human Machine Interface
- **HMMWV** – High Mobility Multipurpose Wheeled Vehicle (a.k.a. Humvee)
- **HUD** – Heads Up Display
- **IDE** – Integrated Development Environment
- **INS** – Inertial Navigation System
- **JSOC** – Joint Special Operations Command
- **JTRS** – Joint Tactical Radio Specification
- **JVMF** – Joint Variable Message Format
- **LNS** – Leapfrog Navigation System
- **LOS** – Line of Sight
- **LSAs** – Link State Advertisements
- **MANET** – Mobile Ad-hoc Network

- **Meaconing** – A system of receiving radio beacon signals and rebroadcasting them on the same frequency to confuse navigation. The meaconing stations cause inaccurate bearings to be obtained by aircraft or ground stations.
- **MCM** – Mobile Computer Module
- **MDS** – Mercury Data Systems
- **MIPS** – Million Instructions Per Second
- **MMU** – Memory Management Unit
- **MTU** – Michigan Technical University
- **NAVGPSDE** – Navigation in a GPS Denied Environment
- **NCLETTC** – National Corrections and Law Enforcement Technical Training Center
- **NIMA** – National Imagery and Mapping Agency map format
- **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.
- **Node** – synonymous with Clique Member Radio, the basic communication and RF ranging hardware component carried by each dismounted soldier in the clique.
- **NPS** – Naval Post-Graduate School
- **OCC** – Occasionally Connected Computing environment
- **ONR** – Office of Naval Research
- **PCB** – Printed Circuit Board
- **pd** – Probability-of-Detection
- **PDOP** – Position Dilution of Precision
- **pfa** – Probability-of-False Alarms
- **PNM** – Personal Navigation Module
- **PNT** – Positioning, Navigation and Timing
- **POD** – Probability-of-Detection
- **PosiFusion ™** – the function/algorithm within the system processor that calculates the node position data that will be shared with the other clique members.
- **PPP** – Point-to-Point Protocol
- **PPS** – Precise Positioning Service
- **PROPs** – Packet Radio Organization Packets
- **QDMA** – Quadrature Division Multiple Access
- **QMFR** – Quadrature Multi Frequency Ranging
- **Relay** – a node that relays or transmits data between communications network nodes, primarily for use in tunnels or cave-like environments, up to 3 may be used as part of the system solution for tracking resources in caves. Every CMR will perform this function as needed for network communications where more than a single hop is required to share data between clique members.
- **RF** – Radio Frequency
- **RFBR** – Radio Frequency Beacon Receiver
- **RFRM** – Radio Frequency Ranging Module
- **RISC** – Reduced Instruction Set Computer
- **RTC** – Real Time Clock

- **RTOS** – Real Time Operating System
- **SAASM** – Selective Availability Anti-Spoofing Module
- **SBAS** – Satellite Based Augmentation System
- **SBC** – Single Board Computer
- **SDD** – Software Design Document
- **SDK** – Software Development Kit
- **SEP** – Spherical Error Probability
- **SINCGARS** – Single Channel Ground and Airborne Radio System
- **SMS** – Short Message Service
- **SPI** – Serial Peripheral Interface
- **SOCOM** – Special Operations Command
- **Software Design Document** – A representation of a software system created to facilitate analysis, planning, implementation, and decision making. A blueprint or model of the software system. The SDD is used as the primary medium for communicating software design information.
- **SOW** – Statement of Work
- **Spoofing** – is a situation in which one person or program successfully masquerades as another by falsifying data and thereby gains an illegitimate advantage
- **SSA** – Situational Spatial Awareness
- **STID** – SOF Tactical Information Display
- **TDS** – TOA-based Data Screening
- **TOA** – Time-of-Arrival Radio Frequency Ranging
- **TDOA** – Time-Difference-of-Arrival
- **TOC** – Tactical Operations Center
- **Triangulation** – the process of finding coordinates and distance to a point by calculating the length of one side of a triangle, given measurements of angles and sides of the triangle formed by that point and two other known reference points, using the law of sines.
- **Trilateration** is a method of determining the relative positions of objects using the geometry of triangles in a similar fashion as triangulation. Unlike triangulation, which uses angle measurements (together with at least one known distance) to calculate the subject's location, trilateration uses the known locations of two or more reference points, and the measured distance between the subject and each reference point. To accurately and uniquely determine the relative location of a point on a 2D plane using trilateration alone, generally at least 3 reference points are needed. Trilateration should not be confused with multilateration or hyperbolic positioning, which uses measurements of time difference of arrival (TDOA), rather than time of arrival, to estimate location using the intersection of hyperboloids. Trilateration is the mathematical basis behind the Global Positioning System (GPS) and similar systems
- **TRPS** – TOA-based Ranging Partner Selection
- **TTFF** – Time to First Fix
- **TTL** – Time-to-Live
- **UDP** – User Datagram Protocol
- **USB** – Universal Serial Bus
- **UTC** – Universal Time Coordinated
- **UWB** – Ultra Wide Band radio transceiver, a.k.a. RF Ranging Module (RFRM), part of the ATNS project system components.

- **VDOP** – Vertical Dilution of Precision
- **VGA** – Video Graphics Array. A standard for graphics displays, implying a resolution of 640x480 pixels, defined by IBM.
- **VPF** – Vector Product Format map format
- **WAAS** – Wide Area Augmentation System
- **WLPS** – Wireless Location Positioning System
- **WNM** – Wireless Network Module