COMMUNICATIONS SYSTEM CONSIDERATIONS FOR UNATTENDED ARMY BATTLEFIELD MUNITION AND SENSOR SYSTEMS

Thomas J. McAdams
Thomas L. Thomas

The MITRE Corporation
Battlefield Tactical Communications
Mt. Arlington, New Jersey

Robert Wade
Fire Support Armaments Center (FSAC)

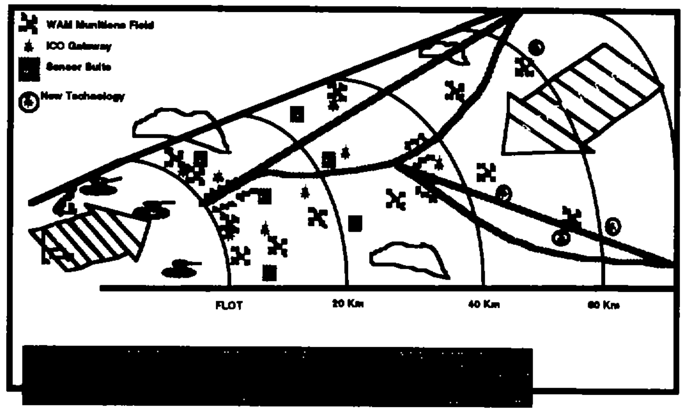
U.S. Army Armaments Research, Development & Engineering Center (ARDEC)
Picatinny Arsenal, New Jersey

ABSTRACT

Current Army munition and sensor systems are activated, or provide limited target information, via user-unique, one-way, short-range, and unprotected data links. This paper defines technical constraints and issues, and describes one technical and programmatic approach to select and to system engineer a common communications system that will meet current and future munition/sensor operational and technical requirements. This development approach involves four primary phases; Alternatives Analysis, System Architecture Development and Prototyping, Integration Planning, and Cost and Schedule Planning. Implementing a flexible, common communications and sensor fusion architectural solution for munition and sensor systems will; ensure interoperability among systems and tactical external operations facilities, allow for technology insertion, reduce acquisition times, and will result in much lower long-term development and life-cycle maintenance and product improvement costs when compared to stovepipe, custom, proprietary solutions on an individual system-by-system basis.

INTRODUCTION

Evolution of Army battlefield operational concepts has resulted in deeper and wider deployment of munitions and sensors, the need for better control and status monitoring to prevent fratricide, and the need to share status information and target data with other echelons. In addition, information passed between munitions and sensors and their controller/user Tactical Operations Center (TOC) is sensitive and must be protected from enemy disruption and exploitation, per Army Communications Security (COMSEC) and Operations Security (OPSEC) guidance. Figure 1 shows how future munition and sensor systems could be deployed on the battlefield.



[redacted]

Figure 1. Munition/Sensor Deployment

Operational Requirements - When system engineering a communications solution to the unattended munition/sensor problem, the system architect must operationally optimize the mission (i.e., effective deployment of munitions/sensors) - command and control (C2) or communications should not be the driver. C2 has a common set of requirements;

-All deployed systems must be capable of remote monitoring, control, and reconfiguration,

-Control, monitoring, and reconfiguration of unattended munitions/sensors from the TOCs should be accomplished through common format messages,

-Munition/sensor status and target information to the TOCs must be in common message format to support processing, distribution, and graphical display, and

-All C2 processes and messages must be compliant with the Army Operational Architecture (AOA).

Technical Requirements - Although there are critical operational considerations involved with deep, unattended munition/sensor system deployment, the technical issues resulting from the following set of requirements pose the greatest challenge to the system architect:

-C2 message/data links must extend from a few kilometers to over 80 kilometers from the TOCs, over all terrain conditions,

-Munition/sensor transceivers must be compact, lightweight, power efficient, easily emplaced and survivable from an air drop,

-Antenna systems must be easily erectable or automatically employable without interfering with mission operations,

-Radio frequency signals from/to the sensors and munitions must have low probability of intercept (LPI), low probability of detection (LPD), and anti-

0-7803-4249-6/97/$10.00

jam (AJ) features to meet all global threat environments,

-Munition/sensor communications processors must be capable of dynamic response to TOC controller commands while performing their primary mission,

-Communications processor speed and link data rates must support standalone and future integrated system data fusion requirements, and

-All processor architecture and interface standards employed by C2 and communications system components must be compliant with the Army Technical Architecture (ATA).

System Development Constraints - In addition to the operational and technical requirements described above, there are operational and programmatic constraints that must be considered in the system design - these include:

-The cost of embedded communications processors, COMSEC chips, transceivers, power amplifiers, and antennas should be a small percentage («10 percent) of the total munition/sensor unit cost,

-Size, weight, packaging, and battery drain of all embedded communication system components must not degrade mission performance,

-Embedded COMSEC and Transmission Security (TRANSEC) must be National Security Agency (NSA) certifiable for unattended and physically unprotected emplacements, and

-Placement and setup of communications relay nodes, if required for deep-deployed munitions and sensors, should not subject the emplacing organization to additional risk.

System Updates - The communications system must also be able to accommodate the evolution of technology and military requirements in several ways; 1) The communications system architecture and design must allow for evolutionary improvements as a result of technology advances and changes in battlefield doctrine and operations, 2) An expandable, flexible modular approach to system design, with reserve capacity built in, is desired to minimize the cost and downtime associated with essential and predictable system upgrades, and 3) The system design should be able to accommodate changes to the Joint Technical Architecture (JTA) and the ATA.

KEY TECHNICAL ISSUES

Three key technical issues must be addressed and resolved during the phased development process. Other important issues include communications range, data rate requirements, and remote C2 of the munition and sensor systems. All of these issues will impact communications system design and development.

1) SECURITY - As the Army moves to the future and the battlefield becomes more digital, the need will exist to secure relay points, remote platforms, and expendable assets. Many of these nodes will be unattended. A problem arises when we realize that nearly all of these assets include critical Government security algorithms that are used to provide COMSEC and TRANSEC. Leaving these assets unmanned increases the risk of compromising these critical algorithms.

(a) Background - A number of Army systems require Anti-spoofing (AS), LPI/D, AJ, and Authentication. COMSEC supports AS, LPI, and Authentication. TRANSEC supports LPD and AJ. AJ will not be discussed due to space and classification constraints. To meet these requirements, the Army invoked policies to require Government security in military systems. The primary governing policy is Army Regulation 380-19 (*Information Systems Security),* which applies to all Army programs. AR 380-19 mandates security for telecommunication and automated information systems. With regards to COMSEC, AR 380-19 requires that all Army COMSEC systems be certified and approved by NSA.

Most COMSEC systems approved by NSA are operated in a classified mode and require attended operation. However, a number of battlefield tactical communication systems must operate in an unattended mode.

(b) Potential Solutions - battlefield information on Army command and sensor/munition nets is sensitive but unclassified (SBU) because it is highly perishable. This situation is more prevalent at lower echelon nets, but could also exist on upper echelon nets. NSA has developed a number of cryptographic algorithms that are approved to protect SBU data. They are categorized as Type II COMSEC. Although not all Type II COMSEC can be left unattended, NSA has, in the past, approved Type II COMSEC systems for use in unattended operations.

(c) Analysis -There are a number of Type II cryptographic algorithms that would support the Army's requirement for unattended COMSEC operations. Skipjack is an example of an NSA approved Type II algorithm (see Figure 2). In addition, the Data Encryption Standard (DES) and Triple DES algorithms could potentially support the Army's requirement for unattended operation. However, to date there is no standard algorithm for unattended operation. A standard algorithm would support the Army's desire to achieve interoperability among its unattended C2 systems.

Figure 2. Examples of COMSEC Algorithms

This standard algorithm would also support LPI. LPI is accomplished through the use of COMSEC. LPD, in turn can be accomplished through the use of directional antennas and spreading techniques enhanced by TRANSEC algorithms. The TRANSEC solution should also be standardized and NSA approved for unattended operations.

(d) Conclusion - There should be a standard COMSEC and TRANSEC algorithm that is approved for unattended operations. This algorithm could be firmware coded and embedded in a microcontroller or designed into an application specific integrated circuit (ASIC) for low power consumption. It should be a highly versatile algorithm and satisfy all Army SBU unattended COMSEC and TRANSEC requirements.

2) SENSOR DATA FUSION

(a) Background - Each acoustic sensor unit is capable of providing information on up to six targets simultaneously; however, this information must be carefully fused with other units in order to accurately determine target position and classification in dynamic battlefield conditions. Figure 3 shows one option for acoustic sensor data fusion.

(b) Analysis - Elementary data fusion concepts have been demonstrated that allow fusion of acoustic bearing data between multiple platforms, and therefore the capability to triangulate on a target. The success of these techniques is largely determined by the geometry/configuration of the platforms, target dynamics, and the particular courses that the targets take through the munition and sensor clusters. The participation of each platform in the overall data fusion equation is varied and dependent on the sensor emplacement scheme and target dynamics. It is for this reason (as well as the overall need for power conservation and system efficiency) that the communications system must be carefully engineered to match the needs of the sensor fusion solution.

A variety of new sensor fusion schemes are being envisioned, each with a different potential impact to the communications networking approach and overall system solution. Emphasis is being placed on the quantity of information that can be transferred and the timeliness of the data, which are both directly affected by the communications system approach.

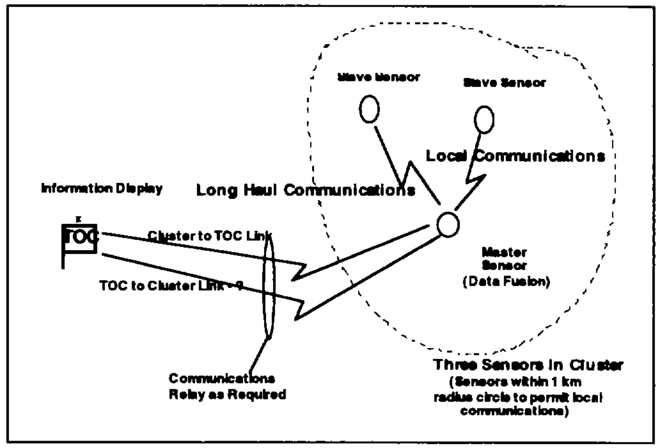


Figure 3. Fusion at the Sensor Cluster

The transmission of "raw" acoustic data (e.g., spectral information), as opposed to "processed" data (e.g., target classification, position), significantly increases the communications load. The overall trend to exploit high performance data fusion techniques places a great challenge on the communications system design due to the inherent need to limit on-the-air communications time.

(c) Potential Solutions - Different sensor fusion operational modes are envisioned, depending on the user's assessment of the target formation size, configuration, and movements. The sensor fusion/ communications needs span from very simple to complex. In cases where the sensor/munition platform has pre-knowledge of (or eventually determines) a prescribed road course for the targets, and when a low quantity of targets is present, communications/fusion needs are low. Other scenarios are very complex and necessitate a "gameplan" regarding how best to utilize sensor/communications resources. Software solutions that provide sensor management/tasking and that help to optimize the communications system based on learning algorithms or artificial intelligence are possible. COTS data fusion software packages can be obtained and will be examined for possible application to this problem.

(d) Conclusion - Overall system flexibility and the capability for user selection of desired functionality should be incorporated where possible in order to limit the overall confusion matrix.

3) ACOUSTIC SENSOR TECHNOLOGY

(a) Background - Current unattended ground sensor acoustic sensor technology does not fully support Army requirements for target range sensitivity, accuracy, and identification performance. Figure 4 shows functionality for one of the Army's advanced acoustic sensor development programs.

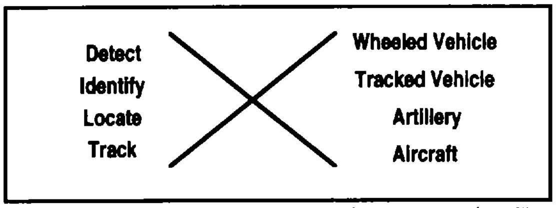


Figure 4. Integrated Acoustic Sensor (IAS) Functionality

Figure 5 provides theoretical estimates of current acoustic sensor accuracy performance.

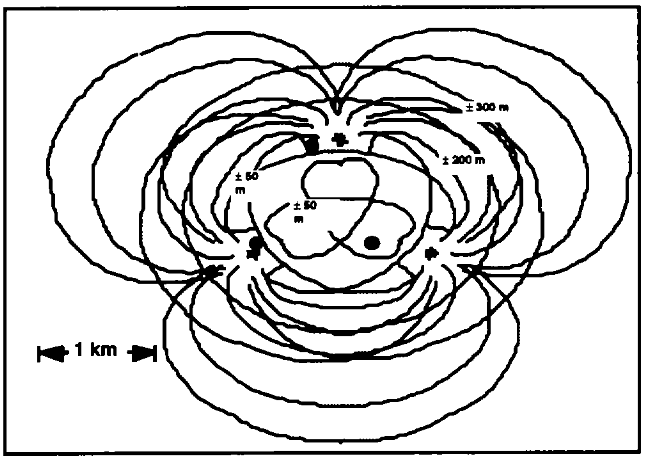


Figure 5. Sensor Accuracy

(b) Analysis - There are three fundamentally different acoustic sensing technologies being developed, each possessing different performance potential as well as performance limitations, and each posing a potentially unique communications/sensor fusion solution. The common communications system must be capable of providing a data fusion capability between each sensor type as well as across sensor platform type so that the full potential of these systems can be exploited by the Army.

(1) Low-cost, very small platforms/acoustic packages: Remote Battlefield Area Sensor System (REMBASS) type area sensors are being considered for sensor fusion upgrade and other similar small sized acoustic sensor packages are being developed. Although each sensor would consist of only one acoustic sensor (with the possible addition of seismic sensor(s)), these platforms are capable of providing accurate classification and tracking of targets, provided the cost per platform is very low and a dense grid of sensors can be deployed. While the individual sensors have limited range and less advanced classification/noise suppression capabilities, networking schemes can be implemented to provide basic target tracking and counting.

(2) Multiple Sensor Arrays, Medium Array Size: Similar to the Wide Area Munition (WAM), which contains an array of three acoustic sensors, or the Air-Dropped Acoustic Sensor (ADAS), which contains an array of five acoustic sensors. These arrays are limited in number of microphones and total array size (up to three feet. in diameter) so as to fit in current smart munition packages. The array technology permits a very accurate bearing estimation of the loudest target of interest, which corresponds to the fundamental need to accurately direct a one-on-one engagement. This type of platform also has the ability to gain further information of up to six vehicles if favorable conditions exist (affected by spacing of targets, type of targets, etc.). Sharing of data on vehicle bearing between two platforms permits an accurate X,Y location of the target, provided the geometry between the platforms is favorable.

(3) Large Arrays: Microphone arrays (eight or more microphones) of 12-ft. diameter and greater are being developed for hand-emplacement or to be used on dedicated vehicles. Large package size permits increased battery capacity and processing potential. Advanced adaptive beamforming techniques, spacial filtering, and noise cancellation yield high performance multiple target classification and tracking from one platform. Elementary data fusion between just two platforms permits multiple target tracking over large areas.

(c) Potential Solutions - The battlefield of the future will undoubtedly contain a mix of all three sensor types. Currently not addressed, as a result of a general inability to support communications and sensor fusion between different sensor types, is the ability to provide one homogeneous system capability. The synergistic effect of using different sensor types for different roles should be exploited, with the goal of improving the overall cost and performance efficiency of the entire system. For example, a linear configuration of Type 1 sensors can be set up along roads or along a front for the purpose of counting targets that enter through an area of interest, thus providing essential information about enemy size and direction. Types 2 and 3, which are high cost and cannot be deployed in large numbers, can combine in a role to XY track and engage target-rich environments over a selected depth of the battle area. Many other combinations are possible depending on the mission.

(d) Conclusion - The synergistic effect possible from the effective use of different sensor types, and the ability to mix and match different sensor types to better perform a particular mission, cannot be realized unless a flexible, common communications/sensor fusion system architecture is engineered.

SYSTEM DEVELOPMENT APPROACH

System engineering and integration of a common communications system involves consideration of many munition/sensor-specific requirements:

(1) The system components must be integratable into a multitude of munition/sensor platforms where available volume, shape and weight allowances will vary, platforms will be exposed to shock and climatic extremes, power will be limited, and mechanical interference with sensor/munition mission operations is not allowed.
(2) Radiation from system components cannot interfere with munition arming/firing commands or sensor/munition overall performance.
(3) Candidate system components will be limited to three primary sources; COTS, Government, and Non-Developmental Item (NDI).
(4) The system architecture must address Government COTS utilization guidance, meet Army interoperable digitization goals, be integratable with downsized and digitized operations centers, support joint and coalition interoperability, be consistent with the ATA and AOA, and be backward compatible with legacy systems.

A proven phased approach for system development and integration is proposed, which will maximize operational flexibility by ensuring architectural compliance and interoperability, and will minimize risks by dividing the process into manageable and reportable segments. Phases are defined below and shown in Figure 6.

Phase 1 - Alternatives Analysis. This phase consists of three initial steps: (1) Downselect feasible alternatives based on a short-term, qualitative and subjective market survey/evaluation. (2) Subject candidate hardware/software components to quantitative/objective laboratory and field testing using a minimal set of benchmark standards. (3) Identify and qualitatively evaluate technology trends and products for future consideration.

Phase 2 - System Architecture Development and Prototyping. Using results from Phase 1, develop a flexible/expandable architecture meeting near-term system requirements; select/acquire integratable

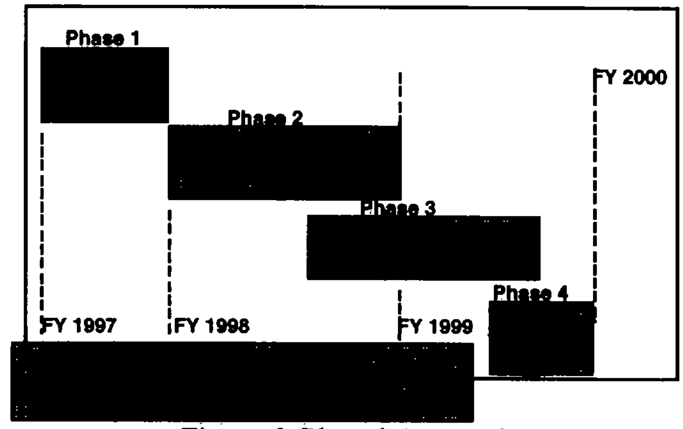


Figure 6. Phased Approach

components to prototype a near-term system; modify/tailor components for integration into selected munition/sensor systems; and integrate/test during scheduled Joint Warfighter Interoperability Demonstrations (JWID), Advanced Warfighter Experiments (AWE), and programmatic munition/ sensor system tests/demonstrations.

Phase 3 - Integration Planning. Following successful completion of Phase 2, an integration and implementation plan will be developed in accordance with each existing munition and sensor system's ATA Migration Plan that also addresses future systems and concepts.

Phase 4 - Cost and Schedule Planning. Component acquisition and engineering cost estimates for each user system will be developed along with acquisition/integration/test schedules to form the basis for Army funding submittals.

CONCLUSION

Implementing a flexible, common communications and sensor fusion architectural solution for munition and sensor systems will: Ensure interoperability among systems, TOCs, and external operations facilities (OPFACs), allow for technology insertion, reduce acquisition times, and will result in much lower long-term development life-cycle maintenance, and product improvement costs when compared to stovepipe, custom, proprietary solutions on an individual system-by-system basis.