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13. ABSTRACT *(Maximum 200 words)* This proposal addresses the development of a Soldier's Radio Architecture (SRA), intended to define the interface and transfer characteristics of modules at the ASIC level, circuit level, software level, and man-machine I/O level, and to encompass and support the ready and frequent insertion of technology-driven and/or mission-driven upgrades in a family of Soldier Radio products. The design and evolution of the SRA will be monitored and informed by a national working group of vendors and users to be formed in this program, and the SRA will be completely open architecture within which vendors may competitively insert proprietary modules.

Military applications of the concepts and radio network achitecture to be developed in the proposed work are as numerous and inclusive as the Army's applications for voice, video and data communication. Commercial applications will include rapid evolution of radio network systems such as police, fireman, emergency workers, commercial pilots and truckers.

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An Architecture and Acquisition Strategy for a Soldier's Radio

SBIR CONTRACT DAABO7-94-C-D304
PHASE 1 FINAL REPORT

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1.0 Introduction

The goal of this SBIR project is to create a scalable architecture for the Soldier's Local Area Networking Terminal (SLANT) that can be used to implement wireless networking devices for voice, video and data communication among a large number of soldiers. The purpose of the architecture, referred to as the Soldier's Radio Architecture (SRA), is to provide a backbone for integration of hardware and software modules to create wireless multimedia LAN terminals for the mobile soldier.

In the course of Phase I, S-TRON has assembled a powerful team with expertise in the SOLDIER RADIO core technologies:

- ITT (developer of the Army-wide SINCGARS system) representing industry
- Angeles Communications Design (ADC) from the UCLA academic center of excellence in telecommunication system and circuit design and implementation.
- and S-TRON with its knowledge of Soldier System integration and man-machine interface.

The SRA to be developed will be a set of standards which will partition the Soldier's Radio into modules: radio-function, microelectronic, computing-function, and human interface modules. The SRA will be a completely open architecture, without proprietary interfaces between modules; this will give the system designer a maximum of interchangeability and selection in modular integration, without limiting vendor innovation and proprietary designs *within* any given module.

S-TRON and its subcontractors are agreed that within the SBIR Rights in Data clause (FAR 52.227-20) that the Soldier's Radio architecture shall be developed as an open architecture with no proprietary restrictions.

In its near-term technological evolution, the Soldier's Radio is anticipated to become simply a card to be inserted in an omnipresent Soldier's Computer, where it will act as the I/O portal between individual soldiers for voice, imagery, and data exchange.

The SRA will integrate with the Soldier's Computer components, and will interface to the helmet display and vehicle interfaces. It will also address specific functions, such as voice mail, addressing, network self-adapting, pre-formatted messages, digital photos/maps, and import and export of video, voice and alphanumeric data. It will deal with antennas, cables, and control functions. It will deal with software modularization and interoperation.

During Phase I two prototypes of a soldier's terminal from other on-going efforts have been studied to determine the problems in integrating, creating and evolving such a terminal. The main conclusion is that the absence of modular approaches in radio design and implementation severely limit the ability to scale performance, functionality and technology in existing radios. In contrast, this form of scalability is common-place in commercial desk-top computers and has been responsible for the dramatic reduction in costs and design cycles while providing higher performance from one generation to the next. The purpose of defining a scalable soldier's radio architecture is to bring precisely these benefits to the Army's soldier Radio Programs.

In the proposed Phase II, a nonprofit forum or working group of defense contractors (including ITT Aerospace Corporation, other commercial communications contractors and Army sponsors) will be formed to help define the standard SRA and promote its use. A CAD framework and component *database will be developed for integration* of various modules (RF, modem, computer, human interface) based on the SRA. A national facility will be created to maintain the design and implementation environment *as an open center for design and simulation*, and will provide an interface between Army sponsors and manufacturers to develop and procure future generation of the soldier's radio based on the SRA. The Open Center would include maintaining the CAD tools, library of software modules, and simulation tools.

2.0 The Problem and Its Significance

> The individual soldier is not presently served by intra-squad radio; development of the desired personal communicator must be intimately connected to development of the soldier's computer if the land warrior's radio net is to be optimized -- and if past discords within the solder system are to be prevented.

PROBLEM : NEED INTRA-SQUAD COMMUNICATIONS

Currently coordination and deployment among squad members is little changed from the Civil War: hand signals, notes, shouts.

One of the most successful features of the recent Soldier's Integrated Protective Ensemble (SIPE) technology demonstration was the unexpectedly high value of the simple voice and image-transfer communications capability which S-TRON built into the SIPE. Though the transmission was intentionally low power and short range, it permitted swift and confident unit maneuver and real-time redeployment -- which the test personnel had not previously found possible.

PROBLEM 'COMPATIBILITIES AMONG SOLDIER SYSTEM COMPONE

Armies and other large organizations have chronically exhibited a major problem: inter-element equipment incompatibility. The SIPE technology demonstration was conceived partially to address this inhibiting and difficult systems integration problem. Historically, the soldier's gas mask, weapon, weapon sight, helmet, gloves, maps and ammunition were developed by different teams at different times, by sometimes quite autonomous agencies.

As a result:

- The rifle's iron sights are not operable with night vision goggles.
- The AN/PAQ-4 infrared aim light [illegible] permits aiming with night vision goggles) is inadequate beyond 30 meters on a [illegible]nlit night, and its emission is so dangerously scattered over the forward hemisphere th[illegible] the soldier commonly declines to use it because it reveals his position like a beacon and draws enemy fire.
- The PASGT helmet rides up unstably on his head, atop his gas mask.
- The gas mask does not provide ballistic eye protection; it neither provides laser eye protection nor is compatible with available LEP devices; it is incompatible with night vision goggles, and inhibits proper use of shoulder-fired weapons
- Most sealed CW headgear makes speech faint and unintelligible, and makes the wearer functionally deaf to normal environmental acoustic clues.
- With chemical agent gloves he cannot adjust and operate individual weapons and equipment.
- The laser eye protection prohibits operations at night due to its low scotopic transmission.
- The night vision goggles are cantilevered from the face and interfere with the PASGT helmet, have low system contrast transfer, block direct through-vision of the scene, have no capability for displaying raster information, and are bright enough to saturate night adaptation but not bright enough to utilize the eye's full resolution.

In particular, the individual soldier has had limited access to personal radios for squad coordination. Our infantry in the Iraqi desert "got the word" to redeploy, take cover or move out just as they did at Gettysburg: hand signals, waving, shouting. Where radios have been provided to the soldier, their design has been burdened by "specmanship" and the conflicting requirements of long range, wide tuning bands, encode/decode, many parametric settings for multiple configurations in the field and use of both hands in operation. Their design consistently has defeated the individual soldier's need for minimum size, minimum weight, and hands free for his usual tasks.

PROBLEM : CUMBERSOME OR NONEXISTENT NETWORKING OF INDIVIDUALS

The network management used in present combat radios is based on the assumptions that there are relatively few nodes, and that these are unchanging. The protocols presently used in battlefield packet radio networks are cumbersome, and degraded by delays in the transmitting and receiving equipment. In "real" radio networks, nodes continuously intrude and drop out, and the packets in re-transmission are in frequent collision. As a result, the network can easily turn to a babble of conflicting data under severe conditions of combat.

In particular, there is no provision for a local intra-squad network of a dozen coordinated individuals operating in conversational mode within a hierarchy of transmission and an algorithm of subnetwork addressing. There is no ready way for a platoon leader to talk with his medic without distracting the point man, or to listen in on the point man's comments while other troops are arguing over the obstacles.

PROBLEM : EASY DETECTION AND INTERCEPTION OF COMMS

When each radio has a range of, e.g., 5 kilometers, then operation of the radio suite can easily be detected from 20 kilometers with an antenna of modest gain, and enemy *interception* of the digital signal stream is readily implemented.

Radio designers attempt to overcome interception with complex techniques of spread spectrum, frequency hopping, code; this has historically made the radios complex, wide band, heavy and vulnerable to cryptographic compromise.

Radio designers attempt to overcome detection with radio silence. This leaves the squad members to coordinate by hand signals, waving and shouting.

PROBLEM : TO TRANSMIT/RECEIVE DATA, VOICE, IMAGES

What each squad member needs to know is what his fellows are planning, thinking, doing, seeing. He needs to access the adjacent platoons for coordination. He needs little information about what the next company is doing, much less information about the next division 5 kilometers away. He needs to be able to transmit, receive and read printed information, maps and other pictorial information, verbal data and numerical data.

While he still can transmit and receive limited digital data over the low-bandwidth SINCGARS radio, he needs a higher bandwidth with capability to handle data, voice, or imagery as a digital stream. And of course he needs network access to a SINCGARS radio or something like a AN/PRC-126, to speak through when long-range communication is required.

PROBLEM : COST, WEIGHT, SIZE

Would the Army ever issue a $2500 radio to a soldier armed with a $350 rifle? Such a comparatively high unit cost would significantly inhibit issue of the radio at the individual level.

The AN/PRC-126 is typical of the most advanced miniature radio technology developed to date by the Army. It is compact (58 cubic inches) and lightweight (2.2 pounds). With its long antenna it has a typical range of 3 kilometers (30 - 88 MHz), or 1 km with the short antenna. The AN/PRC-126 costs the Army $1800; thus the Army only has bought approximately 20,000 of them. In fact, the AN/PRC-126 is simply too heavy, too voluminous, and too expensive to issue to each soldier with his canteen and PASGT helmet. And - since it is easily detected and intercepted to 5 km with an enemy's modest-gain antenna, such individual issue would completely compromise position and code structure.

The design goal for the SIPE radio was a range of 200 meters. With its 4W power booster, the SIPE radio produced a range of 800 meters line of sight (49.8 MHz). The electronics took up about 10 cubic inches. The modules cost less than $200 in small quantities. And it was a huge success: as an effective intercom system.

PROBLEM: CONFLICT BETWEEN MILITARY AND COMMERCIAL PERFORMANCE OBJECTIVES

Products developed for the military are typically 5 to 10 times as expensive as similar products developed for the commercial applications, driven by inflation of specifications and requirements. They are also generally heavier, more bulky, and less adaptable to alternate uses, power sources, etc. Typically these use electronics which are 3 to 5 years behind the current state of the art in commercial electronics when introduced, and are maintained in inventory for 10 years or more. This is largely again the problem of cost, weight, size, compounded by inflation of specification and the Government's propensity for procuring yesterday's technology tomorrow.

Clearly if one compares the utility of ADA with C++ as a programming language, or the strengths of DoD-developed computer and communications systems with the Apple Newton personal communicator, or the Go pen-input computer, or the Hewlett-Packard 95 LX handheld computer, it is fairly evident that the ponderous military procurement cycle actively inhibits incorporation of the state of the art in most hardware accessible to the soldier.

3.0 Results of the Phase I Work and its Relationship to Phase II

Phase I investigations have demonstrated the critical need for a broadly-integrable architecture for the squad-level soldiers' radio, and a path to developing such an architecture.

In Phase I, two problems have been investigated. First, we have studied the requirement of a Soldier's Local Area Networking Terminal (SLANT) and ascertained whether this can be met with existing technology and emerging technologies. Actual prototype wireless terminals (built under parallel programs) have been leveraged to evaluate commercial products available today. The main result of this investigation is that existing wireless networking products do not meet the data rate, capacity, network configuration and security needs of SLANT. However, hardware and software component technologies exist and are emerging that can meet these needs. To harness these technologies in a timely manner as well as to meet changing needs, a unified architecture is needed for integrating the various components. To satisfy this need, the concept of a Soldier's Radio Architecture has been developed and is described in Section 4 (Phase II Technical Objective and Approach).

In addition to developing a technical approach for implementing wireless network terminals for the soldier in the future, we have also investigated the limitations and problems of the process by which radios are developed and acquired by the Army. There are severe problems inherent in this process as discussed below which inhibit the acquisition and deployment of a soldier's radio that meets/satisfies the doctrine currently set out by the Defense Information Systems Agency. Strategies for addressing these problems are also discussed that will allow the U.S. Army to close the massive gap between state-of-the-art wireless computer networking technologies and the existing soldier's radios.

3.1 Problems In Implementing The Soldier's Local Area Network Terminal

The principal difficulty in realizing a SLANT that satisfies all of the Army's needs is not a lack of technology, rather it is in the integration of various technologies. Thus many components exist for assembling a soldier's wireless terminal but the conceptual framework for such an integration is completely lacking. Commercial products deliver point solutions that are inadequate for the Army's needs and existing military products do not exploit state-of-the-art components as discussed below. A global solution to this problem that will be developed in Phase II is to define a unified architecture that can exploit new component technologies to quickly assemble a SLANT device.

3.1.1 Drawbacks of Point-Solution Radio Systems

Designers are forced to pack all requirements from all users into a single new product, adding risk, cost, and time. With this approach radios cannot easily be upgraded once fielded. This is because radios today have no concept of modularity and there is no generic architecture to support a wide range of soldier requirements. The point solution produced in one phase of the soldier's radio program can become completely useless on the next phase even though many components and know-how are reusable on a second phase. Currently there is no mechanism to leverage this reusability to reduce time and cost of meeting new defense requirements.

The lack of a modular approach also prevents the upgrade of existing soldier radios to new software or hardware technologies - an approach which has been common practice in the computer industry for a decade now and substantially reduces costs. Furthermore, without a well defined architecture, there is no methodology for assembling radios for different applications from the same components. Thus each application requires a custom design effort that also adds to the cost.

Finally, as pointed out by ITT, in actual practice it is highly desirable for US Army radios to be able to operate in different modes. Point solution radios do not address this need.

To solve the above problems it is proposed in Phase II to develop a Soldier's Radio Architecture (SRA) as described in Section 4.1. The SRA will also address other problems described below.

3.1.2 Limitations of Commercial and Military Radios

The SINCGARS radios currently used are very bulky and operate at relatively low data rates (16 Kbps). Also they are not designed to meet the needs of networking soldiers, rather they are aimed at higher levels of networking such as ship-to-ship or tank-to-tank networking that require highly limited capacity relative to a soldier's platoon where hundreds of soldier's may become nodes in the wireless network. However, they do provide many of the features such as security that are vital to Army communications. Commercial radios are substantially smaller and lighter (e.g. Plessey, Proxim), but these also provide very limited capacity, and have no capabilities for anti-jamming, LPD and LPI, making them completely unsuitable for the soldier's terminal. New radio architectures are required that leverage the integrated component technologies available in commercial data networking radio modems and combine these with the DoD networking an security requirements.

3.1.3 Limitations of Video Compression Technology

There are no commercial or military components available for implementing the DSP functions required to compress signals, especially video, for wireless transmission. Most existing compression software and hardware is designed for wireline networks (phone networks and computer networks). ARPA research is resulting in new DSP component technologies to enable integration of video compression with wireless computer links. These should be exploited in the SLANT; however, an appropriate architecture is required to permit their insertion. Current radio/compute modules do not provide appropriate interfaces for efficient integration.

3.1.4 Limitations of Network Control Software

Network control software is one of weakest areas in commercial products. Key issues of network configuration, admission control, etc., are not addressed in current commercial or military systems. Most wireless networking products are simply designed to substitute wireline local area networks and therefore do not address issues particularly important in a wireless soldiers network.

3.2 Problems in Defining and Meeting the Army's Radio Needs

Even if the component technologies exist and are available and can be re-used to assemble a soldier's radio terminal with desired characteristics, there is still going to be a large gap in time between the availability for the technologies and the actual deployment of the terminal. The reason for this is two fold: one is the inherent delay in engineering the soldier's radio system based on new component technologies; second is the inherent problems in the acquisition process. Therefore a successful strategy to develop, acquire and deploy a soldier's radio, that meets the present and future need of the Army, requires that we create a process for designing, developing and manufacturing that closely tracks evolution in technology and user requirements.

3.2.1 Evolving User Requirements

Requirements for a given user cannot be defined until a preliminary system has been fielded and used by the real end user. This is a very important problem and a new design approach is needed which makes the end user part of the design process to speed up the insertion of new technologies in the soldier's radio. This is the power in creating this SRA, enabling full simulation of optional modular mixes within a family of Soldier Radio solutions. An ideal solution would be to create a CAD environment like SimCity where users can piece together the exact system they want in a simulation environment and then hand it off for implementation to a national facility. Such a facility would maintain data bases of design options and encapsulate hardware data from prototype experiments to allow rapid feasibility check on the user requirements. Currently there are no design databases available to the Army that would allow a rapid definition of feasible specifications.

New users will forever emerge with their own unique requirements. To address this problem, a design database of the underlying components such as RF front ends, modems, DSPs, network protocols etc. can be leveraged to define the overall system configuration. A good example here is that of cordless phones, pagers and cellular phones. All three are wireless communication devices that require some network protocol, an RF front end, a modem and some DSP. Cellular is clearly the most sophisticated and cordless the least. So if we define a unified radio architecture and design tools such that we can customize the individual components and then piece them together to implement a cordless phone or a cellular phone we can reduce design costs and also leverage a component database for different products. A similar methodology can provide a simple and viable approach to deal with the problem of changing the soldier's radios as the defense information systems evolves over time. Although there is no "magic" solution to this problem, the availability of component databases and automatic search procedures that match system configurations with specifications can greatly reduce acquisition time. Such a database approach coupled with a facility for integrating the microcircuitry will also substantially reduce acquisition costs since it will create an institutional memory of what technologies, systems and requirements already have been created. Thus the Army will not pay over and over again for the same technology.

3.2.2 Excessive Radio Development Time and Cost

It takes far too long to develop a new radio. SINCGARS took at least 15 years and is still not fully fielded. Products are obsolete before they are fielded. Even Non-Developmental Items (NDI), based on commercial products, can't keep pace with technology because it takes so long to contract for the products, and because their cost dictates a long field life in the Army.

Part of the problem is the design turnaround and prototyping infrastructure. ARPA has focused a lot over the past decade on these two problem and we need to find a way to leverage that. In today's military market the customer-vendor relationship is drastically altering. In the traditional procurement process DoD defines the threat, then draws up paper specifications of how to respond to the threats, invite bids and contracts the development. This process typically takes 6 to 8 years to fielding. This time period is well in excess of one or more lifetimes of the technology and today is probably in excess if the lifetime of the defined enemy. We may note that the development wheels are still grinding on "IFF" systems to use in the desert, with nothing close to fielding.

If we set up a design scenario where Army labs are part of the design process (not just the specification process), and the Battle Labs are part of the evolving evaluation, and if we can give the Army direct access to the government or commercial infrastructure for prototyping, that can greatly decrease the development and fielding cycle time and cost. This concept has been demonstrated as part of an on-going ARPA program with the FBI as follows: ARPA research (at UCLA and U.C. Berkeley) has created a CAD framework and component database for digital design which is maintained by a central facility (MSU). Designs developed with this facility can be directly fabricated in integrated circuits by the FBI using a national broker for IC fabrication (MOSIS). This model has been demonstrated to reduce both the time to field as well as the development cost by *an order of magnitude* compared to conventional development and procurement procedure.

Military radios are very expensive, because defense contractors often use less efficient design techniques and technology than commercial contractors who compete in the consumer market. They are also more expensive because they are driven by *a priori* specifications, rather than by practical *a posteriori* technology. By applying novel design technologies and rapid prototyping to support the SRA concept the costs can be significantly cut. For example if the Army goes to a contractor for a simple logic part like a controller IC to make an interface between the radio and the computer, the base price for design and implementation in a gate-array IC is about $100,000. If the Army has an infrastructure of commercial logic synthesis tools (available off-the-shelf nowadays) with interfaces to the gate array vendor, the Army can fully custom-design the part and contract directly with the gate array vendor for manufacturing. This can significantly reduce both time to field and the cost.

3.3 Summary - Phase I Results

Based on the investigation and experience with two prototypes for SLANT, six major problem have been identified as bottle neck in the Army's ability to acquire a SLANT device that meets requirements of the soldier. These are:

1. Current radios are point solutions and lack the modularity to allow easy upgrades

2. Army radios are bulky compared to commercial radios and lack the interfaces for serving as nodes in a high density network such as a network of soldiers.

3. Existing DSP and radio/computer interface technology is inadequate to support compressed video transmission in the battlefield.

4. Network control software lacks modularity to provide adaptation and flexibility required in soldier's environment.

5. Soldier's radio requirements evolve and there is no methodology to keep pace with this evolution in a timely fashion.

6. Lack of computer-aided design and engineering tools and a lack of component databases directly available to the Army make acquisition process lengthy and expensive.

A three-fold solution to these problem has been developed. This approach is embodied in a Phase II proposal under separate cover, and is summarized as follows:

1. Define a unified architecture for the soldier's radio that allows conceptual definition of the radio systems while leaving the option open for insertion as well as replacements of components.

2. Define an infrastructure of design tools and component databases to be managed by a national facility for the Army to specify soldier's radios based on the above architecture.

3. Create a national working group of commercial and DoD vendors as well as Army representatives to help define the architecture and to provide on-going support for the architecture.

Our recommendation is that under a successor Phase II program this Soldier's Radio Architecture be developed at the network, hardware, software, and human-interface levels, and that with the concurrence of the user and contractor communities the SRA be used as a basis for streamlining the rapid and adaptive evolution of future communications systems for the individual soldier.