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Networked unattended ground sensors for battlefield visualization

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The battlefield visualization and connected technology has a very important role in the 21st century battlefield. Using this new process and technologies the decision making process is much more efficiency. One of the most important parts of battlefield visualisation is the intelligence, reconnaissance and surveillance (ISR). Using Unattended Ground Sensors (UGS) – as a new emerging technology – increases power and efficiency of ISR in this process. This lecture gives a short overview about UGS. Interpretation and adaptability are described in the first part of lecture, and finally some existed and new developed UGSs are shown.

Introduction

Battlefield visualization is a key component of digital battlefield. This is a process whereby the commander:

- develops a clear understanding of the current state with relation to the enemy and environment;
- envisions a desired end state which represents mission accomplishment, and then subsequently
- visualizes the sequence of activity that moves the commander's force from its current state to the end state.

This capability allows the commander to see and understand the battlefield by all source intelligence, and reports of friendly forces. There are many technologies and devices, which help to visualize the battlefield. In this paper I'd like to focus on Unattended Ground Sensors (UGS), which are new emerging reconnaissance, surveillance and target acquisition (RSTA) systems.

Existing UGS systems are hand-emplaced or dropped from a helicopter or fighter aircraft. These systems consist of individual units with a single sensor mode (acoustic, magnetic or seismic) connected to the user via a radio network or satellite. Each

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individual unit delivers “single sensor” performance and incorporates no data fusion. Typical legacy UGS systems have the following performance characteristics:

- Magnetic unit – tracked vehicles within 25 meters with a probability of correct classification of <50%
- Seismic unit – tracked vehicles within 350 meters with a probability of correct classification of 50–60%.
- Acoustic unit – tracks vehicles with 500 meters and classifies “Tracked vs. Wheeled” with a probability of correct classification of 50–60%.

In this sense, they are employed as “trip-wires” to alert the presence of a moving vehicle in the region of interest, but they can’t discriminate friendly or enemy troops. Often times, because of unknown geological, vegetation or line-of-sight effects, the warfighter emplaces up to 5 redundant sensors and determines through trial and error the one that works correctly and consistently. Opposite this new UGSs employ multi-sensor fusion and high-speed processing to improve target detection and classification.[10]

What is UGS?

After this short introduction, let’s see what Unattended Ground Sensors are. A *ground sensor* is deployed permanently on the ground in the open. The deployment mode varying from buried, to surface-mounted. An *unattended* sensor works autonomously, without requiring human attention for its operation. This is different from, for example, a hand-held photo camera, which does not work if someone does not press the shutter button.[2] Figure 1 shows the parts of UGS.

As the size and cost of embedded electronics systems decreases while their complexity increases, new avenues are opened up for the applications of networked UGSs in defense, security, and law enforcement. UGSs are generally deployed near the ground, operate off battery power, and communicate over RF wireless links.[5]

UGS could be passive and active. Passive sensors detect a change in the natural field of energy caused by a target and/or detect the energy being emitted from a target. Passive sensor technology includes those sensors, which are based on capacitance, heat, sound, and vibration. Active sensors transmit energy and detect a change in the received energy as the target becomes within range. These sensors include transmitters and receivers. Active infrared is an example of this type of sensor.[12]

UGS can sense one or more phenomenon, including, acoustic, seismic, magnetic, electro-optical (EO) imaging, imaging infrared (IIR), pressure, radio-frequency (RF) resonance, chemical/biological/nuclear, olfactory, mechanical and infrared (IR), and weather.

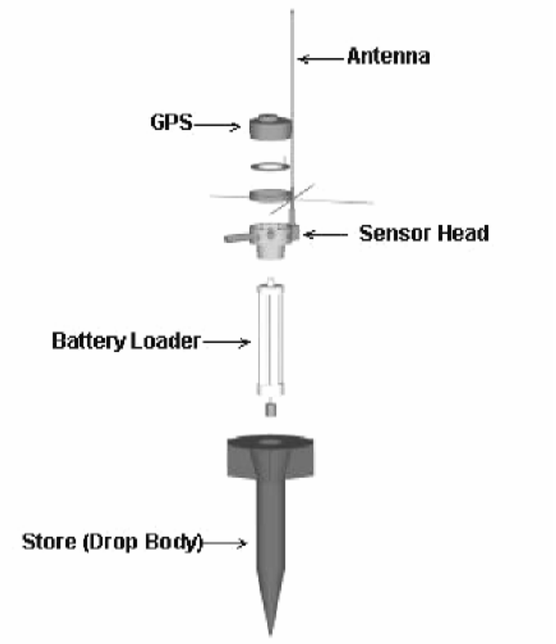

Figure 1. Parts of UGS[9]

UGS have many advantageous attributes using on the modern battlefield. They mostly operate passively (receiving only), resulting in low power requirements and reducing their probability of detection. UGS can operate autonomously for months thanks to modern battery technology. UGS affordability should make it feasible to deploy vast networks of UGS. Further, while various environmental conditions affect the operation of UGS, they would continue to operate in most weather conditions and would be virtually unaffected by the low cloud ceilings that frequently preclude visual and IR-band imaging. Finally, their small size and fixed locations make UGS difficult to detect visually.[11]

The battery primarily drives the size and weight of an unattended sensor. As a result, energy efficiency of the transceiver is critical to maintaining long mission durations without requiring a large power source.[12]

Operational requirements of UGS are:

- passive sensors;
- low cost, small, inexpensive;
- wide area coverage;

- robust, weather proof;
- target recognition;
- remote monitoring, reprogramming;
- long life span (depending on mission);
- robust communication with LPI/LPD transmission;
- protection against tampering.

Numerous sensor types (acoustic, passive infrared, magnetic, seismic, radio-frequency, micro-radar, and imaging) have been integrated into a wireless sensor network system. The networked UGS provide energy efficient and support collaborative data and information processing (Figure 2). Target detection, tracking, localization, and recognition are vital information, which UGS can determine from sensor network. Sensor fusion is the key to the fidelity and accuracy of UGS. Robust target information can be obtained through fusing information obtained from the different sensor types co-located on the same UGS. Higher-level sensor fusion, including information from different UGS can also improve performance. For example, fusing acoustic, seismic and IR information can improve classification and identification, and fusing bearing information from different UGS could be used to triangulate and estimate target location.[7]

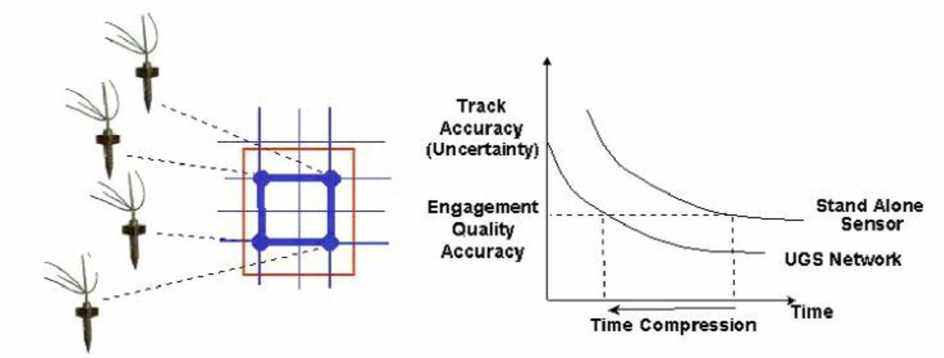

Figure 2. Efficiency of UGS network

Adaptability of UGS

UGS can be applied in various military missions. Specifically, UGS systems add significantly to the capability and security of reconnaissance and surveillance units during military operations by monitoring the battlefield. There are several applications of UGS in military operations and peace operations as well, including:

- minor roads, bridges, crossroads watching,

- border monitoring,
- monitoring of depots and other enclosed areas,
- deploying within an urban area to provide an early warning system
- disaster recovery and
- counter terrorism, etc.

In peace operations unattended ground sensor systems can be deployed at the places of interest, and sense movement or the presence of vehicles, persons or weapons in their vicinity and signal an alarm. This alerts peace-keepers in a monitoring center or command post, who can then immediately send a rapid-reaction patrol to the appropriate site to confront the intruders, to try to stop them. Through the use of sensors thus, continuous watch of minor roads, of rough terrain well-suited for clandestine passage, and even of a designated demarcation line of several hundreds of kilometers, is possible. Sensors can also assist in other monitoring tasks such as the monitoring of depots and other enclosed areas.[2]

UGSs provide the warfighter with a non-line of sight, all-weather situation awareness and precision targeting capability to detect, track, classify, and identify specific mobile time critical targets. Therefore UGS system can be deployed anywhere in a tactical environment in support of reconnaissance, surveillance, and target acquisition (RSTA) operations. This system complements other manned/unmanned surveillance systems such as ground surveillance radar, unmanned aerial vehicles, and night observation devices.[11]

Sensor systems can be deployed within an urban area to provide an early warning system in the event of a terrorist attack.

By linking wireless routers to video cameras, images can be transmitted from disaster areas to other vehicles, fires stations, command centers, and other public safety agencies. Officers in command centers can view video of an incident, analyze it, and relay orders to a responder, all in real time. Relevant databases are made available instantaneously to all officers on the street, regardless of location or vehicle type (foot, bike or car). Furthermore, by incorporating external GPS (Global Positioning System) receivers, mobile wireless routers can provide central command centers with the locations of their responders. This precision tracking and communications with public safety officials helps save lives and increases the speed of relaying time critical information.

In a similar application, the wireless technology used in UGS systems can be leveraged to respond to disaster scenarios. During major disasters, infrastructure-based communication systems, such as cellular, or wire and fiber lines, are often partially or completely destroyed. A cyber-attack on an information network can produce similar results. In these situations, agencies need access to information, but have little time to establish new data connections. Rapidly deployable wireless networks can provide a quick solution during these emergencies by providing a flexible, infrastructure-free, and self-healing IP (Internet Protocol) networks. Emergency response vehicles equipped with wireless routers can easily and immediately create a wireless network that maintains connectivity as vehicles change positions.[12]

Existing and newly developed UGSs

Various types of UGS exist around the world and are used for various missions. Some of them are as follows:

- In Canada there is a sniper location acoustic sensor system called GUARDIAN, which was designed as an area-monitoring device to equip observation posts for border defense.
- In Germany, an acoustic, seismic and magnetic, IR, and pyroelectric UGS system called BSA has been developed with the capability of detection, classification, and type identification of personnel and ground vehicles.
- In the Netherlands, the Monitor of Enemy Movement (MEMO) is a seismic sensor system designed for detection of personnel, in addition to ground vehicles.
- In the UK, an unattended acoustic and met sensors system called HALO is used to monitor artillery fire. These are deployed for long-range detection of a transient signal emanating from artillery fire.
- In the U.S., a system called the REMote Battlefield Acoustic and Seismic System (REMBASS) was originally developed in the early ’70s.[7]

Remote Battlefield Acoustic and Seismic System (REMBASS)

REMBASS is a UGS system that detects, classifies, and determines direction of movement of personnel, wheeled vehicles, and tracked vehicles. It provides world wide deployable, day/night, all-weather, early warning surveillance and target classification. Units operate up to 90 days, or longer, without maintenance.

REMBASS sensors are built for any level of conflict, including special operations, low intensity conflict, and counter narcotics operations. The sensors are placed along likely avenues of approach or intrusion and respond to seismic and acoustic disturbances, infrared energy, and magnetic field changes. The sensor information is incorporated into short, digital messages and communicated by VHF radio burst transmission.

The REMBASS II Seismic-Acoustic Sensor is a target-classifying sensor that employs sophisticated algorithms to detect and validate the presence of targets. These are the identical algorithms used in the battlefield proven Improved Remote Battlefield Acoustic and Seismic System (IREMBASS) sensors (Figure 3). The Seismic-Acoustic sensor discriminates between personnel, wheeled vehicles, and tracked vehicles. The sensor's complex signal processing algorithm results in a high probability of detection with an extremely low false/nuisance alarm rate.

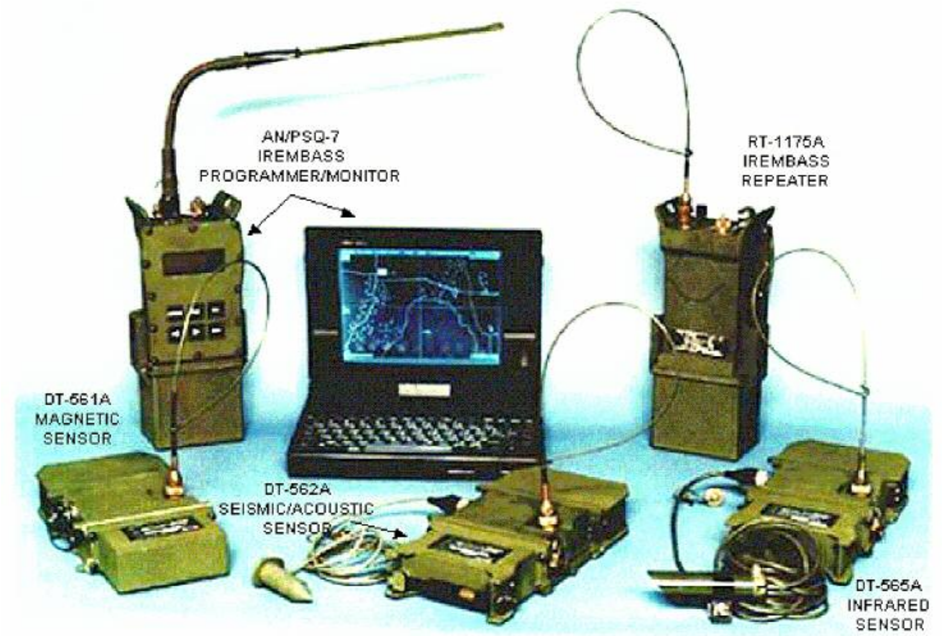

Figure 3. Elements of IREMBASS[6]

REMBASS II Passive Infrared (PIR) and Magnetic (MAG) sensors are implemented as plug-in modules that work in conjunction with the S/A sensor. These modules determine and report the target's direction and can be used to count targets. The REMBASS II PIR and MAG sensors also feature false alarm rejection algorithms. The benefits of the plug-in configuration are a dramatic reduction in size, weight, and cost, and greater operational flexibility.

A remote monitor programmer is used to receive the target detection and classification data, either directly or through repeaters. The monitoring unit can act as an automated sensor monitor by connecting to a PC running a custom graphical sensor mapping application.[6]

The sensors are normally in an idle mode with very low power dissipation. When a target comes into detection range, the sensors note a change in the ambient energy level (seismic/acoustic, thermal, and/or magnetic), and are activated. The sensors identify the target (as a person or a tracked or wheeled vehicle), format this information into short digital messages, and transmit the messages to a monitoring device. Information received at the monitoring device is decoded and displayed, showing target classification and direction of travel.[3]

Advanced Remote Ground Unattended Sensor (ARGUS) Systems

ARGUS is a family of unattended sensors that will initially be based on the STEEL EAGLE Advanced Concept Technology Demonstration (ACTD). ARGUS will initially include seismic and acoustic sensors, low voltage electronics, a battery, a sensor container, an aerodynamic delivery body, air brake subsystems, and a communications transceiver. ARGUS will also be configured as a hand in-place unit.[1]

The ARGUS UGS consists of two unattended MASINT ground sensors:

- the Steel Eagle (air drop) and
- the Steel Rattler (hand-emplaced) (Figure 4)

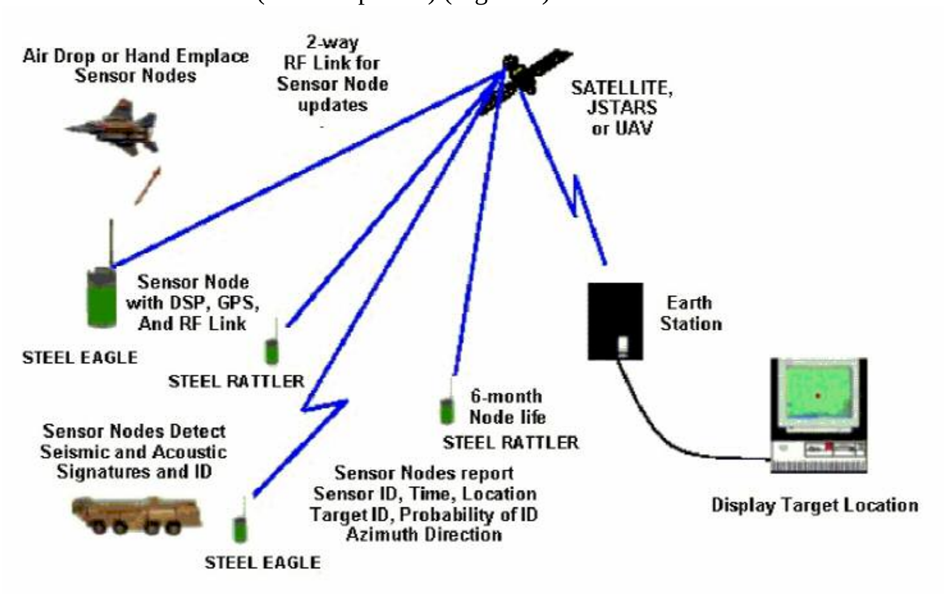

Figure 4. ARGUS Architecture

The Steel Rattler is a hand-emplaced acoustic-seismic sensor with a thermal imager that can detect, classify, and identify time-critical mobile targets by their acoustic-seismic-thermal signatures. Steel Rattler carries an embedded computer that can instantaneously process sound waves produced by moving vehicles. The system provides discriminating detection and targeting in the pre-launch and pre- deployment stages, cueing strike assets before the missile threats are armed and dangerous.

Steel Eagle is an airdropped version of the same package, and has already been fitted for deployment by the F-15, F-16, and F/A-18.[8]

Tactical Remote Sensor Systems TRSS

Tactical Remote Sensor Systems (TRSS) are deployed and operated by Ground Sensor Platoons in support of the Marine Air Ground Task Force (MAGTF) Commander's Intelligence collection effort. TRSS consists of air delivered- and hand emplaced sensors, sensor monitoring and retransmission systems.

Once deployed, the remote systems operate autonomously to provide continuous, unattended surveillance of distant areas of the battlefield (Figure 5).

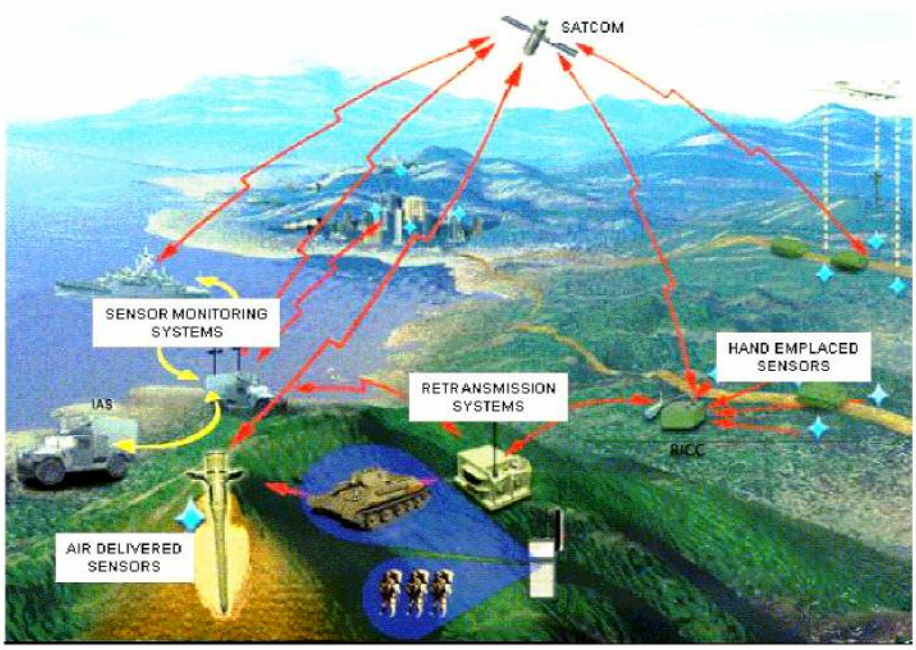

Figure 5. TRSS Architecture[9]

Table 1. Main parameters of TRSS[9]

Parameter	AADS (Air-Delivered)	UGMS (Hand-emplaced)
Sensing (meter)	Tracked Vehicle – 300 Heavy Wheeled – 150 Light Wheeled – 75 Rotary Winged Aircraft – 1000 Battlefield Sounds – 1000	Tracked Vehicle – 300 Heavy Wheeled – 150 Light Wheeled – 75 Rotary Winged Aircraft – 1000 Battlefield Sounds – 1000 Personnel – 20
Communications	Primary – SATCOM Secondary – TRSS Compliant	Primary – TRSS Compliant Secondary – SATCOM
Weight (kilogramm)	Less Than 30	5
Mission Duration	21 Days	21 Days

TRSS are frequently employed to provide surveillance and reconnaissance in places where it is too dangerous to maintain personnel and/or not tactically practical to deploy other surveillance systems.[9] Table 1 shows the main parameters of TRSS.

DARPA Unattended Ground Sensors (UGS)

The sensor system is composed of four sensor nodes, a gateway node and a command console. The system covers an area defined by a radius of 3000 meters. The sensor nodes contain omni-directional passive acoustic and seismic sensors and a short haul communications network to interface with the gateway node. They have GPS and precision self-location capability (Figure 6).

The gateway node collects target information from the sensor nodes to determine target range, bearing, classification, and feature for identification. The gateway also contains the "long haul" communications hardware needed to send information to the User's command console up to 25 km away. Multiple clusters are deployed in any user-defined array to extend coverage. The User's command console hosts the emplacement decision aid, the sensor monitoring software, the situational display and the interface to the "strike" C2 network for targeting dissemination to multiple strike platforms.[10] Table 2 shows the main parameters of DARPA UGS.

UGSs communications architecture

The UGSs communications architecture consists of an all-digital fully-connected adaptive network providing integrated video, voice, and data services (Figure 7). The fundamental component of this architecture based on the IP suite. This enables plug-and-play compatibility with existing wired and wireless commercial off-the-shelf (COTS) communications hardware, including Tactical Internet (TI), Near-Term Digital Radio (NTDR), Joint Tactical Radio System (JTRS), and Warfighter Information Network (WIN).[4]

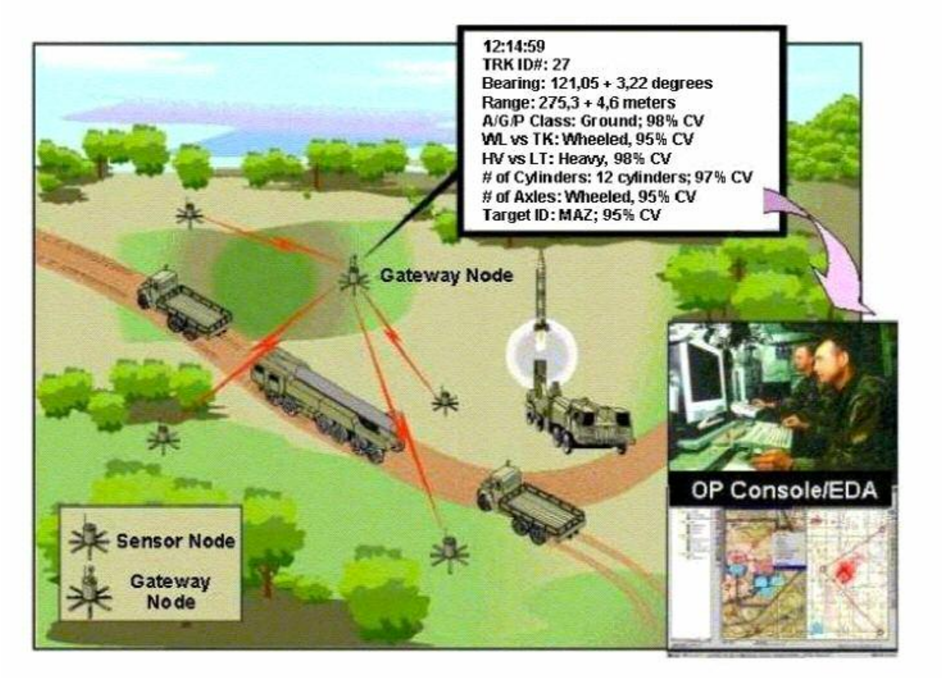

Figure 6. DARPA UGS[10]

Table 2. Main parameters of DARPA UGS[10]

	Range to Target(s) 0–500 m	**Range to Target(s) 500–3000 m**
Probability of Detection	>70%	>70%
Missed Detection	<30%	<30%
False Detection	<10%	<10%
Probability of Correct Classification	>85%	NA
Missed Classification	<5%	NA
False Classification	<1%	NA
Targeting Precision	<20 meter	NA

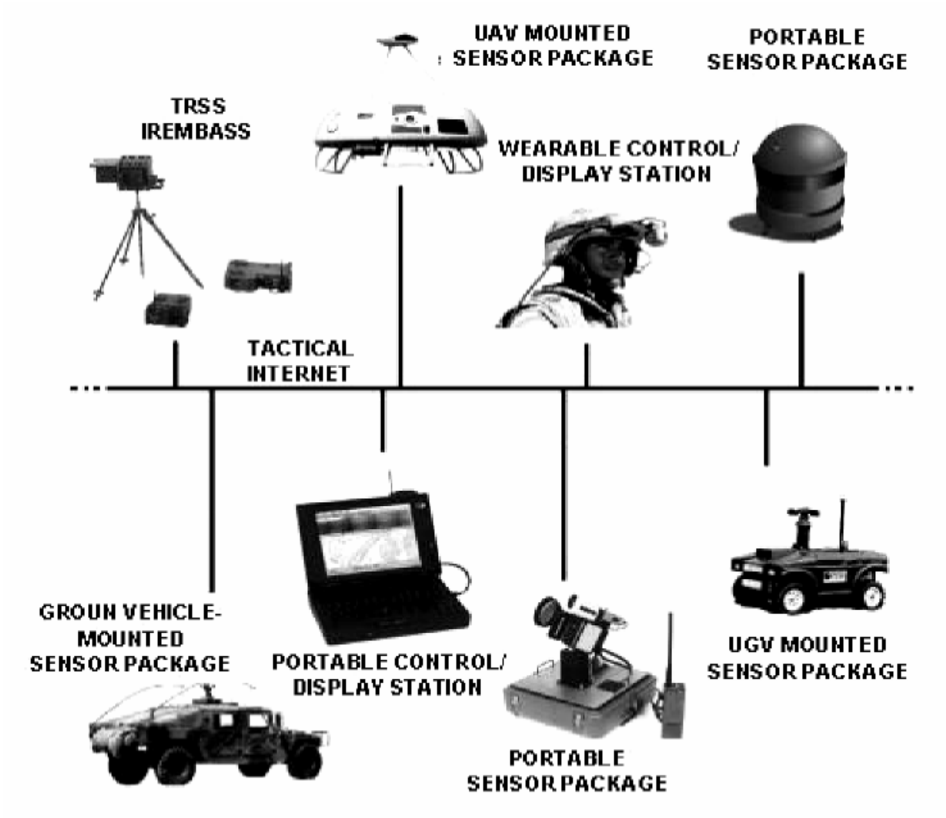

Figure 7. UGSs communications architecture[4]

Summary

The concept of UGSs is an emerging technology in the 21st century. These systems potentially offer both the field commander and the headquarters staff the capability of battlefield early warning, battlefield visualization and situational awareness. Future development promises low-cost, robust systems of small size that can be deployed by many means. Their obscurity and networked application enhance battlefield effectiveness. These systems capable of target recognition, border defense, surveillance, and flank protection in difference operations.

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