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THESIS

ENHANCING THE EXTENDED AWARENESS CAPABILITY OF THE ESG: INTEGRATING SHOTSPOTTER AND CURSOR ON TARGET TECHNOLOGIES WITH UNMANNED AERIAL VEHICLES TO ENHANCE THE MISSION CAPABILITY OF THE ESG

by

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June 2005

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This thesis discusses two emerging technologies and how their integration with UAVs can improve the situational awareness capability of the Expeditionary Strike Group. Shotspotter is an acoustic gunshot detection system and Cursor on Target is an XML based schema to enhance information exchanges. When integrated with UAVs, these two technologies will drastically improve an ESG's efficiency and lethality in combat.

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ABSTRACT

This thesis discusses two emerging technologies and how their integration with UAVs can improve the situational awareness capability of the Expeditionary Strike Group. Shotspotter is an acoustic gunshot detection system and Cursor on Target is an XML-based schema to enhance information exchanges. When integrated with UAVs, these two technologies will drastically improve an ESG's efficiency and lethality in combat.

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EXECUTIVE SUMMARY

This thesis focuses on two emerging technologies and how these technologies can enhance the mission of the ESG when fused with UAVs. Shotspotter and Cursor on Target are two developing technologies that improve situational awareness on the battlefield. Shotspotter is an acoustic sensor system to pinpoint gunshot locations. Originally developed for law enforcement agencies for use in urban environments, it has been modified for military use. Cursor on Target is a system that enhances interoperability by facilitating rapid information exchanges.

In the current War on Terrorism, knowledge and information have proven paramount to success. Maintaining information superiority has become a focus of United States policy on and off the battlefield. The Shotspotter and Cursor on Target technologies will provide the ESG with advanced battlefield awareness to stay one step ahead of our adversaries. These technologies will further close the gap between intelligence and operational activities.

ESGs are playing an increasingly important role in United States strategy and policy; it is vital that they continue to improve and evolve in order to maintain maximum effectiveness. A simple and effectual way to improve the usability and effectiveness of the ESG is through increased usage of Unmanned Aerial Vehicles. UAVs are one of the most versatile platforms and their potential is limitless. UAVs have proven their ability to fulfill a growing list of missions and their growth does not appear to be losing any momentum.

The addition of Shotspotter and Cursor on Target to UAVs will greatly enhance the quality and mission effectiveness of UAVs. These improvements will allow UAVs to achieve new missions and remove American forces from harms way by decreasing the need for manned aircraft. Shotspotter on UAVs will help locate gunshots and provide the gunshot location and important information about the weapon to friendly forces. Cursor on Target enables the accelerated transfer of data between systems. Increased data speed would get vital time critical information into the hands of people and platforms that need the information. These improvements will translate to enhanced extended awareness capabilities of the ESG.

I. INTRODUCTION

A. BACKGROUND

U.S Joint Forces Command is currently conducting a series of experiments to explore the utility of UAVs in urban combat. These Extended Awareness experiments integrate many different technologies with UAVs to enhance the situational awareness of soldiers on the ground. Improved situational awareness allows soldiers to make informed decisions more quickly and increases their decision cycle rate.

The OODA loop is a common decision cycle model used in the military. OODA stands for observe, orient, decide and act. Enhancing the situational awareness of soldiers on the battlefield will directly correlate to an improved OODA loop. Col. John Boyd, USAF (Ret.), the creator of the OODA loop, stressed the importance of a rapid cycle time. He believed that one key to victory was to get inside your opponent's OODA loop. This is accomplished by having a faster cycle time than your adversary, and thus being able to adapt and react faster than the enemy and defeat him. This theory is widely accepted today.

This thesis will explore a few of the new technologies being tested in the Extended Awareness (EA) series of experiments. It will also identify the advantages that these technologies, in conjunction with UAVs, will provide to the Expeditionary Strike Group.

B. TECHNOLOGIES

This thesis will focus on two technologies being tested by the Extended Awareness series of experiments.

Shotspotter is an acoustic gunshot detection system with the ability to locate and identify gunshots within the range of its array of sensors. Cursor on Target is an XML [extensible markup language] schema that facilitates rapid information exchanges between dissimilar systems.

C.   WHY THESE TECHNOLOGIES ARE IMPORTANT

Improving the situational awareness of our troops creates a strategic and tactical advantage over the enemy. "Knowledge of the strategic environment is the first priority. The second, one must be able to interact with the environment and those within it appropriately."[1] UAVs, enhanced by Shotspotter and Cursor on Target, improve soldier's knowledge of the environment and provide the capability to rapidly translate this knowledge into action.

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[1] Hammond, Grant T. The Essential Boyd . May 2005
    <http://www.belisarius.com/modern_business_strategy/hammond/essen
    tial_boyd.htm>.

II. EXPEDITIONARY STRIKE GROUP BACKGROUND

A.   INTRODUCTION

The Expeditionary Strike Group concept was derived from the need for additional protection and strike capability for the Amphibious Ready Group. Traditionally, the ARG consisted of "a group of ships known as the amphibious task force (ATF), and a landing force (LF) of U.S. Marines."[2]   This structure was effective, but commanders believed they would benefit from the additional strike capability provided by the ESG concept.   The Expeditionary Strike Group combines the power of the Amphibious Ready Group (ARG) and Marine Expeditionary Unit\Special Operations Capable [MEU(SOC)] with surface and subsurface combatant ships.   These combatants provide protection to the ARG/MEU(SOC) in transit to and from the combat zone, as well as in the dangerous littoral regions where slow moving transport vessels are highly susceptible to attack from highly maneuverable patrol craft.[3]

B.   EXPEDITIONARY STRIKE GROUP COMPOSITION

The exact composition of the ESG has yet to be defined.   The current model can be logically broken down into two parts, the Navy component and the Marine component.

1.   Navy Component

The Navy component combines the assets of the amphibious task force carried over from the ARG/MEU(SOC)

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[2] The Amphibious Ready Group. Navy Office of Information. May 2005
<http://www.chinfo.navy.mil/navpalib/news/.www/arg.html>

[3] Kemple, Bill G., et al. Expeditionary Strike Group: Command Structure Design Support. Naval Postgraduate School. May 2005
<http://www.dodccrp.org/events/2005/10th/abstracts/364.pdf>.

concept with the addition of a Navy Cruiser, Destroyer, Frigate and attack submarine. The Expeditionary Strike Group is composed of eight surface ships and one attack submarine.[4]

- 1 Large Deck Amphibious Ship

- 1 Amphibious Transport Ship

- 1 Dock Landing Ship

- 1 Guided Missile Cruiser

- 1 Guided Missile Destroyer

- 1 Frigate

- 1 Attack Submarine

2. Marine Component

The Marine Component of the ESG is virtually unchanged in composition from the ARG/MEU(SOC). The MEU(SOC) inherits some enhanced strike capabilities from the additional Naval assets, but its organic assets remain practically unaffected.

C. EXPEDITIONARY STRIKE GROUP COMMAND STRUCTURE

Currently, there are two proposed command structures of the ESG, the East and West Coast models. The East Coast model establishes a supported/supporting relationship between the PHIBRON and MEU(SOC) commanders. This relationship is somewhat vague and extremely flexible by design. The establishing authority is responsible for ensuring both the PHIBRON and MEU(SOC) commanders

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[4] Navy Office of Information

understand the relationship and the authority each have while fulfilling their respective roles.[5]

The West Coast model instills authority of the ESG to a flag or general officer. This commander, a one star Navy or Marine Corps officer, is in command of the ESG. The commanders of the PHIBRON and the MEU(SOC) still work together in a supported/supporting relationship, but ultimately, authority rests with the one star ESG commander.
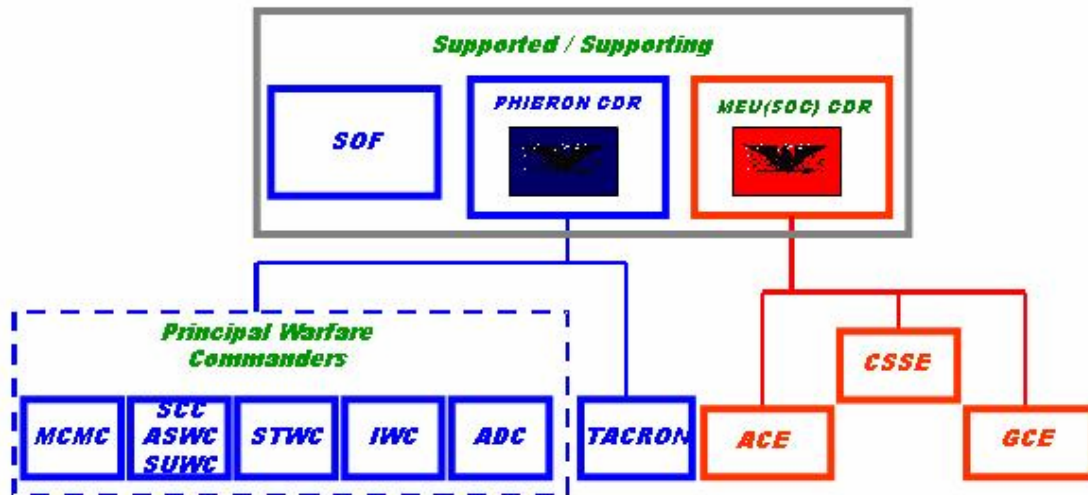
Figure 2.   East Coast ESG Command Structure (From: EWTG Atlantic)

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[5] United States. Department of Defense. <u>Joint Pub 0-2</u>. 10 July 2001.
    Apr. 2005
    <http://www.dtic.mil/doctrine/jel/new_pubs/jp0_2.pdf>.
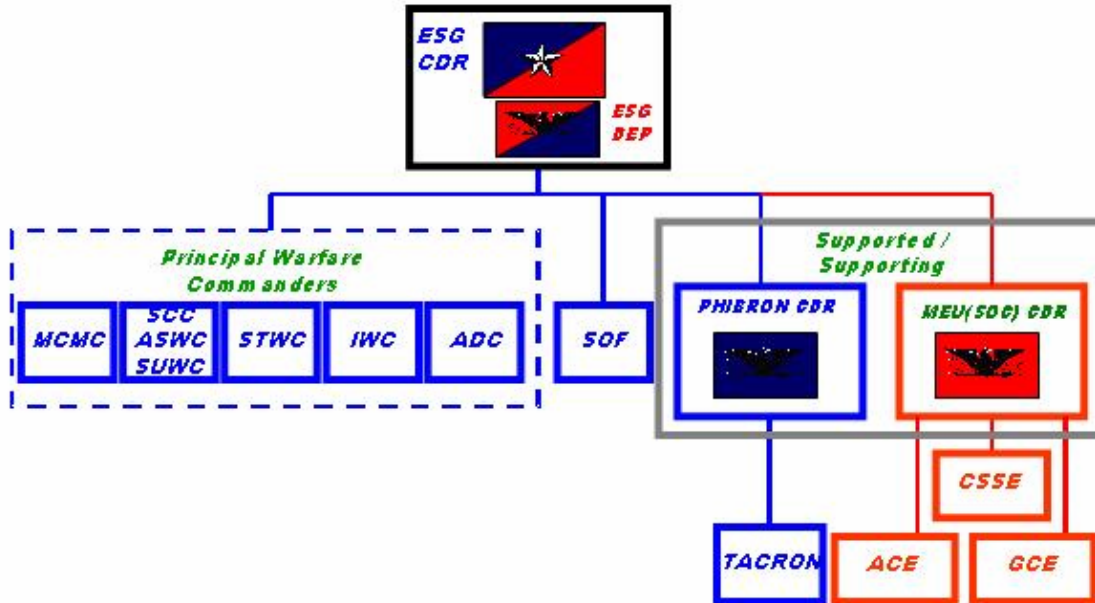
Figure 3.   West Coast ESG Command Structure (From: EWTG Atlantic)

D.   EXPEDITIONARY STRIKE GROUP MISSION

The official ESG mission statement has yet to be formulated. The following mission statement was presented to Lieutenant General Mattis by the Expeditionary Warfare Training Group Atlantic in December of 2004. It reflects what the official mission statement may look like.

> The Expeditionary Strike Group provides the Combatant Commander or Fleet Commander a versatile sea-based operational force that can be tailored to a variety of missions, including quick reaction crisis-response options in maritime, littoral, and inland environments in support of U.S. policy. The ESG is capable of executing all ARG/MEU(SOC) missions and additional offensive and defensive operations in a limited non-permissive environment.[6]

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[6] "Lieutenant General Mattis Brief by the Expeditionary Warfare Training Group Atlantic" given Dec 2004. FIRES Network: ESG Repository. Feb 2005

E. EXPEDITIONARY STRIKE GROUP CAPABILITIES

The full list of the ESG capabilities is continually growing. With each deployment, creative use of the ESG's assets expands its operational capabilities. The following ARG/MEU(SOC) capabilities are enhanced by the ESG concept[7]:

1. Operational Agility and Offensive Capability

The addition of naval assets enables the ESG to perform a wider base of operations. The surface and subsurface combatants provide the ESG improved Tomahawk strike capability to soften or destroy targets before amphibious operations.

2. Options for Forcible Entry, Assault, and Raid

Naval combatants provide naval fire support and missile strike capabilities to increase the lethality of MEU(SOC) operations.

3. Creates a Maritime Interdiction Force

Increased naval resources broaden the search capability of the ESG. Additional search radars allow the ESG to track more targets with improved accuracy. Naval Cruisers, Destroyers, and Frigates are trained and equipped to perform maritime interdictions.

4. Expanded Special Warfare Basing/Delivery/Entry

Attack submarines attached to the Expeditionary Strike Group provide an enhanced capability to base, deliver, insert, and retrieve Special Forces.

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[7] Lieutenant General Mattis Brief by the Expeditionary Warfare Training Group Atlantic.

5.   Enhanced Intelligence Gathering Network

Submarines have always been at the forefront of maritime intelligence collection. They provide the ESG with enhanced intelligence collection and access to remote regions of the world's oceans. In addition, the West Coast ESG model is commanded by a flag rank officer. These officers and their staffs are generally afforded additional intelligence resources.

6.   Improved Force Defense

The additional naval component of the ESG provides another layer of defense to the ARG/MEU(SOC). The Cruiser, Destroyer, and Frigate are the primary defense against air and surface threats. The level of protection they provide far exceeds that of the ARG/MEU(SOC). The Aegis Combat System offers a dramatic improvement to the existing air defense system. The attack submarine provides subsurface protection for the ESG. The ARG/MEU(SOC) alone is virtually unprotected from subsurface threats.

7.   Full-Spectrum Protection for ARG

Naval combatants are well trained and equipped to provide maritime protection. For years, one of their primary missions has been to protect aircraft carriers. Transitioning to protection of the ARG/MEU(SOC) should be seamless.

F. **EXPEDITIONARY STRIKE GROUP MISSION ESSENTIAL TASK LIST (METL)**

1. **Navy Specific METL**

The Expeditionary Warfare Training Group Pacific (EWTGPAC) identifies the following as Navy specific tasks within the ESG structure:

- Provide Theatre Missile Defense Warning

- Provide Sea Lines of Communications Protection

- Provide Sanctions Enforcement

- Deploy/Conduct Operational Maneuver[8]

2. **Marine Corps Specific METL**

The Expeditionary Warfare Training Group Pacific (EWTGPAC) identifies the following as Marine specific tasks within the ESG structure:

- Conduct Amphibious Demonstration

- Conduct Amphibious Raid

- Conduct Amphibious Assault

- Conduct Amphibious Withdrawal

- Conduct Direct Action Operations (Precision Raid or Visit, Board, Search and Seizure (VBSS))

- Conduct Airfield/Port Seizure

- Conduct Security Operations

- Conduct Limited Expeditionary Airfield Operations

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[8] Kleinman, David L. "ESG METL" Expeditionary Warfare Training Center Pacific, PowerPoint slide.

- Employ Non-Lethal Weapons

- Conduct Enhanced Urban Operations

- Conduct Noncombatant Evacuation Operations (NEO)

- Conduct Humanitarian/Disaster Assistance

- Conduct Peace Operations

- Conduct Deliberate Planning

- Conduct Rapid Planning

- Provide Contingency Support Packages (Tactical Recovery of Aircraft Personnel (TRAP), Causality Evacuation (CASEVAC), Quick Reaction Force (QRF), Mass Causality scenarios)[9]

3. Joint Navy and Marine Corps METL

The Expeditionary Warfare Training Group Pacific (EWTGPAC) identifies the following as Joint Navy and Marine Corps specific tasks within the ESG structure:

- Conduct Intelligence, Surveillance and Reconnaissance

- Conduct Information Operations Warfare

- Tactical Deception Operations

- Provide Operational Fires (Joint / Coalition)

- Provide Anti Terrorism/Force Protection

- Conduct Terminal Guidance Operations

- Conduct ESG Force Defense (AD/USW/SUW/DAF)

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[9] Kleinman.

- Conduct Maritime Interdiction Operations (MIO) / Extended Maritime Interdiction Operations (EMIO)

- Conduct Visit, Board, Search and Seizure (VBSS) (compliant / non-compliant)

- Provide Command, Control, Communications and Computers

- Conduct Sustainment Operations

- Conduct Initial Terminal Guidance Operations

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III. UNMANNED AERIAL VEHICLES BACKGROUND

A.   UAV INTRODUCTION

Unmanned Aerial Vehicles, or UAVs, are becoming an increasingly important aspect of today's military. As the modern battlefield becomes more technologically advanced, it inherently becomes more complicated and dangerous. The implementation of UAVs into today's battlefield allows the military to achieve a greater sense of situational awareness while minimizing the threat to the troops. At the same time, UAVs are traditionally less expensive per unit than the manned aircraft that they may one day replace.

UAVs can, and are currently being designed to, execute a vast array of missions. The Department of Defense realizes the importance of UAVs and has subsequently planned for billions of dollars to go into funding for UAV design, testing, and production over the next 5 years.[10]

Examples of funded program initiatives include improved sensors, signal processing and reconfigurable computing subsystems, streaming video and audio compression techniques, multi-modal sensors (EO/IR, SAR, SIGINT/ELINT) that eliminate the need to swap payload packages after each mission, fuel cells for endurance and stealth, compact avionics and robotics, lighter weight weapons, and on-platform communication buses. In general, the DoD is looking for anything that can make the UAV airframe more useful, stay on-station longer, and act more like a human

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[10] Office of the Secretary of Defense.. United States.Department of
    Defense. Unmanned Aerial Vehicles Roadmap 2002-2027. Washington:
    GPO, 2002.

in terms of the signal processing, decision-making and weapons delivery capabilities.[11]

More telling, however, is the fact that the funding increases exponentially from today through the end of the Department of Defense projected investments [see DoD projected spending chart].
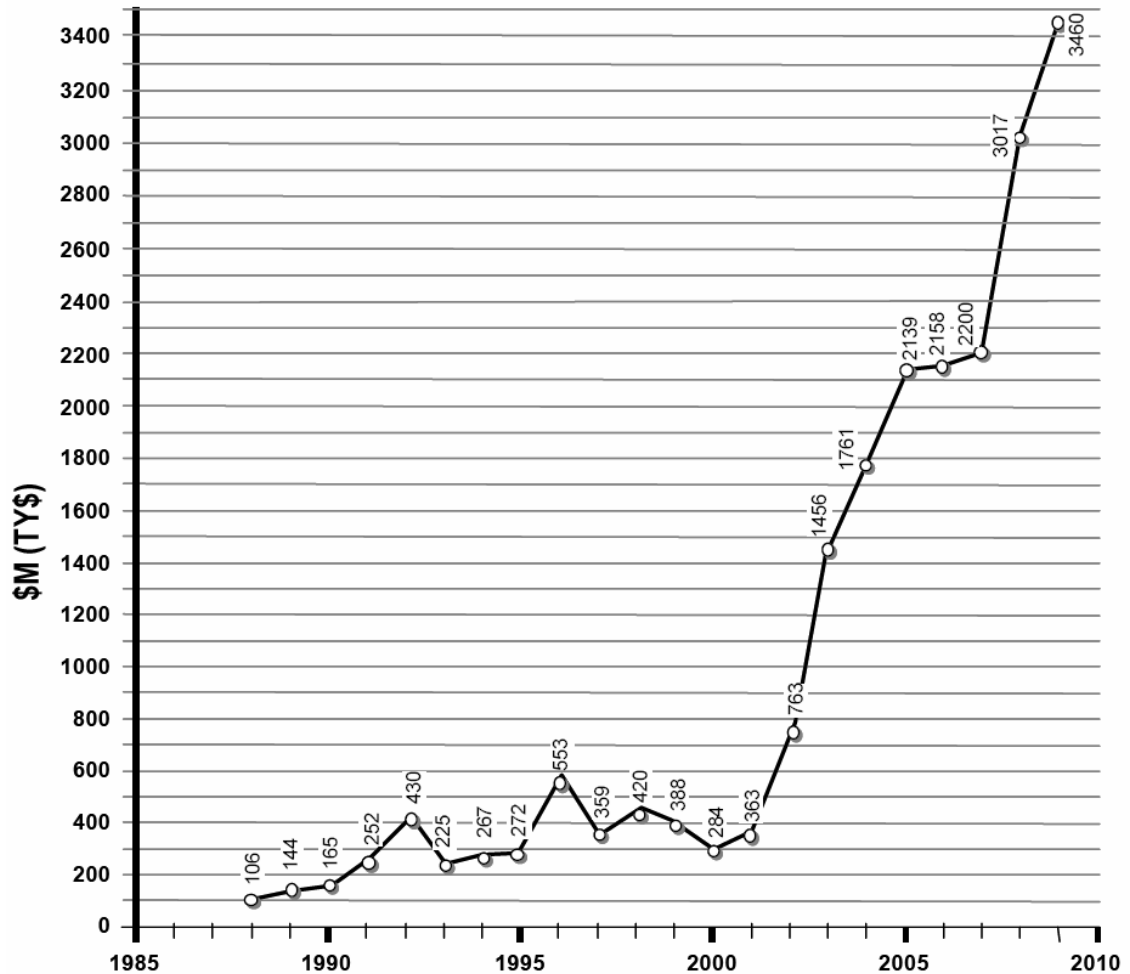
Figure 4.   DOD Spending Chart (From: UAV Road Map)

The exponential increase of UAV funding provided by the DoD starting in the year 2000 indicates that UAV

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[11] Ciufo, Chris A. "UAVs: New Tool for the Military Toolbox." <u>COTS Journal</u> (2003): 66-71.

development and innovation is very high, and continually growing on the list of government priorities.

With UAVs as a clear priority to the Department of Defense, it should come as no surprise that an increase in spending on UAV development and production would spur an increase in the production of current UAV systems as well as an increase in the planning and development of future UAV systems. Over the next 25 years several UAV programs are scheduled for improvement and extension, while several new UAV programs are scheduled for research, development, and production.[12]
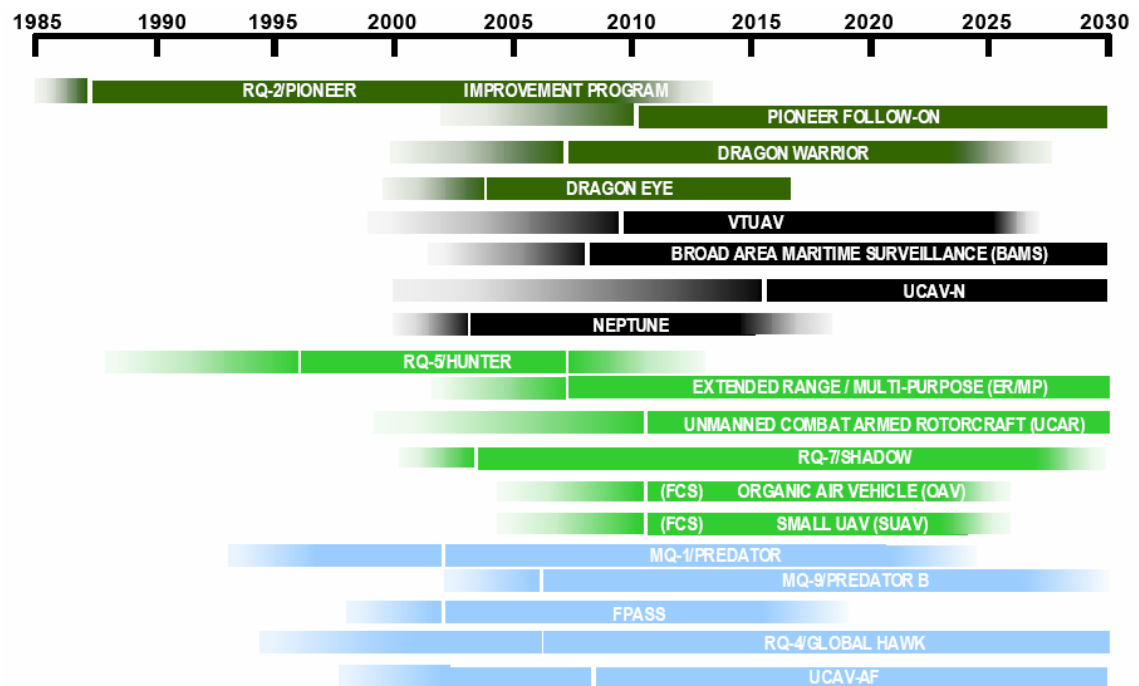
Figure 5.   DoD UAV Road Map (From: UAV Road Map)

The above graphic clearly shows a dramatic increase in UAV planning and production in the future. This is not surprising; it directly correlates with the exponential

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[12] Office of the Secretary of Defense.

increase in DoD funding directed towards UAV production and development.

B.   UAV MISSIONS

UAVs are capable of executing a myriad of missions due to their versatility, size, and capabilities. Traditionally, UAVs fulfill what is known as "3-D missions," dull, dirty, or dangerous[13].

Requirements (Mission Areas)	Justification for UAV Use			Prior UAV Experience (UAV/Payload, Place Demonstrated, Year)
	"Dull"	"Dirty"	"Dangerous"	
Intelligence, Surveillance, & Reconnaissance (ISR)	x		x	Pioneer, Exdrone, Pointer/Gulf War, 1990-91 Predator, Pioneer/Bosnia, 1995-2000 Hunter, Predator, Pioneer/Kosovo, 1999
C2/Communications	x			Hunter/CRP, 1996; Exdrone/TRSS, 1998 Global Hawk/ACN, Predator/ACN, ongoing
Force Protection	x	x	x	Camcopter, Dragon Drone/Ft Sumner, 1999
Signals Intelligence (SIGINT)	x		x	Pioneer/SMART, 1995 Hunter/LR-100/COMINT, 1996 Hunter/ORION, 1997
Weapons of Mass Destruction (WMD)		x	x	Pioneer/RADIAC/LSCAD/SAWCAD, 1995 Telemaster/Analyte 2000, 1996 Pointer/CADDIE 1998 Hunter/SAFEGUARD, 1999
Theater Air Missile Defense (TAMD)	x		x	Israeli HA-10 development, (canceled) Global Hawk study, 1997
Suppression of Enemy Air Defenses (SEAD)			x	Hunter/SMART-V, 1996 Hunter/LR-100/IDM, 1998
Combat Search and Rescue (CSAR)			x	Exdrone/Woodland Cougar Exercise, 1997 Exdrone/SPUDS, 2000
Mine Counter Measures (MCM)			x	Pioneer/COBRA, 1996 Camcopter/AAMIS, 1999 (Germany)
Meteorology and Oceanography (METOC)	x		x	Aerosonde/Visala, 1995 Predator/T-Drop, 1997 Predator/BENVINT ACTD, 2002
Counter Narcotics (CN)	x		x	Predator/Ft Huachuca, 1995 Pioneer/So. California, 1999
Psychological Ops			x	Non-DoD UAV/leaflet dispensing, 1990's
All Weather/Night Strike			x	DASH/Vietnam, 1960s Predator/Afghanistan, 2001
Exercise Support	x			Predator/JOTBS, 2002
Counter Fire			x	none
Anti Submarine Warfare	x			DASH, 1960s
Navigation	x			Hunter/GPS Pseudolite, 2000

Figure 6.   Example of "3D Missions" (From: UAV Road Map)

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[13] Ciufo.

Generally, the "truck" of the UAV is what is used to house the payload. Therefore the "truck" typically dictates the mission of a particular UAV. Depending on the size, duration, and speed of each UAV, many are suitable for multiple missions based upon the payload in the "truck".[14] However, UAV missions are commonly classified into four overarching categories; Information, Surveillance, and Reconnaissance (ISR), Strike / Suppression of Enemy Air Defense (SEAD), Electromagnetic Attack (EA), or Communications Node / Data Relay.[15] Most current and planned UAV operations can be categorized by one of these overarching UAV missions.

Traditionally, UAVs fulfilled very simple and minor tasks with respect to the four major missions. UAVs used to be utilized for surveillance or reconnaissance or used as a communications relay node. Recently, the roles that UAVs play within these missions have been expanding. New missions will be "UAV-accomplished" in the near future. The Department of Defense envisions UAVs accomplishing many new missions that are currently pilot based. For example, UAVs may soon be relied upon for airlifts, aerial refueling, and even counter air defense; all missions that currently require a pilot.[16]

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[14] Office of the Secretary of Defense.

[15] Office of the Secretary of Defense.

[16] Office of the Secretary of Defense.

MISSION	CURRENT AIRCRAFT	INTRODUCTION INTO OPERATIONS					
		2005	2010	2015	2020	2025	2030
Payload with Persistence							
Communication Relay	ABCCC, TACAMO, ARIA Commando Solo	■					
SIGINT Collection	Rivet Joint, ARIES II Senior Scout, Guardrail		■				
Maritime Patrol	P-3		■				
Aerial Refueling	KC-135, KC-10, KC-130			■			
Surveillance / Battle Management	AWACS, JSTARS					■	
Airlift	C-5, C-17, C-130						■
Weapon Delivery							
SEAD	EA-6B	■					
Strike	AV-8, F-117		■				
Integrated Strike/SEAD	EA-6B, F-16			■			
Counter Air	F-14, F-15, F-16					■	
Integrated Strike/SEAD/Counter Air	F/A-18, F/A-22						■

Figure 7.   Future UAV missions (From: UAV Road Map)

Clearly, the Department of Defense has very high expectations for UAVs in the near future. A strong argument can be made that if this roadmap comes to fruition, there may be little need for pilots to fly aircraft from the cockpit.
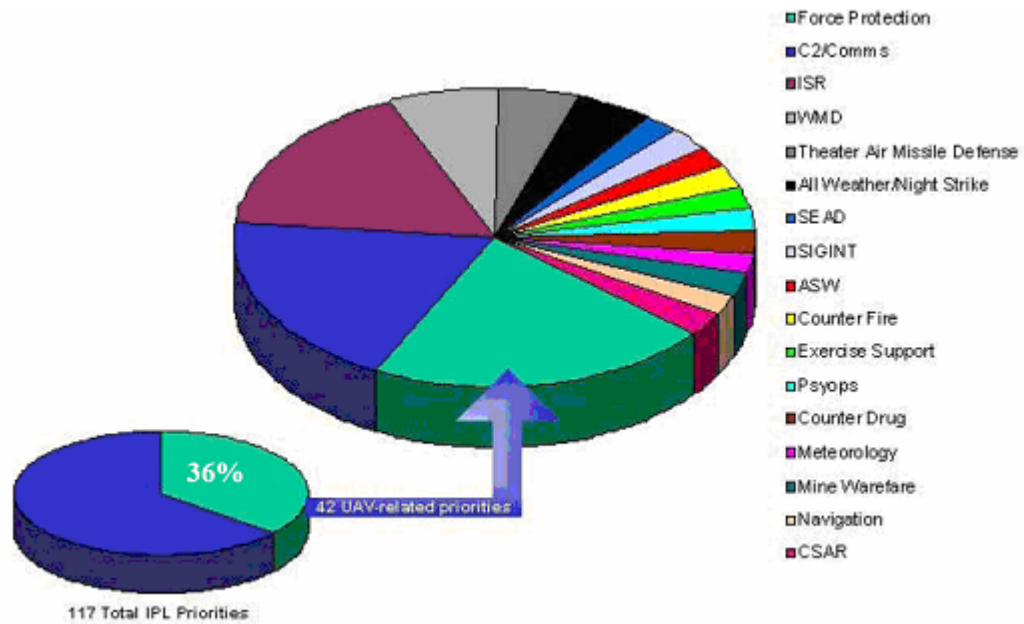
Figure 8.   17 UAV related mission areas (From: UAV Road
Map)

1. Intelligence Surveillance and Reconnaissance

The Intelligence, Surveillance and Reconnaissance
(ISR) mission of UAVs tends to be the most common and
widely used. UAVs are a perfect candidate for ISR missions
due to the wide variety of sensors, payloads, and data
collection devices that they can carry.[17] The versatility
of UAVs also allows for the platforms to perform "Armed
Reconnaissance" and transition from an ISR mission to
engage a target quickly, without much downtime or delay.
Traditionally, separate platforms would be necessary for
both the ISR and Strike missions.

By their nature, UAVs are ideal for ISR missions.
Intelligence, Surveillance, and Reconnaissance missions are
often long and arduous collection missions. They require a
platform to remain on station for an extended period of
time and are often conducted over hostile territory that

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[17] Office of the Secretary of Defense.

can be dangerous for human pilots in the cockpits of traditional aircraft. The use of UAVs mitigates these potentially disastrous problems. "Depending on the specific mission requirements, capabilities such as endurance, altitude, size, survivability, and cost can be optimized to provide capabilities that are not possible with any other collection means."[18] Locating or producing the proper UAV, tailored for the desired mission, is the only restriction on mission requirements when using UAVs.

The threat of an aircrew tiring out from a 20 hour surveillance mission is fading fast. Also, if the UAV is lost, there is no threat to a human pilot, and the platform is far less expensive than a pilot based aircraft. UAVs can also help eliminate the risk presented by air defenses to human aircrews. Furthermore, UAVs are "highly immune" to contaminated airspace from CBR (Chemical, Biological, Radiological) attacks that could be harmful or deadly to a flight crew.[19]

There are three main "sub-missions" inside the ISR mission: Stand-off, Overflight, and Denied Access.[20] Stand-off ISR missions require high altitude and extended endurance. They normally occur when there is an increased probability of platform loss. UAVs in a Stand-off mission fly very high for very long periods of time and carry many sensors in an effort to gather as much information as possible with each pass or attempt. Overflight ISR missions occur during peacetime or in combat when anti-air defenses have been largely neutralized. Overflight

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[18] Office of the Secretary of Defense.

[19] Office of the Secretary of Defense.

[20] Office of the Secretary of Defense.

missions can occur at any altitude or speed depending on what data needs to be collected. Denied Access missions, obviously, are missions that occur in areas where access is denied. That is, no aircraft is supposed to have access to the air space. UAVs operating in Denied Access roles require "attributes of reduced signature, extended endurance, speed, [and] sensor support including reduced signature apertures and operating modes…"[21] Denied Access missions are extremely high risk and are ideal for UAVs.

2.   Strike / Suppression of Enemy Air Defense

The Strike / Suppression of Enemy Air Defense (SEAD) mission is the second mission accomplished by modern UAVs. The SEAD and Strike missions of UAVs are completely different than that of "Armed Reconnaissance," in which a UAV is performing an ISR mission with the ability to engage a potential target.[22] The Strike / SEAD mission describes a case when a UAV is strictly used to attack or engage an enemy target. The evolution of this mission has led to the research and development of UCAVs (Unmanned Combat Air Vehicles), which essentially are UAVs fitted to perform the Strike / SEAD mission. The UCAV is an incredible asset for use in the Strike / SEAD missions. The UCAV eliminates the danger to the aircrew and provides a longer station keeping time on target. UCAVs provide a greater potential for survivability in adverse conditions, have a more efficient acquisition process, and cost less than their manned counterparts.[23]

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[21] Office of the Secretary of Defense.

[22] Office of the Secretary of Defense.

[23] Office of the Secretary of Defense.

Strike missions may be conducted against either lightly or heavily defended targets, but the "level of threat" determines what characteristics (payload, endurance, size, profile, speed, altitude, etc.) are necessary to complete the mission.[24] If the "threat level" of the target remains fairly low, than an armed UAV will suffice to eliminate the target. However, if there are more than a few high risk targets, then a dedicated UCAV would be more suitable.

UCAVs and UAVs will be used against heavily guarded targets for the same reasons that UAVs are used for other missions: higher survivability and reduction of the threat to human life. The maneuverability of a UAV is greater than that of a manned aircraft due to natural constraints of the human body. This increased maneuverability provides a higher degree of survivability over manned aircraft. "Arguably, the strongest argument for UCAV is [the] ability to offer a risk-free use of force." An unmanned vehicle does not carry the risk of harm to any flight crew, which makes UCAVs and UAVs a very attractive option for strike missions.[25]

The chief argument for use of UCAVs and UAVs in attacks on lightly defended targets is "the cost of conducting warfare." "There are predictions of significant reductions in procurement, operations, and support costs for UAVs over manned aircraft." The cost factors are nothing new to UAVs, but why use a very expensive manned aircraft to do a job that a relatively cheap UAV can do without the risk to a pilot's life? The only limitations

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[24] Office of the Secretary of Defense.

[25] Office of the Secretary of Defense.

in these missions are the design of UCAVs and UAVs to carry the necessary payloads for successful mission completion.

> If a UCAV is to reduce the number of manned strike assets required, it will have to offer a robust weapons mix and a payload capacity similar to that of manned strike assets, however at much reduced operational and support costs. In addition, compatibility with the existing and planned weapons inventory for manned strike aircraft will be essential to keep the overall armament development and support costs low.[26]

SEAD missions can be broken up into two separate types of missions: pre-emptive and reactive.[27] Pre-emptive SEAD involves paving a pathway of enemy air defense prior to a strike mission. Reactive SEAD involves the destruction of enemy air defenses in the midst of a strike mission. Survivability is paramount in SEAD missions. Survivability depends on speed, stealth, degree of maneuverability, or a combination there of. A key aspect to any SEAD mission is extensive Battle Damage Assessment (BDA) in order to provide commanders with the situational awareness necessary to proceed with other aspects of the mission at hand.

3.   Electromagnetic Attack

The Electromagnetic Attack (EA) mission for UAVs is fairly simple. "EA is the use of electromagnetic energy to confuse or disable threat defensive systems."[28] Unmanned vehicles are attractive for EA missions for the same reasons they are attractive for other missions. In addition, their electronic signature can be more precisely

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[26] Office of the Secretary of Defense.

[27] Office of the Secretary of Defense.

[28] Office of the Secretary of Defense.

controlled. UAV survivability is increased by enhanced
maneuverability and there is reduced risk for loss of life
when using UAVs.

UAVs can be designed and produced to be particularly
stealthy, which allows them to get closer to potential
targets without detection.[29] The closer the UAV is to the
target when executing an electronic attack, the less
radiated power is necessary to disable the target and
complete the mission. UAVs have the capability to utilize
an electromagnetic pulse (EMP). Generally, an EMP would
significantly damage or disable any platform employing it,
but UAVs can be dispensable due to their relatively low
cost and lack of pilot and aircrew. Thus UAVs are prime
candidates for such an attack. UAVs provide a versatile
and humane alternative to manned aircraft for EA missions.

4.   Communications Node / Data Relay

The Communications Node / Data Relay mission is one of
the simplest, yet most important, missions that a UAV can
be assigned. UAVs functioning in this mission must have
extremely long endurance, be able to operate at high
altitudes, and generate ample power to supply the
communications and data relay equipment onboard.[30] UAVs
fulfilling this mission "will provide an airborne
augmentation to current tactical and operational organic
ground relevant frequencies both beyond line-of-sight and
line-of-sight retransmission capability. Support of the
communications relay mission will require continuous Line-

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[29] Office of the Secretary of Defense.

[30] Office of the Secretary of Defense.

of Sight / Non-Line-of-Sight / Beyond the Line-of-Sight (LOS / NLOS / BLOS) coverage in a 24-hour period."[31]

Commonly in this mission, the UAV will relay VHF / UHF BLOS for battlefield communications and remote sensor data. Additionally, UAVs in this role will provide beyond the line-of-sight capability for Single Channel Ground and Airborne Radio System (SINCGARS) and Enhanced Position Reporting System (EPLRS) radios.[32] Beyond the line-of-sight relay will also be provided for Tactical Internet (TI). The range extension for the TI will be interoperable with tactical communications relays.

UAVs operating in the Communications Node / Data Relay mission are also capable of relaying VHF and UHF voice and data transmissions to various air traffic control agencies. These platforms can be controlled by ground stations in order to change their radio frequencies.

C.   UAV SYSTEMS / PLATFORMS

1.   MQ-1 Predator

Weight:	2250 lb
Length:	28.7 ft
Wingspan:	48.7 ft
Payload:	450 lb
Ceiling:	25,000 ft
Radius:	400 nm
Endurance:	24+ hr

Figure 9.   MQ-1 Predator UAV (From: UAV Road Map)

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[31] Office of the Secretary of Defense.

[32] Office of the Secretary of Defense.

One of the most publicized UAVs; the Predator (Figure 10) is a very versatile UAV that has been in use since the mid 1990s. It has both line-of-sight and beyond line-of-sight capabilities to relay color video in real time. Since 1995, the Predator has flown surveillance missions in every major United States conflict, and in 2001 the Air Force armed and fired Hellfire missiles from the Predator.[33]

2.   RQ-2 Pioneer

Weight:	452 lb
Length:	14 ft
Wingspan:	17 ft
Payload:	75 lb
Ceiling:	15,000 ft
Radius:	100 nm
Endurance:	5 hr

Figure 10.   RQ-2 Pioneer (From: UAV ROAD Map)

One of the oldest active UAVs, the RQ-2 Pioneer has been used by the Army, Navy and Marine Corps since 1986. Deployed from both shore and off of ships, the Pioneer's mission has evolved from gunnery spotting for battleships to reconnaissance and surveillance missions for amphibious forces. The Pioneer can be launched by rocket assist (from a ship), by catapult, or from a runway. It is typically recovered via a net (on a ship) or from arresting gear. The Navy discontinued Pioneer employment in 2002 and handed the platform over to the Marine Corps.[34]

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[33] Office of the Secretary of Defense.

[34] Office of the Secretary of Defense.

3. RQ-8 Fire Scout

Weight:	2650 lb
Length:	22.9 ft
Rotorspan:	27.5 ft
Payload:	300 lb
Ceiling:	19,000 ft
Radius:	150 nm
Endurance:	5+ hr

Figure 11.   RQ-8 Fire Scout (From: UAV Road Map)

The Fire Scout is a vertical take-off and landing (VTOL) tactical vehicle that is currently in the testing and developmental stages.[35] It has the ability to autonomously take off and land on any aviation compatible warship as well as unprepared landing sites in or around combat zones.

> It contains a baseline payload that includes electro-optical/infrared sensors (EO/IR), and a laser designator enabling Fire Scout to find tactical targets; track and designate targets; and accurately provide targeting data to strike platforms and perform battle damage assessment. Fire Scout will act as a communications node within the proposed network centric warfare battlespace of the future, increasing the effectiveness and flexibility of other platforms.[36]

"The Fire Scout's long endurance, excellent performance, sophisticated payloads, ability to take off and land vertically, and autonomous operating capability

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[35] Office of the Secretary of Defense.

[36] VTUAV Fire Scout. 2003. Northrop Grumman. May 2005
    <http://www.is.northropgrumman.com/products/navy_products/vtuav/vtuav.html.>

make it uniquely able to provide long range surveillance and targeting under the most demanding of tactical conditions."[37]

4. Dragon Eye

Weight:	4.5 lb
Length:	2.4 ft
Wingspan:	3.8 ft
Payload:	1 lb
Ceiling:	1000 ft
Radius:	2.5 nm
Endurance:	45-60 min

Figure 12.   Dragon Eye (From: UAV Road Map)

"Dragon Eye is a mini-UAV developed as the Marine Corps Warfighting Laboratory's (MCWL) answer to the Navy's Over-the-Hill Reconnaissance Initiative and the Marine's Interim Small Unit Remote Scouting System (I-SURSS) requirement."[38] Dragon Eye can carry an EO, IR, or low light TV sensor. This small UAV has been designed to fit in a soldier's backpack for easy transport[39] and can be launched "like a paper airplane."[40] The Naval Research Laboratory also has developed "special glasses" that allow

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[37] RQ-8A Fire Scout: Vertical Take Off and Landing TacticalUnmanned Aerial Vehicle (VTUAV). 26 Apr. 2005. GlobalSecurity.org. May 2005 <http://www.globalsecurity.org/intell/systems/vtuav.htm>.

[38] Office of the Secretary of Defense.

[39] Ciufo.

[40] Willingham, Stephen. "Remotely-Piloted Air Vehicles Are Coveted for Coastal Warfare." National Defense Magazine Jan. 2001. May 2005 <http://www.nationaldefensemagazine.org/issues/2001/Jan/Remotely-Piloted.htm>.

operators to see the view offered by any one of three camera lenses (color, electro-optical, lowlight and infrared) that attach to the nose cone of the aircraft.[41]

5. Dragon Warrior

Weight:	340 lb
Length:	7 ft
Rotorspan:	9 ft
Payload:	35 lb
Ceiling:	18,000 ft
Radius:	50 nm
Endurance:	3-5 hrs

Figure 13.   Dragon Warrior (From: UAV Road Map)

"Dragon Warrior is an unmanned rotorcraft designed to provide the Marine Expeditionary unit (MEU) or regiment with an organic reconnaissance, surveillance, precision targeting, battle damage assessment, and communication relay capability."[42]   It is capable of being ship launched as well as providing land based operations. Dragon Warrior is equipped with an EO/IR sensor and laser range finder. The Marine Corps is excited about Dragon Warrior for its "adaptability for operating in confined spaces while in support of troops engaged in urban operations."[43]

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[41] Willingham.

[42] Office of the Secretary of Defense.

[43] Willingham.

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IV. CURSOR ON TARGET

A. CURSOR ON TARGET INTRODUCTION

In April 2002 at the C2ISR Summit, Gen John Jumper (Chief of Staff for the Air Force) gave an impassioned plea to find ways to horizontally integrate machines directly talking to other machines to eliminate time-consuming and error-prone human translations. His "Sergeant Matt" story described a special ops warrior riding a donkey, laser designating targets using a handful of non-integrated machines, and manually performing calculations that ended with long voice transmissions over noisy radios, epitomizing the current state of warfare. What Jumper envisioned was machine-to-machine (M2M) automation that would achieve his vision that "the sum of all wisdom is a cursor over the target."[44]

The Cursor on Target (CoT) technology will revolutionize the technological aspect of war fighting. The implementation of Cursor on Target into Department of Defense systems and platforms will facilitate information sharing that was not conceivable ten years ago. Cursor on Target technology is fueled by XML (eXtensible Markup Language), which allows for fluid Machine to Machine (M2M) communication to improve the speed of data and information sharing as well as weapons lethality and accuracy.

B. XML

Extensible Markup Language is a simple and flexible format that was derived from SGML (Standard Generalized Markup Language). "Originally designed to meet the

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[44] Byrne, Rich. CoT Case Study. MITRE Corporation. May 2005
<http://cot.mitre.org/bin/view/CoT/WebHome>.

challenges of large-scale electronic publishing, XML is also playing an increasingly important role in the exchange of a wide variety of data…"[45]

In February 1998 the World Wide Web Consortium (W3C) approved XML. The W3C is a world wide organization whose goal is to develop common protocols[46] and interoperable technologies.[47] Upon its approval, the W3C established ten basic rules/goals for XML[48]:

- XML shall be straightforwardly usable over the Internet.

- XML shall support a wide variety of applications.

- XML shall be compatible with SGML.

- It shall be easy to write programs which process XML documents.

- The number of optional features in XML is to be kept to the absolute minimum, ideally zero.

- XML documents should be human-legible and reasonably clear.

- The XML design should be prepared quickly.

- The design of XML shall be formal and concise.

- XML documents shall be easy to create.

- Terseness in XML markup is of minimal importance.

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[45] Extensible Markup Language (XML). 07 Apr. 2005. W3C. May 2005
     <http://www.w3.org/XML/>.
[46] Learn XML. Top XML. May 2005
     <http://www.topxml.com/xml/learnxml.asp>.
[47] Home Page. <http://www.w3.org/>.
[48] Learn XML.

These ten guidelines clearly define XML, and how it is to operate. These ten rules also clearly show that XML is the prime candidate to support the Cursor on Target concept.

Technically, XML is an application profile of SGML (essentially a subset of SGML). "SGML has been the standard, vendor-independent way to maintain repositories of structured documentation for more than a decade,"[49] but has not functioned well in utilizing documents (files) over the internet. Since XML is an application profile, XML can be read by any SGML compliant system. With SGML as the industry standard for such an extended period of time, XML documents (files) are accessible by most major systems. At the same time, utilizing XML files does not require a fully conformant SGML system.[50]

XML was designed for use as a language dealing with documents (files) involving structured information. "Structured information contains both content (words, pictures, etc.) and some indication of what role that content plays (for example, content in a section heading has a different meaning from content in a footnote, which means something different than content in a figure caption or content in a database table, etc.)."[51] XML is ideal for CoT because the massive amount of vital information (text, pictures, video, etc.) transferred between platforms must

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[49] Walsh, Norman. A Technical Introduction to XML. 2005. O'Reilly XML.com. May 2005 <http://www.xml.com/pub/a/98/10/guide0.html?page=2#AEN58>.

[50] Walsh.

[51] Walsh.

be able to be differentiated from similar data and remain identifiable.

The manner in which XML utilizes tags also supports the Cursor on Target concept. Tags are a command inserted in a document (file) that specifies how the information, or a portion of the information, should be formatted.[52] XML does not specifically design a tag set, but allows the user to define tags as they see fit. The user customized tags facilitates the "definition, transmission, validation, and interpretation of data between applications and between organizations [and platforms]."[53] With no predefined tag sets, there are not any "preconceived semantics" or rules. All of the semantics will be defined by the applications processing the information.[54] This provides XML with the flexibility necessary to function in the CoT domain.

The Department of Defense requires that XML be able to relay and exchange data and information over various DoD systems, without input from a human in the loop. The Cursor on Target technology only requires a few hundred lines of code, yet all messages and information are transmitted seamlessly, using XML, between platforms allowing "a rapid process of 'cursor on the target' and 'click to approve.'"[55]

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[52] tag. Webopedia. May 2005 <http://www.webopedia.com/TERM/T/tag.html>.

[53] XML. Webopedia. May 2005 <http://www.webopedia.com/TERM/X/XML.html>.
[54] Walsh.

[55] 'Cursor on Target' and 'Click to Approve'. 19 Sept. 2004.Roland
      Piquepaille's Technology Trends . May 2005
      <http://www.primidi.com/2004/09/19.html#a972>.

C.   CURSOR ON TARGET

The MITRE Corporation developed Cursor on Target for the Air Force in order to achieve the Machine to Machine (M2M) communication that the USAF desired. Since its initial development, the Department of Defense has taken a genuine interest in CoT being utilized throughout the DoD. MITRE describes CoT:

> Cursor On Target (CoT) is a strategy for enabling DoD systems to communicate much needed time sensitive position or "What, When, Where" (WWW) information. CoT leverages the ubiquitous XML technology and defines a common, terse yet extensible message format for communicating WWW information. A data strategy akin to object oriented decomposition is used to define and manage extensions to the base WWW data. Using this approach CoT can easily and effectively represent BFT, TST, mayday messages, CSAR reports, spot reports, ISR asset tasking, battlefield reservations, and many other tactical battlefield information exchange needs.[56]

The ability of Cursor on Target to solve the M2M communication problem is very important to the improvement of the military. The ability for all different communities, in all the different services, to be able to share vital information in near real time, almost seamlessly, is critical to the advancement of the armed services, especially in today's "battlefield" environment. "Examples of the power of M2M include passing Link-16 Air/Ground pictures to platforms that don't have Link-16 terminals like the AC-130 gunship and overlaying special ops targets, Army blue force positions, AF air situational awareness, and the joint Common Operating Picture all onto

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[56] Home Page. <http://cot.mitre.org/bin/view/CoT/WebHome>.

one display…"[57]   More importantly, none of these systems
were developed to be able to handle these data flows and
transfers, but M2M, through CoT, can bring this data
synergy to actuality.   These data flows are the essence of
the Cursor on Target concept.

Currently, voice messages are being used to exchange
data and information between the data collection sources,
tactical platforms, human combat controllers, soldiers in
the field, and commands.   "For example, controllers call in
target coordinates to a forward command center, which in
turn relays them to an airborne command center. The data is
then given by voice to an Airborne Warning and Control
System aircraft and then relayed again by voice to a strike
aircraft pilot."[58]   The use of voice messages for the
passing of this information allows for human error and a
significant loss of very valuable time that could prove to
be very costly.   CoT allows this information to be passed
from system to system via a common XML format.   This
system, which has already been tested and used in Operation
Enduring Freedom in Afghanistan and in Operation Iraqi
Freedom, has proven that "sensor-to-shooter paths enabled
with CoT software improve the speed of the process by
nearly 70 percent, while also significantly increasing
firepower accuracy."[59]

Cursor on Target works hand in hand with the "Click to
Approve" concept.   Essentially, if forward deployed

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[57] Byrne.

[58] Miller, William. "Cursor on Target: XML-based software program
     offers low-cost solution to the complex problem of military
     information sharing.." Military Information Technology 8 (2004).
     May 2005 <http://www.military-
     informationtechnology.com/article.cfm?DocID=596>.
[59] 'Cursor on Target' and 'Click to Approve.'

soldiers request air support, a command center worker can simply reference the operational picture display and put his cursor over the target in question and "click to approve." Upon clicking on the target, all necessary tasking orders and data about the target, which is accumulated and sent by any and all information sources via XML format, are sent directly to the required aircraft.[60] Human interaction within the loop has been reduced, and therefore, critical time is saved and human error is minimized. CoT facilitates the ability for "space, air and ground forces [to] work as a synchronized unit." All of their communications are brought together into a single network without the problem of "incompatible user formats" since the common XML format is understood by all of them.[61] Mission critical information can now be expeditiously transferred from platform to platform regardless of the operation language of the individual systems. Currently, the Army's "Blue Force Tracker" information (used to identify friendly forces) is being incorporated with CoT.[62]

Recently, contributions from MITRE, ESC (Electronic Support Center), AFRL (Air Force research Laboratory), the Navy, and AFSOC (Air Force Special Operations Command) combined to "dramatically improve the speed and accuracy of real time targeting performed by Special Forces conducting

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[60] Mayer, Daryl. <u>Software translator bridges information gaps</u>. 16 June 2004. AFMC Public Affairs LINK. May 2005 <http://www.afmc.wpafb.af.mil/HQ-AFMC/PA/news/archive/2004/June/0622-04.htm>.

[61] Miller.

[62] Mayer.

deep operation missions."[63] This "test" showed some further CoT M2M capabilities:

- provide special forces the ability to click on a laser rangefinder designating a hostile target

- pass precision coordinates

- send menstruated target coordinates to an airborne strike asset

- download these directly into GPS guided munitions[64]

The results showed a 67% targeting timeline improvement, an impressive accuracy improvement, as well as a cost reduction with quicker delivery time.

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[63] Cursor on Target: Finding the Bad Guys. 22 Sept. 2004. The   MITRE
    Corporation. May 2005
    <http://cot.mitre.org/open/CoT_Narrative_9.22.04.pdf>.
[64] Cursor on target: Finding the Bad Guys.

V. SHOTSPOTTER

A. SHOTSPOTTER INTRODUCTION

Shotspotter technology uses an array of sensors and computer software to determine the precise location of gunshots within its sensor footprint. Conceived in the early 1990's by Dr. Robert Showen, Shotspotter software is based on an earthquake detection system that has been modified to detect gunshots. Originally marketed to urban police departments, the technology has proven useful for military and rural environments as well. Shotspotter was initially designed as a static system, where sensors would be placed in fixed locations to create a grid of acoustic detectors. As the technology evolved, mobile sensors were created that could be worn by soldiers and policemen to create a dynamic grid of acoustic detectors. This capability could prove very useful in battlefield environments.

Currently the technology is being used by police departments across The United States from California to cities along the eastern seaboard. Most recently, Shotspotter aided the FBI and local law enforcement in the apprehension of the Columbus, Ohio highway sniper. This technology is extremely versatile and its list of applications will continue to grow within domestic police departments and military units.

B. ORIGINAL SHOTSPOTTER TECHNOLOGY

Gunshot detection can be achieved in a variety of ways. With each gunshot there is a series of distinct sounds and events that can be measured and detected. When

a bullet is fired, the propellant explodes inside the barrel of the gun. As this blast propels the bullet out of the barrel, an explosive event can be heard. This is called the muzzle blast. The sound energy from the muzzle blast radiates in all directions from the gunshot. Additionally, when the bullet exits the muzzle an intense flash of radiant energy is emitted, called the muzzle flash. This flash is most visible directly down range from the shot. Depending on the speed of the projectile, a sonic boom may trail the bullet as it passes through the air. When a bullet reaches its destination, the impact will create a distinctive sound called the impact noise. Finally, the weapon may make distinctive sounds after the shot is fired. This would include the sound of the gun reloading or the noise created when dispensing an empty shell.[65]

Systems that focus on detecting the sonic boom created by a gunshot are called "counter sniper" systems. These systems are very limited in their utility. In order for them to detect a gunshot "they must be downrange of the weapon and within a fairly narrow cone swept out by the sound waves. Thus, sonic boom counter-sniper systems must be shot *at* in order to be effective."[66] Systems that detect muzzle flashes or heat from the propellant explosion are limited to line of sight detection.

Shotspotter detects a shot acoustically, by identifying the unique sound of a muzzle blast and, in some cases, the sonic boom created as the bullet travels through the air. This process can be broken down into three parts,

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[65] Technology Overview: Detecting Gunshots. Shotspotter Inc. Apr. 2005
    <http://www.shotspotter.com/tech_overview.htm>.
[66] Technology Overview: Detecting Gunshots.

detection of a possible gunshot, validation and location of the gunshot event, and notification to the proper personnel when a gunshot has been identified.[67]

1. Detection

Shotspotter utilizes an array of small acoustic sensors spread over a wide area to detect a gunshot event. These sensors are placed in weather proof casings to protect them from nature's harsh conditions. These casings are attached to buildings, rooftops, utility poles or anything else that provides the appropriate elevation and concealment. Gunshots can be uniquely identified by their acoustic strength, normally between 140 and 160 decibels, and their abruptness. Firecrackers and automobile backfires are some of the only sounds found in urban environments which approach a gunshot's strength and abruptness.[68]

Shotspotter detects gunshots using a unique idea called "spatial filtering." Previous gunshot detection systems utilized many more individual sensors than the Shotspotter system. In urban environments, Shotspotter generally requires only 8 to 15 sensors per square mile, while some previous systems required 80 per square mile.[69] Fewer sensors will actually improve Shotspotter's ability to detect gunshots.

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[67] Technology Overview: Detecting Gunshots.

[68] United States. United States United States Patent #5,973,998. and Trademark Office. <u>United States United States Patent #5,973,998.</u> <u>#5,973,998</u> . 26 Oct. 1999. Apr. 2005 <http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF& p=1&u=/netahtml/search-bool.html&r=2&f=G&l=50&co1=AND&d=ptxt&s1=showen .INZZ.&OS=IN/showen&RS=IN/showen>.

[69] United States Patent #5,973,998.

Many different events common in urban environments can approach the abruptness of the sound created by a gunshot, such as a ball bouncing on the ground. However, these sounds are not as audibly strong as a gunshot. The further away from the origination of the sound, the weaker the sound becomes. While this is true for all sounds, only events in the decibel range of a gunshot will not be automatically filtered out as noise by the detector. Due to the increased spacing of sensors, the sound created by a bouncing ball will not rise above the noise level of multiple detectors. If a ball is bounced very close to a given detector, it may trigger that particular device, but as the sound travels to other detectors it will not have the strength to rise above the filtered level of the sensor.

"Spatial filtering" not only makes Shotspotter more efficient than its competitors at detecting gunshots, but it also saves already limited computational capability. By not processing false alarms, valuable resources are not overloaded.

Two methods currently exist for passing acoustic and timing information from sensors to the central processing computer for evaluation.

a.   *Continuous Transmission*

This method places complete control in the central processing unit. All data from the sensors is sent to the central processor for evaluation. The central processor is in charge of detecting anomalies for all of the sensors. While this method seems overburdening to the network, it allows the humans in the process to review all

data and make decisions on explosive events. The data
transmissions from the sensors "can be accomplished by
telephone, cable, radio, optical or other medium."[70]

b.   Remote Processors

The other option for data transmission between
the central processing unit and the sensors is placing
small processing units with each sensor. These processors
could control the flow of information and only send the
central processor pieces of data likely to contain
gunshots. This technique would lighten the load on the
network and require fewer central processors for large
sensor grids. The small pieces of data likely to contain
gunshots could also be heard by humans in the process to
make decisions on explosive events.[71]

The following figure is an illustration of a sensor
grid where sensors 1, 2, 3 and 4 are detecting a gunshot
muzzle blast. Each of the sensors are connected to the
central processor.

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[70] United States Patent #5,973,998.

[71] United States Patent #5,973,998.
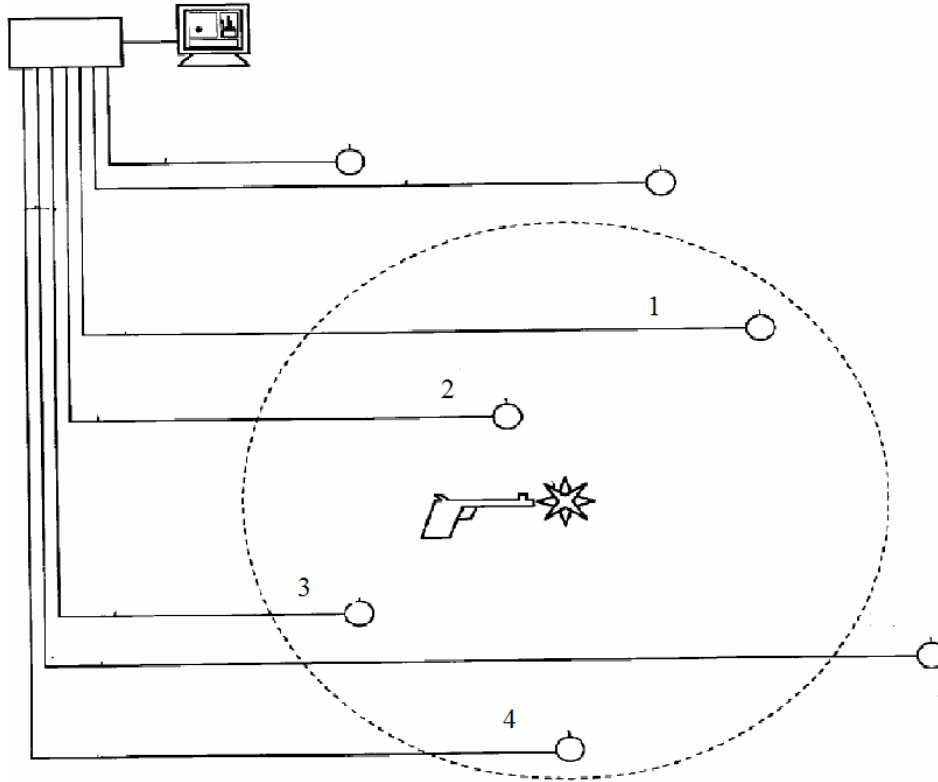
Figure 14.   Gunshot Detection Illustration (From: United
States Patent #5,973,998)

2.   Validation and Triangulation

Shotspotter sets clearly defined rules when
designating impulsive sounds as gunshots. Each detector
continually receives noise from its surrounding location.
When an impulse exceeds the amplitude threshold set by the
sensor, the sound bit is flagged for inspection.   A
sharpness test is done to determine if the sound has a high
probability of being a gunshot.   The test establishes if
the sound is adequately abrupt.   It does this by selecting
"against loud, but slow-rising, [noises] which are unlikely
to be gunfire."[72]   Once an impulse passes the initial
sharpness test, data is collected from all other sensors in
the grid.   If two other sensors pass subsequent sharpness

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[72] United States Patent #5,973,998.

tests, triangulation is attempted. If successful, a gunshot, as determined by the system, has occurred. The data is archived for later inspection and the proper personnel are notified.

The sharpness test can be broken down into three parts, the initial threshold, triangulation threshold and confirmation threshold. Each has a descending threshold value to correspond with the increased distance each sensor is from the origination of the gunshot.

> These distinct threshold values help to improve the performance of the system by taking advantage of the fact that sharpness decreases with distance traveled. By subjecting an initial signal to a more restrictive threshold test, many false events are effectively filtered. Conversely, by not subjecting triangulating and confirming signals to such restrictive thresholds, actual gunshot events, which may not be so sharp due to the distance traveled, are not rejected.[73]

When impulses pass the triangulation threshold at three different sensors, a triangulation attempt is made. All sensors on the grid have a common clock since each is outfitted with GPS.[74] Using this common time, the known arrival times of the impulses at the different sensors, and the fact that the speed of sound through air is relatively constant, triangulation is possible. Many different algorithms exist to calculate position based on

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[73] United States Patent #5,973,998.

[74] United States. United States Patent and Trademark Office. <u>United States Patent #6,847,587</u>. 25 Jan. 2005. May 2005 <http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF& d=PALL&p=1&u=/netahtml/srchnum.htm&r=1&f=G&l=50&s1=6,847,587.WKU. &OS=P N/6,847,587&RS=PN/6,847,587>.

triangulation such as hyperbolic intersection or matrix inversion. For improved accuracy, environmental sensors that measure temperature, humidity and air pressure can be used to more accurately calculate the speed of sound around each particular sensor.[75] These improved speeds of sound "constants" derived from the environmental sensors will enhance the accuracy of the triangulated location.

When more than three sensors surpass the triangulation threshold, and thus multiple triads exist to triangulate the location of the gunshot, each triad is tested against a series of criterion to determine the best triad for triangulation. The criterion is as follows:

1.   Select that trio of sensors which gives the greatest number of confirming impulses from other sensors.

2.   Select that trio which produces the most widely-spread direction vectors to the event (and hence the most geometrically robust solution).

3.   Select that trio which has the highest sum of sharpness.

4.   Select that trio which gives, among the calculated locations from all possible triads, the most central location.[76]

Once a candidate location has been identified by successful triangulation, expected arrival times are calculated for other sensors on the grid. For improved reliability, a fourth sensor must pass the confirmation threshold at or near the expected time calculated from the

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[75] United States Patent #6,847,587.

[76] United States Patent #5,973,998.

triangulation. This fourth impulses arrival time must be within 60ms of the expected arrival time. This confirmation threshold is less than the triangulation and initial threshold values. "The fourth signal may be a signal from another sensor, or a signal from a subsequent gunshot at one of the three sensors used for triangulation."[77] Requiring this fourth sensor confirmation reduces the number of false reports and increases the efficiency of the network by decreasing the amount of data transmitted.

In the case of multiple gunshots, such as a drive-by shooting, Shotspotter provides the capability to determine the velocity of the vehicle carrying the shooters. Once the initial gunshot location is confirmed, subsequent gunshot locations are relatively more accurate than the initial calculation. "While the absolute locations of the shots may be in error by 20 to 50 feet, the relative accuracy of shots fired is usually within 3 feet."[78]

Providing velocity information when multiple shoots are fired in relative proximity of time and space is a tremendous asset. This demonstrates future knowledge. For instance, it is more likely than not that a car would be traveling on a street during a drive by shooting, and since Shotspotter provides the direction, speed and location of the vehicle, authorities can use this information to limit the possibilities of the current location of the car and its passengers.

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[77] United States Patent #5,973,998.

[78] United States Patent #5,973,998.

3.   Personnel Notification

Once a candidate location is confirmed automatically by Shotspotter, the proper personnel are notified. These personnel are provided with an audio sound bite of the event to allow them to certify that the impulse flagged and tested by the system is indeed a gunshot and not fireworks or car backfire.

Shotspotter provides many options for dissemination of the information. Computer interfaces can display the gunshot locations on a screen using a variety of symbols. These gunshot locations can be overlaid on a map at computer terminals to provide an address of the location and relative surroundings. Location information can also be sent to personnel in the field and posted on the internet. Using map coordinates and gunshot location information, a synthesized voice can automatically broadcast address information over radio frequencies to personnel in the field.

Different models of firearms have different acoustic signatures. This fact enables Shotspotter to identify the type of weapon fired at a given location. Prerecorded muzzle blast sound bites can be stored in databases and compared to sensor recorded muzzle blasts. Knowledge of the type of firearm discharged may help identify the person who fired the weapon.[79]

The following figure outlines the flow of information from initial detection of the gunshot, through the threshold testing phase and finally to the dissemination.

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[79] United States Patent #6,847,587.

Background noise, gunfire and other sounds continuously received by widely spaced elevated microphone sensors.

Average noise level continuously updated for each sensor, and amplitude threshold set at 3 times rms noise level.

When gunfire or other sounds exceed amplitude threshold, data snippet is flagged for inspection by computer.

If initial sharpness threshold is passed on any single sensor, all sensors are inspected.

If three impulses pass another (lower) sharpness threshold, then triangulation using relative arrival times is attempted.

If triangulation is possible, a candidate location is obtained.

Data is saved to file for further analysis or for legal purposes.

Arrival times expected from candidate location are calculated for other sensors, and if an impulse passes a third threshold test, then the location is confirmed.

Confirmed location is annuniciated to dispatchers via audio and/or light alarm and location is presented on community map.

Dispatchers listen to saved sound snippet to assist in discrimination between gunfire, fireworks, or backfire.

Ignore the event.

Immediately dispatch police

Reverse 911 call made to location.

Delayed response by community police officer.

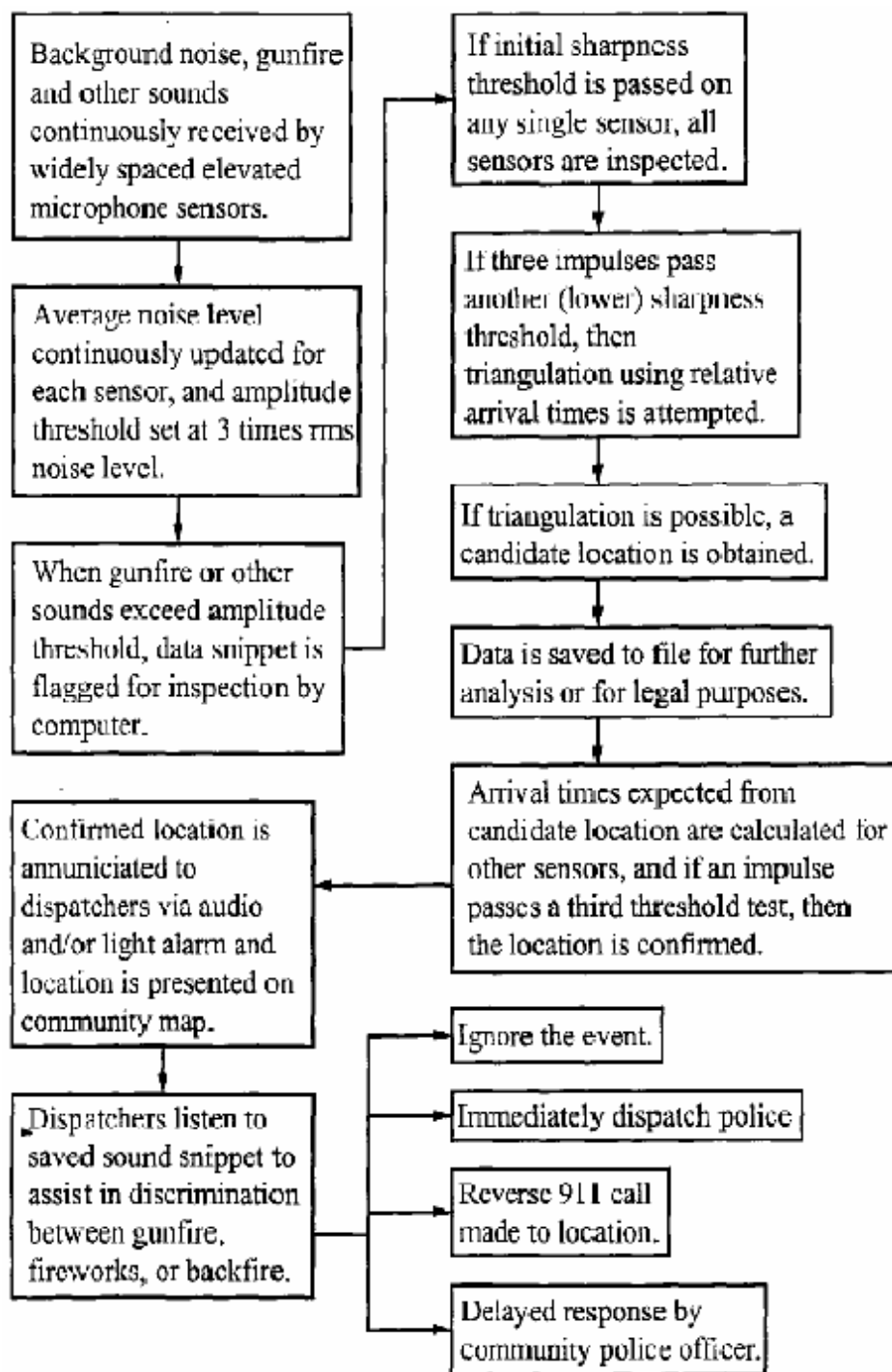Figure 15.   Original Shotspotter Data Flow Diagram (From: United States Patent #5,973,998)

C.   SHOTSPOTTER MILITARY TECHNOLOGY

The backbone of Shotspotter technology has remained unchanged when modified for military use.   Methods and

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algorithms for detection maintain basic similarities with the original system. The modifications that were made enabled the sensors to become mobile. This implies that the sensors no longer need to remain in fixed positions. They can be attached to aircraft (manned and unmanned), vehicles, personnel, or any other piece of equipment the user desires.

Shotspotter's military capability provides three interoperable overlapping layers of force protection. Sensors in each of these layers can interact with each other, and sensors from any layer can be used to triangulate an acoustic event.[80]

1.   Layer 1: Squad Layer

The first layer of force protection is the Squad Layer. This layer consists of small mobile sensors worn by soldiers in the field. These detectors have a relatively narrow aperture compared to sensors in Layers 2 and 3. Their range is not as robust as sensors in other layers. This is due, in large part, to low power availability and the sensors proximity to the ground. Each squad sensor has a range of approximately five hundred meters.[81]

The detectors designed for the Squad Layer are two dimensional. They have the capability to distinguish acoustic events by range and azimuth only.[82] Each is outfitted with GPS to provide a common clock among the sensors, but this also provides Blue Force Tracking

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[80] "Shotspotter Unveils Multi-Layer Suite of Gunshot Location Systems For Military Market." 18 Mar. 2005. May 2005 <http://www.shotspotter.com/prod_mildef.htm>.

[81] "Shotspotter: Military Capabilities" FIRES Network: EA Repository. May 2005

[82] Shotspotter: Military Capabilities.

capabilities.   In order to triangulate gunshot locations,
the sensor position must be known.   Since the soldiers are
wearing the sensors, their location can be tracked.

Figure 16.   Squad Layer Acoustic Sensor (From:
Shotspotter: Military Capabilities)

In   addition   to   solider   mounted   sensors,   Layer   1
consists   of   compact   portable   displays.   These   tactical
analytical displays are designed for combat environments.
Each display depicts gunshot events in near real time.
This allows the unit leader to identify the direction and
relative location of enemy fire.   They also display the
location of each member of the squad.

Figure 17.   Portable Shotspotter Display (From: Shotspotter: Military Capabilities)

The Shotspotter system also provides the capability to deliver gunshot locations to other units on the battlefield.[83]   This enables the generation of a robust common gunshot identification picture of the battle space.

Similarly to the original Shotspotter technology, this mobile system can be configured to identify the type of weapon fired at each gunshot event.[84]   This can help squad leaders differentiate between red and blue forces.   For instance, if the squad leader knows that his men are firing M-16 assault rifles, and a gunshot location is confirmed as an AK-47, he can confidently draw the conclusion that his man did not fire from that position.

2.   Layer 2: Vehicle/Aircraft/UAV Layer

As implied by the name, sensors in this layer are fixed to vehicles, aircraft or UAVs.   Each "carrier" can be outfitted with more than one sensor.   This increases the number of sensors on the ground, or in the air, and

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[83] Shotspotter Unveils Multi-Layer Suite of Gunshot Location Systems For Military Market.

[84] Shotspotter: Military Capabilities.

improves the quality and efficiency of the system. This can also provide a single vehicle, or aircraft, the unique ability to locate a gunshot on its own. If a UAV has acoustic detectors fixed to each wing and both sides of its tail, then it can single handedly triangulate a gunshot location. This is called micro-azimuthal technology. The four distinct sensors mounted on the UAV are separated by known distances and the speed of sound is constant through air, therefore triangulation is possible with just one UAV outfitted with multiple sensors. This capability is illustrated below. When a muzzle blast emits sound waves and they radiate in all directions. The detectors pick up the sound waves sent skyward and, with the aid of onboard processors, calculate the origination of the pulses.[85]
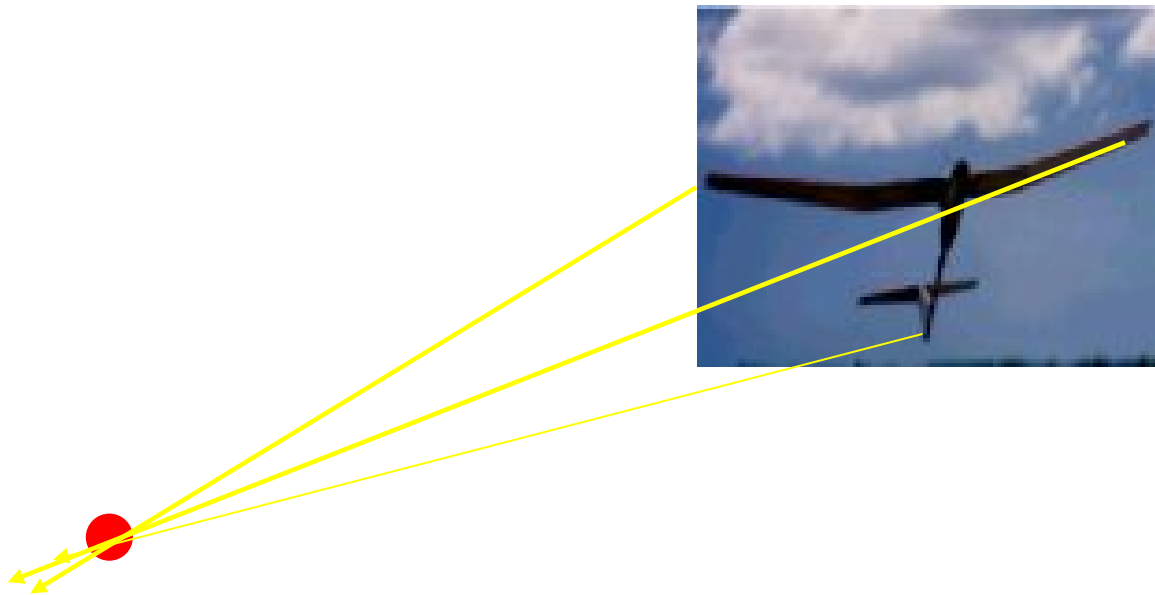
Figure 18.   Micro-azimuthal Technology (From: Shotspotter: Military Capabilities)

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[85] Shotspotter: Military Capabilities.

UAVs are not the only aircraft that can be outfitted with Shotspotter sensors. Other aircraft, such as helicopters, can also be outfitted. Due to the noisy environment associated with aircraft, active noise reduction sensors are used in concert with weapons detection sensors when Shotspotter is deployed on aircraft.

Active Noise Reduction Sensors
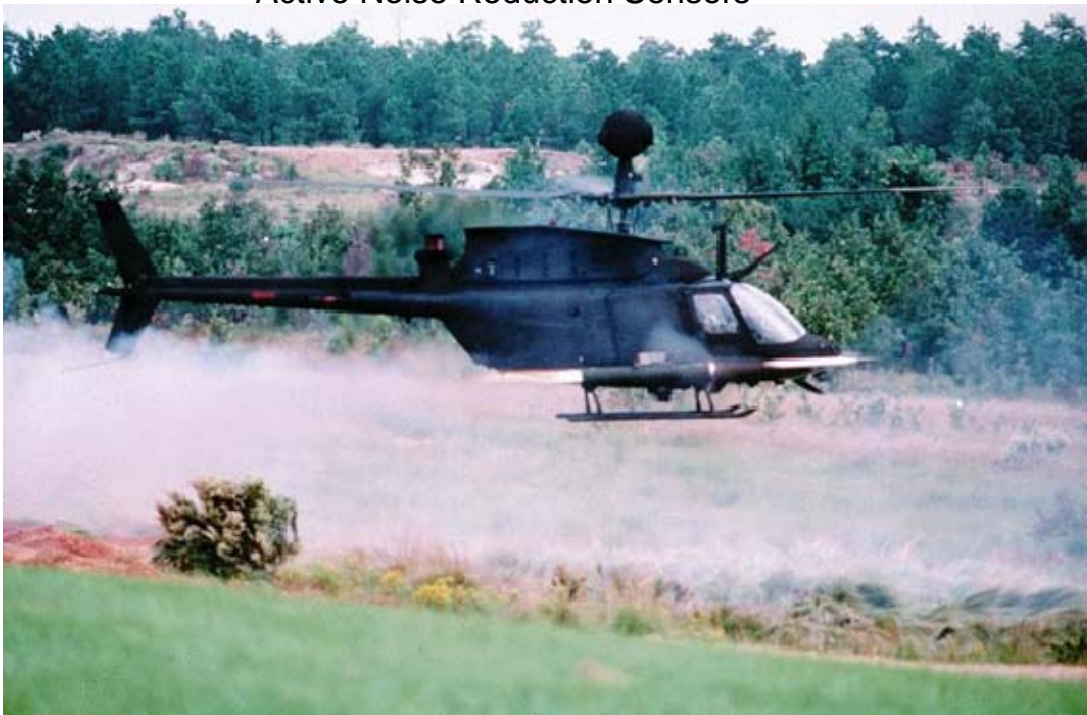
Figure 19.   Shotspotter Aircraft Instillation (From: Shotspotter: Military Capabilities)

The sensors in Layer 2 have a wider aperture than the Squad Layer sensors. They are not as restricted by power and weight requirements. They also have an increased range. These detectors are effective for roughly one square mile.[86]

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[86] Shotspotter: Military Capabilities.

Layer 2 sensors calculate gunshot locations in three dimensions, range, azimuth, and height. This enables them to provide more accurate location information. Similar to the previous layer, these sensors can be configured to identify the type of weapon fired at each gunshot event.[87]

3. Layer 3: Semi-fixed Sensors

Sensors in this layer can be attached to buildings, mobile command structures, planted on the ground, or even dropped from the sky. These sensors have the longest range, providing many square miles of coverage area. Layer 3 sensors are most closely related to the time tested Shotspotter technology being used to detect gunshots in cities across the country. Similar to the previous two layers, these sensors can be configured to identify the type of weapon fired at each gunshot event.[88]

Building-Mounted Sensors
Fixed single or azimuthal sensors

Drop-Ahead Sensors
Fixed single or azimuthal sensors

Leave-Behind Sensors
Fixed single or azimuthal sensors

Figure 20.   Examples of Semi-fixed Sensors (From: Shotspotter: Military Capabilities)

[87] Shotspotter: Military Capabilities.

[88] Shotspotter: Military Capabilities.

All three layers of the Shotspotter Force Protection System can interact with all other layers for increased detection capability and force protection. Each overlapping layer provides redundant protection for troops on the ground. The following illustration provides an example of how layers can provide protection and redundancy for the other layers.
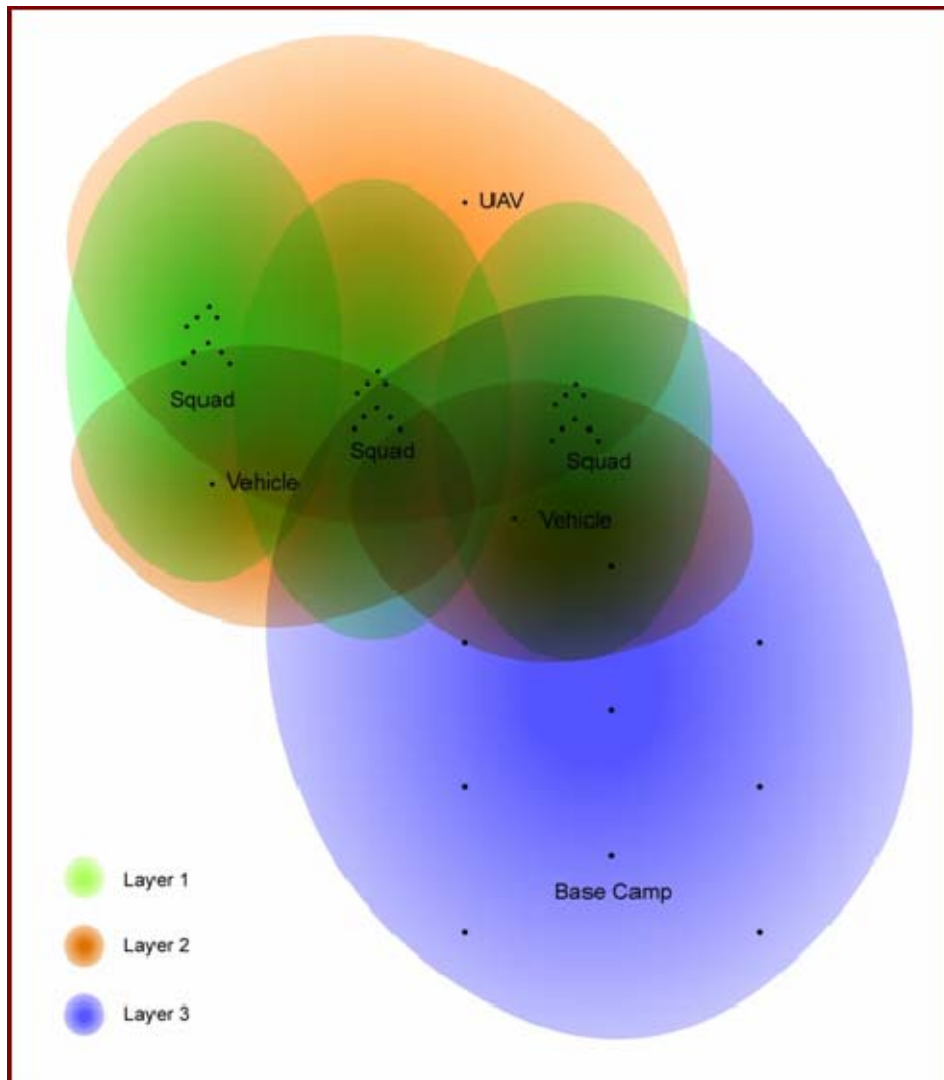
Figure 21.   Overlapping Layers provides Overlapping Protection (From: Shotspotter: Military Capabilities)

As the number of sensors increase on the battlefield, the effectiveness of the system can be improved. Akin to earlier Shotspotter technology, the military Shotspotter system utilizes the principle of "spatial filtering."[89] When employing this concept, there is an increased probability that a detector within the sensor grid will detect a clean, echo free, pulse sample. Better samples allow for more accurate location calculations.
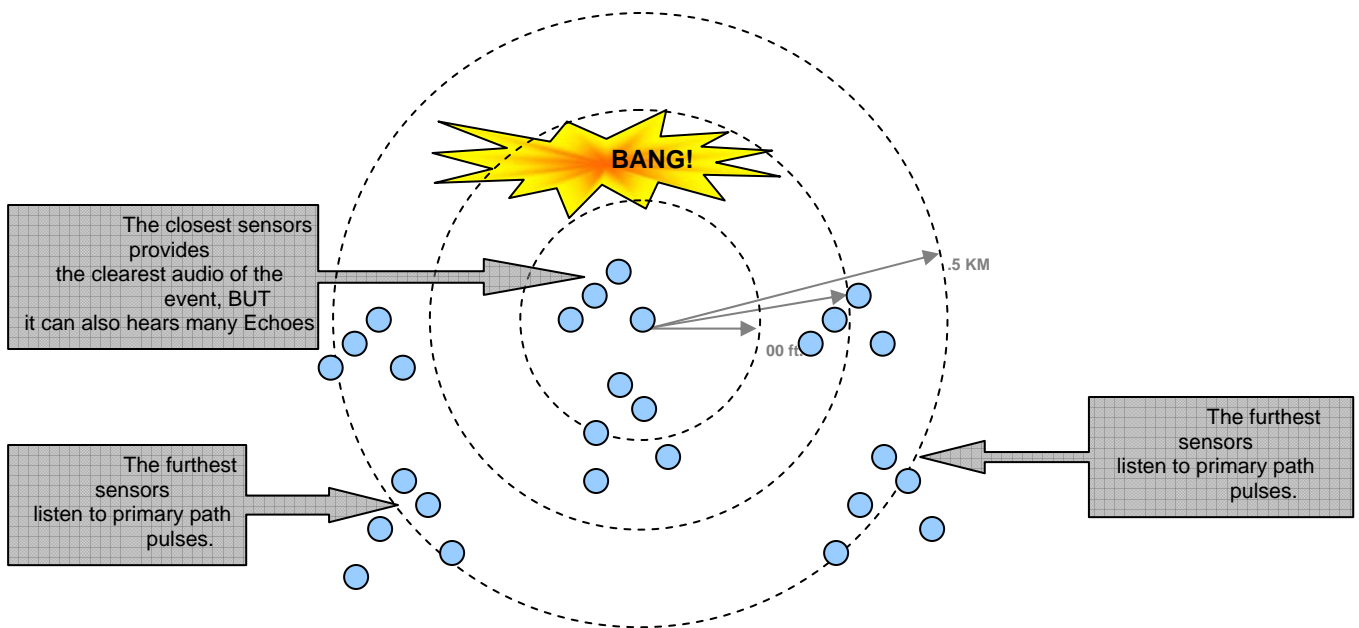
Figure 22.   Spatial Filtering Diagram (From: Shotspotter: Military Capabilities)

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89 Shotspotter: Military Capabilities.

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VI. ENHANCED UAV CAPABILITIES

A.   SCENARIO

Investigating an unverified tip that a top Al Qaeda lieutenant is in hiding in the northeast sector of downtown Baghdad, Iraq, a squad of young Marines goes door to door investigating the tip's validity. Their support comes in the form of a lone UAV following their movements from above. The Marines and lone UAV are equipped with the newly commissioned Shotspotter technology in conjunction with Cursor on Target.

As the Marines question local Iraqis, the afternoon silence is shattered by gunshots forcing the Marines to quickly take cover in the remains of a bombed out building and report that they are under fire. After regrouping, the 2nd Lieutenant leading the squad discovers that none of the Marines are able to place the origin of the gunshots because the narrow streets created an intense echo from the blasts.   No one is hit, and the gun fire has stopped, but the shooters have informed the squad of their presence with deadly intent.   The Marines cannot leave their cover without knowledge of the shooters' positions or they will likely come under fire again.

The 2nd Lieutenant reaches into his pack and retrieves his Shotspotter portable display. Almost instantaneously the 2nd Lieutenant is able to identify the azimuth, range, and height of the shots. These positions are triangulated from the Shotspotter sensors mounted on himself, his men, and the UAV loitering above. This data was also made available to the Command Center and other military platforms in the area via Cursor on Target.

The 2nd Lieutenant requests backup and the Command Center identifies his squad's location based on the GPS positions of the Marines mounted sensors. Another squad in the area is diverted to their location for additional fire support. Shotspotter data (enemy and friendly positions) automatically uploads to the reinforcing squad's displays. They swiftly and covertly are able to detain the terrorists without another shot being fired.

This mission was safer and streamlined due to the Shotspotter technology on the Marines and UAVs, Cursor on Target software enabling seamless information exchanges, and knowledgeable Marines implementing the technology effectively. Lives were saved because the shooters' locations were easily identifiable (Shotspotter) and the information was easily and quickly shared (Cursor on Target).

B.   SHOTSPOTTER AND UAV INTEGRATION

The incorporation of Shotspotter with UAVs can improve many UAV missions. Shotspotter does not require UAVs to be functional, but the integration of Shotspotter with existing UAV technology expands Shotspotter's capabilities. UAVs deployed with Shotspotter (but without Cursor in Target) will have their Information, Surveillance, and Reconnaissance (ISR), Communications Node / Data Relay missions enhanced, while the Strike / Suppression of Enemy Air Defense (SEAD) missions will be slightly improved. Shotspotter integrated with UAVs will not improve upon the Electromagnetic Attack (EA) mission of UAVs.
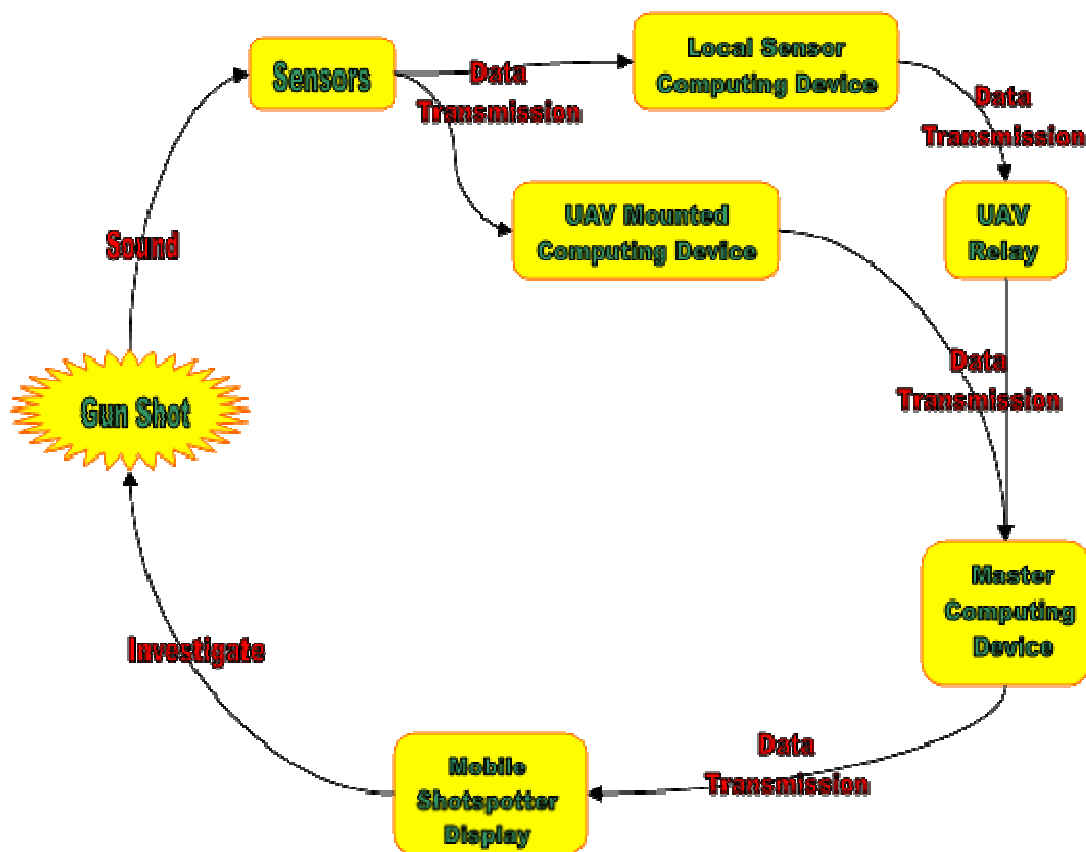
Figure 23.   Shotspotter / UAV integration Data Flow
Diagram

1.   **Shotspotter Improvements on UAV ISR Missions**

Information, Surveillance, and Reconnaissance UAV missions will be greatly enhanced with the addition of Shotspotter technology. The very nature of Shotspotter is an ISR capability: providing information about gunshot locations, often times without the shooter's knowledge. Shotspotter equipped UAVs can provide mission improvements to all three elements of the mission.

As portrayed in the scenario, a UAV can provide vital enemy statistics to troops on the ground. While the troops themselves can wear Shotspotter sensors and obtain azimuth and range information about the gunshot location, the addition of the UAVs allows for a third dimension: height.

Knowledge of the height of the gunshot can prove to be very advantageous. Normally, the human ear can determine that a gunshot took place, but determining the direction and height of the shooter can be more difficult. Obviously, in a combat scenario higher ground is ideal and if the height of the shooter is known, finding cover will be easier because possible shooting angles are understood.

UAVs equipped with Shotspotter can simply be used to loiter over specified areas and track down people firing weapons. This surveillance information can then be relayed to troops, artillery, aerial assets, etc. to investigate or destroy hostile targets firing weapons. This method would be safer and more efficient then simply patrolling areas with reported gunfire in search of gunman. Shotspotter would be able to report general locations to focus the search.

In this same role, the gunshot location information can be taken over a length of time and recorded. Over the long run, this information can provide gunshot "hot spots." These "hot spots" can be utilized for planning purposes. Knowing where "hot spots" are located can be very valuable information. The "hot spots" could provide the location of terrorist cells, street gangs, or simply overly aggressive people; all of whom may need to be subdued or eliminated in a war zone. Knowledge of the location of the "hot spots" can aid in the planning of humanitarian and aid missions (medical supplies, food, shelter, construction, voting, etc.). Also, patrols would be alerted to the location of the "hot spots," since violence may be expected in a greater volume in those areas.
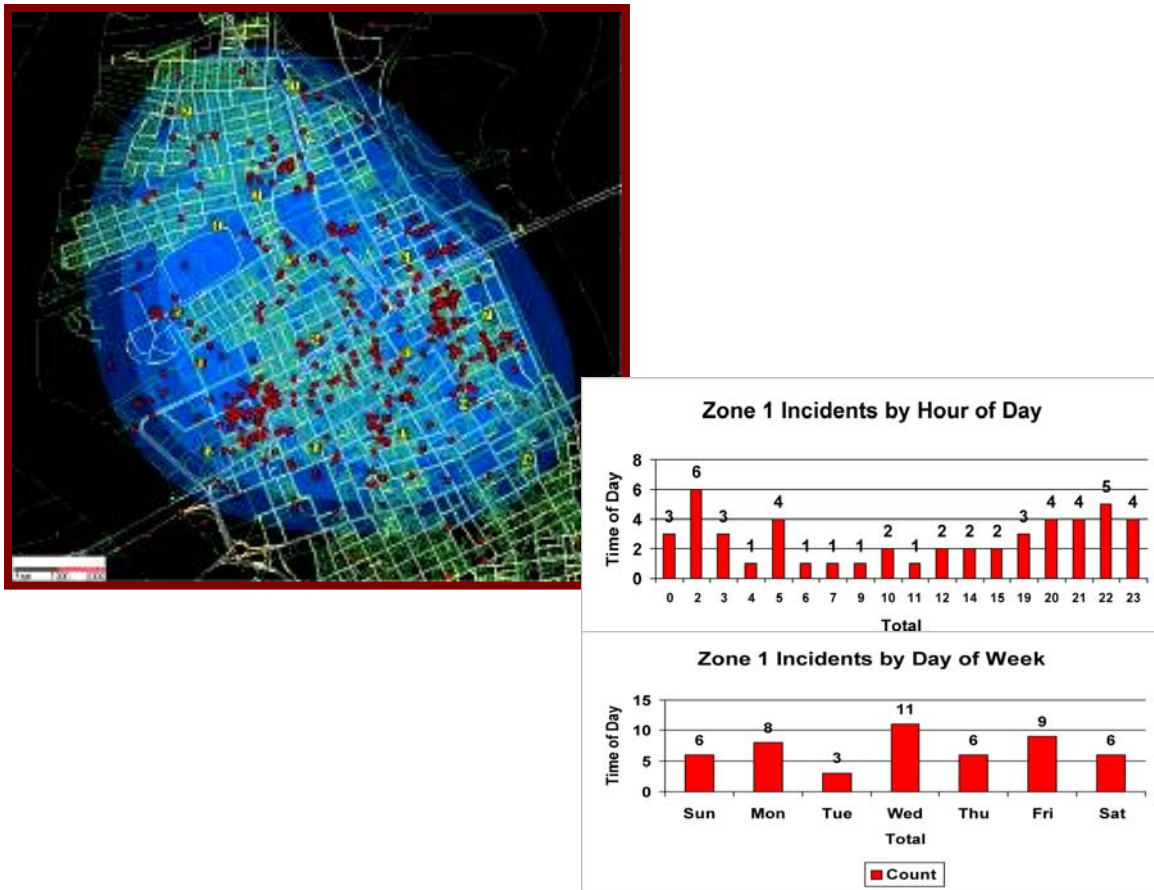
Figure 24.   Shotspotter "Hot Spot" Detection (From:
Shotspotter: Military Capabilities)

One aspect of ISR missions that could be greatly
enhanced is the armed reconnaissance mission.   Armed UAVs
(Hellfire missiles, guns, etc.) equipped with Shotspotter
could be utilized to eliminate targets without the need for
deployed forces in the area.   The weapon system on the UAV
could be designed to automatically aim at the gunshot
location (a similar technology is being tested and
implemented on HMMWVs). A video camera on the UAV would
allow the UAV operator to view the location of the target
almost instantaneously, and decide to engage it (man-in-
the-loop).   This would be especially useful if the area is
notoriously hostile, environmentally or strategically

unsafe for friendly forces, or the target is of high value or a flight risk. Obviously, restrictions would be placed on when a Shotspotter target could be attacked by a UAV (i.e., no friendly forces in the area to avoid automated attacks initiated from friendly gunshots), but the capability is a clear possibility for UAVs equipped with Shotspotter.

2. Shotspotter improvements on UAV Communications Node / Data Relay Missions

The Communications Node / Data Relay UAV missions will be slightly enhanced with the addition of Shotspotter. While Shotspotter cannot improve the communications aspects of these missions, its presence can help improve data relay missions.

The addition of Shotspotter to UAVs will improve the data relay aspects of the Communications Node / Data Relay mission, but only Shotspotter data will be effectively relayed. Shotspotter will not help in the data transfer of any other kind of information other than the Shotspotter data itself.

The ability of UAVs to relay the Shotspotter data takes the original Shotspotter technology to another level. The Shotspotter central processing device can be mounted on a UAV flying overhead of any type of military operation. The Shotspotter processing device on the UAV can coordinate and manage the personnel, vehicular, and fixed sensors in locating gunshots. The addition of the central processing device allows the UAV to collect data from all of the sensors operating in its area. This UAV mounted processor can analyze and store the gunshot location information for

transfer to high levels within the Shotspotter architecture. Furthermore, the UAV could transfer collected data back to a master processing device for further analysis or to Shotspotter displays located throughout the theater of operation, on or off the battlefield. This capability allows for other people or systems with access to UAV and Shotspotter terminals to see gunshot locations and other information without having to personally be in the combat zone.

    3. Shotspotter Improvements on UAV Strike/SEAD Missions

The Strike / SEAD missions of UAVs can be slightly or partially enhanced when the UAV is equipped with the Shotspotter technology. Since a Strike mission is clearly defined as a distinct attempt to engage or destroy a particular target, Shotspotter cannot improve its effectiveness very much. However, the addition of Shotspotter to a UAV will greatly improve the Suppression of Enemy Air Defense aspects of the Strike / SEAD UAV mission.

A Strike mission executed by a UAV equipped with Shotspotter is not a vast improvement compared to the same mission done by a UAV without Shotspotter capabilities. However, the UAV equipped with Shotspotter would be slightly improved with regards to certain targets. If the strike is be carried out against a building or facility of known location, Shotspotter on the UAV would not improve the mission, other than to provide information about any gunshots detected while traveling to the target or at the targets location. But if the target was a convoy or mobile

personnel, Shotspotter could help the UAV locate its target. Shotspotter could assist the Strike mission only if the target shoots a weapon within the UAVs Shotspotter sensor range. If the target were to shoot (whether at the incoming UAV or at anything else in the area) and Shotspotter were to get a fix on the gunshot location, the target could be more easily identified.

Shotspotter equipped UAVs would be able to help in the SEAD aspects of the Strike / SEAD missions. The first phase of suppression of enemy air defense would clearly be to locate the enemy's air defense. A simple, relatively cheap, and safe way to locate the enemy's air defense (without prior intelligence) would be to fly a Shotspotter equipped UAV in the area in question. The downside to this mission is that in order for Shotspotter to detect enemy anti-aircraft gunfire, the UAV is going to be put at risk by the enemy air-defenses it is trying to detect. Essentially, the UAV would be considered a sponge for anti-aircraft fire, but Shotspotter sensors onboard the UAV would be able to locate the position of the gunfire (and create a profile of the weapons being fired) as it is being fired upon. Obviously, the longer the UAV can penetrate and survive in the hostile area, the more gunshot locations the Shotspotter sensors can identify and relay back. Shotspotter will be able to differentiate anti-aircraft gunfire from regular personnel gunfire in two ways. If Shotspotter detects multiple gunshots from the same location over an extended period of time this could indicate ant-aircraft fire and Shotspotter is able to create a weapons profile from the gunshot itself by

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comparing the collected acoustic signature to known samples.

Shotspotter's acoustic threshold levels for detection could be tweaked to provide identification of potential missile launches. Even though an anti-aircraft missile poses a larger threat to the UAV than standard anti-aircraft gunfire, if the UAV can evade the missile, it may be able to determine the location of the launch (depending on the acoustic threshold levels for detection). Utilizing only UAVs with Shotspotter on a SEAD mission is essentially a sacrificial mission. It should be understood beforehand that the UAV will most like be destroyed, but that is a better option than sending in manned aircraft without any knowledge of the location of enemy ant-aircraft weapons.

UAVs with Shotspotter can also be used in conjunction with manned aircraft. If manned aircraft are conducting air operations in a particular area, Shotspotter UAVs can be flown in the same area, recording any fire in the vicinity of the aircraft. Locations of the enemy's anti-aircraft fire can then be sent to forces on the ground, or to the aircraft themselves, so they can neutralize the enemy's anti-air assets.

C. CURSOR ON TARGET AND UAV INTEGRATION

The addition of the Cursor on Target technology significantly improves almost every aspect of UAVs. The ability for Cursor on Target to speed up data transfers and Machine to Machine communication will prove to be invaluable to the armed forces of the United States. The transfer of critical "What, When, Where" data is essential to overall mission effectiveness. Like Shotspotter, Cursor

on Target does not require a UAV to function. However, when Cursor on Target is used in conjunction with UAVs, the capabilities for both technologies are greatly improved. All four major missions of UAVs [Information, Surveillance, and Reconnaissance (ISR), Strike / Suppression of Enemy Air Defense (SEAD), Electromagnetic Attack (EA), and Communications Node / Data Relay] will be greatly improved through the integration of Cursor on Target with the UAVs.
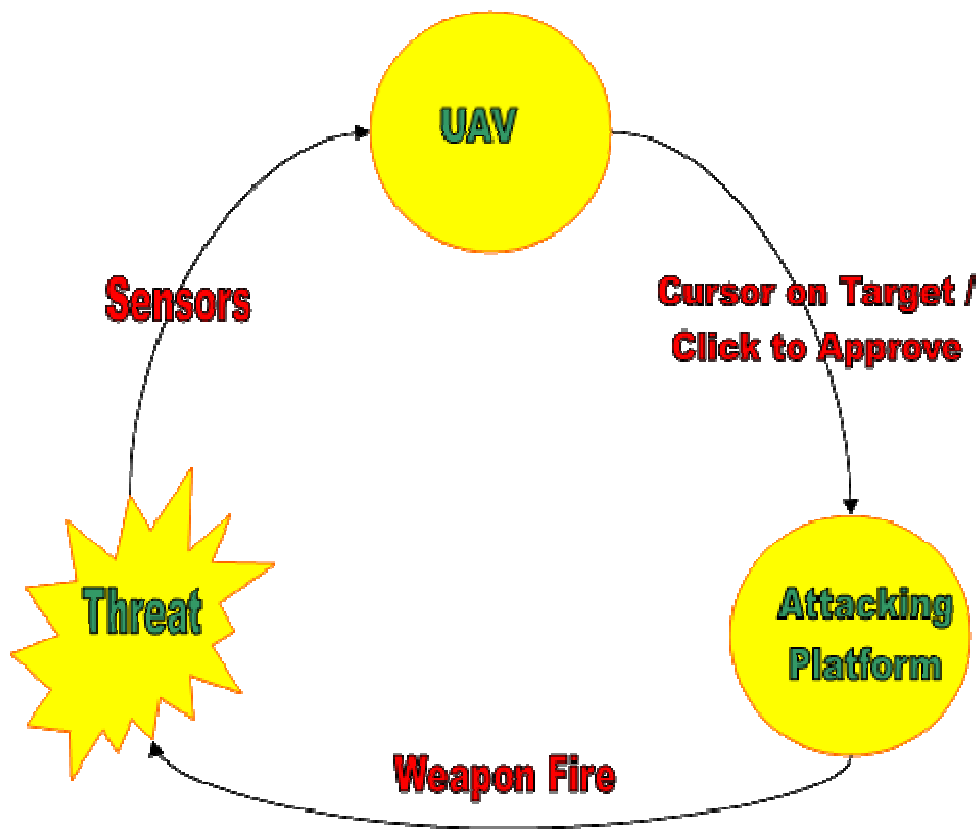
Figure 25.   Cursor on Target/UAV integration Data Flow Diagram

1.   Cursor on Target improvements on UAV ISR Missions

Information, Surveillance, and Reconnaissance missions center on data collection and transfer, and the ability to get that information to the necessary players.   The

implementation of Cursor on Target with UAVs would improve the speed and accuracy of transmission, by reducing human interaction and error, for the data they collect. ISR UAV missions are the primary recipients of the improvements Cursor on Target provides for UAVs.

Oftentimes, collected data is time critical and it is essential to get the information to the decision makers as quickly as possible. Battlefield situations can be expected to change rather frequently, so what was true two minutes ago may not be true now. If only for this matter alone, the time that passes between the collection of data, its exposure to the decision makers, and the response generated from the data is very critical. Cursor on Target facilitates rapid transfer of data between platforms that would normally require slower human interaction.

When equipped with Cursor on Target, the "What, When, Where" information collected by the UAV can be readily shared with the other platforms in the area. Without Cursor on Target, the UAV collected data would have to be sent back to the UAV operator, who would filter it through to the command center, who would then interface and convert the data for re-dissemination to other systems and the field. Cursor on Target facilitates the automation of this process. It allows for data to flow from the UAV directly to the interested platforms and forces in the field without human interaction (i.e., from the UAV directly to a HMMWV or squad leader without the need for humans to perform translations between inoperable systems). The time difference between these two options could be the difference between enemy forces being in or out of range of a retaliatory response. The elimination of the human from

the loop also reduces the chance for human error, such as mixing up position coordinates or forgetting vital information during verbal transfer.

UAVs equipped with Cursor on Target can also provide vital targeting information quicker than UAVs without CoT, and with a reduced chance for error. A UAV flying overhead can locate a potential target (with video, pictures, electronic signature, etc.) and the "What, When, Where" data can be sent directly to artillery batteries or aircraft in flight via the "Click to Approve" feature of the system. Not only will the targeting coordinates be sent directly to the platforms requesting or requiring them, but so will other relevant target data, as well as the necessary tasking orders for the engagement of the target. Again, the human error is neutralized in the equation and the process time is dramatically decreased.

The armed reconnaissance facet of a UAV's ISR mission would be significantly enhanced with the implementation of Cursor on Target. An armed reconnaissance mission focuses itself on a target of opportunity. The UAV performs simple reconnaissance, but is armed and has the capability to engage targets that may present themselves. Obviously, in armed reconnaissance missions, time is a very critical element, and with the help of Cursor on Target, the UAV would be much more effective in this role. The "What, When, Where" data must reach the UAV quickly in order to maintain an adequate window to engage the target. The elapsed time between the confirmation of the target and the launch of the weapon, in an effort to destroy the target, would be significantly decreased with Cursor on Target's Machine to Machine communicative features.

A very important aspect of ISR UAV missions is Battle Damage Assessment (BDA). Since Cursor on Target speeds up the data transfer process between DoD systems, UAVs equipped with Cursor on Target become a more important player in the BDA process. The ability to share BDA data (pictures, video, electronic emissions, etc.) from a UAV with almost all DoD platforms is revolutionary in itself, but Cursor on Target allows this data to be shared faster than ever before. UAVs equipped with Cursor on Target are significantly more important in the BDA process.

Finally, Cursor on Target could be used to transmit the vital "What, When, Where" data to a UAV in order for the UAV to conduct an ISR operation. Especially if the target is mobile, the speed with which specific targeting information reached the UAV would be paramount. Transmitting this important data via Cursor on Target to the UAV would get the information to the UAV quicker than normal, allowing the UAV to perform its ISR mission more quickly than without Cursor on Target (up to 70% faster in some tests).

Essentially, Cursor on Target would allow the sharing of the ISR data collected by the UAVs. Cursor on Target would facilitate the ISR data transfer from the UAV to other DoD systems and platforms. ISR UAV missions, in general, would be significantly enhanced by the integration of Cursor on Target into existing UAV technologies. Cursor on Target would significantly improve UAVs response time and overall effectiveness and lethality.

2. Cursor on Target Improvements on UAV Strike/SEAD Missions

Strike and Suppression of Enemy Air Defense UAV missions are greatly enhanced through the integration of the Cursor on Target technology with the UAVs. Again, the addition of Cursor on Target speeds up the decision makers' loop with M2M communication. Cursor on Target transmits the "What, When, Where" targeting data to the necessary platforms to carry out the Strike or SEAD mission. Both Strike and SEAD missions would see considerable improvements with the implementation of Cursor on Target

Cursor on Target's capability to share time critical data between various DoD systems is key to the improvement of the UAVs Strike mission. The goal of a strike mission is to destroy an enemy target. Cursor on Target enables essential targeting information for a strike mission, the "What, When, Where" data, to be seamlessly transferred to the UAV along with the tasking orders necessary to successfully carry out the strike. This data transmission is made possible by Cursor on Target technology in conjunction with the Click to Approve concept. Essentially, with a simple cursor click, all of the "What, When, Where" data and tasking orders for the strike mission are sent directly to the UAV. Human error and lag time is all but eliminated from the process.

SEAD UAV missions are also augmented by the addition of Cursor on Target. Very similar to a Strike mission, the "What, When, Where" targeting data (and tasking orders to engage) for the enemy's air defense assets can be instantaneously sent to the UAV.

UAVs with Cursor on Target technology can be utilized in pre-emptive and reactive SEAD missions, but the largest beneficiary of Cursor on Target are the reactive SEAD missions. The pre-emptive SEAD missions are improved by providing the capability to quickly change the priority of targets with Cursor on Target transmissions. However, the reactive SEAD missions stand to be improved to a greater degree than the pre-emptive missions. A UAV that comes under anti-aircraft fire while on a strike mission has a very limited amount of time to react before it will be shot down. The speed that Cursor on Target provides, permits for mid-mission changes to be made much faster than ever before. New tasking orders and target locations ("What, When, Where" information) can be sent instantaneously to a UAV, instructing it to abandon its established strike mission and engage the air defense.

3. Cursor on Target Improvements on UAV EA Missions

Cursor on Target enabled UAVs can provide some improvements to Electromagnetic Attack (EA) UAV missions. Like all Cursor on Target improvements, the EA UAV mission is improved by speeding up the process required to fulfill the mission. Cursor on Target significantly improves the response time for EA missions.

Cursor on Target enables the UAV to speed up the EA loop involving potential targets and threats. If a UAV is in an area, and it is deemed necessary to perform an electronic attack, Cursor on Target would be able to track and communicate the "What, When, Where" information for the target to the necessary platforms assisting in the EA mission. At the same time, Cursor on Target could transmit

the "What, When, Where" information directly to the UAV in order for the UAV to conduct the EA itself, provided it has the necessary equipment. Cursor on Target allows for M2M (Machine to Machine) communication to speed up the EA process.

UAVs operating in EA missions generally have two roles: locating a target for EA or performing the EA itself. Cursor on Target enhances the UAVs ability to effectively perform both of these aspects of the mission by quickening the transfer of the vital "What, When, Where" targeting information.

4. Cursor on Target Improvements on UAV Communications Node / Data Relay Missions

Communications Node / Data Relay missions are also highly improved due to the addition of Cursor on Target. Like all other Cursor on Target advancements, the greatest enhancements come from the improved data transfer and sharing time. Cursor on Target allows data and communications to be disseminated faster and also made more accessible to DoD systems.

Cursor on Target facilitates data transfers between different systems. Cursor on Target's presence in Communications Node / Data Relay missions instantaneously improves them. The communications and data will be transferred faster and made accessible to many systems that normally would not be able to receive the data directly. These systems can now receive data directly from the source as opposed to having to wait for it to be reformatted to fit their particular system requirements. Since Cursor on Target utilizes XML formatting, the data and information

can now be relayed directly to the systems that need them instead of to a middle man to perform inoperable system translations.

The presence of Cursor on Target undoubtedly improves every aspect of the Communications Node / Data Relay UAV mission. Through the XML standard employed by Cursor on Target, information sharing would occur at a faster rate.

D.   SHOTSPOTTER, CURSOR ON TARGET AND UAV INTEGRATION

UAVs equipped with Shotspotter and Cursor on Target are enhanced UAVs that are much more powerful than the sum of the individual parts. While the addition of Shotspotter does little to improve Cursor on Target, Shotspotter is endlessly improved by the presence of Cursor on Target. Cursor on Target is a means to improve data transmissions, Shotspotter does not have the capability to further improve Machine to Machine communication. Shotspotter is a "data service," so it stands to be significantly improved by the presence of Cursor on Target. Almost every aspect of Shotspotter information dissemination will be improved by the implementation of Cursor on Target. The combination of Shotspotter and Cursor on Target will improve all aspects of UAV missions, except for Electromagnetic Attack (EA).
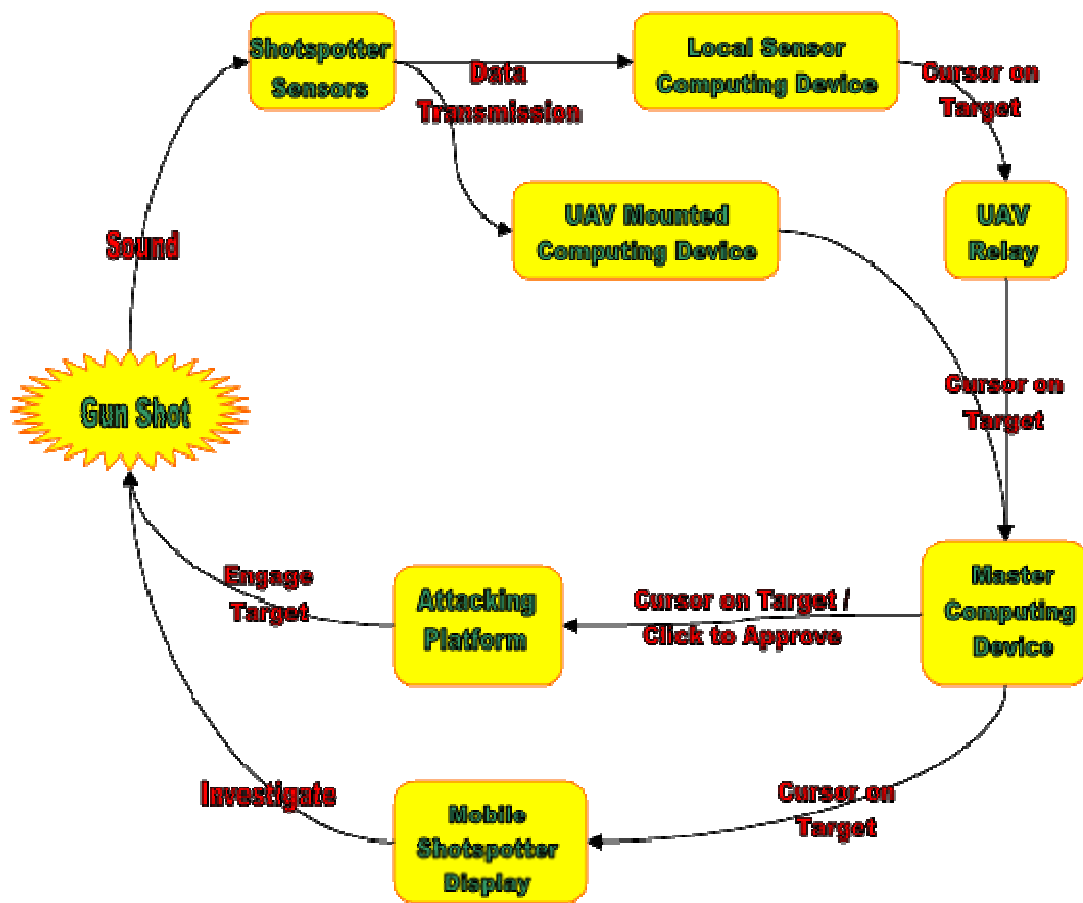
Figure 26.   Shotspotter, Cursor on Target and UAV
integration Data Flow Diagram

1.   Shotspotter and Cursor on Target Improvements on UAV ISR Missions

As stated before, Shotspotter provides an ISR capability and Cursor on Target facilitates data transmission. Shotspotter provides gunshot location information and Cursor on Target speeds up the time critical transmission of that information. Shotspotter provides improvements to the ISR missions of UAVs. The presence of Cursor on Target simply improves the speed with which the original Shotspotter improvements can be carried

out. Every ISR aspect of Shotspotter is improved through the addition of Cursor on Target.

2. Shotspotter and Cursor on Target Improvements on UAV Strike/SEAD Missions

Much like the ISR missions, enhanced UAVs (UAVs equipped with both Shotspotter and Cursor on Target) do not provide any new missions or tasks that cannot be accomplished with a UAV equipped with Shotspotter only. However, the addition of Cursor on Target would improve the speed at which these new mission subsets can be performed.

The combination of Cursor on Target with Shotspotter would facilitate in the expedited transfer of the time critical "What, When, Where" data that is essential to the successful completion of a Strike / SEAD mission. Shotspotter's gunshot location data could prove to be the key to locating a strike target, and with the addition of Cursor on Target, that data would be streamlined to the necessary platforms (strike aircraft, armed UAV, etc.) in order to execute the strike. The Click to Approve feature also helps speed up the process by immediately sending the location and target data along with tasking orders to the "striking platform."

Similarly, the "What, Where, When" gunshot location data for the enemy's air defenses would reach the necessary platforms more quickly than ever before. The speed of the Machine to Machine communication in SEAD missions could very well determine how many, if any, friendly aircraft are affected by the enemy's anti-aircraft fire, so it is essential that this data is put in the proper hands as soon as possible.

With Shotspotter and Cursor on Target used in conjunction with UAVs, all of this extremely time critical information would be passed seamlessly to the people and systems that require it to complete their mission faster and more effectively than ever before.

3. Shotspotter and Cursor on Target Improvements on UAV Communications Node / Data Relay Missions

The Shotspotter and Cursor on Target combination affects the Communications Node / Data Relay mission just as it affects the other missions, by expediting the transfer of the Shotspotter data through Cursor on Target's enhanced Machine to Machine communicative abilities. While this combination does not have the ability to improve the Communications Node aspect of this mission, it does have the ability to improve the Data Relay aspect.

Again, Shotspotter provides a "data service" and Cursor on Target facilitates expedited data transfer, so it is logical how the enhanced UAVs can improve upon the Data Relay missions. Shotspotter determines gunshot locations and Cursor on target facilitates the transfer of that data to the necessary parties, faster and more accessible than before.

E. PREVIOUS TESTS AND EXPIREMENTS

The groundwork for the testing of enhanced UAVs was laid by the Forward Look experiments. "Considered the first step toward the network-centric operation of unmanned aerial vehicles (UAVs), the experiment integrated the location information and sensor points of interest of Predator, ScanEagle, Shadow and Silver Fox UAVs in a common

operational picture (COP)."[90]   UAVs, by design, normally display their vital statistics (position, sensor data, etc) on their own individual ground control station, so the ability to receive this data from multiple UAVs into a single COP via Cursor on Target was a major step for enhanced UAVs.

With the capability to view all relevant UAV data on a single COP, the next step was to take advantage of this ability and integrate new technologies into the UAV arsenal. Extended Awareness-1 "…planned to experiment with the utility of dissimilar unmanned aerial vehicle (UAV) capabilities supporting ground forces in urban warfare… UAV situational awareness tools and communications architectures proven during the Forward Look experiment series including the cursor-on-target (CoT) situational display were augmented with additional innovative capabilities to enhance UAV systems interoperability."[91] Included in these "additional innovative capabilities" were Shotspotter and additional tests with Cursor on Target.

Several major accomplishments were achieved during EA-1, including:

- Demonstrated effectiveness of using Shotspotter CoT for cueing UAV support for gunshot response and blue force position for high and low speed moving convoy operations.

- Demonstrated the effectiveness of moving unclassified data to and from both classified and

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[90] Lawlor, Maryann. "Communications Capabilities Connect." SIGNAL Magazine Apr. 2005. May 2005 <http://www.afcea.org/signal/articles/anmviewer.asp?a=735&z=4>.
[91] "EA 1 Quicklook." FIRES Network: EA Repository. May 2005.

unclassified systems to form the Common Operating
Picture (COP).

- Observed the potential of a rapid tactical image and
  video capture, archive, retrieval and distribution
  network based upon the CoT situational awareness
  tool.

- Successfully integrated the Shotspotter acoustic
  sensors into the CoT data transfer system.

- Successfully integrated the CoT capability into the
  native Scan Eagle ground control station.

- Automatically cued the Scan Eagle sensor to the CoT
  Shotspotter resolved gun shot location and other CoT
  locations.[92]

Joint Forces Command summed up the success of EA1 with
regards to Cursor on Target and Shotspotter being
integrated with UAVs:

> Combining the capabilities of the Shotspotter
> ground sensor with the distributive powers of the
> CoT network greatly increased the effectiveness
> of both independent capabilities. An example was
> their collective use in providing a highly
> effective means of conducting UAV support to low
> and high-speed convoy operations. This shows
> that increasing machine-to-machine interaction is
> important to increasing mission effectiveness.[93]

Essentially, JFCOM states that not only can Cursor on
Target and Shotspotter effectively integrated with UAVs,
these enhanced UAVs also have a tremendous upside. EA-1
effectively showed the vast potential available for the

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[92] "EA1 Quicklook."

[93] Shotspotter: Military Capabilities.

enhanced UAVs, and provided a sampling for what will come in the future. These technologies and concepts will be put to further tests during future Extended Awareness experiments.

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VII. EXPEDITIONARY STRIKE GROUP METL IMPROVEMENTS FROM ENHANCED UAVS

A. **IMPROVEMENTS ON NAVY SPECIFIC MISSIONS**

The following table breaks down the Navy specific missions, identified in section II.E.1, into three categories based on the degree they are affected by UAVs enhanced with the Shotspotter and Cursor on Target technologies:

Greatly Enhanced
• N/A
Enhanced
• Provide Sea Lines of Communications Protection • Provide Sanctions Enforcement
Unaffected
• Provide Theatre Missile Defense Warning • Deploy/Conduct Operational Maneuver

Table 1.   Effects of Enhanced UAVs on Naval Missions

1. Enhanced Naval Missions

UAVs can provide extended loitering abilities to increase surveillance and communications relay capabilities over a prolonged period. UAVs can aid in the enforcement of sanctions and protection of sea lanes of communication by extending the surveillance area of the ESG. Not only can they be placed over the horizon to perform surveillance, UAVs can be used as relay points for communications from platforms already stationed over the horizon. Cursor on Target provides UAVs performing this mission the flexibility to distribute targeting or surveillance information to a variety of dissimilar

systems. Pertinent information can be provided to shooters quickly through Machine to Machine dialogue via Cursor on Target, and operators can "Click to Approve" targets for elimination. Sanction enforcement often involves multiple nations and agencies. Cursor on Target can aid in information sharing among these entities, curbing the interoperability problem.

2. Unaffected Naval Missions

Enhanced UAVs do not aid naval assets with Theater Missile Defense Warning or Deploying and Conducting Military Maneuvers.

B. IMROVEMENTS ON MARINE CORPS SPECIFIC MISSIONS

The following table breaks down the Marine Corps specific missions, identified in section II.E.2, into three categories based on the degree they are affected by UAVs enhanced with the Shotspotter and Cursor on Target technologies:

Greatly Enhanced
- Conduct Amphibious Raid   - Conduct Amphibious Assault   - Conduct Airfield/Port Seizure   - Conduct Security Operations   - Conduct Enhanced Urban Operations   - Conduct Direct Action Operations (Precision Raid or Visit, Board, Search and Seizure (VBSS))   - Provide Contingency Support Packages (Tactical Recovery of Aircraft Personnel (TRAP), Causality Evacuation (CASEVAC), Quick Reaction Force (QRF), Mass Causality scenarios)
Enhanced
Conduct Amphibious Demonstration

• Conduct Amphibious Withdrawal • Conduct Limited Expeditionary Airfield Operations • Employ Non-Lethal Weapons • Conduct Noncombatant Evacuation Operations (NEO) • Conduct Peace Operations • Conduct Deliberate Planning • Conduct Rapid Planning
Unaffected
• Conduct Humanitarian/Disaster Assistance

Table 2.   Effect of Enhanced UAVs on Marine Corps Missions

1.   Greatly Enhanced Marine Corps Missions

All the missions in this category involve combat, where enhanced UAVs are most effective. Assaults, raids and other combat operations will benefit from UAVs enhanced by Shotspotter and CoT.   These UAVs provide the capability to quickly and accurately locate gunshot events while simultaneously providing targeting information for supporting fire.   Security operations can benefit from Shotspotter as well.   Shotspotter grids setup around permanent or semi-permanent installations will help facilitate a rapid response in the case of an attack. Additionally, the blue force tracking capability of Shotspotter will allow safety patrols to be continually monitored. Cursor on Target will facilitate the transfer of vital information between the participating platforms and systems.

2.   Enhanced Marine Corps Missions

These missions can benefit from the use of UAVs enhanced by Shotspotter and Cursor on Target, but not as directly as the missions in the previous category.   The

ability of enhanced UAVs to locate gunshots will provide intelligence on enemy location and movement. This will facilitate mission planning and assist in selecting optimum locations to conduct evacuation or demonstration operations. Forward deployed Shotspotter grids can help identify enemy hotspots based on the frequency of gunshot events. Again, Cursor on Target improves the data and information sharing between participating platforms and systems.

3. Unaffected Marine Corps Missions

Enhanced UAVs have little or no benefit for Humanitarian or Disaster Assistance Operations.

C. IMPROVEMENTS ON JOINT NAVY AND MARINE CORPS MISSIONS

The following table breaks down the Joint Navy and Marine Corps missions, identified in section II.E.3, into three categories based on the degree they are affected by UAVs enhanced with Shotspotter and Cursor on Target technologies:

Greatly Enhanced
• Conduct Intelligence, Surveillance and Reconnaissance • Provide Operational Fires (Joint /Coalition) • Provide Anti-Terrorism/Force Protection
Enhanced
• Conduct Information Operations/Warfare • Conduct Maritime Interdiction Operations (MIO) / Extended Maritime Interdiction Operations (EMIO) • Conduct Visit, Board, Search and Seizure (VBSS) (compliant / non-compliant) • Provide Command, Control, Communications and Computers

• Conduct Terminal Guidance Operations • Conduct Initial Terminal Guidance Operations
Unaffected
• Tactical Deception Operations • Conduct ESG Force Defense (AD/USW/SUW/DAF) • Conduct Sustainment Operations

Table 3.   Effect of Enhanced UAVs on Joint Navy and
Marine Corp Missions

1.   **Greatly Enhanced Joint Missions**

Missions falling in this category will have noticeable improvements when using enhanced UAVs utilizing CoT and Shotspotter.   ISR and Anti-Terrorism/Force Protection operations will gain a tactical advantage over the enemy when using these systems.   The capability to accurately locate and identify targets of opportunity through gunshot detection will increase the lethality of these missions.

The ESG's ability for providing Operational Fires can also be improved from enhanced UAVs using Shotspotter and CoT technologies.   Shotspotter can rapidly identify gunshot locations, from any of its three layers including UAVs, and pass these locations through CoT to various targeting systems and pertinent platforms.   The speed with which CoT can accurately pass information between dissimilar systems is very important.   Shotspotter can identify the location where an enemy fired a gun or other explosive device, but it can not track the current location of the shooter. Therefore, the speed with which the location of the explosive event is identified, processed and sent to the proper targeting system is vital to the success of the system.   The faster the offensive asset can bring force to bear on the location of the gunshot, the more likely the shooter will be there to feel the effects.

2. Enhanced Joint Missions

Maritime Interdiction Operations and Visit, Board, Search and Seizure (VBSS) will not likely gain the full benefit of UAVs enhanced by Shotspotter and CoT. Shotspotter technology has not been proven in enclosed environments. Therefore, a boarding party searching below decks of a suspect vessel would not benefit from its capabilities.

Cursor on Target integrated with UAVs will most definitely benefit Command, Control, Communication, and Computers. Seamlessly integrating dissimilar technologies will facilitate information sharing and cooperation among services and our allies.

Guidance Operations will benefit from the ability of the enhanced UAVs and Shotspotter to catalog enemy hotspots based on the frequency of gunshots. This will help identify areas to avoid or possibly target, depending on the mission.

3. Unaffected Joint Missions

Tactical Depiction Operations, Sustainment Operations and ESG Force Defense Will find little benefit from enhanced UAVs, Shotspotter or CoT.

VIII.   CONCLUSION

The Expeditionary Strike Group is a major part of the future of the Navy Marine Corps team. The ESG's importance will continue to increase over time as future Marine deployments are accompanied by naval surface vessels and the ESG concept matures, improving efficiency and lethality. The centerpiece of the ESG is the Marine Expeditionary Unit. ESGs were created to provide naval support for the deployed Marine elements.

With ESGs playing an increasingly important role in United States strategy and policy, it is vital that they continue to improve and evolve in order to maintain maximum effectiveness. A simple and effectual way to improve the usability and effectiveness of the ESG is through increased usage of Unmanned Aerial Vehicles. UAVs are one of the most versatile platforms and they possess unlimited potential. UAVs have proven their ability to fulfill a growing list of missions and their growth does not appear to be losing any momentum. UAVs traditionally execute missions that fall into four major categories: Information, Surveillance, and Reconnaissance (ISR), Strike / Suppression of Enemy Air Defense (SEAD), Electromagnetic Attack (EA), and Communications Node / Data Relay.

Two new technologies, only recently being associated with UAVs, are creating a buzz. Shotspotter and Cursor on Target are two technologies that have the potential to significantly improve UAVs, and therefore ESGs as well. When both Shotspotter and Cursor on Target are integrated into existing UAV technology, all three systems are significantly improved.

Shotspotter provides vital gunshot location and weapon information through triangulation of various acoustic sensors that can be mounted on buildings, vehicles, personnel, or even UAVs. Cursor on Target facilitates mission essential Machine to Machine communications and expedited data transmissions using XML. Both of these technologies can independently advance UAVs (Shotspotter providing gunshot location, blue force tracking, etc. and Cursor on Target speeding up data transfers and helping DoD systems communicate via XML formatting), but when both are integrated into the existing UAV structure all three systems see major improvements.

The addition of Shotspotter and Cursor on Target to UAVs will greatly enhance the quality and mission effectiveness of UAVs. These improvements will allow UAVs to achieve new missions and remove American forces from harms way by decreasing the need for manned aircraft. Shotspotter on UAVs will help locate gunshots and provide the gunshot location and important information about the weapon to friendly forces. Cursor on Target enables the accelerated transfer of data between systems. Increased data speed would get vital time critical information into the hands of people and platforms that need the information.

The addition of enhanced UAVs to the ESG will greatly enhance the quality and mission effectiveness of ESGs. ESGs are in their early stages of development and have significant room for expansion. The addition of enhanced UAVs will significantly improve many missions conducted by the ESG.

The opportunity to improve both UAVs and ESGs exists. By integrating enhanced UAVs into the fledgling ESG, the mission capabilities and effectiveness would dramatically increase. As ESG doctrine evolves, enhanced UAVs equipped with Shotspotter and Cursor on Target should be heavily considered to play a larger role within the ESG.

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