Results from Real Time Simulation Experiment of an Integrated Concept for UAV/Direct Fire Weapon Systems

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ABSTRACT

During the last several years, there have been a large number of design studies, system simulations, and battlelab experiments that have sought to improve the integration of UAV-based sensor systems with "shooters" by providing real time intelligence data to C4ISR C^2 Centers.

These initiatives have contributed significantly to the improvement of the state of the practice of integrating UAV-based sensor systems with a variety of indirect weapons such as artillery, rockets, Army aviation, and Air Force Close Air Support systems. Intelligence and targeting information for these indirect fire weapon systems has been necessarily connected to "shooters" via C4ISR C^2 centers, because of the complex fire coordination required prior to target engagement.

While indirect fire systems are a critical element of the modern field army, they represent only a portion of the combat power of a combined arms team available to armored/mechanized forces. The direct fire weapon systems of the Army's armored forces (cannon and missile) provide the Army with an additional and extremely potent capability to destroy threat forces. Historically, these direct fire weapon systems have relied on, and to some degree have been limited to, on-board sensor systems (Commander's binoculars, gunner's sight system, and thermal imaging systems) for real time targeting and situation awareness.

To assess the payoff of providing sensor data from platforms external to the individual weapon system, MITRE, in support of the Army PM Combat Identification has developed a simulated environment for the evaluation of advanced sensor concepts. These advanced concepts seek to integrate situation awareness data with point of engagement information for tank crews. In support of this task, MITRE recently completed a man-in-the-loop study that examined the operational utility of providing a tank crew with data from a multisensor (MTI radar, cooperative friendly ID, and FLIR based ATR) UAV system to assist in maneuver and target prioritization. The paper will

present the results of the study and its implications for near-real time exploitation of tactical UAV sensors in direct fire engagements.

INTRODUCTION

The Mission Need Statement (MSN) for the Tactical UAV states, *"Warfighting Commanders in Chief (CinCs) have a need to provide lower level tactical units a real-time responsive Reconnaissance, Surveillance, and Target Acquisition (RSTA), Electronic Warfare (EW), Battle Damage Assessment (BDA), and Nuclear, Biological and Chemical (NBC) detection capability against defended areas in close proximity to friendly forces." This capability is urgently needed to provide Army Brigade Commanders with improved situational awareness, to permit maneuver forces to move to points of positional advantage with greater speed and precision, avoiding enemy strengths, and then combine the effects of direct and indirect fires to seize and retain terrain or destroy enemy forces. Additionally, the CR-TUAV will give maneuver brigade commanders superior situational awareness for improved wide-area target acquisition and tracking of High Value Targets (HVT) to conduct both shaping and decisive operations with greatly increased lethality. The need is for a day/night, adverse weather, multi-sensor collection system with improved connectivity to joint forces that provides needed, real-time battle information that can not be observed from standoff airborne sensor systems, ground collection systems, and scouts.*

To meet this diverse set of requirements, the Army envisions a TUAV that is capable of supporting a number of different modular payloads to meet mission specific requirements. Candidate sensor payloads include EO/IR, SAR/MTI, SIGINT, SIGINT EA, as well as a number of other battlefield unique missions. These modular payloads are to be "plugged-in" to the UAV as a function of the specific mission.

As suggested by Figure 1, no single sensor can be expected to provide the full spectrum coverage required. At a global level, these mission requirements can be defined to include target detection, accurate target location, target tracking (if moving), target classification (track/wheel), target identification (type vehicle) and battle damage assessment (when engaged).

INTEGRATED TUAV/DIRECT FIRE WEAPON SYSTEM CONCEPT

As shown in Figure 2, the expectation is that wide area surveillance (WAS) systems will be employed to monitor the total battlefield to provide initial target detection and location information. In some cases, these WAS sensors may be capable of providing sufficient data to permit inferences to be drawn as to Order of Battle (OB) intelligence. For example, MTI radar can provide estimates of unit size, while SIGINT systems can provide estimates of the type of unit by virtue of the specific set of radios detected in a localized area. While these inferences are useful it is evident that other RSTA sensors will be required to provide additional intelligence information if the battlefield is to be accurately defined.

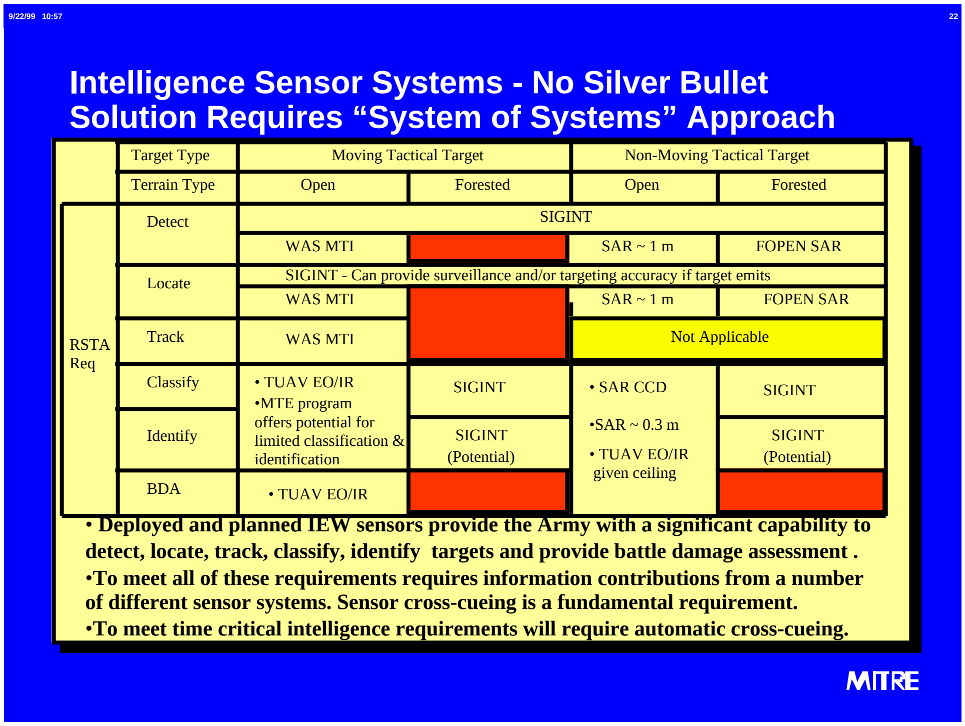


Figure 1. - Need for "System of Systems" Approach

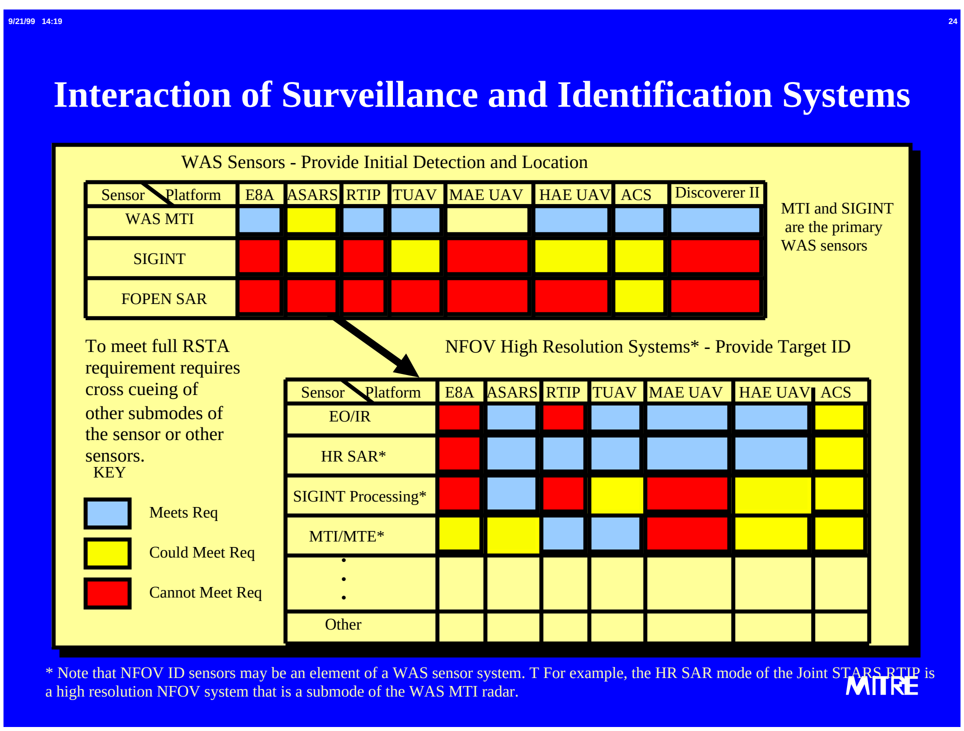


Figure 2. – Interaction of Surveillance and Identification Systems

As an example of the concept of using multiple sensors, consider the situation show in Figure 3, in which a target has been detected by the Joint STARS MTI radar. That information (target location, size of unit, speed and direction of movement) has in turn been used to provide steering commands to a TUAV equipped with a high resolution SAR radar to provide imagery required for target identification.

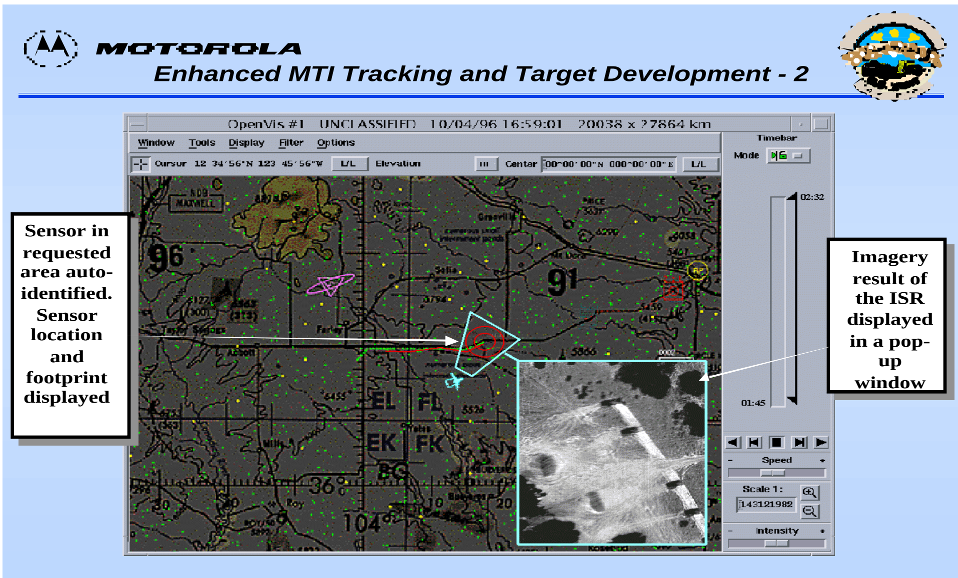


Figure 3 0 - Integrated CGS Display – Joint STARS MTI and TUAV EO/IR

Figure 3 portrays a Joint STARS Common Ground Station with both the MTI data and the representative EO/IR imagery from a TUAV superimposed on a common map background. As illustrated, the location of the TUAV and its EO/IR "footprint "on the ground are displayed graphically to insure that the EO/IR imagery displayed corresponds to the target of interest. Also shown in a "window" on the screen is the actual EO/IR imagery.

This integrated multisensor approach is anticipated to lead to significant improvements in the operational performance of the TUAV as it will:

• Permit the UAV to search limited area of selected areas of reported target activity rather than attempt to accomplish wide area search with an inherently narrow field of view sensor.

• Reduce the exposure time of the TUAV platform to hostile fire by minimization of general search operations.

• "Tag"" targets detected by the MTI radar with identification data. As the target track will be maintained by the MTI radar this integrated approach permits the UAV to be tasked to accomplish another missions.

While this is but a single example it does illustrate the tactical advantages of a "system of systems" approach to the successful accomplishment of the tactical RSTA mission. TUAVs are expected be a significant player in this dynamic environment given their ability to select flight paths that can eliminate or minimize terrain masking, mission tailorable payloads outlined earlier.

All of that said, there remains the problem of the time delay caused by the requirement to integrate the TUAV data with other intelligence information to eliminate or at least minimize false and or duplicative target reporting.

As one of the objectives of the integrated SA and TI study effort was to synthesize and assess “out of box” thinking, one alternative of the GITIS study included a direct link between a multisensor TUAV and the crew of the ground. This alternative was included in the experiment to obtain experimental data as to the operational utility of “raw” intelligence in addition to the integrated intelligence picture of the battlefield provided by the All Source Intelligence System (ASAS)

GITIS SIMULATION EXPERIMENT

This experiment consisted of a real-time, interactive, man-in-the-loop simulation in which participants serve as a tank crew fighting a dynamic and interactive battle. The simulated tank is equipped with the Battlefield Combat Identification System (BCIS), as well as improved concepts for friend and enemy Target Identification (TI) and Situation Awareness (SA). These include the Tactical Internet (TIN), a Situational Awareness Latency Mitigation Algorithm (SALMA), an Aided Target Recognition (ATR) system, and the BCIS. In addition, a hypothetical UAV equipped with its own BCIS, an MTI radar and an ATR system. By systematically varying the equipment provided to the simulated tank and measuring the combat effectiveness, the operational utility and integration of the TI and SA capabilities can be assessed. A set of metrics was devised to permit comparison between unlike combat identification systems in different battle scenarios. Results show the advantages and disadvantages of combining MTI, cueing, and ATR with BCIS

Figure 4 shows the functional block diagram of the GITIS Simulation Facility. This facility consists of seven computers connected by a local area network (LAN). It provides three stations for participants to interact with the simulation – a tank commander, a gunner, and a driver station. The tank crew stations are linked by a sophisticated audio system, which allows the tank commander (TC), the gunner, and the driver to communicate through their headsets. In addition, the system allows the crew’s communication to be monitored.

The baseline system consisted of a daytime visual scene of the battlefield, and the Battlefield Combat Identification System (BCIS). This system provides positive friend identification for platforms equipped with BCIS. The system is a Ka band interrogater/responder that provides highly reliable positive friend identification in all battlefield conditions. Figure 5 illustrates the functional operation of the BCIS system.

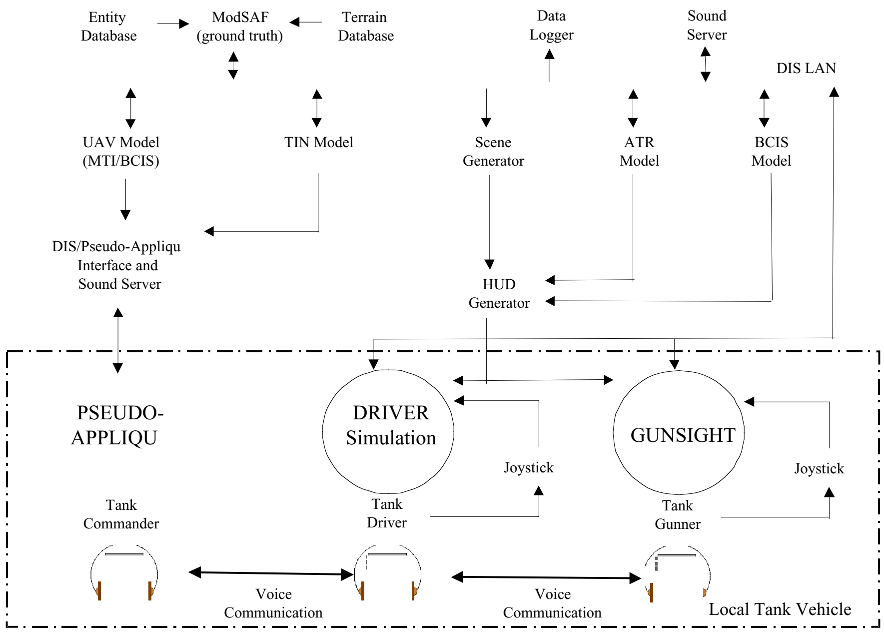


Figure 4.0 — Ground Integrated Simulation Facility

The other key element of the GITIS concept is tactical Situation Awareness (SA) data. SA data includes the location of both friends (as reported by the FBCB2 system) and the Enemy Situation Awareness (ESA) as reported by the ASAS. The FBCB2 system is a netted system that uses tactical radio links (SINCGARS SIP and EPLRS) to distribute SA (Friend and Enemy) and other tactical information from HQ to individual weapon platforms.

With this baseline as a reference a number of alternative concepts for the integration of TI and SA were synthesized. These can be partitioned into three functional categories: These included:

¥ Man Machine Interface (MMI) techniques

-Commander s point & click target designation

- Terrain Line of sight display

• Application of tracking concepts (Kalman filter) to reduce the latency of reported friend SA data

• Postulated ATR capabilities for the tank's FLIR system that provided non-cooperative friend, enemy, unknown target identification.

• Externally derived combat intelligence.

- ASAS
- TUAV multisensor system with direct downlink .

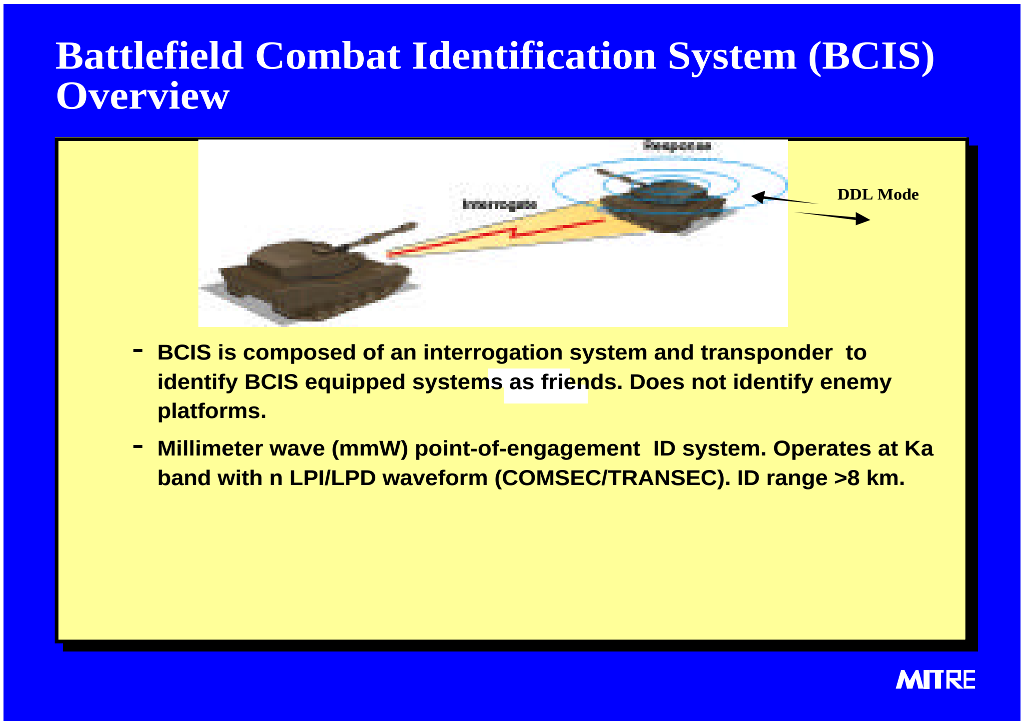


Figure 5. – Battlefield Combat Identification System (BCIS)

Enhanced MMI techniques.

Two concepts were explored in the MMI area. The first was a non-verbal technique by which the tank commander could hand-off “intelligence” targets to the gunner. Targets provided by external systems (in this case by either ASAS or a TUAV with a multisensor payload) were displayed on his Situation Display as Icons. To direct the gunner to a specific target the commander simply selected the target of interest on the Situation Display with a mouse click. This target location data was combined with own platform information to generate range and azimuth cues to the target. The Commander’s cueing system is shown in Figure 6.

The second MMI technique included in the experiment was the modification of the Situation Display to portray Line of Sight (LOS) from own platform. During an earlier GITIS simulation assessment we experienced a case in which the commander selected the nearest target (two threats were displayed with one at 800 meters and the other at 1500 meters) as the highest priority threat. In fact, as the nearest target was terrain/vegetation masked it was not a threat. To assist future commanders in avoiding this confounding situation, the map display was modified to show local line of sight graphically.

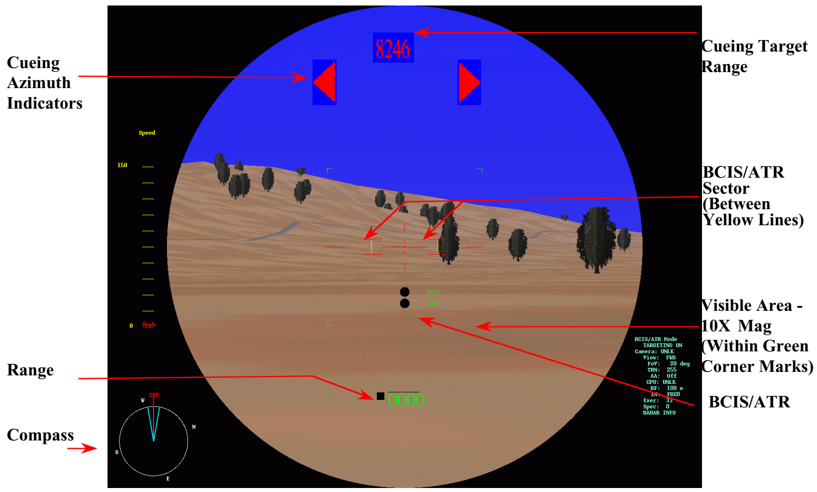


Figure 6. — Commander s Systems:Cueing

• **Application of tracking concepts (Kalman filter) to reduce the latency of reported friend SA data.**

Network and communication delays in the FBCB2 system introduce latencies in the reported position of friendly forces. To the degree that vehicles move in a relatively consistent way it is possible to apply Kalman filter techniques to predict future location as a hedge against FBCB2 latencies. A terrain module that constrained the predicted future location of a vehicle to feasible terrain modulated the Kalman filter prediction of future location.

• **Postulated ATR capabilities for the tank's FLIR system that provided non-cooperative friend, enemy, unknown target identification.**

A postulated FLIR based ATR system was introduced into the experiment as an additional aid in target identification. This system was credited with a representative capability to automatically identify friend, enemy, and unknown vehicles based on FLIR imagery. Note that the BCIS can only identify friend or unknown; however, the BCIS is significantly more reliable. Thus the concept explored was whether ATR, in conjunction with a BCIS to minimize the possibility of fratricide, could improve combat effectiveness.

• **Externally derived combat intelligence: ASAS**

As described earlier, ESA data was generated with a latency that approximated that expected from the ASAS system at Brigade. ASAS intelligence was always available to the commander. When TUAV derived combat intelligence was available it was displayed on the Situation Display with a different icon so that the tank commander could readily distinguish between the two data sets.

• Externally derived combat intelligence: TUAV

For this experiment, the TUAV was assumed to be equipped with a multisensor capability that consisted of an MTI radar (credited with a track/wheel classification capability) and a scanning BCIS interrogator. This system provided information as to the location of friends (both moving and stationary) based on BCIS responses (location and ID). In addition it reported all moving targets within the area of coverage (radius of approximately 15 KM). The UAV information was transmitted to a workstation at which unknown targets were selected and passed to the tank commander's display.

E. Virtual Sensor" Experiment Overview

To this point the discussion has been focused on a critical combat intelligence shortfall – lack of near real time intelligence for ground combat platforms - and an approach to resolve it.

Since the "Virtual Sensor" concept breaks new ground relative to the tasking and delivery of intelligence data directly to the warfighter it was thought to be useful to gain some insight the operational payoff of the proposed concept in a virtual experiment. More specifically, in support of the PM Combat Identification, MITRE conducted a man-in-the-loop virtual experiment to evaluate improved concepts for the integration of Target Identification (TI) with Situation Awareness (SA) information.
This experiment can be thought of as providing an initial assessment of the operational utility of a "Virtual Sensor" concept.

Figure 7 illustrates the tactical scenario used to support the GITIS experiment. The scenario was developed by the Army 's TRADOC Analysis Center at the White Sands Missile Range, New Mexico (TRAC-WSMR) and was designed to be a challenging tactical scenario relative to fratricide. As shown, a U.S. Scout platoon (the gray icon in the middle right of the picture) is returning to its own force location closely followed by a threat force. As the unit returns, ample opportunities for fratricide occur. Friendly position data on the Scout force is provided to other U.S. forces in the area via the FBCB2 system.

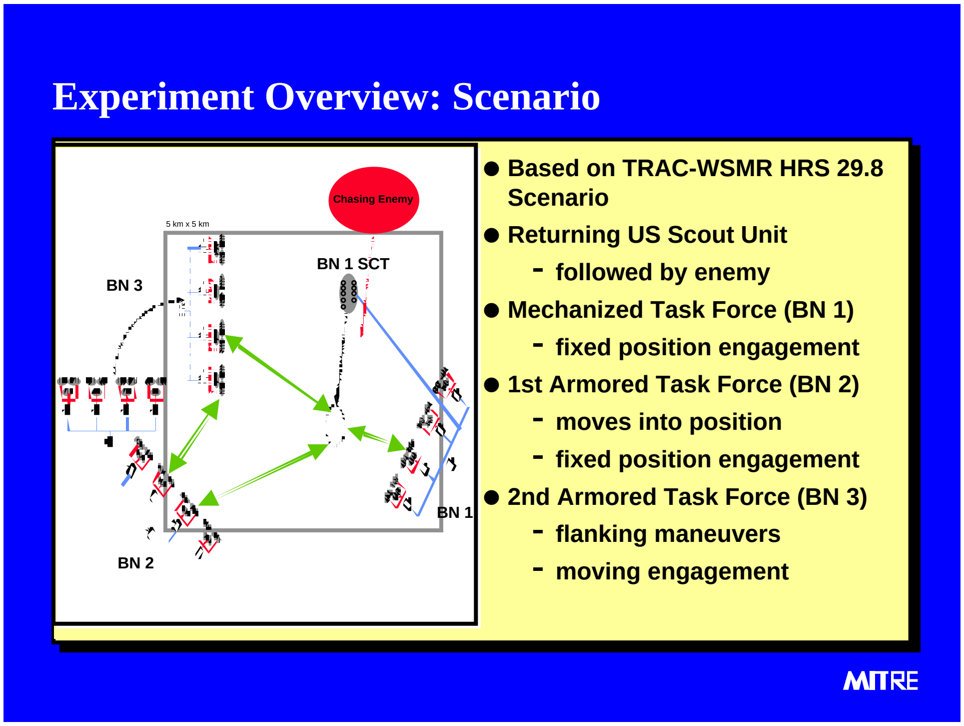
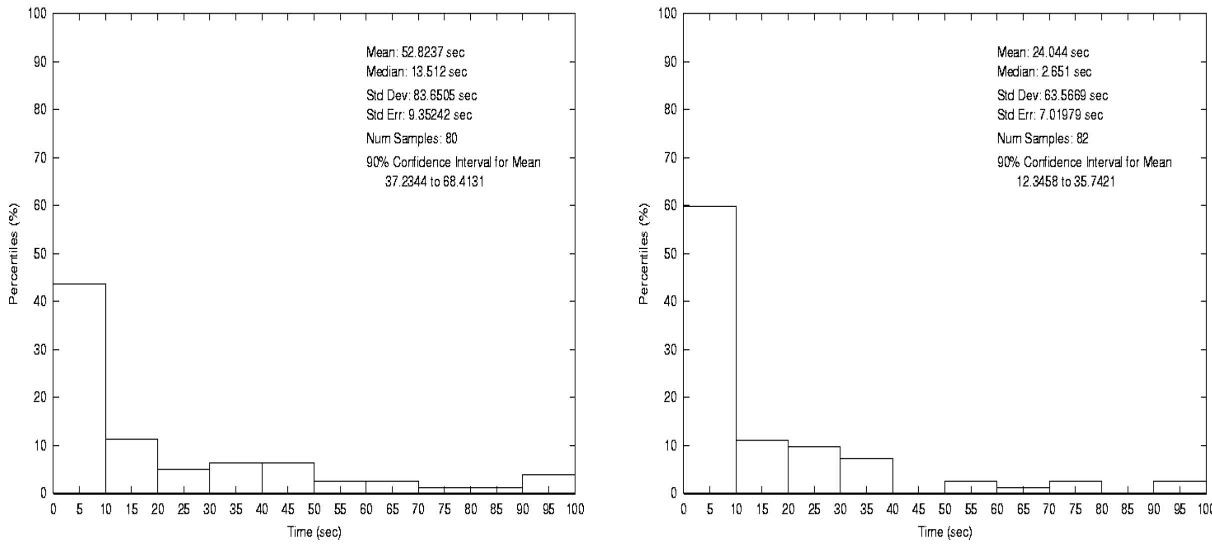


Figure 7. 0 –Experiment Overview: Tactical Scenario

EXPERIMENT RESULTS: TUAV MTI/ATR/BCIS and Cueing

The first metric used to analyze the effects of MTI was the line-of-sight (LOS) target acquisition time. The LOS target acquisition time was measured from the time the crew first had line-of-sight to a vehicle until the gunner aligned his sight with the vehicle. This value was only computed for the first vehicle the gunner acquired for every run. Figure 8 shows the percentile distribution of the LOS target acquisition time without MTI/Cueing and with MTI/Cueing. Without MTI/Cueing the LOS target acquisition time is less than10 seconds in 43% of the cases, with a mean acquisition time of 52.8 seconds. Whereas with MTI/Cueing the LOS target acquisition time is less than 10 seconds in approximately 60% of the cases, with a mean acquisition time of 24.04 seconds. When the TC received MTI data on his situation display, the TC knew the location of moving targets and was able to indicate that location to the gunner. In many cases the TC cued the gunner to the location of the enemy vehicles and the gunner scanned that sector until the enemy appeared. Often, the gunner spotted the vehicles just as they entered his line-of-sight. Without MTI/Cueing, the TC and gunner relied on enemy SA data (which was often several minutes old) and terrain features to determine the location of the enemy.

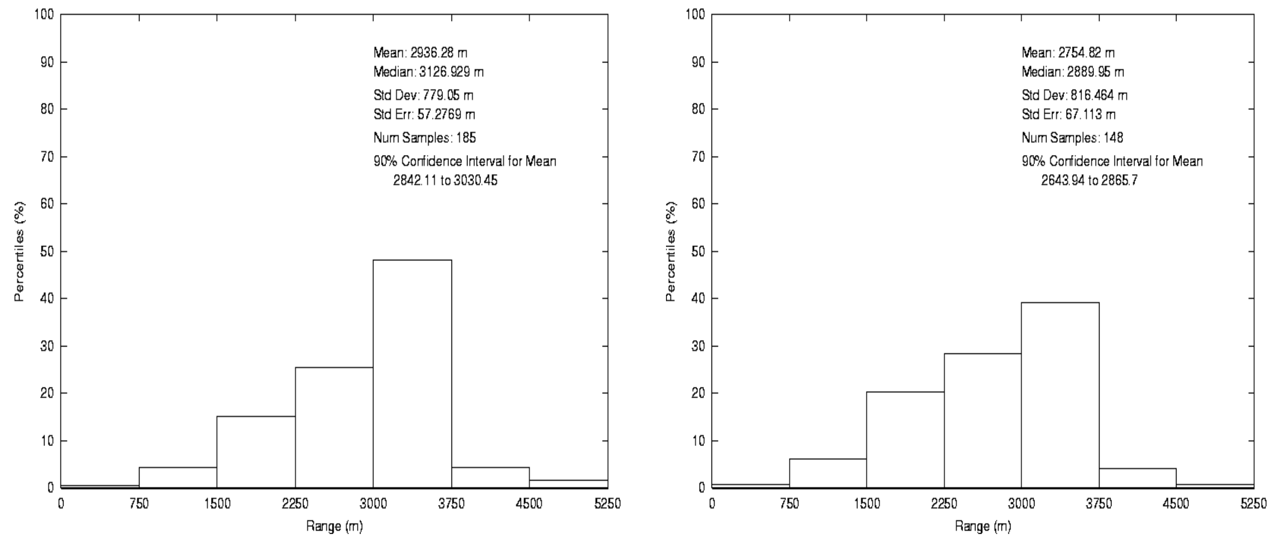


(a) **(b)**

Figure 8. Target Acquisition Given LOS
a) without MTI/Cueing b) with MTI/Cueing

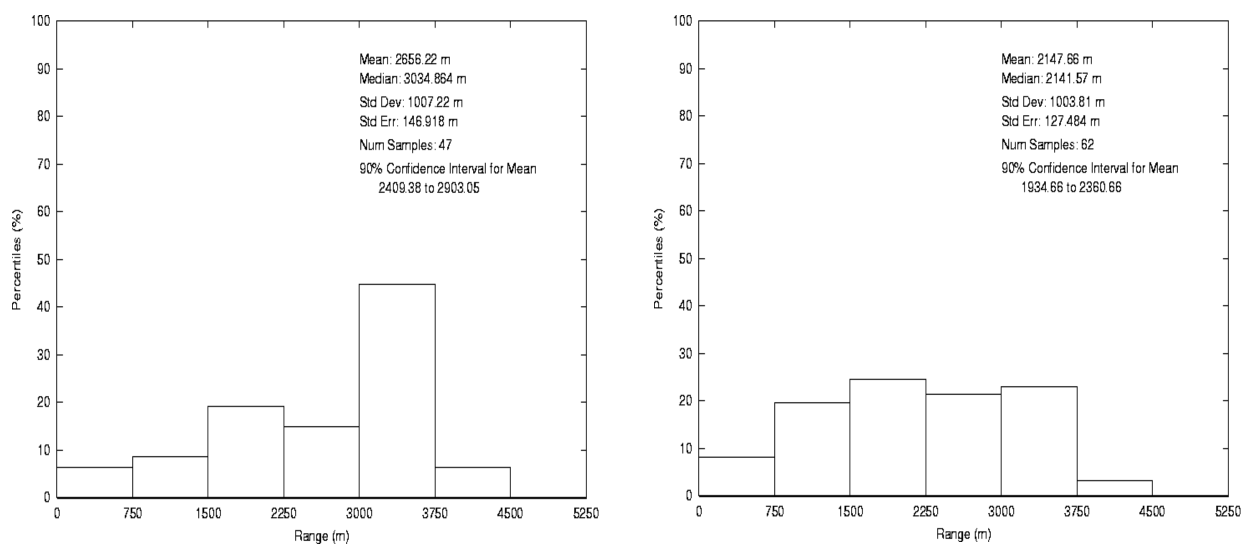
Another metric used to evaluate EC effectiveness was the range at which the crew first fired on each enemy platoon. The firing range of the tank was approximately 3500 meters; therefore most of the crews waited until the enemy was within 3500 meters to fire. We found that the crews were more aggressive when they had the MTI data. With MTI data, the crews had a better idea of the location of the enemy vehicles. As a result, the often moved towards the enemy vehicles rather that staying in their initial location for stationary scenarios or following the specified path for moving scenarios. Because the crew moved towards the enemy, they engaged the enemy at closer range.

Figure 9 shows the percentile distributions of the range at which the gunner first fired on the every enemy platoon with and without MTI data for a stationary scenario. Without the MTI data, the mean firing range was 2936.28 meters. With MTI, the mean firing range was 2754.82 meters. This difference is due to the fact that in some of the stationary runs with MTI, the crew moved towards the enemy vehicles or repositioned themselves based on the MTI data rather than remaining in their initial position. This effect is even more pronounced in the moving scenarios. In the moving scenarios, if the TC received MTI data, the crew usually moved towards the potential hostile location indicated by the MTI icons. In moving scenarios without MTI, the crew usually followed their assigned path. Figure 3 shows the percentile distributions of the range at which the gunner first fired at the enemy with and without MTI data for a moving scenario. In the runs without MTI, in approximately 45% of the cases, the crew engaged the enemy between 3000 and 3750 meters with a mean range of 2656 meters. In the runs with MTI, the crew only engaged the enemy at a range of 3000 to 3750 meters approximately 23% of the time, with a mean range of 2147.55 meters.



(a) **(b)**

Figure 9. Firing Range in Stationary Scenarios
(a) without MTI
(b) with MTI



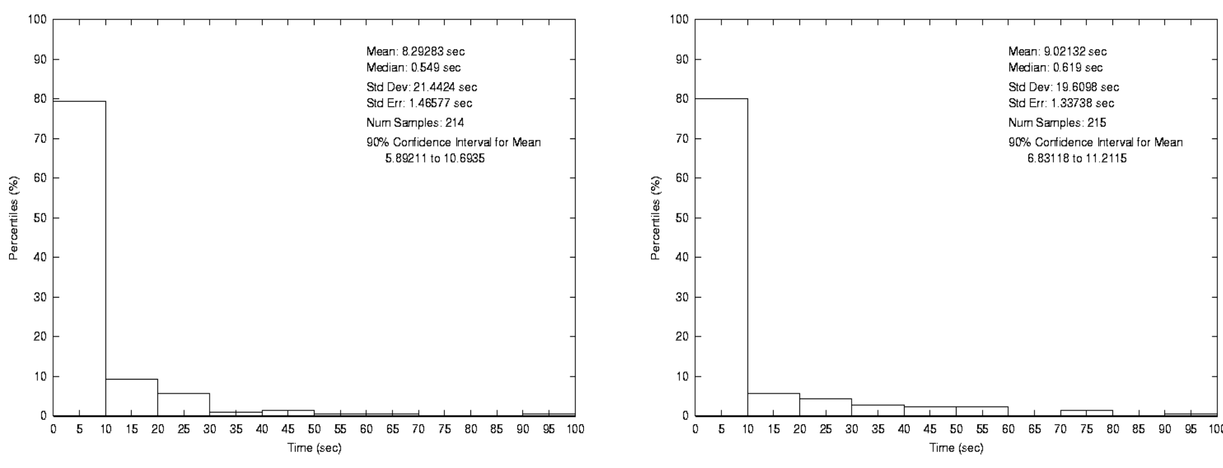
(a) **(b)**

Figure 10. Firing Range in Moving Scenarios (a) without MTI (b) with MTI

In general, the feedback from the participants through questionnaires and discussions was positive with regards to MTI/Cueing. The participants believed MTI/Cueing allowed them to acquire targets faster. MTI/Cueing gave them an improved picture of the battlefield, as they knew the location of moving targets and in which direction the targets were moving. They also believed the knowledge of the location of the enemy allowed them to maneuver into a better position. The crews also felt the BCIS data supplied with the MTI icons (color coding of friendly and unknown) was very useful. They knew which targets to concentrate on. The feedback on the ATR identification of the moving targets as tracked or wheeled was mixed. Some of the participants indicated that the ATR was useful because it gave the crew a better idea of how dangerous the threat was. Others felt the ATR information was not reliable and they ignored it.

Target Identification Systems – BCIS and BCIS/ATR

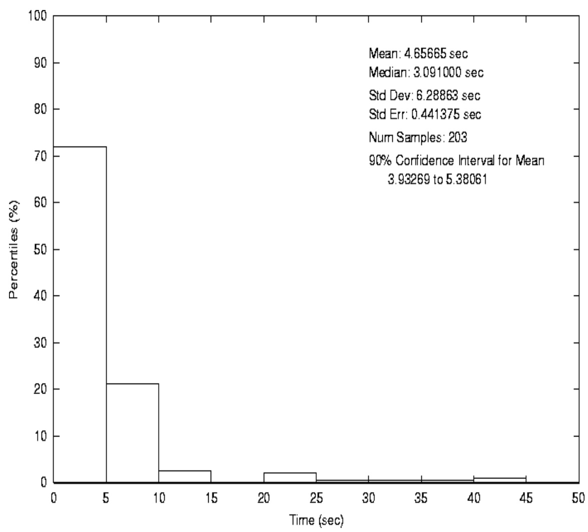
For this experiment, target identification time and identification to engagement time were the measures used to evaluate the effectiveness of the BCIS and the BCIS/ATR system configurations. Target identification time was measured as the time from the first interrogation of a vehicle until the last input from either the TI or the Cueing systems prior to firing. Figure 11 presents two histograms of the percentile distribution of the target identification time for a) the BCIS only runs and b) the BCIS/ATR runs. There is a small difference in the target identification times for BCIS versus BCIS/ATR. The mean target identification time for BCIS/ATR is 9.02 seconds versus 8.29 seconds for BCIS. From the figure, there are slightly more target identifications times between 0 – 10 seconds with BCIS/ATR than with BCIS. But there are also more long target identifications times for BCIS/ATR (greater than 20 seconds). In these cases the crew performed multiple BCIS/ATR queries.



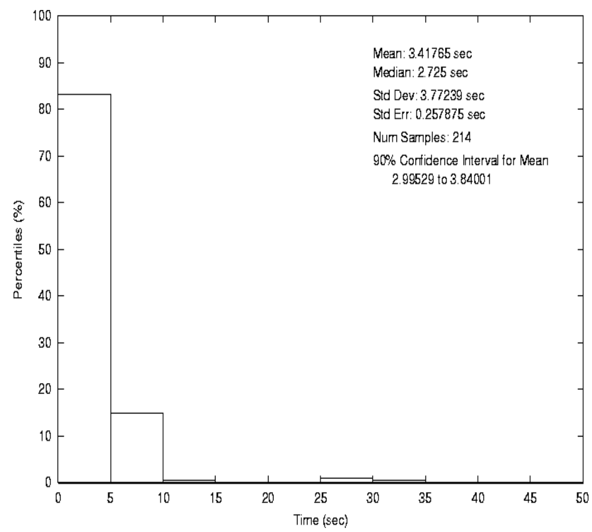
(a) **(b)**

Figure 11. Target Identification Time
a) BCIS
b) BCIS and ATR

Figure 5 presents the percentile distribution of the identification to engagement time for BCIS versus BCIS/ATR. Identification to engagement time was measured as the time in seconds between the receipt of the last target identification response and the time at which the gunner fired at the target. The identification to engagement time with BCIS/ATR was shorter than with BCIS. With BCIS, the mean identification to engagement time was 4.65 seconds, yet the mean identification to engagement time was 3.42 seconds for BCIS/ATR. In addition nearly 83% of the identification to engagement times for BCIS/ATR were between 0 and 5 seconds, whereas approximately 72% of the identification to engagement times for BCIS were between 0 and 5 seconds. It appears that BCIS/ATR may slightly increase the target identification time, but it decreases the identification to engagement time. This implies that providing ATR data to the crew, in addition to BCIS, increased their confidence that the targets were threats, thus decreasing the identification to engagement time.



(a)



(b)

Figure 12. Identification to Engagement Time
a) BCIS
b) BCIS and ATR

The ATR TI System received mixed reviews from the participants. Some of the participants found it useful because it provided an enemy identification. The ATR enemy identification, when combined with BCIS, increased their confidence that the target was an enemy. Despite this positive result they indicated that ATR accuracy should be improved. Other participants were more critical. They indicated that BCIS was a more reliable and useful system. Some participants felt that ATR increased identification time and also caused hesitation, especially when there was a BCIS unknown result and an ATR friendly result. One participant believed that the addition of ATR was unnecessary and overloaded the gunner with information. He indicated that BCIS alone was perfect.

CONCLUSIONS

The concept of having a TUAV provide data directly to a ground weapon platform has been assessed in a man-machine experiment using Army M1A1 crews. Results of the experiment established that such a concept could greatly improve the combat effectiveness of ground combat weapon platforms. Using the simulated UAV equipped with an MTI radar, an ATR capable of distinguishing tracked from wheeled vehicles, and a BCIS for positive friend/unknown identification, significant improvements in combat effectiveness were quantified. The time between an enemy vehicle having line of sight to target and the tank gun rotating to the enemy was cut by over half, from 52 seconds to 24 seconds. In a combat situation, that is a critical factor. Another key metric was the distance to the target when the gun was fired. Having the UAV data available allowed the crews to adopt more aggressive tactics. Rather than waiting for the enemy to appear, the tank was able to maneuver toward the enemy, find a better firing location and gain the tactical advantages of time and terrain.

· FUTURE PLANS

The GITIS experiment was quite successful in quantifying the value added of "raw" but near real time intelligence data to ground combat vehicle crews. Crews had little or no difficulty in integrating "raw" and processed intelligence data. Feedback from the M1A1 crews has identified other areas in which further improvements in system performance can be sought. For example, it was suggested that it would be very useful for the tank platoon leader to know which targets in a multi-target environment other members of the platoon are engaging. Displaying laser-ranging icons on the situation display to show weapon-target pairing is one approach to meet this objective. This information would assist in minimizing multiple engagements of the same target while avoiding the "cost" of not engaging other targets.

Since tanks seldom operate on an individual basis on the battlefield the next logical step in this analysis process would be to increase the scope of the experiment to that of a tank platoon (four vehicles) to further assess the utility of integrated SA and TI system concepts. It is anticipated that the concept of a direct link from a TUAV to ground weapon platforms will remain as the central element of any future GITIS investigation.