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The Potential Value Added from the Employment of the Heterogeneous Airborne Reconnaissance Team (HART) System to Operational Effectiveness

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The Potential Value Added from the Employment of the Heterogeneous Airborne Reconnaissance Team (HART) System to Operational Effectiveness

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PREFACE

This Institute for Defense Analyses conducted a study for the Program Manager for the Heterogeneous Airborne Reconnaissance Team (HART) within the Information Processing Technology Office of the Defense Advanced Research Projects Agency (DARPA) under task DA-1-2614. The task deliverable to DARPA was two working papers. This publication was created and funded by IDA's Central Research Projects to document the analyses for future use of IDA researchers.

The project team is pleased to acknowledge the insightful and constructive guidance provided by the IDA Review Committee. The committee was chaired by Dr. Steve Warner, Director of IDA's System Evaluation Division, and included Mr. Joshua A. Schwartz, Mr. Scott E. Shaw, and Ms. Jennifer J. Yopp.

The project team also acknowledges the contributions of Northrop Grumman Corporation personnel directly involved in the development, testing, and evaluation of the HART system. We also thank personnel assigned to the Army Combined Armor Center for reviewing the brigade-level battlefield scenarios used to underpin our analyses of the HART. Lastly, our interactions with operators previously assigned to combat units in Iraq provided important insights into the command of unmanned air vehicles in theater and the dissemination of video and imagery products.

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Appendixes

EXECUTIVE SUMMARY

Enhancing the reconnaissance, surveillance, and target acquisition (RSTA) services provided directly to low-echelon units, at company level and below, operating in complex battlefield environments, may in turn improve the operational effectiveness of those units. On behalf of the Defense Advanced Research Projects Agency (DARPA), IDA conducted a task[1] to assess the degree to which the Heterogeneous Airborne Reconnaissance Team (HART) system delivers those services depicted in Figure ES-1.

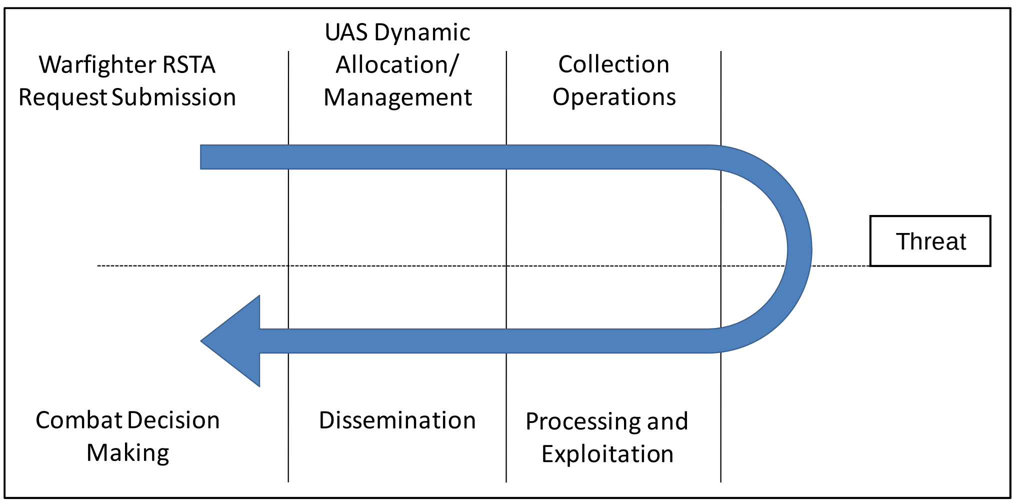

Figure ES-1. RSTA Cycle Supporting Real-Time Combat Decision Making

The IDA study strived to meet two overall objectives. First, we described possible employment scenarios suitable for integrating DARPA's HART system concept into Army and Air Force unmanned air system (UAS) operations. The five, exemplary brigade-level scenarios developed by IDA illustrate the RSTA support provided by UAS assets across a range of military operations. Each of the scenarios performs the following functions:

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1 This Institute for Defense Analyses conducted a study for DARPA under task DA-1-2614. The task deliverable to DARPA was two working papers. This publication was created and funded by IDA's Central Research Projects to document the analyses for future use of IDA researchers.

- Establishes initial battlefield conditions that depict all units within the brigade-assigned UAS assets, as well as division-level and echelon above division (EAD) UAS assets allocated to support brigade operations
- Disperses company-level and above units across the brigade's area of responsibility (AOR) in a credible fashion
- Appropriately sizes the brigade's AOR based on the type of military operation
- Realistically injects multiple events that will lead commanders to retask UAS assets.

These scenarios form a suitable framework for meeting our second overall objective: assessing how HART contributes to the operational effectiveness of a collection of UAS assets. We developed an analytical framework for quantatively and qualitatively exploring the value added by HART, which takes into consideration the UAS tactics, techniques, and procedures (TTPs) adopted during real-world operations in Iraq and Afghanistan. Our assessment shows that HART has the potential to enhance UAS performance and capabilities, based on planned performance capabilities related to UAS reallocation, coordination, and control; target location accuracy; and imagery dissemination. Specifically we assessed HART has the potential to:

- Shorten control and coordination timelines associated with dynamic retasking of UAS assets from the 10 to 15 minutes currently experienced by warfighters
- Enhance the ability to shift collection activity and capture specific images required by the warfighter, by eliminating the need to "talk on" the UAS using imprecise voice communications
- Reduce the data latency for those disadvantaged ground forces below company level currently unable to receive direct video feeds from UAS flying overhead in near-real time
- Enable crews flying fixed-wing tactical aircraft (TACAIR) platforms to gather situational awareness before arriving over the target area by delivering imagery from Air Force and Army UAS directly to the cockpits of those strike platforms, offering an enhancement over current capability
- Provide wider and faster access to previously collected, still timely, mission data through integration of image compression, storage, and archiving and video mining and searching technologies and techniques
- Potentially improve fire support mission effectiveness by enabling less restrictive control of combat aircraft engaged in close air support; improve

first-round impact performance of ground-based fire support systems; and allow forces to more fully exploit the use of GPS-guided smart munitions.

The HART system is still under test and development, and IDA did not conduct a review of the system's technical and performance specifications. We also did not observe any of the developmental live and simulated flight exercises. DARPA reports of the capabilities demonstrated to date during live flight exercises include: automated task management, automated flight path and sensor planning, automated airspace deconfliction, imaging of designated targets and dissemination of live full motion to HART handheld laptops. The range of platforms included during those live flight exercises included the Raven and Shadow UAVs.

The basic system concept includes a handheld interface through which users initiate an unambiguous request for RSTA services. A HART command and control center (HC3) collects and prioritizes those requests based on priority battlefield situations, such as troops in contact, and information needs as established by operational commanders. The HC3 interfaces with the airborne platforms native controllers and battle management airspace control, coordination, and deconfliction systems. Upon completion of the data collection mission, the information flows from the airborne ISR platform, through its native transceiver and is routed by the HC3 back to the warfighter using available battlefield communications.

This study assumes that the technical and operational goals and challenges of the HART program can be achieved and focuses on the implications for operational effectiveness.

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I. INTRODUCTION

The Heterogeneous Airborne Reconnaissance Team (HART) system, designed by the Defense Advanced Research Projects Agency (DARPA), is intended to integrate the control and output of a collection of unmanned air systems (UASs) in order to enhance the reconnaissance, surveillance, and target acquisition (RSTA) services provided directly to small unit leaders, at company level and below,[1] in complex battlefield environments. More specifically, the HART system has potential to provide troops on the ground with the following:

- Access to additional imagery from all unmanned air vehicle (UAV) platforms in the area, from the Raven to the Warrior
- Access to target coordinates from geo-registered imagery with a 10-meter target location error (TLE) or better
- Ability to assist in coordination of tasking and retasking Army and Air Force RSTA assets in the area
- Ability to rapidly provide targeting information and imagery to Army and Air Force command and control, attack, and fire-support assets.

DARPA asked IDA to identify and assess the potential contributions of HART to military operations. The IDA effort assumes that the above technical goals of the HART program can be achieved and focuses on the implications for operational effectiveness. To meet the goal of this task, we had to understand current Army and Air Force tactics, techniques, and procedures (TTPs) for using UAS to conduct RSTA support. IDA also identified a range of missions and scenarios for exploring HART's potential of improving operational effectiveness.

Following this introduction is a summary of the Army and Air Force service-specific and joint concepts of operations (CONOPs) for the employment of UAS. This CONOPs summary is followed by a discussion of issues leading to ineffective

[1] A discussion on the information needs of units at company level and below is presented in Appendix A.

employment of UAS that HART attempts to address and mitigate. The next section then presents, in a top-level manner, how HART could be integrated into the RSTA-related missions. The subsequent sections contain our detailed assessments of the potential value added by HART to operational effectiveness.

II. ARMY AND AIR FORCE APPROACHES TO UAS ASSIGNMENT AND ALLOCATION

Combat operations in Iraq and Afghanistan have demonstrated to the Army that warfighters need a capable UAS that performs RSTA in direct support of ground commanders. Operators contend that centralized control of an asset with the scheduled predictability of UAS allocation does not operationally support ground commanders given the limited time available to reduce risk appropriately to ground forces in the tactical dynamic battlespace.[2]

The Air Force, on the other hand, has supported centralized control of forward-based UAS assets from the United States using satellite links in a concept called "remote split operations." The Air Force contends that the Army approach would allow some unmanned aircraft to remain idle. In addition, the Air Force conducted a demonstration of its remote split operations concept with an Army Shadow UAS. The Shadow was launched via a ground control station at Fort Belvoir and was flown by operators located at the Naval Air Weapons Station in China Lake. Although feasible, the Army does not support the remote split operations approach for its UAS assets because of commanders' concerns of missions getting "short shrift" in the apportionment process, coupled with a cumbersome dynamic retasking request and approval process.

A. ARMY UAS ASSIGNMENT AND ALLOCATION

The Hunter and Warrior Alpha UAS, and the Hunter planned replacement, a derivate of the Predator UAS called the Extended Range Multi-Purpose (ERMP) UAS, provide RSTA, communications, and target attack capabilities at the Army division level and below. The Shadow tactical UAS (TUAS) provides an organic tactical RSTA capability at the brigade level and below. Shadow UAS platoons are typically organic to a brigade-sized unit such as an infantry, heavy or Stryker Brigade Combat Team (BCT) or to a fires brigade. When equipped with a Communications Relay Package, the

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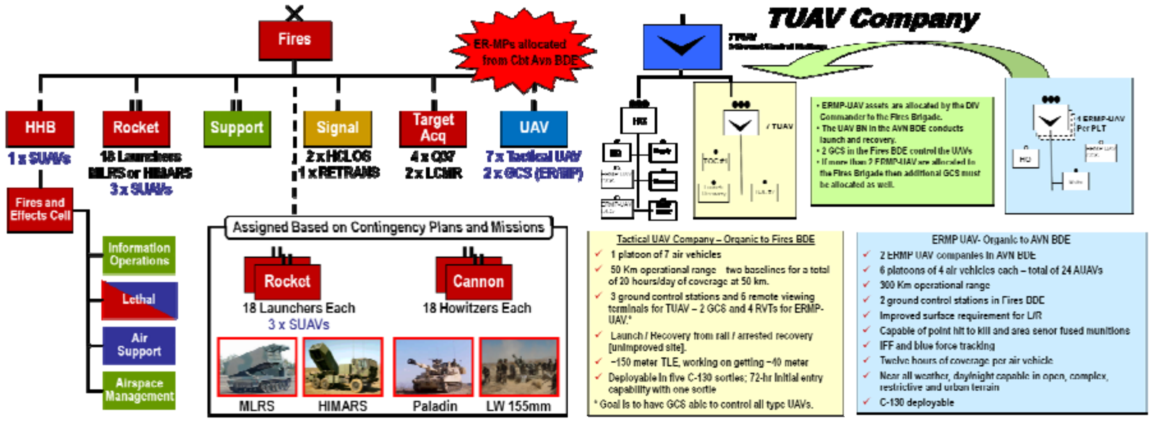
2 "Army Unmanned Aircraft Systems Decisive in Battle" by Jeffrey Kappenman (*Joint Forces Quarterly*, Issue 49, 2nd Quarter 2008).

Shadow enables long-range communication, up to 200 km, between ground or aviation forces.[3] Figure 1 shows a notional Fires Brigade organization with direct support unmanned air assets. The figure shows that ERMP assets may be allocated by the division commander in direct support to a major subordinate command (MSC) such as a BCT or fires brigade.



Source: U.S. Army Field Artillery Center

Figure 1. Fires Brigade UAS

Shadow UAS platoons are manned and equipped in a manner to enable employment of split-site operations. The mission planning and control site (MPCS) receives tasking from the supported unit, plans the mission, takes control of the unmanned aircraft during the actual conduct of the mission, and receives the imagery transferred from the air vehicle. To maximize real-time or near-real-time flow of information to supported unit commanders, the MPCS is typically collocated at the supported unit's tactical operations center or forward command post. The UAS platoon sets up a launch and recovery (L/R) site in the supported unit's rear area.

Normally a Shadow TUAS platoon provides direct support to its brigade. But during operations in Iraq, the Army developed an ad-hoc CONOP for employment of the Shadow TUAS in response to the stability and security operations mission tasked to U.S. forces within a fairly concentrated area. Because several brigades were operating in a multinational division area of responsibility (AOR), the Army consolidated all Shadow

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[3] "25th Unmanned Aerial Systems Company Always Watching Over the Iraqi Skies" by Col A.T. Ball (*NewsBlaze*, October 4, 2007

platoons into one central launch, recovery, and maintenance site. The air vehicles launched from this central site were not necessarily restricted to operate only within the AOR of the brigade to which the Shadow platoon was organizationally assigned, but were operated in accordance to the airspace priority,[4] dictated by the division commander based on the threat and the benefit UAS coverage would provide.

The effective control, coordination, and deconfliction of UAS operations at the brigade level is possible due to the presence of the brigade aviation element (BAE), which provides a 24-hour capability to plan and synchronize aviation operations and perform Army airspace command and control (A2C2).[5] The battlespace management systems assigned to the BAE include the Tactical Airspace Integration System (TAIS), a digitized decision support system that automates A2C2 planning and operations. The BAE coordinates directly with the A2C2 element at division level for detailed mission planning for aviation assets, including UASs.

The Army's Raven small UAS (SUAS) provides a situational awareness system to commanders at the battalion level and below. No A2C2 element is assigned to those lower-level units. The battalion operations officer has overall responsibility for coordinating, deconflicting, and managing airspace within the battalion's AOR. However, the battalion depends on the brigade BAE for airspace command and control throughout the brigade battlespace. The procedure undertaken to plan, request, and receive approval of a SUAS mission is shown in Figure 2.

Battalions have the option of leaving Raven control at the company level or directing some or all Raven operations centrally. Currently centralized control of Raven operations is not typically ordered because of the Raven's limited operational range and duration. The asset, flown remotely or by GPS waypoint navigation, is used primarily by platoons or other small units to develop situational awareness and understanding. Ravens have also been used by Navy SEALs to support airborne strike missions by F/A-18F aircraft. The Raven initially acquired the target and its video was used to generate a target location. The imagery was embedded into a Joint Tactical Airstrike Request,

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4 *Unmanned Aerial Vehicles Show Battlefield to Soldiers* by Pfc April Campbell (American Forces Press Service, 14 Jan 2008).

5 *U.S. Army Aviation: Balancing Current and Future Demands* (USA, 9 January 2008) and FMI 3-04.155, *Army Unmanned Aircraft System Operations* (Department of the Army, April 2006).

which was transmitted to the fighters. The F/A-18F targeting pod was then automatically cued onto the target allowing the pilot to confirm the target detected by the Raven.[6]

According to the Department of the Army, the Service's UAS strategy "embraces the principle of modularity to create more adaptable, flexible, robust and reliable organizations, which are better able to operate within dynamic, complex and unpredictable environments." The elements of this strategy include:

- Soldier/operator
- One System Ground Control Station (OSGCS)
- One System Remote Video Transceiver (OSRVT)
- Raven
- Shadow
- ERMP.

HART implementation has the potential of becoming another element of this modular strategy and provide operational benefits at all three Army echelons of command supported by UAS assets.

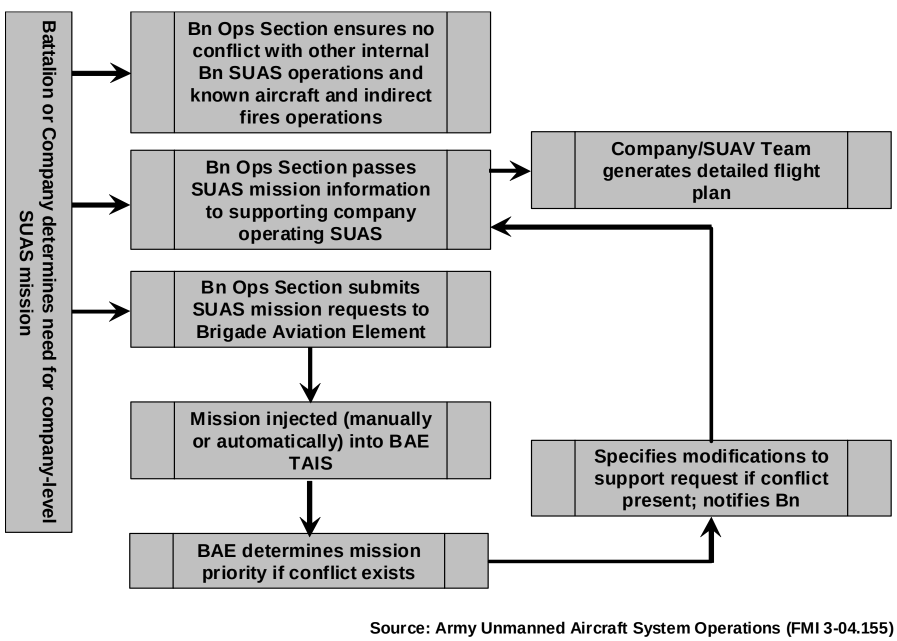

Figure 2. Battalion Ad-Hoc C2A2 Process

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6 "Mini-UAVs Rack Up Big Gains" by David Eshel (*Defense Technology International*, 15 May 2008).

B. AIR FORCE UAS ASSIGNMENT AND ALLOCATION

The Air Force stood up an UAS wing totally dedicated to operating the MQ-1 Predator[7] and the MQ-9 Reaper UAS in May 2007 at Creech Air Force Base, NV. The wing was later designated as the 432nd air expeditionary wing (AEW) by the Air Combat Command (ACC) in May 2008. The wing includes two operational Predator Reconnaissance Squadrons—the 15th and 17th squadrons stationed at Creech Air Force Base—tasked to provide theater commanders with deployable, long-endurance, near-real-time RSTA in support of warfighters. The AEW includes the 42nd Attack Squadron, also stationed at Creech AFB, which operates the Reaper UAS.

Since 2005, the Air National Guard has stood up Predator and Reaper squadrons. Predator air patrols are flown by Air Guard units in California, Arizona, North Dakota, and Texas. The New York Air National Guard operates a Reaper squadron. In August 2008, the Air National Guard reported that guard units were flying a third of the Predator UAV air patrols in Iraq and Afghanistan.[8] Today, guard aviators and the active-duty Air Force UAS wing collectively deploy 78 MQ-1 and 19 MQ-9 assets to maintain 39 around-the-clock overseas air patrols.

The Air Force also operates the RQ-4 Global Hawk UAS―a high-altitude, long-endurance ISR collection platform. Three deployed RQ-4 assets maintain one overseas combat air patrol (CAP). The Predator, Reaper, and Global Hawk UAVs have been integrated to the HART System during testing and demonstration.[9]

The Air Force Predator and Reaper assets flown in the U.S. Central Command (CENTCOM) AOR are tasked by the Combined Force Air and Space Component Commander (CFACC). The Predator and Reaper UAVs are launched and recovered in-theater by forward-deployed teams. The aircraft are piloted in theater for takeoffs and landings because of a 2-second time delay in satellite transmissions. Once airborne, ACC crews actually fly combat missions over Iraq and Afghanistan using ground control stations located in CONUS, primarily at Creech Air Force Base, NV, and Cannon Air Force Base, NM. The average duration of Predator sorties in theater is 20 to 22 hours,

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7 The Air Force changed the Predator system designation from "RQ-1" to "MQ-1" in 2002 to reflect the addition of the armed reconnaissance role to the platform.

8 *Pushing Horizons* by William Matthews (National Guard, August 2008).

9 *You Gotta Have HART: Northrop Gramman Develops ISR Aircraft Control System* (Defense Industry Daily, 17 Feb 2010).

and crews work in shifts that last more than 10 hours. Predator and Reaper pilots are typically logged on to multiple web pages to track weather, to read the latest intelligence reports, or to view grid overlays of maps. Pilots also connect to chat rooms to talk to airspace coordinators in theater and forward observer troops on the ground.[10]

For operations in Iraq, a certain number of Predator and Reaper CAPs flown by ACC are apportioned to Multi-National Force–Iraq. Through Multi-National Corps–Iraq (MNC-I), those patrols are further allocated to the various major MSCs, which can typically rely on a specific time block of a given Predator or Reaper CAP and schedule the asset to cover missions in accordance to the unit's operational priorities. The objective is for the MSC to cover as many preplanned ISR missions as possible based on known Predator or Reaper allocation.[11]

To dynamically retask a CFACC CAP asset supporting another MSC requires approval from MNC-I (who must weigh priorities between the two units) and the Combined Air Operations Center (CAOC). Even shifting an allocated CFACC asset between MSC missions requires approval from both MNC-I and the CAOC. When compared to retasking Army division assets between MSCs or within an MSC, CFACC assets require an additional level of approval.

C. ARMY AND AIR FORCE JOINT UNMANNED AIR SYSTEMS CONCEPT OF OPERATIONS

Despite those differences in UAS assignment and allocation philosophies, the Army and the Air Force have agreed on a new joint CONOP for the use of UAVs in a joint theater. The joint CONOP stipulates that high-altitude, strategic UAV missions conducted by unmanned aircraft such as the Global Hawk will be controlled by the Air Force. The Army will control tactical UAV operations flown at altitudes under 10,000 feet. The CONOP further states that information collected during medium-altitude missions flown by both Services[12] will be made available to all users and broadcast over a common data dissemination network. In addition, the two Services had to agree on an

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[10] "Predator Ground Stations Need Redesign, Say Pilots" by Grace V. Jean (*National Defense Magazine*, August 2008).

[11] "Control of Theater Intelligence, Surveillance and Reconnaissance for the Ground Commander" by Maj Steven Maceda, USAF (*Air and Space Power Journal*, Winter 2008).

[12] The Air Force flies the Predator and Reaper unmanned aircraft and the Army operates the Sky Warrior and Shadow UASs.

approach for dynamic retasking—how to satisfy requests that divert existing missions to new target priorities. In other words, how should a medium-altitude UAV already in flight and conducting a dedicated Air Force mission become retasked to an urgent Army request or vice versa?

According to a multiservice TTP for the tactical employment of UAS, the potential operational payoff as a result of dynamic retasking should be carefully considered before undertaking the necessary rapid planning and approval steps. Because of the reduced station time allocated per objective,[13] implementing dynamic retasking can degrade the original mission while providing incomplete or less critical information during the retasked mission.

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13 AFTTP(I) 3-2.64—*Multi-Service TTP for the Tactical Employment of UAS* (Air Force Doctrine Center, August 2006).

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III. ISSUES LEADING TO INEFFECTIVE EMPLOYMENT OF UAS

Despite achieving a joint CONOP for UAS operations in a joint theater, a number of inefficiencies remain in the operation of Air Force and Army UAS, which HART is intended to address.

A. INABILITY TO RAPIDLY EXPLOIT AIRBORNE AND GROUND-BASED FIRES CAPABILITIES

Fixed- or rotary-wing strike platforms providing close air support (CAS) and ground-based artillery providing indirect fires often require a UAS to provide precise grid locations for targets. The multi-service TTP for tactical UAS divide UAS TLE into the six categories shown in Table 1. Consider the TLE required for the Excalibur guided, artillery round now being used by the Army in Iraq and Afghanistan. It has been reported that the Excalibur requires a TLE of 20 meters to defeat targets with fragmentary effects—30 meters to engage exposed personnel and 10 meters to strike lightly armored targets.[14]

Table 1. TLE Categories

TLE Categories	I	II	III	IV	V	VI
Meters Circular Error Probable	0 – 6	6 – 15	15 – 30	30 – 91	90 – 300	>300

Source: FM 3-04.15

The HART concept will provide a UAS targeting accuracy of 10-meters circular error probable (CEP) (CAT I) from all UAVs equipped with the sensors to provide the required target location accuracy, which will enable ground commanders to engage targets with both unguided and guided weapons systems. This increases the likelihood of first round hit on target during weapons engagements using the full range of UAVs to provide target location information.

[14] "Excalibur: Extended-Range Precision for the Army" by Maj Donny J Sprengle (ARNG) and Col Donald C. DuRant (USA) (*Field Artillery*, Mar-Apr 2003).

B. INABILITY TO SUPPORT OPERATIONAL WARFIGHTERS AT ALL ECHELONS

Current UAS tasking adheres to the principle that there is one user, supported commander or unit, per tasking (including a dynamic retask). This has led operational commanders to conclude that when executing fluid, high tempo battlefield operations, a highly centralized UAS bureaucracy is too slow and cumbersome to be tactically relevant. Therefore, the best possible employment option is to push more direct support assets to the lowest tactical level and increase available organic collections. By effectively integrating UAS assets into a team that is tasked as a pool of capabilities,[15] the HART concept has the potential to enhance ISR support to ground commanders by enabling the following capabilities:

- Involve the supported units in submitting statements of need for UAV support, whether or not those units are assigned organic UAV assets, and compile those requests to maximize UAS imagery intelligence (IMINT) collection and targeting opportunities while tasking, managing, and simultaneously controlling a limited number of in-theater unmanned airborne platforms.
- Incorporate a capability to effectively distribute tasking among the UAV assets operating in theater to meet stated warfighter information needs, based on UAV system characteristics, battlefield geometry such as the location of launch and recovery sites and ISR locations, UAS availability, and commander's information priorities.
- Provide a range of control options to fit the tactical situation from centralized to fully decentralized control of UAS to ensure planned tasks are correctly scheduled and conducted, including interfacing with the TAIS for effective airspace command and control and deconfliction.
- Enable the possibility for warfighters to insert dynamic task requests and reallocate UAV assets when the current tasking becomes irrelevant due to battlefield events or an in-use UAS is unable to complete tasking due to airframe or sensor failure.
- Leverage the planned Army and joint line of sight (LOS), beyond line of sight (BLOS), and satellite communications (SATCOM) in-theater communications architecture for providing secure ground-to-ground, ground-to-airborne and ground-to-satellite communications. This will enable HART to pass full

[15] *Heterogeneous Urban RSTA Team (HURT) Broad Agency Announcement* (BAA-04-05, DARPA, 5 December 2003).

motion video, captured video snippets, and still frame images to warfighters at various Army and Air Force echelons of command, including warfighters at company level and below, and into the cockpits of manned airborne strike platforms.

C. LACK OF SITUATIONAL AWARENESS PROVIDED BY CURRENT FULL MOTION VIDEO (FMV) AND IMAGERY PRODUCTS

Consider a situation in which a ground force commander intends to use a UAS to adjust artillery fire from a remote location instead of from an observer near the target area. For this application, the UAS allows the tactical operations center to see where the rounds impact and provides the opportunity to adjust fires accurately. According to the recently released multi-service TTP for employment of tactical UAS, the observer must use 0 or 6,400 mils as the direction for making corrections on subsequent rounds, as opposed to using observer-to-target direction since the UAS is constantly moving. During operations, if the remote video terminal used to view full motion video from the UAS does not have a north-seeking arrow, the observer may need to ask the UAS operator to assist with orientation if unable to orient by the visible terrain features of the imaged area. To address this issue, operators can use the Falcon View application to create "geo-location smart" video by integrating UAV video with geo-referenced overlays.[16] HART automatically provides stabilized, geo-registered imagery, including imagery derived from micro-UAVs and video to requesting units. HART also incorporates a video mosaicing capability to maintain persistent wide-area views.

D. LACK OF FMV OR IMAGERY REPOSITORY

The joint CONOP between the Army and Air Force stipulates that information collected during medium-altitude missions flown by both Services be made available to all users, broadcast over a common data dissemination network. During flight operations Predator and Shadow UAVs are collecting thousands of hours of video footage. In some instances, the areas of interest to maneuvering units may have been reconnoitered without the commander's awareness during scheduled Predator missions or missions flown by other unmanned and manned theater-level assets. The HART concept supports

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[16] *L-3 Communications' Video Exploitation and Management System Integrates with Military Mapping Software—Improves Situational Awareness Across the Battle Space* by Karen Johnson (L-3 Communications, August 2006).

information collected during all altitude missions, including small UAVs. Timely retrieval and dissemination of information to requesting units is enhanced by the creation and indexing of digital video archives, and the conversion of reconnaissance video footage to still-image representation.

IV. HART CONTRIBUTION TO UAS MISSIONS

To assess the potential contributions of the HART program to air and ground commanders, the program should explore how the Army and Air Force family of UASs conducts operations today and how HART could be integrated to enhance the effectiveness of RSTA operations. Before describing how HART may be integrated into the current UAS CONOPs, it's helpful to define terminology.

- *Reconnaissance* is a mission undertaken to obtain, by visual observation or other detection methods, information about the activities and resources of an enemy or adversary, or to secure data concerning the meteorological, hydrographic, or geographic characteristics of a particular area. (JP 1-02)
- *Surveillance* is the systematic observation of aerospace, surface, or subsurface areas, places, persons, or things, by visual, aural, electronic, photographic, or other means. (JP 1-02)
- *Screen* is a task to maintain surveillance; provide early warning to the main body; or impede, destroy, and harass enemy reconnaissance within its capability without becoming decisively engaged. (JP 1-02)

UAS operations often transition from a reconnaissance mission to a surveillance mission. For example, if during a reconnaissance flight a UAS locates three people leaving a known IED bombmaker residence by truck, the air vehicle may switch to performing surveillance to maintain contact with those persons of interest.

With regard to enhancing UAS operations, the HART program has set the following three capability objectives:

- *Persistence*—Plan and control the execution of cooperative unmanned aircraft
  - Support 24/7 operations
  - Multiple aircraft in flight simultaneously
  - Multiple users participating simultaneously
- *Agile Tasking*—Handle task allocation and coordination between multiple heterogeneous UAVs
  - Support multiple tasks with each platform
  - Automatically retask collection of low-quality images

  - Adherence to airspace management constraints
- Tailored Dissemination
  - Georegister all imagery
  - Vary compression to fit dissemination bandwidth
  - Blend electro-optic (EO) and infrared (IR) imagery at day/night transitions

A review of FMI 3-04.155, *Army Unmanned Aircraft System Operations, the Multi-Service Tactics, Techniques, Procedures for the Tactical Employment of Unmanned Aircraft Systems* (FM 3-04.15) and *The Air Force Tactics, Techniques and Procedures for the Tactical Employment of RQ/MQ-1* revealed several RSTA-related missions routinely conducted by current UAS .

A. MOVEMENT TO CONTACT

Movement to contact begins as a zone reconnaissance mission using a UAS asset. During the conduct of this mission, a UA is tasked to observe an area of interest to obtain combat information about enemy dispositions and actions. Once an enemy unit has been located, the UAS transitions to surveillance of the enemy contact, thus ending the zone reconnaissance mission. The surveillance continues, and the UAS asset is used at the supported unit's discretion to support a hasty attack—provide targeting location or designation or conduct a handover of the target to an airborne attack platform.

HART Persistence

HART would enable flying this zone reconnaissance/movement to contact mission while simultaneously facilitating one or more separate UAS assets to fly additional reconnaissance missions (route, area, or zone) within the same single unit-of-action (battalion or brigade) operations area or within the operations area of adjacent or nearby units, if the ground commander deems that operations in that area are to take equal priority.

HART would enable the reconnaissance zone to be expanded in size by facilitating use of multiple aircraft or sensor types to fly simultaneous, coordinated, and complementary orbits/tracks within the same area or zone. The reconnaissance mission would not have to be completely interrupted after enemy contact is made and one of the UAS assets transitions to surveillance.

HART Agile Tasking

If a UAS asset with a higher resolution sensor is conducting a Priority I reconnaissance mission, which takes precedence over all other requests, HART enables it to possibly fill lower priority missions at the same time it is completing the Priority I task. Once that Priority I mission is completed, the UAS asset could be retasked to supplement the UAS that has a low-resolution sensor currently conducting the movement-to-contact mission and revisit the part of the zone already reconnoitered.

B. AREA SECURITY

Area security includes reconnaissance and surveillance of airfields, forward operating bases, unit convoys, facilities, lines of communication, and major surface roads. Focusing specifically on convoy security or ground route reconnaissance operations, UAVs are used to conduct surveillance on a periodic or continuing basis for a specified time to keep lines of communication or MSRs open as well as provide updated information about the specific route and all adjacent terrain from which the enemy could influence movement along the route. From the supported unit's perspective, imagery transmitted from the UAV is used to meet the following objectives:

- Locate sites for constructing hasty obstacles to impede enemy movement
- Reconnoiter all defiles along the route for possible ambush sites
- Locate a bypass around built-up areas, obstacles, and contaminated areas
- Find and report all enemy who can influence movement along the route.

UAS may modify flight patterns to fly large circles around noncontiguous perimeters. And tasking more than one aircraft in the pattern reduces time between passes. When conducting area security around key sites, the commanders viewing UAS video can immediately employ ground forces, aviation, or fire support assets against the threat.

HART Persistence

HART would facilitate the operation of dedicated multiple UAS assets to fly area security missions in order to maintain continuous surveillance for a specified period of time.

HART Agile Tasking

HART facilitates the tasking of the multi-UAS assets to conduct the mission. This requires HART to distribute tasks among the UASs, plan and schedule the UASs, coordinate and deconflict flights, and control the execution of the UAV platforms.

C. MORTAR, ARTILLERY, AND CLOSE AIR SUPPORT

HART provides geo-located target imagery from all UAV platforms at an accuracy that allows first-round fire-for-effect missions. The observer, from a remote location, is able to view and save an image of the target and surrounding environment. The target engagement is observed and rounds can be adjusted on the target if needed. This same image chip can be sent from the observer to the cockpit for target identification and engagement by manned Air Force and Army assets.

D. SCREEN OPERATIONS

During screen operations, UAS assets must maintain continuous surveillance of the avenues of approach of a supported ground unit through which a movement or maneuver is planned and performed. A screen protects by providing early warning of the location of the lead elements of enemy forces, maintain contact with those lead elements, and report their activities.

Based on the screen's capabilities, aircraft conducting screen operations may be tasked to destroy or repel enemy reconnaissance forces, or impede and harass the enemy main body with indirect or direct fires.[17] The Sky Warrior UAS will carry four laser-seeking, Hellfire, air-to-ground missiles enabling the UA to engage enemy targets with its own weapons payload. Because the Shadow UAS has no weapons payload, the Shadow UAS may be teamed with ground and airborne assets.

The Army is continuing to explore and evolve the concept of using manned-unmanned (MUM) team missions in direct support to ground forces in tactical operations. For those missions, the UAS is teamed with either fixed-wing strike aircraft or those rotary-wing attack assets currently assigned to Army Air Cavalry Squadrons (Kiowa Warrior and Apache helicopters). The UAS can use its sensor and laser designator

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[17] FM 1-114, *Air Cavalry Squadron and Troop Operations* (Department of the Army, February 2000).

payloads to locate and pass target locations to, or to direct laser-guided munitions from, manned strike platforms.

HART Persistence

HART would facilitate the operation of dedicated multiple UAS assets to fly screen missions in support to a maneuvering ground force in order to maintain continuous surveillance of all potential avenues of approach tied to decision points for the movement of forces related to accomplishing military objectives. Allocating multi-UAV assets with the endurance and payloads required to conduct wider screen operations in support to a ground unit provides the information to the commander and sets the conditions for maneuvering to gain advantage over an enemy.

HART Agile Tasking

Screen operations provide space to maneuver and create flexibility for the ground forces to respond to unanticipated enemy initiatives. The commander's intent determines the buffer size in terms of time and space between friendly forces and the enemy's lead elements. HART facilitates tasking of multi-UAS assets to conduct the mission. This requires HART to distribute tasks amongst the UASs, plan and schedule the UASs, coordinate and deconflict the MUM flights, and control execution of the UAV platforms to meet the buffer size defined by the commander.

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V. OPERATIONAL BENEFITS OF HART

Having determined that much of the information deemed important by forces may be captured by UAS assets, IDA then considered the potential operational benefits of HART from three perspectives:

- How HART affects information flow and data availability
- How HART affects UAS access and area observability
- How HART affects the sensor-to-shooter thread.

A. HART EFFECT ON UAS OPERATIONS ON INFORMATION FLOW AND DATA AVAILABILITY

Figure 3 shows the activities associated with satisfying the RSTA service requests made by ground and air forces to support real-time combat decision making.

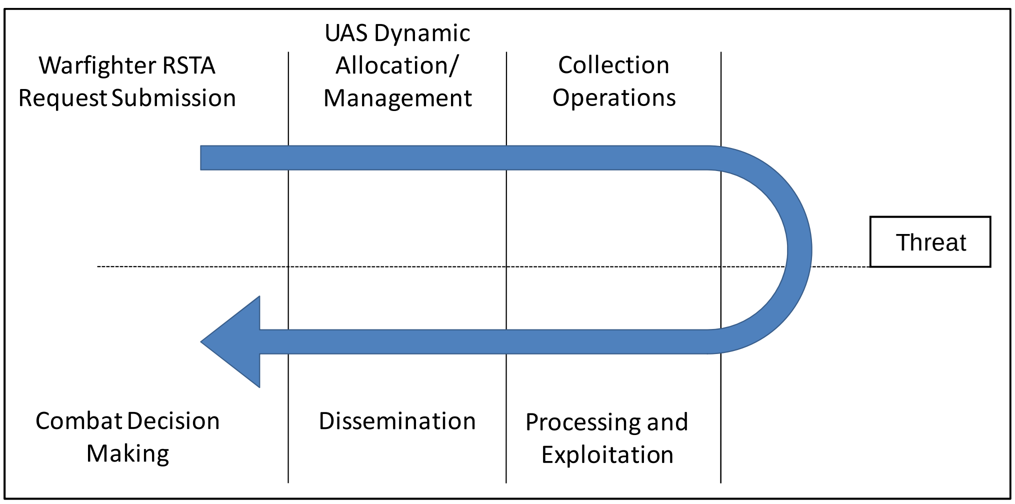

Figure 3. RSTA Cycle Supporting Real-Time Combat Decision Making

From a command and control standpoint, the HART implementation intends to streamline the way RSTA requests are submitted by warfighters; accelerate ad hoc collection, dynamic retasking, and resource reallocation of UAS assets in response to the evolving battlefield situation; enhance the ability of the supported unit to direct the overhead unmanned aircraft (UA) to acquire specific images during collection operations;

and ensure imagery or full motion video is disseminated in a timely manner to relevant warfighters at all levels of command, including airborne ground attack and indirect fires support platforms.

IDA recently developed an analytical framework to assess how Information Flow (IF) affects the Quality of Information (QoI) provided by the DoD ISR enterprise.[18] Many of the metrics for assessing IF—the ability to task, collect, process, and move RSTA information—are directly affected by HART implementation.

The IDA study considered five QoI metrics and eight IF metrics. The QoI metrics characterize the "quality" of the intelligence information received by the warfighter user and include the following:

- *Completeness*—The warfighter is provided the essential elements of information for the combat situation with the objective of reducing uncertainty and increasing the likelihood of a successful mission outcome.
- *Focus*—The warfighter is able to handle the amount of information delivered, even when actively engaged with enemy forces.
- *Clarity*—The information provided allows the warfighter to make combat decisions with confidence, thereby, furthering the mission.
- *Accuracy*—Is a measure of how correct is the information provided.
- *Timeliness*—When the information arrived to the warfighter, whether it was still relevant and useful.[19]

The IF metrics considered by the study include:

- *Agility*—The ability to shift activity
- *Filtering*—The ability to block out irrelevant information or collect only relevant information
- *Selection*—The ability to identify relevant information in collected data
- *Detection*—The ability to collect relevant exposure modality effectively (primarily a measure of the performance of the sensor payload)
- *Latency*—A delay in processing and transmission of data

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18 *Effective Customer-Centric Intelligence, Surveillance, and Reconnaissance (ISR),* IDA Paper P-4173, November 2006.

19 The study defined intel as being late when either its continued correctness is suspect or there is insufficient time for the warfighter to act upon the information.

- *Data Availability*—The capability to effectively convey collected/processed data to customer
- *Asset Availability*—The likelihood of sufficient/timely asset allocation
- *Access*—The ability to reach and maintain collection station and to focus collectors on potential exposure.

The extent to which the QoI is affected directly by HART is difficult to assess without data that explicitly connects a combat decision to an ISR product, including a video snippet, imagery, or moving target indicator (MTI) tracks. Instead we focused on the effect of HART implementation on the above IF metrics. This requires an examination of the communications and imagery dissemination architecture used during the conduct of UAS missions. Our effort focuses specifically on UAS integration into close air support and indirect fire support missions.

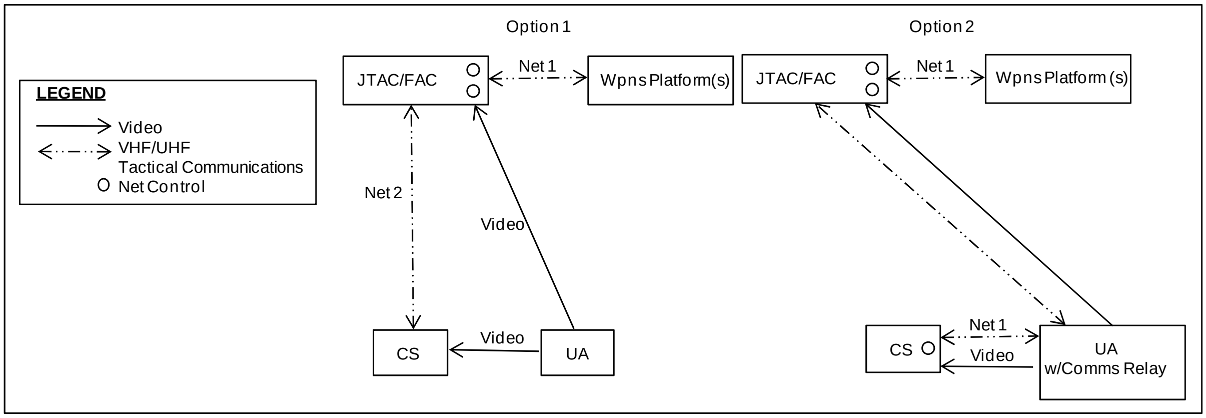
To enable warfighter users to respond quickly to emerging threats and evolving battlefield situations, the UAS communications architecture must be robust. The goal of the imagery dissemination architecture should be to enable warfighter users to view full motion video, video snippets, or images in near-real time to support combat decision making.

Our effort focuses specifically on UAS integration into close air support (CAS) and indirect fire support missions. Those two missions are included in the five brigade-level scenarios we developed. We assessed how HART implementation enhances UAS command and control and imagery dissemination over the current baseline architectures for CAS and indirect fire support missions by considering the previously defined IF metrics: agility, filtering, selection, latency, data availability, and asset availability. We also consider the effect of HART on those IF metrics within the context of Predator UAS RSTA support.

1. Close Air Support Architecture

UAS are regularly integrated into CAS operations, defined as air action against hostile targets that are located in close proximity to friendly forces, as both an ISR platform and, when armed, to directly engage ground targets. The *Multi-Service Tactics, Techniques, and Procedures for the Tactical Employment of UAS* document (FM 3-04.15) details several command and control options for integrating a UAS into CAS operations. The architecture shown in Figure 4 assumes a Joint Terminal Attack

Controller (JTAC) or Forward Air Controller (FAC)[20] receives a direct video downlink from the UAS on a remote video terminal: a One-System Remote Video Terminal (OSRVT) or the Remote Operated Video Enhanced Receiver (ROVER).[21]



Source: FM 3-04.15

Figure 4. CAS Command and Control Architecture

The OSRVT provides a capability similar to that of the Air Force Rover III, enabling users to directly receive video from airborne ISR platforms using both analog L and C bands as well as digital C and Ku band datalinks. The systems also provide the ability to overlay UAS telemetry data directly on a moving map for improved situational awareness. The OSRVT constantly scans through its operational range for other UASs and displays those UASs on the screen so soldiers can switch to a UAS with a better view of the target area by tuning into the downlink frequency.[22] Stryker vehicles, HMMWVs, and the Airborne Command and Control System UH-60 Black Hawk helicopter are equipped with the video terminal. The Army's mid- to long-term strategy for FY 2008 and beyond is to field a Block 2 OSRVT with a transceiver capability. The Block 2

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[20] A JTAC is a certified Service member who, from a forward position, directs the action of combat aircraft engaged in CAS and other offensive air operations. A FAC is an officer (aviator/pilot) member of the tactical air control party who, from a forward ground or airborne position, controls aircraft in close air support of ground troops (JP 1-02: *Department of Defense Dictionary of Military and Associated Terms*, As Amended through 17 October 2008)

[21] Both systems receive and display video and data from Army, Marine Corps, or Air Force unmanned ISR platforms using an UA-specific datalink and compatible LOS antenna. The terminals receive metadata so warfighter users know exactly where the sensor is looking and from what direction.

[22] "One System Remote Video Terminal Instantly Connects Soldier and Sensors" (*Defense Daily*, 2 October 2007).

configuration will give soldiers the capability to communicate with the unmanned air vehicle and control the payload.[23]

The Air Force ROVER system has continued to evolve since its introduction in 2002. ROVER I allowed ground forces to view video feeds from a Predator UAVs or AC-130 gunships (equipped with the Scathe View advanced surveillance system). ROVER I was mounted on a HMMWV because of its large interface. Later ROVER II allowed forces to receive UAV video on a ruggedized, laptop computer. ROVER III, fielded in September 2004, is a backpack unit that incorporates a multi-band receiver (Ku-band digital, C-band digital, C-band analog, and L-band analog) to receive video from a range of UAS and fixed-wing tactical aircraft equipped with the LITENING or SNIPER targeting pods. The targeting pods are updated with a transmitter called the ROVER module.[24] This video downlink capability supports CAS missions by assisting pilots flying fixed-wing attack aircraft to positively identify a target prior to engagement in an attempt to minimize collateral damage. ROVER IV adds an S-band analog receive capability. ROVER IV also incorporates C- or Ku-band transmit capability, transferring up to 45 mb/sec of data. This transmit capability combined with a “Madden” type software allows the JTAC or FAC to use a stylus to circle targets or make notations on the video screen that a pilot can also see.

The JTAC uses the video feed and collaboratively works with the UAS operator at the ground control station (GCS) using voice communications to develop situational awareness of the target area and to locate targets. Once a target has been located, the JTAC uses the video to develop a nine-line CAS brief and to talk a strike platform onto the target for engagement. Depending on the UAS payload configuration, the JTAC may use the UAS laser target designator to direct laser-guided munitions from strike aircraft onto the target. For this mission, the UAS must be deconflicted with other unmanned aircraft, manned aircraft, and surface fires within the battlespace.

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[23] Testimony on U.S. Army Unmanned Aerial Vehicle Programs by BG Stephen Mundt (Director, Army Aviation Directorate) before the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee.

[24] “Team test pods at ‘LITENING’ speed” by Senior Airman Francesca Carrano (*Air Force Print News*, 18 April 2006).

The *Joint Tactics, Techniques and Procedures for Close Air Support* publication (JP 3-09.3) specifies three types of CAS terminal attack control. The three types of JTAC control and implications for UAS are summarized in Table 2.

Table 2. Types of JTAC Control

<table>
<tr><th>Control Type</th><th>Definition</th><th>Implication for UAS</th></tr>
<tr><td>Type 1</td><td>Requires the JTAC to visually acquire the attacking aircraft and the target under attack.</td><td>None</td></tr>
<tr><td>Type 2</td><td>JTAC assesses that visual acquisition of the attacking aircraft or target at weapons release is not possible.
~ or ~
JTAC assesses attacking aircraft are not in a position to acquire the target prior to weapons release.</td><td rowspan="2">JTAC coordinates CAS attacks using targeting information from an observer with real-time targeting information, including a UAV.
The JTAC considers the timeliness and accuracy of targeting information when relying on remote targeting.</td></tr>
<tr><td>Type 3</td><td>JTAC assesses CAS attacks impose low risk of fratricide.</td></tr>
</table>

Implementing Type 2 or Type 3 terminal attack control based on UAS observations requires the force commander and the JTAC to have confidence in the UAS target location accuracy. During a 2002 initial operational test and evaluation (IOTE) event at Fort Hood, TX, the Shadow demonstrated a TLE over 200 meters[25]—the threshold requirement was 80-meters CEP with the objective of 20-meters CEP.[26] However, in the March 2006 testimony before the Tactical Air and Land Forces Subcommittee of the U.S. House of Representatives Committee on Armed Forces, the Director of the Army Aviation (Office of the Deputy Chief of Staff, G-3) stated that the Service has funded the research and development to achieve a 10-meter TLE level of accuracy on the Shadow UAS. The UAS improvements to 10-meter target location accuracy requires multiple upgrades to include sensor, software, and navigation. In addition, the Navy has established a TLE technical performance measure for its Fire Scout UAV at 23-meters spherical error probable (SEP) at a sensor range of 6 km.[27] This measure is similar to the TLE threshold requirement set by the Army for its Future

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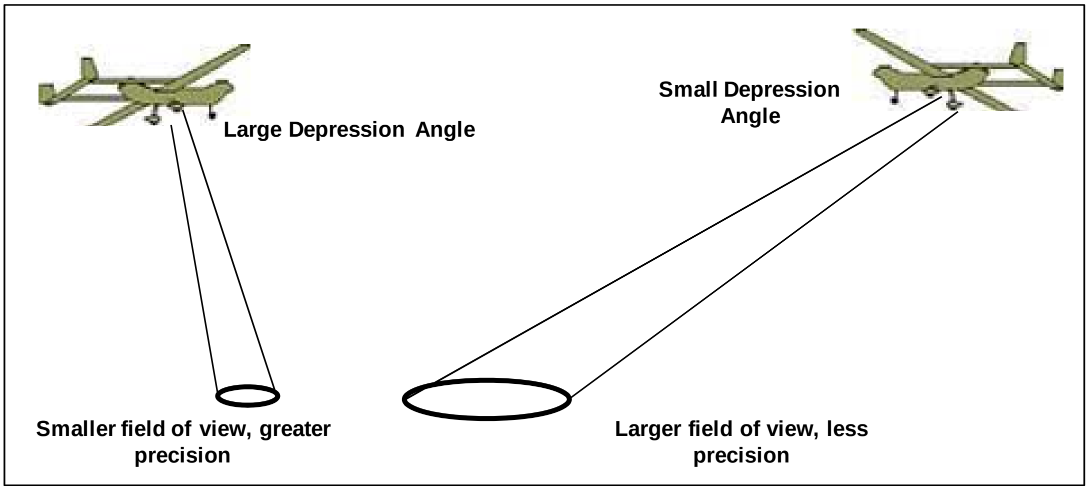
[25] *OTA roundtable: Applying the T&E Requirements Process to Unmanned/Autonomous Vehicles* by Stephen C. Daly (Deputy director, Operational Test and Evaluation for Land And Expeditionary Warfare, 28 February 2008).

[26] *Unmanned Aerial Vehicles: Their Value in Security Operations* by COL Leonard J. Samborowski (January 2000).

[27] PMA-263 NAVAIR Unmanned Air Systems Programs briefing on the MQ-8B Fire Scout.

Combat System Class IV (Fire Scout) UAS of a 25-meter TLE.[28] In the absence of a system like HART, several methods and approaches are available to improve the quality of UAS TLE:

- Increase the depression angle of the UAS sensor (Figure 5)
- Use a laser designator/laser range finder that can reduce TLE to under 10 meters CEP
- Perform multiple sweeps of the UAS for coordinate validation
- Use terrain association software to mensurate the image.



Source: FM 3-04.155

Figure 5. Sensor Depression Angle and Location Precision

Because the attacking aircraft are not required to visually acquire the target for Type 2 and Type 3 JTAC control, the UAS video, disseminated to multiple levels of command, provides immediate and accurate battle damage assessment (BDA) following a strike. The UAS can also track targets fleeing from attacks to increase the chances of successful re-attack.

The architecture in Figure 4 does not show direct video feeds from UAS to strike platforms. However, in 2008, the Army began equipping Apache helicopters with a data link system called the "Video from UAS for Interoperability Teaming–Level II," or

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[28] *Micro-Aerial Vehicles A Tactical Perspective* by COL Michael Lingenfelter (TRADOC, 19 September 2005).

VUIT-2. This action followed a demonstration during which the video from a Shadow was successfully streamed to the Apache helicopter cockpit.[29.] In addition to the Shadow UAS, the system enables Apache aircrews to view streaming video and metadata from the Raven, Hunter, Predator, Warrior A, Reaper, and other unmanned aircraft systems to be displayed in the cockpit out to a range of 40 km.[30] Because the VUIT-2 integrates with the OSRVT, ground controllers using the video terminal can see imagery from the Apache's sensors. Predator video is also fed directly to the cockpit of the AC-130 gunship, allowing those crews to gather situational awareness before arriving over the target area.[31]

2. Artillery Support Architecture

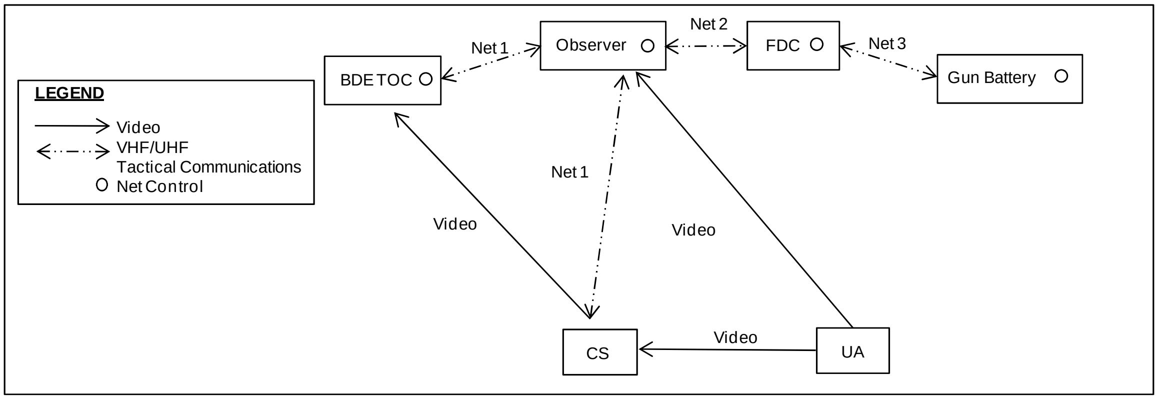
Figures 6 and 7 depict two surface-to-surface attack architectures for integrating UAS operations into artillery engagements. Figure 6 shows both the TOC and forward observer receiving a direct video feed from an UAS. The architecture assumes that the forward observer is equipped with an OSRVT or ROVER. The observer communicates direction of the UA and sensors over voice communications. Whereas the architecture in Figure 7 assumes the observer is collocated with the UAS ground control station (GCS) in the TOC or command post (CP). According to the *Multi-Service Tactics, Techniques, and Procedures for the Tactical Employment of UAS* publication, the following steps occur before transmitting a call-for-fire for artillery support:

- The UA arrives on station to support the mission.
- The GCS checks-in with the element providing terminal guidance (JTAC/FAC/FO) and receives a situation update.
- Collaboratively, using voice communications, the FO and GCS work to orient the UAS sensors on the suspected target area and look for one or more specific targets.
- The target is detected, identified and located.

29 "Apache Helicopter Pilot Gets Visual Aid" by Kim Henry (*Army News*, 19 February 2008).

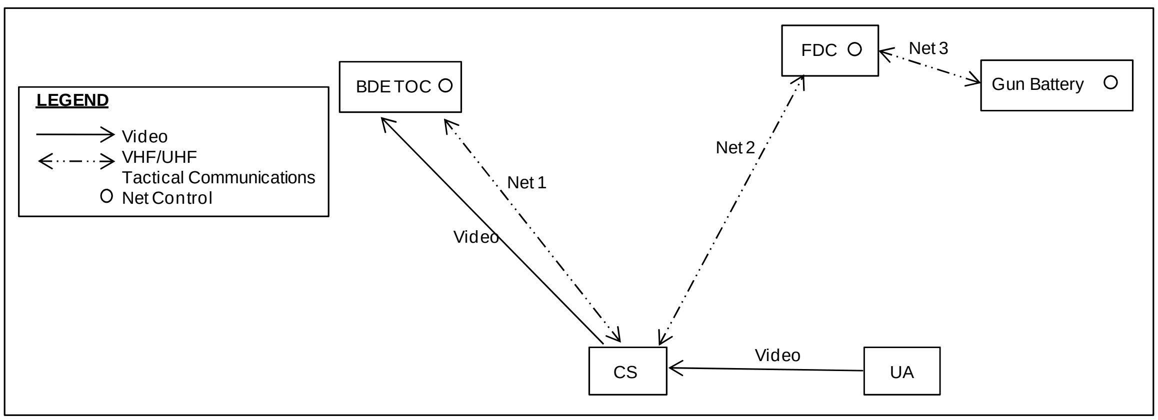
30 "VUIT-2" by Scott R. Gourley (*Army Magazine*, January 2009) and "VUIT-2 Connects Apaches, UAVs" by Kris Osborn (*Defense News*, 10 December 2008).

31 "The Little Predator That Could" by Richard J. Newman (*Air Force Magazine*, March 2002).



Source: FM 3-04.15

Figure 6. Artillery Command and Control Architecture



Source: FM 3-04.15

Figure 7. Alternative Artillery Command and Control Architecture

Figures 6 and 7 show the forward observer initiating a fire support mission by viewing video feeds from UAS flying over the target. The UAS must provide accurate target location data for the fire direction center (FDC). If the UAS TLE does not meet the criterion set by the commander or required for the artillery round, the observer must have another means for validating the target location.

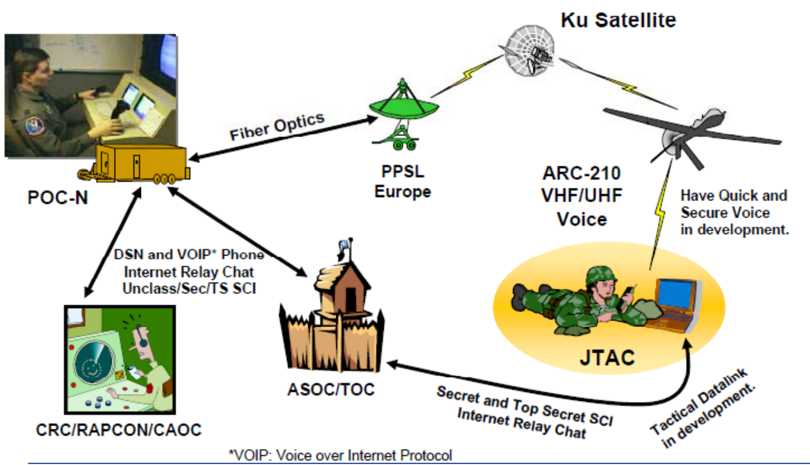
After a target has been engaged by land-based indirect fires, the observer uses UAS video to assess the effects on target and orders an adjust fires mission using voice communications to the FDC. The *Multi-Service TTPs for the Tactical Employment of UAS* describe two approaches for adjusting fire using UAS FMV:

- Use terrain association against the video images to estimate how far to the left or right and short or long the first round landed.

- Use remote video terminal (RVT) to get the grid location of the center of impacts and transmit to the FDC to allow the FDC to compare "did hit" data to "should hit" data and make the necessary ballistic corrections.

3. Predator Tactical Communications and Imagery Dissemination Architecture

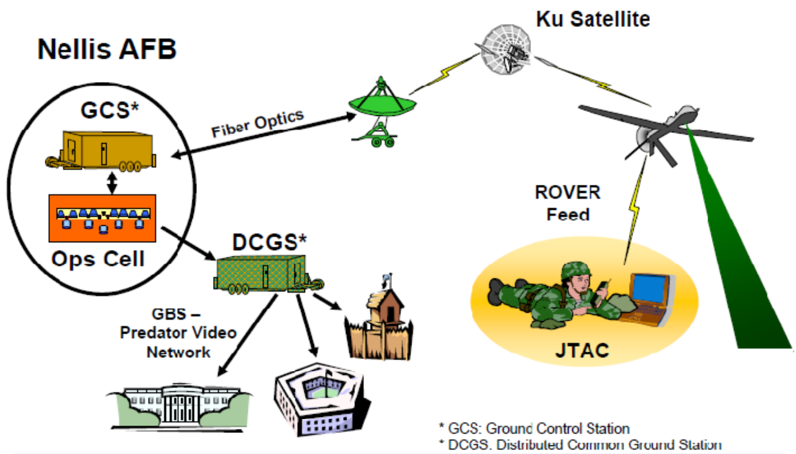
Figure 8 shows the tactical communications architecture used by Predator units during remote split operations. This CONOPS requires a launch and recovery element (LRE) at a forward operating location to conduct aircraft takeoff and recovery using the launch and recovery ground control station (LRGCS) and C-band LOS ground data terminal to control the aircraft. After takeoff, the LRE links the Predator to the ground control station at the CONUS-based Nellis Main Operating Base (MOB) for mission execution using Ku-band SATCOM and severs the C-band LOS link.



Source: Briefing by the Office of the Director of Operations, 17th Reconnaissance Squadron presented at the Cognitive Engineering Research Institute 2006 UAV Workshop.

Figure 8. Predator Tactical Communications

Figure 9 shows the multiple paths for dissemination of Predator imagery. Predator FMV is transmitted from the platform over Ku-band to a Predator primary satellite link (PPSL) receive terminal at a regional satellite node (RSN) located outside the AOR. The RSN is connected to the Predator Operation Center at Nellis (POC-N) using fiber optics pathways. When received at POC-N, the video is digitized, compressed, and encrypted for dissemination to units using various DoD intelligence broadcast and publishing systems, including the Distributed Common Ground System (DCGS). Users can also receive Predator video using a ROVER terminal. Although not shown on Figure 8, Predator video is fed directly to aircrews in attack platforms such as the Apache when operating within 40-km LOS of the Predator and to the AC-130 gunship.



Source: Briefing by the Office of the Director of Operations, 17th Reconnaissance Squadron presented at the Cognitive Engineering Research Institute 2006 UAV Workshop

Figure 9. Predator Video Dissemination

The Air Force DCGS consists of deployable ground stations (DGS), remote sites, and the DCGS processing, exploitation, and dissemination (PED) operations center. The DGSs are capable of exploiting U-2 imagery, Predator FMV, and Global Hawk imagery and provide both near-real-time products characterized as voice and chat reports, textual reports, and secondary imagery.

Secondary image products include still-frame images and video snippets. Those products are sent via file transfer protocol (FTP) or SIPRNet e-mail to specific supported units. Those images are also posted to an image product library, a server-based archive for imagery products, and Joint Worldwide Intelligence Communications System (JWICS) and SIPRNet websites. Direct Communication Channel allows DGS analysts to send secondary imagery products directly over chat. This dissemination approach is reserved for small products such as JPEG images or 10-second video snippets.

The AFTTP for tactical employment of the Predator UAS (AFTTP 3-1, 29 December 2006) contains general timelines for the dissemination of actionable intelligence to support time-sensitive combat decisions. The rule-of-thumb timelines presented assume exploitation by an experienced crew and dissemination without major equipment or system failures. From the receipt of processed Predator video to a DGS workstation, an imagery analyst can provide the following to a supported unit:

- IMINT products
  - A voice report is disseminated in 8 minutes.
  - An annotated image is disseminated directly to the warfighter via e-mail or posted to the image product library within 15 minutes.
  - Initial Phase Interpretation Report (IPIR) are textual reports[32] created within 20 minutes and sent via e-mail to the supported unit and posted to JWICS and SIPR web pages.
- FMV products
  - A voice report is disseminated in 3 minutes.
  - A video snippet is created and disseminated in 15 minutes.
  - An additional 5 minutes are required to create the IPIR.

Fully leveraging Predator capabilities using HART would require agreement from the Air Force to allow a HART C3 to interface with the CONUS-based Predator GCS, or more likely, to a deployable GSC located at a forward operating location in-theater. This would enable the Predator to operate as one element of the HART UAS team for dynamic retasking for ad hoc or emerging collection missions within the extent of UAS control authority dictated by the Air Force. The C-band LOS ground data terminal can transit commands to the aircraft out to a range of 275 km.[33] If the Air Force decides to opt out of HART control, connecting the HART C3 (with a robust video storage and image retrieval capability) to the Predator GCS still potentially enhances the support provided to warfighter users by enabling the dissemination of Predator video snippets or still images to RSTA service requesters whose information requirements are satisfied by the planned Predator sortie scheme of maneuver.

4. How HART Implementation Affects IF Metrics

Table 3 shows how integrating HART into the above architectures affects the IF metrics. A "+" sign indicates HART enhances performance and responsiveness. The table shows that HART would improve seven of the eight information flow metrics considered by the study.

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32 A first-phase interpretation report presenting the results of the initial readout of new imagery to answer the specific requirements for which the mission was requested.

33 Briefing by the Office of the Director of Operations, 17th Reconnaissance Squadron presented at the Cognitive Engineering Research Institute 2006 UAV Workshop.

Table 3. HART Effects on Information Flow Metrics

IF Metric	HART Effect	Comments
Agility (ability to shift activity)	+	• The introduction of metadata to OSRVT/ROVER feeds does not eliminate the potential for confusion while issuing voice commands for directing the UAS to capture specific images. • Lists of communications brevity codes have been developed to enhance the efficiency of voice communications between the warfighter and UAS operator. However, those codes have not been formally adopted across the Services and still rely on the imprecise use of cardinal directions or clock positions to slew sensor or reposition the aircraft in a given direction and distance based on a north-orienting arrow on the display. • HART handheld touch screen allows the warfighter to indicate the exact location for the UAS sensor field of view to cover. The inputs to the HART handhelds are translated into commands that control the platform and sensors, which are communicated to the unmanned aircraft by interfacing the HART command and control center (HC3) to the platform native controllers.
Filtering (ability to block out irrelevant information or collect only relevant information)	+	• Improving agility will enhance collecting only relevant information. • Operationally, a lot of ISR time is wasted when UAVs are transiting between target/coverage areas or to/from the launch and recovery site. • Because HART compiles RSTA requests from multiple users across all echelons of command, a service request may be satisfied while a UAV is flying a preplanned mission or during transit periods, thereby maximizing the UAS support.
Selection (ability to identify relevant information in collected data)	+	• HART strives to provider wider and faster access to collected and stored mission data. • Raven feeds are currently not stored—data is available in real-time only. • At brigade level, a digital video receiver (DVR) is attached to the Shadow GCS to provide a 24-hour buffer of imagery storage. Adjacent BCT or subordinate units can request stored information by specifying a location that is matched against missions flown during the past 24 hours. When the information is retrieved, an e-mail with a still image attachment is sent to the requester using tactical communications links. • Hunter imagery is stored for a few days and can be exploited in hours to days by request to division. EAD UAV imagery is requested through division. • HART has as a goal to implement and integrate additional information management capabilities, including image compression, storage, and archiving, video mining, and searching to support RSTA request. (BAA 04-05, HURT Team, DAPRA, December 2003)
Detection (ability to collect relevant exposure modality effectively)		*HART will not enhance this metric as it is primarily a measure of the performance of the sensor payload.*

IF Metric	HART Effect	Comments
Latency (delay in processing and transmission of data)	+	• Army UAS FMV and Predator FMV are transmitted directly to the Apache attack helicopter cockpit when equipped with the VUIT-2 and within 40 km LOS of the UAS. • Army UAS FMV is fed directly to the Black Hawk Airborne Command and Control helicopter equipped with an OSRVT out to a range of 50 km. • Ground units equipped with the OSRVT/ROVER receive feeds from Army and USAF UAS out to LOS range of 50 km, or 80 km with an extended range antenna. • HART pushes information products to requesting units via the HART handheld devices. Requesting units equipped with an OSRVT/ROVER still receive near real time information even when those units are not positioned within the required LOS range of the UAS for direct video downlink. • HART also pushes data to attack and fires support platforms located beyond LOS range of UAS collecting target information.
Data Availability (to effectively con-vey collected/ processed data to customer)	+	• HART strives to provide wider and faster access to collected and stored mission data. • Because HART C3 in conjunction with HART handhelds directs video snippets or JPEG pictures to service requesters via tactical communications, data availability is enhanced throughout the BCT. Warfighters users at company and below will not have to wait until operators manning Army multisource analysis systems receive data from Predator and tactical UAS to capture video snippets or JPEG images for secondary dissemination to meet information request. • HART will provide a target grid location accuracy of less than 5-meters CEP for gimbaled sensors and less than 10-meters CEP for fixed sensors.[a] This is better than the FCS Class IV UAS threshold and offers a substantial improvement in target location accuracy over what is achievable today for UAS not equipped with laser rangefinder capability: – Supports Type 2 and Type 3 JTAC control for CAS missions. – Will improve first round impact on target performance for indirect surface-based fire support weapons. – Supports the use of GPS-guided smart munitions for attack aircraft.

IF Metric	HART Effect	Comments
Asset Availability (likelihood of sufficient/timely asset allocation)	+	• The dynamic retasking of UAV platforms in response to an emerging battlefield situation is routine for Army UAS. For brigade and higher-level assets, BCT and division conduct the necessary coordination by voice or mIRC to ensure airspace is cleared to re-route the UAS to the new target area. If directed by battalion or agreed between two company-level commanders, an adjacent unit operator can take control of a Raven by tuning to the Raven flight control frequency. Anecdotally, it has been reported that the command and control for dynamically retasking those assets can be accomplished in 15 minutes or less. • Retasking a CFACC platform (such as Predator) often requires 10 minutes or more to get the necessary approval from Corps and the CAOC and to perform airspace deconfliction and coordination. • The HART shortens those C2 timelines and increases the responsiveness to RSTA requests submitted by the warfighter. • A single Shadow ground control station controls the UAV by data link through the ground data terminal up to a LOS distance of 50 km. A Shadow GCS can only communicate with and actively control one UAV at a time. The GCS can place a mission UAV in programmed flight and then acquire another UA during a handover from another GCS or to the L/R site. • A single Hunter GCS controls the UA by LOS datalink out to a distance of 125 km, or to a range of 200 km with retransmission (well within the battlespace dimensions of rural security and stability operations scenarios). • The current Raven ground control unit has a LOS range of 10 km. Retasking a Raven to support an adjacent unit requires operators to execute handover procedures to another GCU. • The One System Ground Control Station (OSGCS) is currently fielded with the Shadow UAS. The U.S. Army is planning to transition all UAV ground control systems to the OSGCS standard. The consolidation of Army UAS control stations enables qualified soldiers to control UAS within their battlespace from one ground control station to another and also makes HART implementation into UAS operations seamless from the standpoint of the HC3 hardware and software.
Access (ability to reach and maintain collection station, and to focus collectors on potential exposure)	+	• Detailed assessment is presented in the following section.

[a] *Heterogeneous Airborne Reconnaissance Team (HART)* by Dr. Michael Pagels (DARPA Information Processing Techniques Office, December 2008).

B. UAV ACCESS ANALYSIS

The unpredictable nature of hostile incidents (such as location and time) that require UAV observation [particularly during stability and counter-insurgency (COIN) operations], combined with the uncertainty of UAV location and remaining loiter time when an incident occurs are too complex to analyze in terms of a closed-form solution. There are simply too many combinations of conditions to calculate every possible outcome. As a result, this analysis uses a FORTRAN-based Monte-Carlo simulation to assess the ability of a team of UAVs to reach and sustain a retasked collection station in response to evolving battlefield conditions. The output of the simulation is a measure referred to as the Probability of Observation, defined as the probability that a hostile incident can be observed for the required observation time without gaps in coverage. This measure of area observability has direct implications for whether a team of UAVs can responsively provide the RSTA support needed to develop situational awareness and engage targets.

To aid our assessment of the operational benefits of HART, we considered three brigade-level scenarios described in detail in Appendix C: the advanced guard offensive operation scenario, the rural area security scenario, and the route security scenario. This analysis generates the Probability of Observation for each of those scenarios by executing the simulation for 1,000 iterations. The Probability of Observation measure provides a way to compare retasking UAV assets using the HART concept against current techniques and procedures for retasking UAS.

The airborne ISR platforms available for the assessment include Shadow and Hunter. The Raven UAVs are usually assigned at the company level or below within a BCT. For our brigade-level battlefield scenarios, the utility of Raven is limited due to its insufficient range and/or general desire for organic control. As a result, the Raven UAVs were not considered for the simulation. For company-level vignettes, such as safehouse overwatch missions, Raven is likely to be a valuable contributor to the HART concept. The performance of the Shadow and Hunter UASs, including the endurance time and airspeed, are based on the values specified in the OSD Unmanned System Roadmap (2007-2032).

The initial loiter time for airborne UAVs is based on a uniform distribution between the minimum loiter time required to return to the original launch and recovery site and the maximum endurance time available for that particular UAV type. The initial orbit of each airborne Shadow and Hunter UAV is specified by the scenario (the actual initial location of the UAV is randomly varied along the orbit).

We assumed that hostile activities begin based on a normal distribution with a pre-described frequency that depends on the scenario. For example, the rural security operations scenario evolved with four incidents occurring sequentially at 30- to 45-minute intervals: a riot in a refugee camp, an IED attack followed by sporadic direct fire on a platoon evacuating casualties, a mortar and small arms attack on the brigade FOB, and the detection of possible insurgent infiltration activity near the brigade boundary by an initial airborne Shadow UAV. The location of the hostile incidents and required UAV observation time are also based on the scenario description. Also based on the scenario, hostile incidents occur one at a time (uncoordinated) or concurrently (coordinated).

Once a hostile incident occurs, the simulation determines the closest UAV with sufficient loiter time to fly to the incident and return to its recovery site. Other UAV utilization CONOPs, such as tasking the UAV with the longest available observation time (regardless of its distance from the incident), were not considered because we deemed the timeliness of UAV arrival to be more important than UAV loiter potential. The closest UAV is then flown to the hostile incident location and observes. If observation time that the UAV can provide is less than that required, a subsequent UAV is tasked to fill the gap. Untasked UAVs stay on orbit as long as fuel permits and then return to the original launch and recovery site. After a predetermined refueling and turn-around time (set for 1 hour for the current simulations), the UAV returns to its original orbit.

This analysis considers two operational control approaches for current UAS missions. For the first approach, although assigned to a brigade, each Shadow UAS is managed at division. Therefore, retasking the Shadow to support an adjacent unit requires division approval. For the second approach, each Shadow UAS is managed by the brigade commander. For both approaches, the division Hunter is initially allocated to support the brigade for a specified time over a specified coverage area. So retasking the Hunter also requires division approval in addition to conducting the required airspace coordination and deconfliction across the brigade area of responsibility.

This analysis distinguishes HART from current UAS operations by varying the C2 time necessary for retasking—gaining approval from the required echelon commander(s), conducting the airspace coordination and deconfliction, and establishing the necessary airspace control measures prior to the UAV transiting through the airspace to a new coverage area. Appendix A has a summary of the current TTPs for dynamic retasking of UAS assets and average timelines reported. For the HART concept, it is assumed that the C2 time was 5 minutes. For division-level C2, two C2 times were assumed: 15 and 25 minutes. For brigade-level C2, 30 and 60 minutes were used.

The analysis takes into consideration that, at certain instances, some UAVs may not be available for retasking because of higher priority missions or the desire of a unit to retain organic control of its asset. Accordingly, the number of airborne UAVs available for retasking is varied in the simulation to capture this effect. Finally, two UAV reliability rates, 100 percent and 95 percent, were assumed as UAVs occasionally suffer airframe, sensor, or datalink failure.

1. Advanced Guard Offensive Operation

This scenario is a conventional warfare operation in which a heavy BCT is employed as the division advanced guard unit. As the HBCT initiates its march, two Shadows are ahead of the lead element with an additional Shadow flown by a following BCT at the right flank of the division. The division Hunter is forward of the BCT Shadows to provide imagery to lead BCTs. Once the advanced guard makes contact on its right front, we assumed that the Shadows and Hunter must provide 1 hour of uninterrupted coverage time. The results of the simulation are shown below in Table 4.

When contacts with the enemy occur at a single location (uncoordinated attack), the probability of observation is high regardless of the availability of HART, number of UAVs available for retasking, or UAV reliability. For simultaneous contacts (coordinated attack), the probability of observation drops significantly when the number of UAVs available for retasking is small, with or without HART.

It should be noted that the resulting Probability of Observation is just one component of the entire kill chain and does not represent the overall operational benefits of HART or the current division-/brigade-level control approaches.

Table 4. Advanced Guard Probability of Observation

Uncoordinated Attack

	HART			Division Level C2 (wo/HART)			Brigade Level C2 (wo/HART)		
Area of Interest (km)	25 x 20			25 x 20			25 x 20		
UAV Aloft	3(S) + 1(H)			3(S) + 1(H)			3(S) + 1(H)		
UAV Available for Retasking	3(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)	3(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)	3(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)
C2 Time for Retasking (min)	5	5	5	15 / 25	15 / 25	15 / 25	30 / 60	30 / 60	30 / 60
Probability of Observation (%)	***100***	***99.4***	***96.8***	***100. / 99.8***	***99.4 / 98.8***	***95.6 / 94.9***	***99.7 / 99.1***	***98.7 / 96.8***	***94.8 / 92.4***

Coordinated Attack

	HART			Division Level C2 (wo/HART)			Brigade Level C2 (wo/HART)		
Area of Interest (km)	25 x 20			25 x 20			25 x 20		
UAV Aloft	3(S) + 1(H)			3(S) + 1(H)			3(S) + 1(H)		
UAV Available for Retasking	3(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)	3(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)	3(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)
C2 Time for Retasking (min)	5	5	5	15 / 25	15 / 25	15 / 25	30 / 60	30 / 60	30 / 60
Probability of Observation (%)	***90.6***	***86.5***	***72.4***	***88.6 / 86.9***	***83.3 / 80.8***	***68.2 / 65.2***	***86.2 / 80.5***	***79.3 / 71.1***	***63.7 / 55.9***

Uncoordinated Attack (95% UAV Reliability)

	HART			Division Level C2 (wo/HART)			Brigade Level C2 (wo/HART)		
Area of Interest (km)	25 x 20			25 x 20			25 x 20		
UAV Aloft	3(S) + 1(H)			3(S) + 1(H)			3(S) + 1(H)		
UAV Available for Retasking	3(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)	3(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)	3(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)
C2 Time for Retasking (min)	5	5	5	15 / 25	15 / 25	15 / 25	30 / 60	30 / 60	30 / 60
Probability of Observation (%)	***99.8***	***98.9***	***96.1***	***99.4 / 99.3***	***98.3 / 97.4***	***95.4 / 94.7***	***99.3 / 98.5***	***96.9 / 95.1***	***94.3 / 91.5***

Coordinated Attack (95% UAV Reliability)

	HART			Division Level C2 (wo/HART)			Brigade Level C2 (wo/HART)		
Area of Interest (km)	25 x 20			25 x 20			25 x 20		
UAV Aloft	3(S) + 1(H)			3(S) + 1(H)			3(S) + 1(H)		
UAV Available for Retasking	3(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)	3(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)	3(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)
C2 Time for Retasking (min)	5	5	5	15 / 25	15 / 25	15 / 25	30 / 60	30 / 60	30 / 60
Probability of Observation (%)	***82.9***	***79.4***	***64.7***	***81.4 / 79.0***	***77.0 / 75.0***	***60.7 / 57.8***	***77.7 / 71.5***	***73.4 / 65.3***	***56.4 / 47.7***

Furthermore, the C2 time necessary for retasking is based on anecdotal reports. Consequently, if the necessary C2 time for the current approaches increases as a result of difficulty in gaining approval from the required echelon commander(s) for UAV airspace coordination and deconfliction, the probability of observations should drop significantly when compared to the HART concept.

2. Rural Area Security

A HBCT conducts area security of a 30 x 30-km rural environment to protect the population, support government institutions, secure selected roads, conduct counter-insurgent activities, and provide humanitarian relief.

Two Shadows are available to provide continuous orbit over the rural area while a Hunter overwatches an important MSR, which passes through the BCT AOR.

For this scenario, a number of hostile incidents occur sequentially at 30- to 45-minute intervals: a riot in refugee camp ; an IED attack followed by sporadic direct fire on a platoon evacuating casualties; a mortar and small arms attack on the FOB; and insurgent infiltration activity near the HBCT boundary. We assumed that the riot requires 45 minutes of observation time; the IED attack, 30 minutes; the mortar and small arms attack, 15 minutes; and finally the insurgent infiltration activities, 45 minutes. For the coordinated attack case, we assumed that the riot and IED attack and the mortar attack and insurgent infiltration occur concurrently. The results of the simulation are shown below in Table 5.

The overall resulting trends are similar to the Advance Offensive Operation scenario. Furthermore, despite the somewhat larger area of interest when compared to the previous scenario, the probability of observation is higher due to the shorter required observation times for the hostile incidents.

Table 5. Rural Area Security Probability of Observation

Uncoordinated Attack

	HART		Division Level C2 (wo/HART)		Brigade Level C2 (wo/HART)	
Area of Interest (km)	30 x 30		30 x 30		30 x 30	
UAV Aloft	2(S) + 1(H)		2(S) + 1(H)		2(S) + 1(H)	
UAV Available for Retasking	2(S) + 1(H)	1(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)
C2 Time for Retasking (min)	5	5	15 / 25	15 / 25	30 / 60	30 / 60
Probability of Observation (%)	***99.9***	***98.4***	***99.7 / 99.6***	***97.7 / 97.0***	***99.4 / 98.4***	***96.7 / 94.2***

Coordinated Attack

	HART		Division Level C2 (wo/HART)		Brigade Level C2 (wo/HART)	
Area of Interest (km)	30 x 30		30 x 30		30 x 30	
UAV Aloft	2(S) + 1(H)		2(S) + 1(H)		2(S) + 1(H)	
UAV Available for Retasking	2(S) + 1(H)	1(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)
C2 Time for Retasking (min)	5	5	15 / 25	15 / 25	30 / 60	30 / 60
Probability of Observation (%)	***92.1***	***79.3***	***89.6 / 87.5***	***76.5 / 73.1***	***86.0 / 77.7***	***71.0 / 61.7***

Uncoordinated Attack (95% UAV Reliability)

	HART		Division Level C2 (wo/HART)		Brigade Level C2 (wo/HART)	
Area of Interest (km)	30 x 30		30 x 30		30 x 30	
UAV Aloft	2(S) + 1(H)		2(S) + 1(H)		2(S) + 1(H)	
UAV Available for Retasking	2(S) + 1(H)	1(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)
C2 Time for Retasking (min)	5	5	15 / 25	15 / 25	30 / 60	30 / 60
Probability of Observation (%)	***99.3***	***98.4***	***99.1 / 99.0***	***97.7 / 97.2***	***98.8 / 96.2***	***96.6 / 93.7***

Coordinated Attack (95% UAV Reliability)

	HART		Division Level C2 (wo/HART)		Brigade Level C2 (wo/HART)	
Area of Interest (km)	30 x 30		30 x 30		30 x 30	
UAV Aloft	2(S) + 1(H)		2(S) + 1(H)		2(S) + 1(H)	
UAV Available for Retasking	2(S) + 1(H)	1(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)
C2 Time for Retasking (min)	5	5	15 / 25	15 / 25	30 / 60	30 / 60
Probability of Observation (%)	***85.2***	***72.9***	***83.0 / 80.6***	***69.3 /66.0***	***79.2 / 71.4***	***63.7 / 53.6***

3. Route Security

In this scenario, an HBCT is tasked to secure a paved highway from Balad to Baghdad for movement of a large convoy. The highway distance is approximately 75 km with a 10-km buffer zone that also needs protection.

The BCT is supported by four planned Shadow orbits to observe convoy movement, and an additional Hunter is employed in the BCT OA on another mission reconnoitering the Tigris River.

The overall resulting trends are similar to the previous two scenarios. Despite the extremely large area of interest, this scenario has the highest probability of observation during a coordinated attack, as shown in Table 6. This is due to the higher number of tasked UAVs flying localized orbits along the convoy route where the IED detonations occur.

Table 6. Convoy Route Security Probability of Observation

Coordinated Attack

	HART				Division Level C2 (wo/HART)				Brigade Level C2 (wo/HART)			
Area of Interest (km)	60 x 50				60 x 50				60 x 50			
UAV Aloft	4(S) + 1(H)				4(S) + 1(H)				4(S) + 1(H)			
UAV Available for Retasking	4(S) + 1(H)	3(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)	4(S) + 1(H)	3(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)	4(S) + 1(H)	3(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)
C2 Time for Retasking (min)	5	5	5	5	15 / 25	15 / 25	15 / 25	15 / 25	30 / 60	30 / 60	30 / 60	30 / 60
Probability of Observation (%)	***93.7***	***92.4***	***91.3***	***77.2***	***92.7 / 91.3***	***91.2 / 90.4***	***88.7 / 86.0***	***74.6 / 70.8***	***90.8 / 85.3***	***89.8 / 85.0***	***84.7 / 75.9***	***69.2 / 59.6***

Coordinated Attack (95% UAV Reliability)

	HART				Division Level C2 (wo/HART)				Brigade Level C2 (wo/HART)			
Area of Interest (km)	60 x 50				60 x 50				60 x 50			
UAV Aloft	4(S) + 1(H)				4(S) + 1(H)				4(S) + 1(H)			
UAV Available for Retasking	4(S) + 1(H)	3(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)	4(S) + 1(H)	3(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)	4(S) + 1(H)	3(S) + 1(H)	2(S) + 1(H)	1(S) + 1(H)
C2 Time for Retasking (min)	5	5	5	5	15 / 25	15 / 25	15 / 25	15 / 25	30 / 60	30 / 60	30 / 60	30 / 60
Probability of Observation (%)	***87.4***	***86.3***	***84.5***	***70.7***	***86.0 / 84.4***	***85.2 /83.2***	***81.8 / 79.4***	***67.1 / 63.7***	***83.9 / 78.7***	***81.8 / 75.9***	***77.8 / 70.0***	***62.2 / 52.0***

C. HART AND THE SENSOR-TO-SHOOTER THREAD

Figure 10 illustrates the Joint Targeting Cycle and the sensor-to-shooter thread within that cycle. The Joint Targeting Cycle, defined in Joint Publication 3-60, *Joint Doctrine for Targeting* (April 2007), is the basis for the sensor-to-shooter operational concept discussed in the following sections.

The operational activities within the targeting cycle can be mapped into generic sensor-to-shooter operational steps: detect/cue, track/locate, identify, decide, and strike. The order of the operational steps can differ in practice. For example, tracking may occur after identification, or persistent tracking may occur after a decision was made to strike.

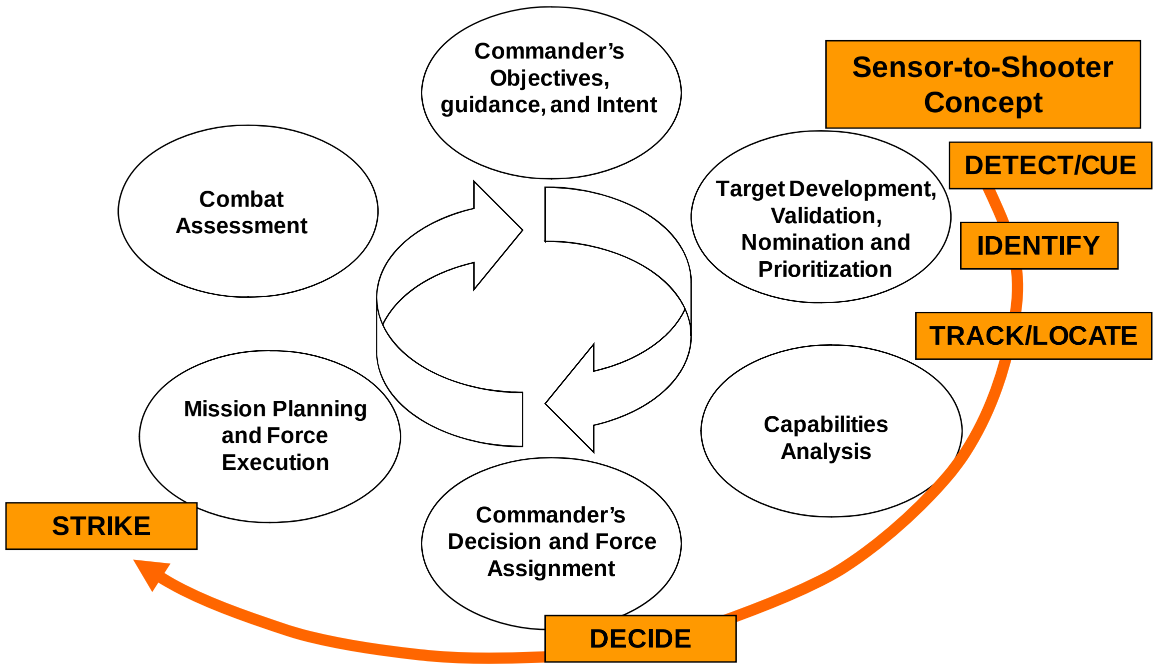

Figure 10. Joint Targeting Cycle

This construct allows one to examine the sensor-to-shooter thread and the potential operational benefits that HART has to offer.

- ***Detect/Cue***: Capability to detect a target of interest across the battlespace whenever it is exposed and cue potential strike platforms.
  - For effective detect capability, assured access to the battlespace is very important. The HART concept can effectively employ ISR assets by compiling multiple RSTA requests and prioritizing them to maximize the use of limited number of in-theater unmanned airborne platforms.
- ***Identify***: Capability to obtain sufficient resolution and geolocation accuracy to permit classification or identification and to initiate a track.
  - To identify a target, multiple sensors and platforms may be required to collect sufficient data of the right types to discriminate real targets from the background and to support initiating a track. The HART concept has the potential to increase the platform and sensor utilization rate that can result in better identification capability.
- ***Track/Locate***: Capability to geolocate target and maintain awareness of the location of the target until an engagement is possible and with sufficient accuracy to support the engagement.

  - For efficient tracking, frequent revisits to maintain track through target maneuvers may be necessary as gaps in tracking coverage can result in target loss. HART's direct access to multiple tiers of UAVs allows the use of high-altitude sensors to fill gaps between proliferated low-altitude platforms, which may alleviate this problem.

- ***Decide***: Determine whether a strike is feasible while ensuring that the involved systems—sensors, platforms, and weapons—work as a coherent whole to provide the flexible and timely response required under provided Rules of Engagement (ROE).
  - HART may provide the timeliness and connectivity necessary to pass information to strike platforms before the target becomes inaccessible or the track is lost by automating tasking, airspace deconfliction, flight path, and sensor control.
  - The HART concept allows the warfighter to submit dynamic task requests and reallocate UAV assets for unplanned higher priority incidents or when an in-use UAV is unable to complete tasking because of a platform or sensor failure.
  - The HART concept also allows UAV-collected digital imagery and full motion video to move freely and rapidly between systems involved in the engagement using secure ground-to-ground, ground-to-airborne, and ground-to-satellite communications.

- ***Strike (Engagement)***: Capability to get a weapon to its release point and guide the weapon until seeker acquisition or terminal engagement.
  - Strike platforms must be responsive to minimize the risk of losing or dropping the track before the target can be engaged.
  - Weapon and delivery platform must be survivable to assure that the weapon can reach the target.
  - Weapon must have sufficient knowledge of the target location at time of weapon release for the weapon's seeker to find the target or have midcourse guidance from a tracking system to the weapon.
    - Although precision munitions that rely on midcourse guidance, which may be provided by GPS or Inertial Navigation System (INS), can correct for aiming errors and precision errors, it cannot compensate for target location errors. In fact, midcourse guided munitions can be less effective when TLEs are large because the munition will precisely fly to the wrong location. Consequently, the best way to correct for TLE is

to provide better targeting information (The HART concept will provide a targeting accuracy of less than10-meters CEP).

– Weapon must have the necessary lethality against the target type

VI. CONCLUSIONS

We found that HART has the potential to provide a number of operational benefits in the areas of command and control, information sharing, asset availability and access, and airborne attack and surface-based fires support. HART has the potential to provide the following specific operational benefits.

A. COMMAND AND CONTROL

HART has the potential to shorten control and coordination timelines associated with dynamic retasking of UAS assets from the 10 to 15 minutes currently experienced by warfighters in Operation Enduring Freedom/Operation Iraqi Freedom (OEF/OIF) by:

- Allowing owners of UAS assets, and those units allocated coverage, to opt into HART and provide authorization for those assets to be automatically retasked in response to a pre-defined set of priority battlefield situations, such as troops in contact, personnel recovery, and medical evacuation.
- Interfacing with air mission management and airspace integration systems to automatically deconflict and establish the coordination measures necessary to execute dynamic retasking of UAS assets.

From an operational perspective those HART TTPs and shortened timelines:

- Increase the ability to acquire increased UAS support from a limited number of assets.
- Enhance UAS response to critical battlefield situations and enhance the ability for UAS to collect the information needed for real-time combat decision making.
- Remove reliance on voice, e-mail, or internet chat communications (and a dependence on the personal relationships between the parties involved) to secure expeditious approval for UAS retasking.
- Allow operators involved in requesting and coordinating a retasking to focus on other critical tasks and activities instead, such as coordinating rapid response air strikes.

B. INFORMATION SHARING

- HART enhances the ability to shift collection activity and capture specific images required by the warfighter by eliminating the need to "talk on" the UAS using imprecise voice communications.
- HART reduces data latency for those disadvantaged ground forces below company unable to receive direct video feeds from UAS flying overhead in near-real time. As of September 2007, the Army had fielded its 200th OSRVT to Iraq and Afghanistan. The system is built-in laptop-based, backpack, and airborne and ground vehicle-mounted terminal configurations. The intent is to push the system down to company commanders. Consequently, lower-level warfighters rely on personnel at company, battalion, and brigade to e-mail a JPEG image from collected UAS data or send a video snippet using the tactical communications links down to those units.
- HART will enable crews flying fixed-wing TACAIR platforms, such as the F-16 and F/A-18F, to gather situational awareness before arriving over the target area by delivering imagery from Air Force and Army UAS directly to the cockpits of those strike platforms, offering an enhancement over current capability. Today, Predator and Army UAS transmit full motion video directly to Apache attack helicopter cockpits and to the Air Force AC-130 gunship. Those airborne strike platforms must be within 40 to 50 km LOS of the UAS.
- HART strives to provide wider and faster access to previously collected, still timely, mission data through integration of image compression, storage, and archiving and video mining and searching technologies and techniques. This becomes relevant given that today Raven feeds are currently not stored. In addition, a digital video receiver attached to the Shadow GCS provides only a 24-hour buffer of imagery storage, with requests for imagery retrieval submitted to the brigade intelligence section.

C. ASSET AVAILABILITY AND ACCESS

For the advanced guard, rural area stability operations and route security scenarios analyzed for this effort, the shortened command and control timelines offered by HART slightly increase the probability of retasking and positioning a UAS to collect the information needed to develop situational awareness and make combat situations in response to a critical battlefield event. The advantage offered by HART increases when battlefield events are coordinated (occur nearly simultaneously) and as fewer UASs are available for retasking relative to the number of airborne UAVs.

The access tool used for this analysis did not consider the Raven SUAS because the scenarios developed for this study are at the brigade-level, in which the smallest unit depicted is a company. To fully explore the effects of HART on Raven operations, a company-level vignette, showing locations of platoons or squads, should be developed looking at, for example, the takedown of a safehouse and detaining a high value target.

D. CAS AND FIRES SUPPORT

HART will provide a target grid location accuracy of less than 10-meters CEP. This is better than the FCS Class IV UAS threshold and offers a substantial improvement in target location accuracy over what is achievable today for UAS not equipped with laser rangefinder capability. From an operational perspective, the resultant higher degree of confidence in target grid location data may enable:

- Ground commanders to direct Type 2 and Type 3 JTAC control for CAS missions, instead of the more restrictive Type 1 control, which requires controllers to visually acquire the target and attack platform.
- Artillery units to improve first-round impact on target performance for indirect surface-based fire support weapons.
- Forces to more fully exploit the engagement effectiveness offered by the use of GPS-guided smart munitions for attack aircraft.

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Appendix A

COMPANY AND BELOW INFORMATION NEEDS

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COMPANY AND BELOW INFORMATION NEEDS

HART is designed to provide an operational benefit to ground forces by enabling warfighters at company level and below to directly request RSTA services from a team of UAS assets. This aspect of HART can become important upon consideration of the most important types of information warfighters seek over a range of tactical situations.

A 2006 study conducted by the Army Research Institute for the Behavioral and Social Sciences asked 106 non-commissioned officers with combat experience as squad leaders to identify the top 10 types of information believed to be most important in battle from a list of 88 different types of battlefield information of potential interest to squad leaders.[1] This was done for four types of combat situations:

- Planning before an operation
- Assaulting an objective
- Consolidating and reorganizing on the objective
- Defending the objective from counterattack.

Tables A-1 through A-3 show the 10 types of information deemed most important by experienced squad leaders during the execution of assault, consolidation, and defense operations, respectively. The highlighted rows in each table indicate the types of information obtained by tasking reconnaissance assets, including UAVs, to named areas of interest or target areas of interest.

For the three combat situations considered, squad leaders want to know the locations of units in contact with the enemy and the locations of enemy personnel, vehicles, and weapons. Also, during assault operations, squad leaders want to know the direction of movement of enemy forces and the locations of booby traps and mines or other obstacles that may impede maneuver. A team of dynamically allocated UAS assets

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[1] *What Squad Leaders Want to Know in Battle* by Kenneth L. Evans (U.S. Army Research Institute, August 2006).

is ideally suited to providing these types of battlefield information. In addition, locations of Blue or friendly forces can be provided by airborne reconnaissance and surveillance assets. However, we note that the locations of friendly forces and combat service support sites, and logistical status information will be provided by currently fielded or planned information systems, such as Blue Force Tracker (BFT).

Table A-1. Battlefield Information Most Important to Assaulting Forces

Type of Battlefield Information	Percentage of Squad Leaders
1. Location of Units in Contact with the Enemy	65.1
2. Personnel Location in Adjacent Friendly Units	51.9
3. Location of Threat Personnel, Vehicles, and Weaponry	50.0
4. Location of Personnel in My Squad	47.2
5. Location of Mines, Obstacles, Booby Traps, and IEDs	47.2
6. Casualty Collection Point (CCP) Location	43.4
7. My Location Relative to Other Personnel	42.5
8. Ammunition Remaining	36.8
9. Direction of Movement for Enemy Personnel	36.8
10. SALUTE[a] Reports from Squad Members	33.0

[a] Size, Activity, Location, Unit, Time and Equipment

Table A-2. Battlefield Information Most Important to Consolidating Forces

Type of Battlefield Information	Percentage of Squad Leaders
1. CCP Location	74.5
2. Ammunition Remaining	56.6
3. Location of Personnel in My Squad	54.7
4. My Location Relative to Other Personnel	38.7
5. Location of Nearest Medical Treatment Site	38.7
6. Location of Threat Personnel, Vehicles, and Weaponry	35.8
7. Personnel Location in Adjacent Friendly Units	34.9
8. Status of WIA, KIA and EPW[a]	33.0
9. Location of Units in Contact with the Enemy	31.1
10. Food and Water on Hand	31.1

[a] Wounded in action, killed in action, and enemy prisoners of war

Table A-3. Battlefield Information Most Important to Defending Forces

Type of Battlefield Information	Percentage of Squad Leaders
1. Personnel Location in Adjacent Friendly Units	53.8
2. Location of Threat Personnel, Vehicles, and Weaponry	53.8
3. Ammunition Remaining	52.8
4. Location of Personnel in My Squad	50.0
5. Location of Units in Contact with the Enemy	49.1
6. My Location Relative to Other Personnel	43.4
7. Food and Water on Hand	34.9
8. Availability of Supporting Fires (Mortars and Artillery)	34.0
9. CCP Location	33.0
10. SALUTE Reports from Squad Members	32.1

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Appendix B

TTPs FOR CONDUCTING DYNAMIC ALLOCATION AND RETASKING OF UAS ASSETS

Appendix B
TTPs FOR CONDUCTING DYNAMIC ALLOCATION AND RETASKING OF UAS ASSETS

A. ARMY SHADOW OR HUNTER OPERATIONS

Requests for hasty missions or in-flight diversions are submitted to division or brigade. At the brigade level, the aviation elements are equipped with the Tactical Airspace Integration System (TAIS), which displays the location and movement of aircraft within the battlespace. Consequently, brigade headquarters personnel know which adjacent BCTs are being supported by Army UAV assets. Army personnel in-theater have developed a procedure in which a BCT operations or intelligence officer with an emerging ISR requirement initiates a direct request via voice or mIRC chat to those adjacent Shadow- or Hunter-supported units for dynamic reallocation of UAV assets. It is noted that shifting an inorganic UAV asset between supported units requires approval from the appropriate echelon of command with operational control of the UAV and additional airspace control and deconfliction measures. Division and brigade aviation elements use the TAIS and the Army Advanced Field Artillery Tactical Data System (AFATDS) to deconflict airspace, including establishing new restricted operations zones (ROZs), as required, for UAS operations.[1] Retasking Shadow or Hunter UAS assets using the above procedure can normally be accomplished in about 15 minutes or less.[2]

B. RAVEN OPERATIONS

If directed by battalion or agreed between two company commanders, an adjacent unit can take control of a Raven by tuning to the Raven flight control frequency. However, the Raven's limited operational range and duration limits such handovers.

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1 ROZ information is distributed throughout theater, including a contact frequency for aircraft needed to transition through the ROZ. A smaller restricted operations area (ROA) may be established within the ROZ for UAS operations if multiple aircraft elements will be conducting separate operations within the ROZ.

2 Telecon on 22 January 2009 with the Operations Officer assigned to the 1st Brigade Combat Team (BCT), 1st Cavalry Division during the OIF surge.

C. PREDATOR OPERATIONS

Surveillance of ad hoc targets or dynamic retasking by the major subordinate commander currently being supported by the Predator may be executed once the Combined Air Operations Center (CAOC) or Joint Air Operations Center (JAOC), depending on the campaign and partners involved, and the combined or joint force commander approve the shift to a new mission. The supported unit transmits a standard ISR target brief using mIRC to detail ISR requirements for the new targets to the Predator crew.

When a dynamic retasking request to a new target is received from another supported unit before the current target essential elements of information (EEI) are satisfied, the Predator mission coordinator must verify with the currently supported unit that the Predator is cleared to proceed to the new target without satisfying the current target EEI. Again, the air operations center and combined or joint force commander must approve the shift to a new mission.

Appendix C

BATTLEFIELD SCENARIOS FOR UAS EMPLOYMENT

Appendix C
BATTLEFIELD SCENARIOS FOR UAS EMPLOYMENT

To assess the potential operational benefits and to demonstrate how the HART concept addresses the shortfalls in UAS operations previously described, HART should be explored against a range of brigade-level battlefield scenarios, comparing the ISR support provided to ground commanders using airborne ISR assets with and without HART. Those scenarios also serve to contrast today's UAS CONOP with how UA assets may be operationally tasked and controlled using HART, and how HART enables ground commanders to better exploit the information collected by airborne ISR platforms operating in theater.

The following scenarios exemplify the types that should underpin an analysis of HART capabilities. Each scenario describes a main effort with supporting efforts across the brigade's area of operations. The main and supporting operations, and the maneuver units conducting those operations, are dispersed throughout the operations area. Meeting the ISR requirements of brigade, battalion, company, and platoon commanders requires UAS and manned ISR platforms to fly concurrent and sequential coordinated missions. Lastly, the range of airborne platforms available providing airborne ISR include Air Force Predators; Army Sky Warrior, Shadow, and Raven UASs; and Army manned helicopters.

This document identifies five scenarios upon which to base further analyses. The scenarios cover three of the four basic types of operations conducted by Army operational units across the spectrum of conflict: offensive operations, defensive operations, and stability operations.[1] These three types of operations were selected because they appear to be among the most challenging from a UAS employment perspective. The descriptions that follow are based on the TTPs for employing heavy, infantry, and Stryker BCTs during the conduct of conventional or irregular warfare found in the Army Field Manual 3-90.6, *The Brigade Combat Team*.

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[1] Civil Support is the fourth type of Army operation.

The description of each scenario establishes initial battlefield conditions using a notional force laydown and shows all units with assigned UAS assets. The scenarios also depict those division-level and EAD UAS assets allocated to support brigade operations. FM 3-90.6 does not depict battle space dimensions. Leveraging the operational experience of retired and active military personnel at IDA, the study team applied reasonable dimensions, which were vetted by doctrine experts (including the proponent for the Field Manual) at the Army Combined Armor Center. For each scenario, the initial battlefield conditions evolve as a result of a developing dynamic situation that would cause a ground commander to respond, including retasking or reallocating UAV assets. The objective is to compare how UAS assets and their collected information can be retasked, controlled, and exploited today, and then in the future following HART implementation.

A. SCENARIO 1—ADVANCED GUARD OFFENSIVE OPERATION

This scenario is a conventional warfare operation in which a heavy BCT (HBCT) is employed as the division advanced guard unit. The initial battlefield situation is shown in Figure C-1. The HBCT is leading the movement to contact in non-urban complex terrain. The lead combined arms battalion is guard for the HBCT. The armed reconnaissance squadron is screening the right flank, and the remaining elements are dispersed along the route of march. The BCT would move at a speed consistent with the terrain and anticipated likelihood of contact at any key point.

Prior to movement, any reconnaissance needed to support planning by the division would be flown by division-level Hunter and Shadow UAVs organic to the division BCTs. The division would request CAP support from CFACC assets. Also the division and its BCT would request recent archived data on the route of march.

The HBCT is notionally assigned 17 Raven UASs (at the company level and below). There are three Raven UAs in each system. The HBCT is also assigned a Shadow UAS containing four UAs. The locations of the HBCT Raven UASs are depicted by the “asterisks” in Figure C-1.

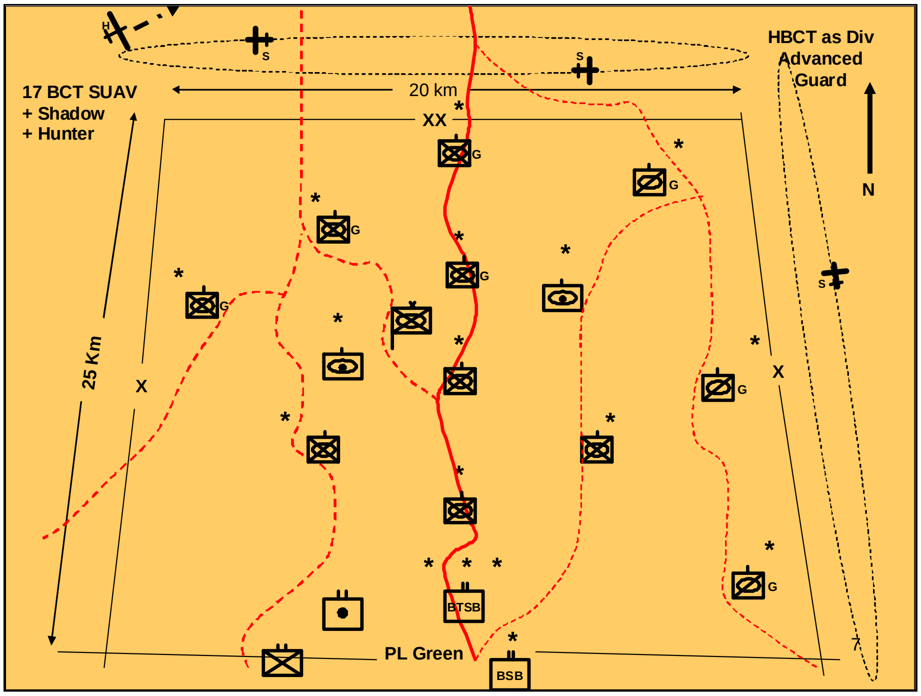

Figure C-1. Initial Battlefield Situation—Advanced Guard Offensive Operation

Once the HBCT begins its march, the mechanized infantry companies would employ their organic Raven to support movement. The BCT would employ one or two Shadows ahead of the lead elements. Also shown is a Shadow flown by a following BCT providing additional observation of the division right flank. The division Hunter probably would be operating where it could observe forward of the BCT Shadows and would be providing collected imagery to the lead BCTs.

As the march continues, the advance guard makes contact on its right front (Figure C-2.) As a result, two maneuver companies from the guard battalion move to fix the enemy. The reserve battalion also maneuvers to a position from which it can assault the enemy position once its size and strength are determined, thereby permitting the guard battalion and armed reconnaissance squadron to disengage and continue forward movement.

Following significant contact by lead units on its right front, Shadows are retasked to increase reconnaissance or surveillance at the incident location. The lead BCT dedicates one Shadow to the incident site. The follow-on BCT Shadow on the right flank is directed to assume an orbit to view the incident site from the southeast. The

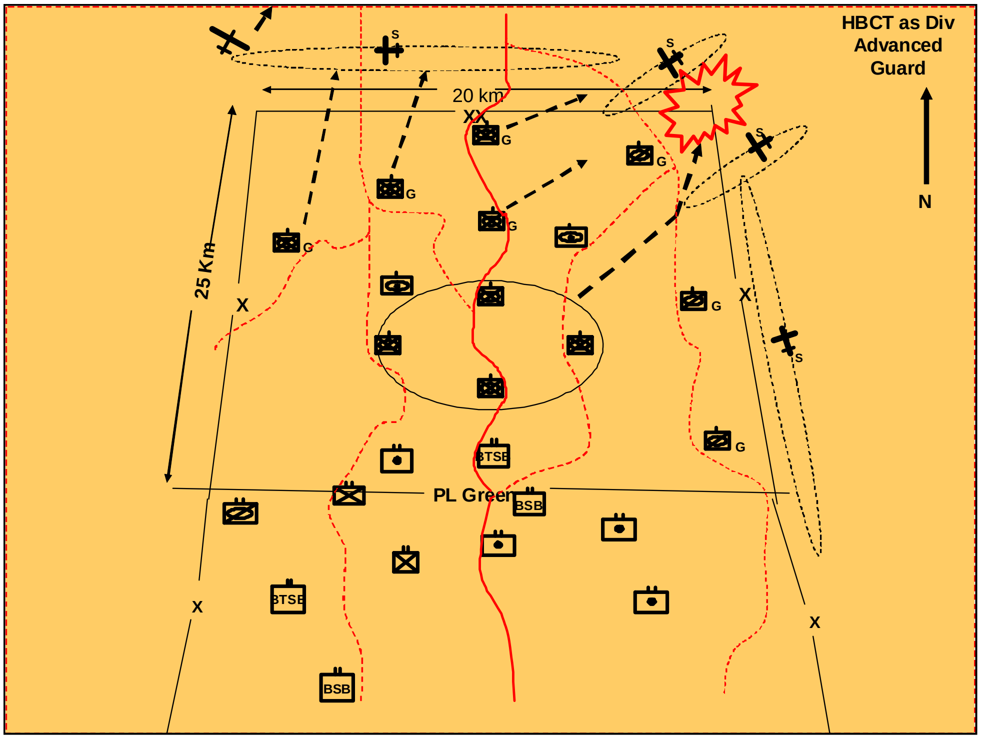

Figure C-2. Evolving Battlefield Situation—Advanced Guard Offensive Operation

follow-on BCT then launches a second Shadow to assume a position from which it can cover the flank mission. Company-level Raven UAVs are employed to support company movement or contact.

B. SCENARIO 2—DEFENSE-IN-DEPTH DEFENSIVE OPERATION

This scenario is a conventional warfare operation in which a HBCT defends in depth. The initial battlefield situation is shown in Figure C-3. The HBCT security force consists of two troops of the brigade's armed reconnaissance squadron operating forward of the forward edge of the battle area (FEBA).[2] The security force is supported by two artillery batteries, also forward of the FEBA, and an engineer company. The third troop of the armed reconnaissance squadron is screening the right flank.

Raven UAVs are employed by owning company, troop, or battery. The HBCT employs its Shadow in the security area. Hunter is forward of the HBCT security area, covering the division's most dangerous avenue of approach.

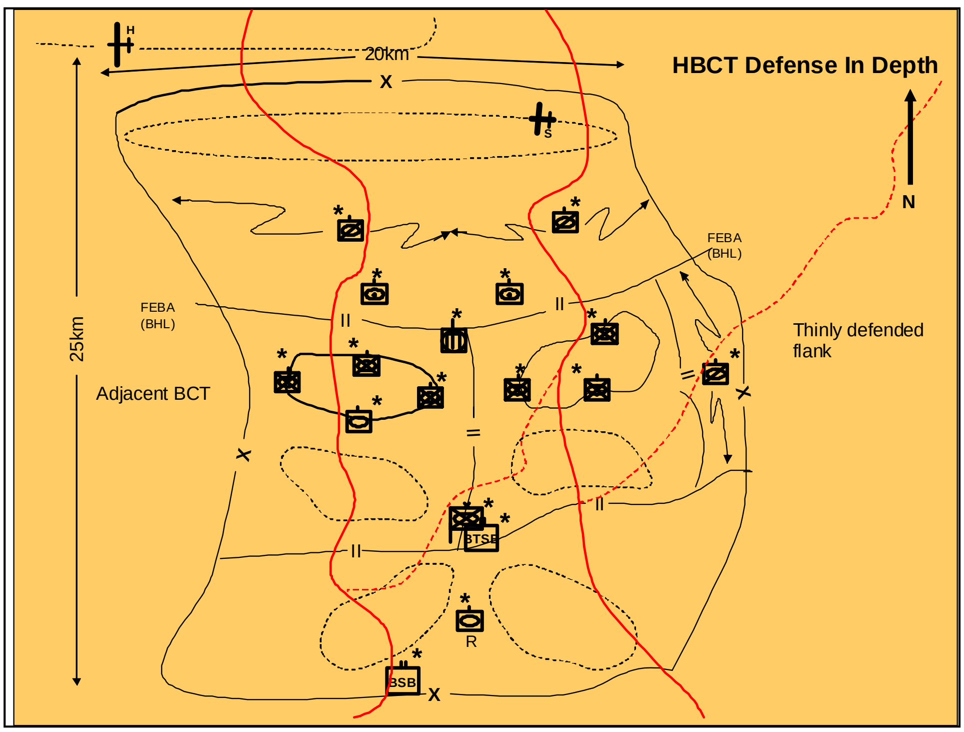

Figure C-3. Initial Battlefield Situation—Defense-in-Depth Operation

As enemy lead elements approach (Figure C-4), the HBCT security force withdraws to right flank and rear maintaining contact until passage of the line of

[2] The foremost limits of a series of areas in which ground combat units are deployed, excluding areas in which the covering or screening forces are operating (Joint Publication 1-02, Department of Defense Dictionary of Military and Associated Terms (Joint Chief of Staff, 17 October 2008).

demarcation for the first phase of withdrawal. At the appropriate time, the artillery withdraws to supplemental positions. Similarly the engineers withdraw to prepare rear fighting positions further to the rear. Forward combined arms battalions then defend in sector.

The Raven UAVs are employed by owning companies to support own operations. The Shadow is repositioned to an orbit behind the FEBA with a good view of the security area, but relatively safe from enemy fire. The Hunter under Division control withdraws to an orbit rear of the FEBA with a good view of the security area.

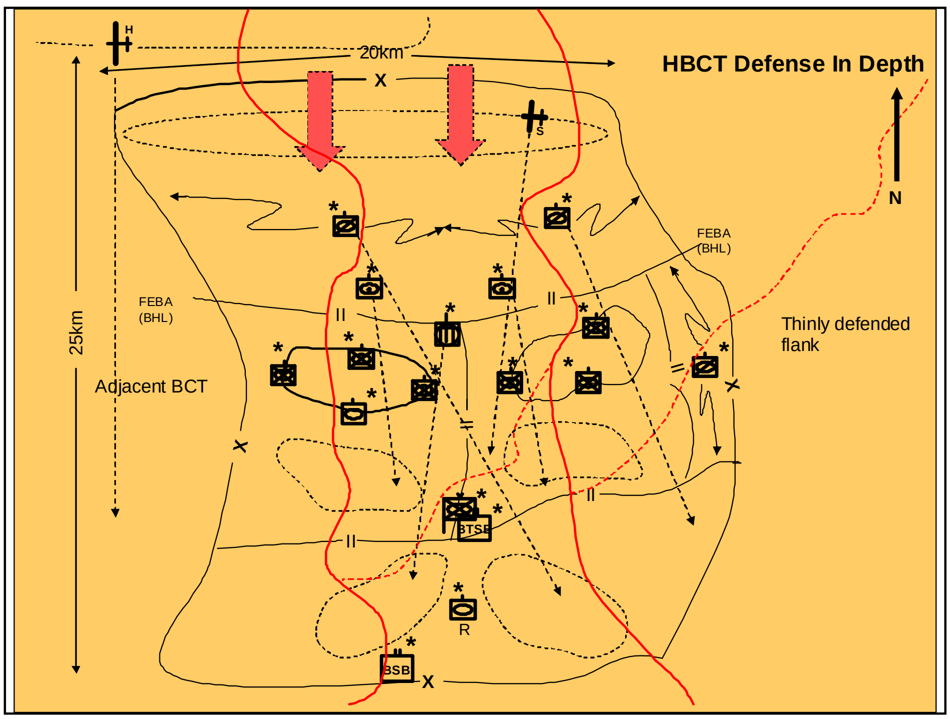

Figure C-4. Evolving Battlefield Situation—Defense-in-Depth Operation

As the situation further develops, as shown in Figure C-5, and the HBCT continues its disengagement and withdrawal, Raven UAVs continue to be employed by owning company-level and below units. The HBCT Shadow continues to be employed to the rear of the FEBA to cover the security area. A second Shadow, when available, might be used to observe the thinly defended right flank. Hunter would be employed by division to cover security area and areas it deems most threatened.

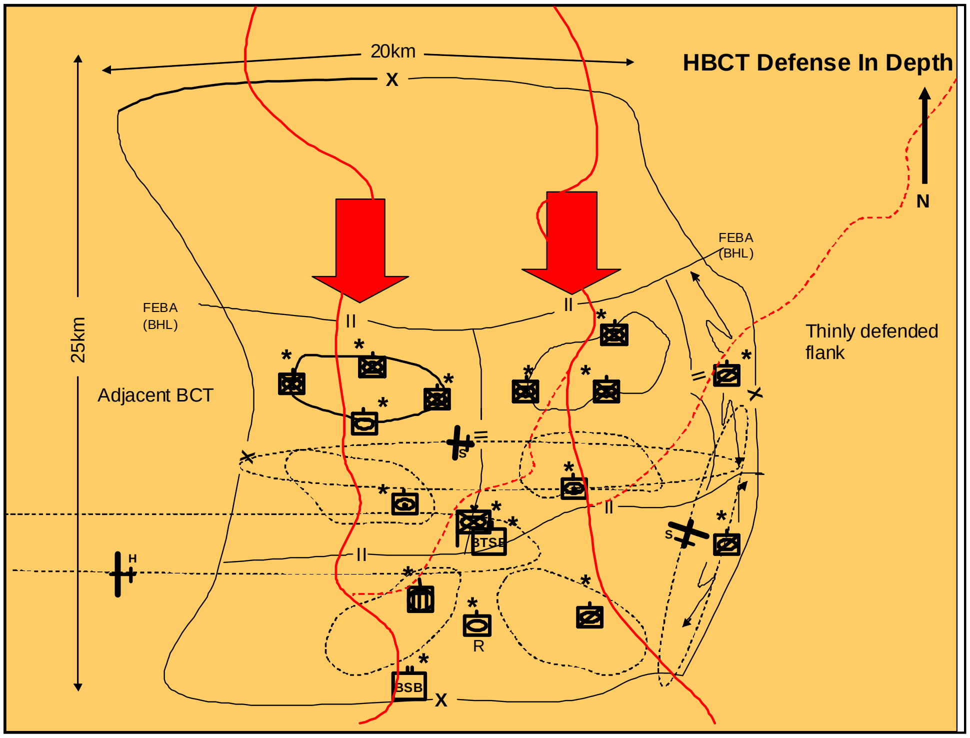

Figure C-5. Evolving Battlefield Situation Continuation—Defense-in-Depth Operation

C. SCENARIO 3—URBAN AREA SECURITY (STABILITY OPERATION)

A HBCT is tasked to conduct area security operations over an 11 x 9-km urban area. Figure C-6 is a sketch based on southwest Baghdad. The number of tertiary roads in built-up areas, such as Baghdad, are too numerous and therefore are not shown on the figure. The HBCT's companies are securing assigned neighborhoods in conjunction with Iraqi Security Forces: the local police and Iraqi Army. The HBCT headquarters and support units occupy a small forward operating base (FOB). The companies and units stationed at the FOB conduct routine area security operations including establishing and manning checkpoints; conducting patrols; gathering intelligence; conducting counter improvised explosive device (C-IED) sweeps and major supply route (MSR) security; locating and capturing high value targets (HVT); and performing cordon and search. The battalions and or HBCT may direct specific operations if actionable intelligence is generated. In event of incidents, units support each other as able and directed.

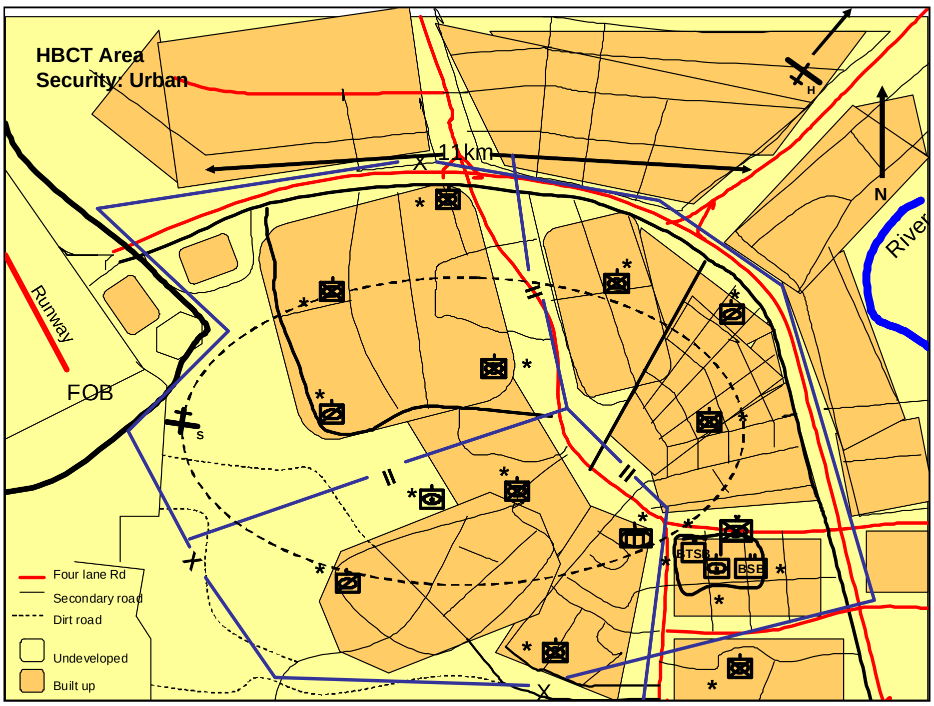

Figure C-6. Initial Battlefield Situation—Urban Area Security (Stability Operation)

The company Raven UAVs are normally used in their own sectors. The HBCT Shadow UAVs, supplemented division, and other BCT UA assets, fly a continuous orbit over the HBCT operational area. Absent an incident or ongoing priority mission, the

UAs are collecting according to plans for future operations. The division Hunter normally is used by the division to support HVT operations. However, the UAS is periodically available for BCT general support or if an incident warrants its use. In this scenario, Hunter UAVs are launched, recovered, and maintained at a site located roughly 15 km away.

While conducting area security operations, the HBCT experiences four near-simultaneous incidents (Figure C-7). In the northwest, a battalion has been tasked to capture and detain an IED engineer (HVT) and shut down his bomb-making factory. The battalion has designated one of its companies to execute the search and take down and three companies to seal the area so the HVT cannot escape.

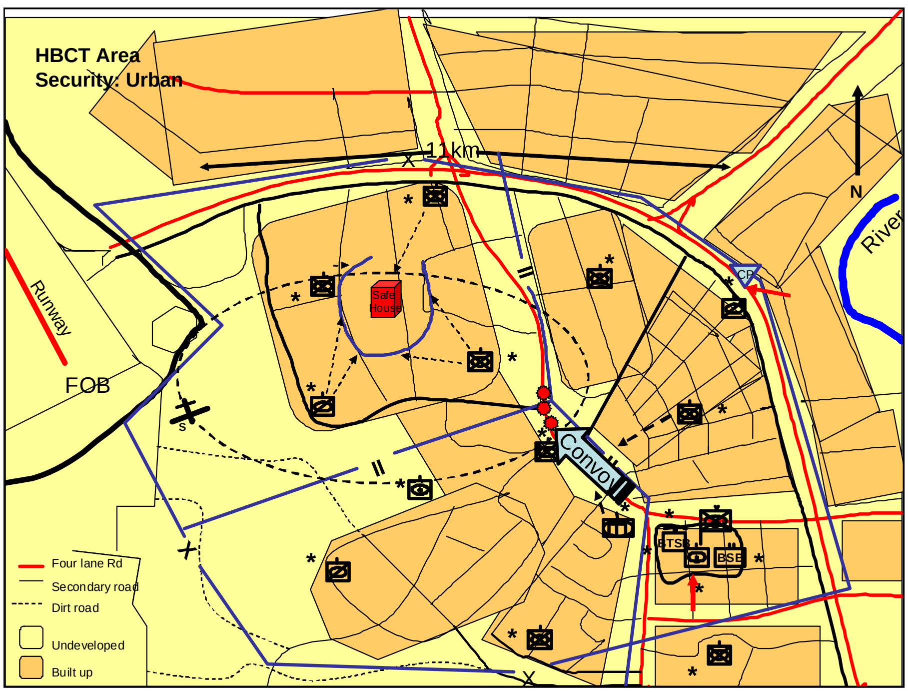

Figure C-7. Evolving Battlefield Situation—Urban Area Security (Stability Operation)

Meanwhile, near the boundary between two battalions, a routine route sweep finds a package of three IEDs. As a result, a convoy is temporarily halted and vulnerable. This is of heightened importance due to recent intelligence reports indicating insurgents may be planning a ground attack to seize prisoners. Therefore, two companies are directed to send platoons to overwatch the static convoy until it is able to move.

In addition, there is sniper fire on a check point in the east and rocket-propelled grenade (RPG) fire on the HBCT FOB.

The HBCT determines that the HVT mission is the highest priority because of the potential long-term operational benefit. Therefore, the HBCT Shadow UAS operates in direct support to the battalion tasked with the HVT mission. In addition, Raven UAVs assigned to this northwest battalion cover possible escape routes.

Elsewhere in the HBCT operational area, the owned Raven UASs support quick responses executed by ground forces in response to the other three events. To enhance convoy protection, the HBCT might launch another Shadow UAV, possibly affecting the ability to maintain a 24-hour CAP capability over the operational area. Or the HBCT may request support from the division Hunter, request Shadow support from an adjacent BCT, or request support from a manned ISR aircraft until the convoy holdup is resolved.

D. SCENARIO 4—RURAL AREA SECURITY (STABILITY OPERATION)

An HBCT conducts area security of a 30 x 30-km rural environment with at least 50 percent open space. The terrain is dotted by occasional small towns and villages, a few agricultural areas, occasional wooded areas, and a few streams. The population includes a mix of friendly and hostile towns and villages with a few (5-7) interspersed insurgent cells. The HBCT mission is to protect the population, support government institutions, secure selected roads, conduct counterinsurgent activities, and provide humanitarian relief.

Figure C-8 shows the HBCT and battalions, each of which have a designated operational AOR. Within each respective AOR, company- or platoon-sized ground units conduct a range of stability operations including route security, wide area surveillance, cordon and search, FOB security, raids and ambushes, foreign internal defense (FID) and counterterrorism, peacekeeping, and humanitarian assistance. The initial battlefield situation includes the following ongoing operations:

- Humanitarian relief at a refugee camp at 1.
- A routine presence patrol at 2
- FOB security at 3
- Surveillance of a suspected insurgent infiltration route along the BCT boundary at 4
- Other area security operations.

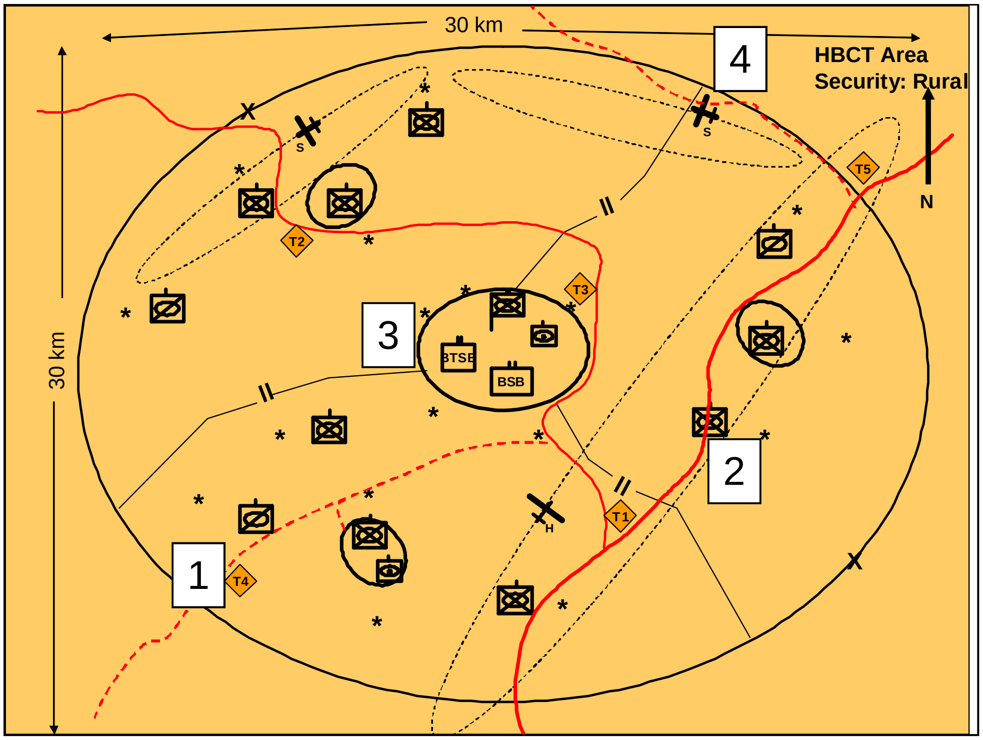

Figure C-8. Initial Battlefield Situation—Rural Area Security (Stability Operation)

The HBCT or battalions normally maintain a reaction force in case a unit is decisively engaged.

Raven UASs are employed by the owning units to support their own operations. Two Shadow UAS orbits are flown to cover the boundary at 4 and a battalion patrol and search operation in the northwest. The division has allocated a Hunter UAV to overwatch an important MSR, which passes through the BCT AOR. All Hunter imagery in the AOR is disseminated to the BCT and to the eastern battalions and squadrons.

Figure C-9 shows the battlefield situation evolves as a number of incidents occur sequentially at 30- to 45-minute intervals: a riot in refugee camp during humanitarian operation at 1; an IED attack followed by sporadic direct fire on a platoon evacuating casualties at 2; a mortar and small arms attack on the FOB at 3; and Shadow detection of possible insurgent infiltration activity near the HBCT boundary at 4.

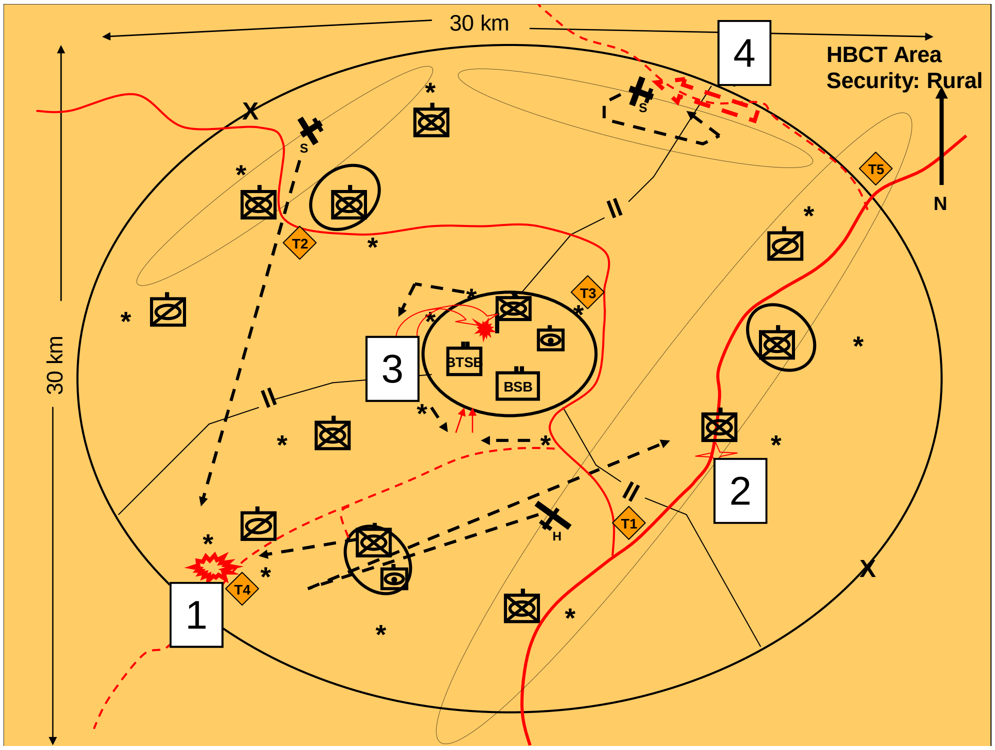

Figure C-9. Evolving Battlefield Situation—Rural Area Security (Stability Operation)

For the riot in the refugee camp at 1, the Hunter is diverted initially after brief coordination with division. In addition, the on-site troop and reinforcing company employ their Ravens locally to help determine the situation. When the complex IED attack occurs at 2, the Hunter is redirected to the attack site, and the northwest Shadow is diverted to the refugee camp. Local Ravens within range of the incident site at 2 provide support within capabilities. When the mortar and small arms attack on the FOB occurs, the five available Ravens are employed by the owning units but are coordinated by the FOB commander. Finally, when the Shadow at 4 detects possible insurgent infiltration activity in vicinity of the HBCT boundary, the UAV is directed to follow the insurgents to confirm hostile intentions and then support attack by manned aircraft.

E. SCENARIO 5—ROUTE SECURITY (STABILITY OPERATION)

Figure C-10 shows an HBCT tasked with a mission to secure the paved highway from Balad to Baghdad for movement of a large convoy. The road distance is approximately 75 km. A few medium-sized and several small towns are along the route. The road passes through a mix of scrub vegetation, agricultural areas (especially to the east) and open terrain (especially to the west). The BCT cross-attaches companies and troops to create three task forces, each of which is given a section of the road to secure. Battalions employ their companies along the route in sectors to clear the MSR and then secure the convoy route. Two artillery batteries are deployed along the route to ensure maximum indirect fire coverage. The engineer company is assigned to accompany the convoy and provide a second sweep of the road as the convoy moves south.

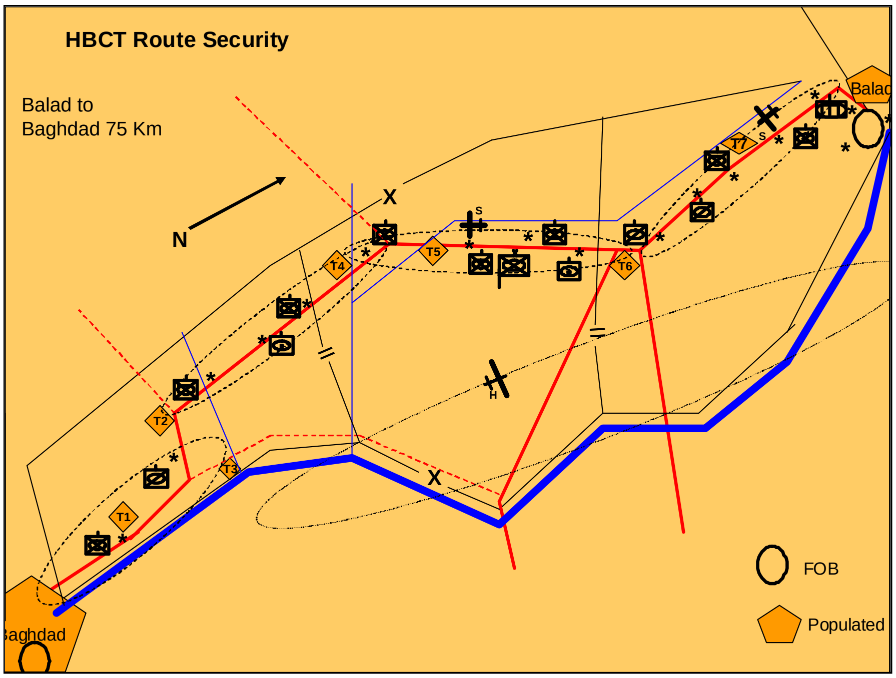

Figure C-10. Initial Battlefield Situation—Route Security (Stability Operation)

Companies and batteries when in position employ Ravens locally for route reconnaissance, surveillance, and intelligence (RSI). The engineer company (reinforced) moves along the route ahead of the lead convoy employing its own Raven. One Raven UAS from the Base Support Battalion (BSB) and two Raven UASs from the Brigade Special Troops Battalion are employed for RSI at the Balad FOB. The BCT is supported by four planned Shadow orbits to observe convoy movements. The division Hunter is employed in the BCT OA on another mission reconnoitering the Tigris River.

As the convoy lead elements move south to vicinity of T5, an engineer company encounters an IED complex ambush on the south edge of the town. The IED detonation results in friendly casualties requiring medical evacuation (MEDEVAC). Following the IED detonation, a series of attacks occur, possibly coordinated with the complex ambush: four rockets each salvo on the Balad FOB and a band of insurgents launches a direct fire attack on the artillery battery southwest of T4 as shown in Figure C-11. The IED detonation and coordinated attacks all occur within a 90-minute time span.

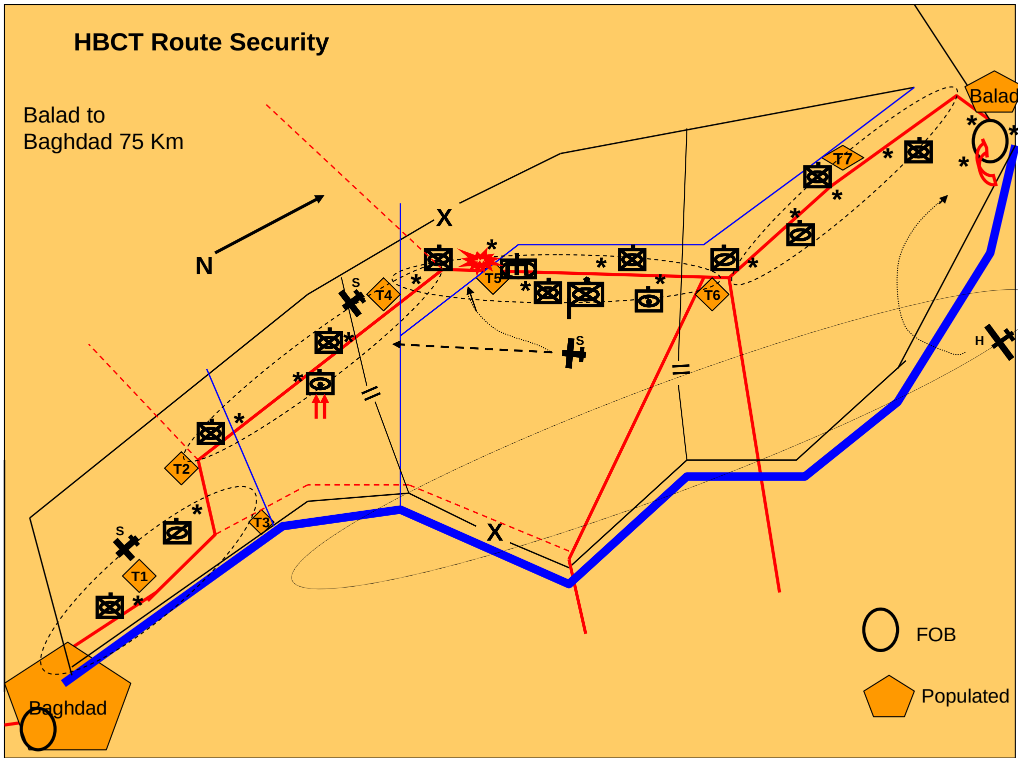

Figure C-11. Evolving Battlefield Situation—Route Security (Stability Operation)

The companies, troops, and batteries employ their assigned Raven UAS in respective sectors. Distances preclude most opportunities for mutual support even if feasible. However, near T5, three Ravens may be in range of the IED attack site. If so, they support as able. The Shadows are on orbit forward of the convoy moving south when the IED attack occurs. At the time of the IED detonation, a third Shadow was en route to replace the Shadow in orbit southwest of T4. Therefore, the BCT redirects the en route Shadow to the T5 attack site and extends the route coverage of the Shadow near T1. The HBCT requests that the Hunter in obit location near Balad support the rocket search.

Appendix D

GLOSSARY

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GLOSSARY

A2C2	Army airspace command and control
ACC	Air Combat Command
AEW	air expeditionary wing
AFATDS	Advanced Field Artillery Tactical Data System
AFSOC	Air Force Special Operations Command
AOR	area of responsibility
BAE	brigade aviation element
BCT	Brigade Combat Team
BDA	battle damage assessment
BFT	Blue Force Tracker
BLOS	beyond line of sight
BSB	Base Support Battalion
CAOC	Combined Air Operations Center
CAP	combat air patrol
CAS	close air support
CCP	Casualty Collection Point
CEP	circular error probable
CFACC	Combined Force Air and Space Component Commander
C-IED	counter improvised explosive device
CONOP	concept of operation
CONUS	continental United States
CP	command post
DARPA	Defense Advanced Research projects Agency
DCGS	Distributed Common Ground System
DGS	deployable ground stations
DVR	digital video receiver

EAD	echelon above division
EEI	essential elements of information
EO	electro-optic
EPW	enemy prisoners of war
ER/MP	Extended Range/Multi-Purpose
FAC	Forward Air Controller
FDC	fire direction center
FEBA	forward edge of the battle area
FID	foreign internal defense
FM	Field Manual
FO	forward observer
FOB	forward operating base
FTP	file transfer protocol
FY	fiscal year
GCS	ground control station
GPS	global positioning system
HART	Heterogeneous Airborne Reconnaissance Team
HBCT	heavy BCT
HC3	HART command and control center
HVT	high value targets
IF	Information Flow
IMINT	imagery intelligence
INS	Inertial Navigation System
IOTE	initial operational test and evaluation
IPIR	Initial Phase Interpretation Report
IR	infrared
JP	Joint Publication
JTAC	Joint Terminal Attack Controller
KIA	killed in action

km	kilometer
L/R	launch and recovery
LOS	line of sight
LRE	launch and recovery element
LRGCS	launch and recovery ground control station
MEDEVAC	medical evacuation
mIRC	Internet Relay Chat (Microsoft)
MNC-I	Multi-National Corps–Iraq
MOB	Main Operating Base
MPCS	mission planning and control site
MSC	major subordinate command
MSR	major supply route
MTI	moving target indicator
MUM	manned-unmanned
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OPCON	operational control
OSGCS	One System Ground Control Station
OSRVT	One System Remote Video Transceiver
OSRVT	One-System Remote Video Terminal
PED	processing, exploitation and dissemination
POC-N	Predator Operation Center at Nellis AFB
PPSL	Predator primary satellite link
QoI	Quality of Information
ROA	restricted operations area
ROE	rules of engagement
ROVER	Remote Operated Video Enhanced Receiver
ROZ	restricted operations zone

RPG	rocket-propelled grenade
RSI	reconnaissance, surveillance, and intelligence
RSN	regional satellite node
RSTA	reconnaissance, surveillance, and target acquisition
RVT	remote video terminal
SALUTE	Size, Activity, Location, Unit, Time and Equipment
SATCOM	satellite communications
SEP	spherical error probable
SIPRNet	Secret Internet Protocol Router Network
SOF	special operations force
SUAS	small UAS
TACAIR	tactical aircraft
TAIS	Tactical Airspace Integration System
TLE	target location error
TTPs	tactics, techniques, and procedures
TUAS	tactical UAS
UA	unmanned aircraft
UAS	unmanned air system
UAV	unmanned air vehicle
USCENTCOM	U.S. Central Command
USSOCOM	U.S. Special Operations Command
VUIT-2	Video from UAS for Interoperability Teaming–Level II
WIA	wounded in action

Appendix E

LIST OF FIGURES AND TABLES

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REPORT DOCUMENTATION PAGE						*Form Approved OMB No. 0704-0188*
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14. ABSTRACT Enhancing the reconnaissance, surveillance, and target acquisition (RSTA) services provided directly to low-echelon units operating in complex battlefield environments is the objective of the Heterogeneous Airborne Reconnaissance Team (HART) system sponsored by the Defense Advanced Research Projects Agency. IDA was asked to explore the enhanced capability offered by HART to deliver unmanned air vehicle sensor data directly to those units. We focused our efforts on three specific activities associated with the RSTA cycle: warfighter RSTA requests submission, dynamic allocation, and management of unmanned airborne assets and dissemination of video and imagery products to the warfighter. Our analyses also considered three brigade scenarios with varying battlefield dimensions, notional force laydown and assignment of UAS assets. We found that when compared to current unmanned air system (UAS) tactics, techniques and procedures, the information flow to small units at company level and below, dispersed over a brigade operations area, is enhanced by the HART system, which in turn may improve the operational effectiveness of those units.						
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