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NAVAL COMMAND AND CONTROL FOR FUTURE UAVS

by

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A description of contemporary and proposed UAV systems is presented, and this Thesis uses a scenario to illustrate current limitations and develop the requirements for UAV command and control.

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NAVAL COMMAND AND CONTROL FOR FUTURE UAVs

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ABSTRACT

The primary purpose of this thesis is to examine the requirements of naval command and control for future Unmanned Aerial Vehicles (UAV) and to propose solutions for current limitations.

Currently, UAVs co-exist as a collection of independent systems that have poor interoperability and limited functionality beyond strategic reconnaissance. As UAVs mature, they will increasingly be deployed at the unit level and employed tactically, increasing the need for coordination and the dissemination of information. Command and control systems must evolve to keep pace with this development.

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EXECUTIVE SUMMARY

The purpose of this Thesis is to demonstrate the increasing sophistication and growing utility of modern UAVs and the underlying problem with command and control, which is unprepared to leverage these capabilities into combat effectiveness. The problem can be summarized as a strategic imagery analysis structure that cannot meet the dynamic requirements of tactical reconnaissance and under-developed CONOPS that do not address necessary requirements.

This Thesis first outlines the history and impetus of the trend towards greater use of UAVs. This shows that UAVs have entered a period of increasing need for worldwide reconnaissance during a sustained U.S. military downsizing. The concurrent maturation of key aeronautical technologies thrusts UAVs into a role of providing primary reconnaissance capabilities.

The HAE class of UAVs is able to provide sustained surveillance that matches, and in some measures exceeds satellite and manned overflight capabilities. They provide real-time, high-resolution imagery that has the potential to greatly improve battle space awareness and the ability to improve strategic decision-making.

The VTUAV brings advanced reconnaissance capabilities to the fleet end user. No longer dependent on tactical aircraft and external intelligence support, the fleet gains the capability with VTUAVs to maintain organic 24-hour surveillance over areas of interest. With the addition of the Tactical Control System and satellite reception, each ship in the battle group has access to this imagery.

The Thesis develops a scenario that highlights the difficulties that can be expected when these advanced UAVs are deployed. The HAE UAV is intended as a strategic reconnaissance asset, but employed with current technology provides imagery analysis and dissemination that will deliver stale data to tactical users. This problem lies not in the technology available for delivering the imagery, because GBS has been successfully demonstrated in this capacity, but with the analysis process, our CONOPS, communications and intelligence.

The primary problem with the HAE UAV is that the analysis will occur within the bounds of a strategic system, which was developed primarily to support strategic decision

making and not the tactical customer. This imagery analysis and dissemination cycle has only recently been pressured for quicker turnaround. The overriding constraint is the labor intensive nature of imagery analysis, and even with plans to move the analysis into theater, the bottleneck remains the man in the loop.

Additional problems with the HAE UAV command and control structure are the inability to respond to dynamic situations and the lack of a mechanism for effective sensor to shooter engagements. The HAE UAV is a strategic asset that is properly tasked through the ATO, but it will undoubtedly be requested to respond to dynamic situations. These requests will come from the tactical warfighters and from the fleet.

The command and control structure must be able to quickly forward and evaluate these requests against other collection requirements. When these requests result in a bonified requirement for a sensor to shooter engagement, the target data must either be quickly passed to a suitable shooter or the target must be handed-off to a tactical UAV for continued surveillance.

The VTUAVs will be the fleet's primary tactical reconnaissance asset, especially over geographically remote or hostile areas. The fleet, however, must be upgraded to harness this significant capability. Primarily, the fleet requires a command and control structure and imagery processing pipeline that is responsive to tactical requirements.

The command and control problem is partially solved by TCS, which provides the GMCS connectivity to distribute track information. The remaining problem is how to get dynamic mission tasking across the fleet to the vehicle operator, preferably in a visual format. The clearest command will be a fly-to point on the operator's console.

The VTUAV image processing problem is mainly due to the lack of trained fleet imagery analysts and limited ship to ship bandwidth. The imagery analyst problem can be partially overcome by leveraging the available resources with technology. An imagery analysis center would best execute the analysis by co-locating these scarce personnel with sophisticated analysis software.

Once this analysis is performed, the imagery must be directed to the best platform for sensor to shooter engagements. The only current solution is to utilize the direct receipt of imagery (level 2) capabilities of TCS. The lack of ship to ship bandwidth makes any other transmission path difficult

I. INTRODUCTION

This Thesis examines the command and control structure that will be necessary to leverage the additional capabilities presented by the proliferation of UAVs. A history and overview of the impetus for this trend is presented in this chapter.

A. HISTORY OF UAVs

Unmanned Aerial Vehicles (UAVs) are not new to warfare or to the Navy. Although examples of unmanned aircraft can be traced to World War I, the first UAV used for reconnaissance was the BQM-34 Firebee [Ref. 1: p. 30-31]. This drone was initially developed in 1954 as a jet-powered target drone, but when Gary Francis Powers was shot down over the Soviet Union the Firebee was quickly converted for reconnaissance duties.

The BQM-34 was demonstrated using existing photo reconnaissance cameras. Later, a BQM-34 with larger wings designed to fly at high altitude was developed as the first UAV designed specifically for the reconnaissance mission. [Ref 2] This UAV, the AQM-34Q, allowed the US to conduct sensitive reconnaissance missions without risking political embarrassment through the loss of human life. It was used extensively for intelligence collection against Cuba and later Vietnam. In Vietnam, during an operation called Buffalo Hunter, the Firebee proved the unmanned aircraft concept with a mere 4% attrition rate during over 3000 combat missions. [Ref 3] Figure 1-1 illustrates the AQM-34Q.

Figure 1-1. AQM-34Q in Vietnam.

The secretive Buffalo Hunter missions were flown mainly to cover areas determined too hazardous for manned reconnaissance aircraft. Some were at altitudes of 60,000 feet and above; others were below 1,000 feet. Missions involved photography and real-time TV relay to a DC-130, electronic intelligence (ELINT) that increased the safety of our manned aircraft in hostile areas, and communications intelligence (COMINT). Some UAV missions, conducted at very low altitudes necessitated by poor weather conditions, provided battle damage assessments (BDAs) to confirm that our strike aircraft had hit their assigned targets. In all cases, these missions were conducted at a fraction of the cost of and risk to manned aircraft.[Ref 4]

In the 1980's United States military operations in Grenada, Lebanon, and Libya identified a need for an on-call, inexpensive, unmanned, over-the-horizon targeting, reconnaissance, and BDA capability for local commanders. The result was the Pioneer UAV system.[Ref 5] The US Navy kept at least one Pioneer airborne at all times during Desert Storm, where it was used for surveillance, targeting and damage assessment. The Pioneer has also been used extensively in subsequent operations.
[Ref.6] Figure 1-2 illustrates the Pioneer.

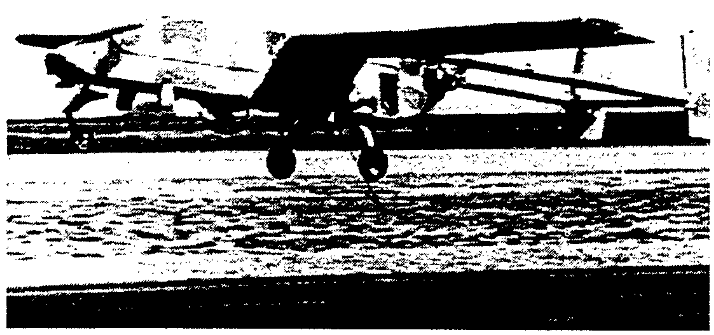

Figure 1-2. Pioneer UAV.

The Pioneer information was provided to theater and component commanders, and as a result, Iraqi patrol boats were detected, a strike on two high-speed patrol boats was directed, and two Silkworm anti-ship missile sites were located. LtGen Boomer, USMC Central Command, praised pioneer as "the single most valuable intelligence collector". ADM Jeremiah, Chairman JROC, stated "[Pioneer] proved that the utility of the unmanned aerial vehicle can be decisive in future battles." During Desert Storm, with 85% of the U.S.'s manned tactical reconnaissance assets committed, UAVs emerged as a "must have" capability. [Ref 5]

This success of the Pioneer during Desert Storm and other factors led to an expanded effort to incorporate UAVs into the intelligence hierarchy. The result has included such advanced UAVs as the Predator, Outrider, Global Hawk and DarkStar, with many others in development. UAVs clearly have a bright future.

B. THE GROWING ROLE OF UAVS

The time for UAV acceptance appears to be here for a number of reasons. First, the declining force structure, people, and equipment necessitates innovative thinking about solutions that more cost-effectively accomplish Navy missions. UAVs are more cost effective and mission effective in many of the traditional manned aircraft mission areas. Replacing these manned missions with UAVs not only frees manned aircraft to be utilized elsewhere, but expands reconnaissance into areas that were not accessible or prudent for manned aircraft overflight.

Secondly, technologies have emerged and matured as very significant enablers for unmanned missions. The development of GPS, for example, allows UAVs to operate autonomously over extended distances with great accuracy. Advances in sensors, electronics, propulsion, and satellite communications are precursors to the advanced capabilities of modern UAVs. These UAVs will continue to mature as the technology develops.

Finally, the U.S. is still expected to maintain a global response capability. Our nation must maintain an effective military force that can contribute to both deterrence and quick-reaction situations. Further, emerging political realities will demand our forces be used with greater precision, less risk, and more effectiveness.[Ref 4]

These basic tenets have led to a greater appreciation for the value of timely information. We need to know what is on the battlefield before we get to the battlefield. This reconnaissance must also be performed over long periods of time, regardless of weather. It must provide information products that are both timely and readily accessible to weapon system operators as well as to commanders. UAVs increasingly fill this role. [Ref 4]

C. THE CHALLENGE OF UAVS

While it is clear that UAVs have developed rapidly to fill a critical reconnaissance need, the underlying command and control structure has not kept pace to fully utilize these advances. Command and control has not evolved to leverage UAV reconnaissance information into a true force multiplier. The goal of this Thesis is to examine the limitations the current command and control structure imposes on the utility of UAVs and to develop solutions.

This Thesis will be organized in five chapters. Chapter I introduces the dichotomy between UAV technological advancement and underlying command and control development. Chapter II builds background information on several UAV classes pertinent to the Navy and the Tactical Control System. Chapter III develops a scenario to expose the limitations of current UAV doctrine. Chapter IV proposes solutions to the limitations identified in Chapter III. Finally, Chapter V provides a conclusion and recommendations.

II. UAV SYSTEMS

Chapter I discussed the history of UAVs and their growing role in the modern military force structure. This chapter will examine several programs with the greatest impact on future Navy command and control requirements.

A. HAE UAVs

The High Altitude Endurance Unmanned Aerial Vehicles (HAE UAV) is designed to provide extended reconnaissance capability to the Joint Force commander.

1. Background

In November of 1993, the Congressional Authorization Conference published a report that stated, "tactical reconnaissance is relatively more important to national security than at any other time in our history." [Ref 7] Consequently, the Deputy Secretary of Defense created the Defense Airborne Reconnaissance Office (DARO) to unify current reconnaissance architectures and manage the future acquisition of all joint service and Defense-wide airborne manned and unmanned reconnaissance and surveillance capabilities. [Ref 7: p. ES-1] Therein lies the great challenge for DARO: to develop standard data formats and common tasking strategies for all the disparate systems ranging from U-2 and its unique tasking, processing, and dissemination architectures to the smallest tactical UAV with its own non-developmental item architectures, while insuring appropriate interfaces with national collection systems to support the warfighter [Ref 7: p. 1.7-8].

UAVs have been grouped into four operational categories: maneuver range, tactical range, medium range and endurance. The endurance UAV category describes a class of vehicles operating at medium and high altitudes, carrying payloads with multi-mission performance capabilities and on-demand support across all mission areas, with flight duration normally in excess of 24 hours.[Ref 8: p. 1.4]

Endurance UAV systems provide a broad spectrum of intelligence collection capability to support joint combatant forces in worldwide peace, crisis, and wartime operations. The capabilities of these UAV systems will provide for adaptive real-time planning of current operations, to include: monitoring enemy offensive and defensive positions, deception postures and combat assessment. Endurance UAVs will provide a rapid turnaround of raw data to aid a robust targeting cycle following a 'First Look, First Shoot, First Kill' methodology.[Ref 8: p. 2.1]

The endurance UAV classification includes both Medium Altitude Endurance and High Altitude Endurance divisions. The HAE UAV program consists of two complementary air platforms, the Tier II Plus Global Hawk and the Tier III Minus DarkStar, and a common mission ground control station.

The Global Hawk air vehicle is optimized for supporting low-to moderate threat, long-endurance surveillance missions in which range, endurance and persistent coverage are paramount. The DarkStar vehicle features an incorporation of low observables, or stealth, and is optimized for a moderate endurance, high-altitude reconnaissance mission in which ensured, survivable coverage is more important than range and endurance. This dual approach provides a flexible and cost-effective mix of platforms. For the purposes of this thesis, Global Hawk and DarkStar will be jointly considered as the HAE UAV class, but each will be described here separately.

2. System Capabilities

The HAE UAV system is designed to provide 24-hour continuous broad area coverage of areas of interest within the entire theater of operations. It will be able to provide Real-time Surveillance, Targeting, and Acquisition (RSTA) and Battle Damage Assessment (BDA) imagery of areas up to 3000 nautical miles from the base of operations. It will provide imagery with the necessary geolocation accuracy and resolution in a timely manner to operational commanders so as to support real-time combat planning and execution

According to the HAE UAV CONOPS, potential applications of HAE UAVs include [Ref 8: p. 2.1]:

- **Near-Real-Time (NRT) Targeting and Precision Strike Support**. Endurance UAVs will shorten the targeting cycle through NRT precise location of mobile enemy forces. Endurance UAV sensor resolution and accuracy will enable expanded use of precision-guided munitions, improving battlefield accuracy.

- **NRT Combat Assessment**. Immediate feedback of planned and executed operations will assist with the efficient prosecution of campaigns and minimize the fog and friction of war.

- **Enemy Order of Battle (EOB) Information**. Allows a rapid means to develop and track enemy order of battle information, especially in areas where information is sparse.

- **Battle Damage Assessment (BDA)**. Provides high-resolution, NRT imagery of target damage. Immediate feedback will accelerate planning for restrike requirements.

- **Intelligence Preparation of the Battlefield (IPB)**. Survey areas of interest in preparation for battle or amphibious assaults and landings.

- **Special Operations**. UAVs can track high-interest individuals or organizations. UAVs also have the potential to provide direct imagery down links to ground Special Forces operations units.

A complete HAE UAV weapon system will consist of an air vehicle segment, a launch and recovery element (LRE), a mission control element (MCE), a ground communications element (GCE), and a support element (SE). A >5000-foot runway is required for HAE air vehicles. [2.5.4]

The MCE contains four workstations: the mission planning station, air vehicle operator, image quality control, and communications management. All equipment is contained within a standard shelter, which houses the crewmembers at their stations, generators, a Ku band earth terminal and other necessary equipment. All equipment is air transportable in C-17, C-141 or C-130 aircraft as part of the system deployment. The HAE UAV ground segment, including the MCE, LRE and SE is common between the Global Hawk and DarkStar and can be used interchangeably between the two.

a. Global Hawk

The Global Hawk is considered the workhorse of the HAE UAV mix. It is a conventionally designed, jet-powered aircraft optimized for payload, range and endurance. It is a 24,000-pound vehicle capable of operating at 65,000-foot altitude with up to forty-two hours of endurance. In terms of physical size, it has an overall wingspan of 116 feet and a length of 44 feet. Its overall size is comparable to a U-2. Figure 2-1.

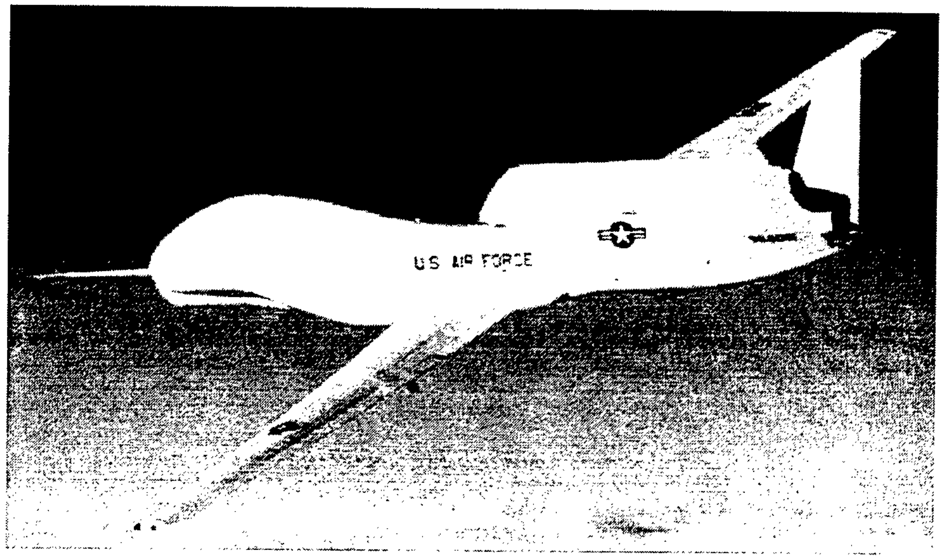

Figure 2-1. Global Hawk during test flight.

The Global Hawk is optimized for supporting low-to-moderate threat, long endurance surveillance missions in which range, endurance and time on station are paramount. The survivability is enhanced by its mission profile (i.e. high altitude and standoff). Table 2-1 shows a summary of Global Hawk characteristics.

Table 2-1. Global Hawk UAV system characteristics. From Ref []

Characteristic	Global Hawk HAE UAV
Operating Radius	3000 nautical miles
Operating Altitude	Up to 65,000 feet
True Air Speed	300-400 Knots
Time on Station	24 hours at maximum radius
Fuel Reserve	1 Hour
Survivability Measures	Threat Warning and limited ECM
Sensors	SAR: 1 m search, 0.3 m spot EO: NIIRS 6+ IR: NIIRS 5+ Ground Motion Target Indication

b. DarkStar

The DarkStar is more of a special purpose aircraft targeted for use in high-threat environments prior to suppression of hostile air defenses. It incorporates unconventional design and is optimized for the incorporation of low observability, or stealth, for survivability. It has a gross weight of 8,600 pounds and can operate at a 45,000-foot altitude for more than eight hours. Figure 2-2.

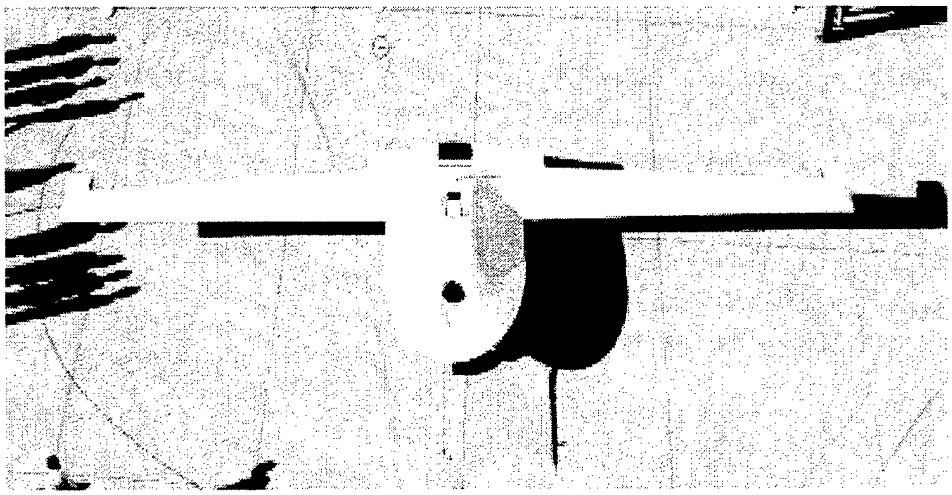

Figure 2-2. DarkStar on flight ramp.

The DarkStar is designed to penetrate into high-threat areas where the risk to the Global Hawk UAV is high. This vehicle is designed for low observability and is optimized for moderate endurance, high-threat reconnaissance missions in which ensured coverage is more important than range or endurance. The DarkStar operates with the same GCE as the Global Hawk, but its limited range and Differential GPS require that it operate from a field where the LRE is located. Its lower endurance and smaller size also require that it be transported into theater, whereas the Global Hawk air vehicle has the capability to self-deploy. Table 2-2 shows a summary of DarkStar characteristics.

Table 2-2. DarkStar UAV system characteristics. From Ref []

Characteristic	DarkStar HAE UAV
Operating Radius	500 nautical miles
Operating Altitude	Greater than 45,000 feet
True Air Speed	>250 Knots
Time on Station	8 hours at maximum radius
Fuel Reserve	30 minutes
Survivability Measures	Very low observable
Sensors	SAR: 1 m search, 0.3 m spot EO: NIIRS 6+ IR: none

3. Command and Control

The HAE UAV command and control structure is important because it delineates the authority to make employment policy decisions, particularly during contingency operations. These decisions include the policy for handling requests for immediate imagery support and subsequent dynamic tasking. The following information is taken from the HAE UAV CONOPS, it describes how command and control might work when the HAE UAV is deployed.

The United States Atlantic Command (USACOM) has Combatant Command over all HAE UAV assets. Operational Command (OPCON) of endurance UAVs will be the responsibility of Air Combat Command (ACC), USACOM's Air Force component, during peacetime operations. Such operations include training, readiness, and the development of tactics and sensors.

Theater CINCs who want to use the HAE UAV system must issue a request to the Joint Chiefs of Staff (JCS). The JCS may approve the request based upon coordination with USACOM and the availability of HAE UAV assets. An HAE UAV detachment will then be deployed to support the CINC. During these exercises, HAE UAVs will fall under the exercise command structure.

During contingency or support of wartime operation OPCON of deployed endurance UAVs transfers to the theater CINC once the asset is in the supported area of responsibility (AOR). OPCON of deployed endurance UAVs transfers to the theater CINC once the asset is in the supported AOR. Consequently, all HAE UAVs will be considered theater assets to be used to support the theater CINC or Joint Force Commander (JFC). [Ref 8: p. 4.0]

4. Tasking

According to the HAE UAV CONOPS, routine tasking of endurance imagery collection is accomplished through the established JTF Collection Management Process via the Air Tasking Order (ATO). The process starts with the theater J-2 assigned by the JFC. The J-2 will be responsible for collection management of the HAE UAV system. This will involve accepting all Requests for Information (RFI), prioritizing these requests based on JFC objectives, and defining reporting requirements.

Once the J-2 has fulfilled these responsibilities, the Joint Force Air Component Commander (JFACC) will schedule sorties for the HAE UAV based upon the requirements given him by the J-2. The JFACC will also integrate the HAE into the Air Control Plan (ACP) in order to deconflict manned operations from unmanned operations in the same airspace. The final product is the ATO. Due to the endurance characteristics (>24 hours) of these UAVs, a single endurance UAV mission may cross several ATO cycles.

Ad Hoc tasking is also envisioned in the endurance UAV CONOPS. The ground control station will likely receive ad hoc tasking while the UAV is in flight. The latency of these requests passing through the chain of command and the total delay in an ad hoc tasking decision is not known. Furthermore, procedures for ad hoc requests and performance thresholds for execution have not been determined.

5. Imagery Dissemination

The HAE UAV imagery dissemination pipeline begins at the air vehicle sensor and, for the purposes of this thesis, ends with the fleet user. The pathway consists of communications both internal and external to the HAE UAV system. Internal communications are comprised of the links within the HAE UAV system, while external communications describe how the imagery gets distributed to analysis centers, the fleet, and other end users. Figure 2-3 shows how the HAE UAV will have the capability to

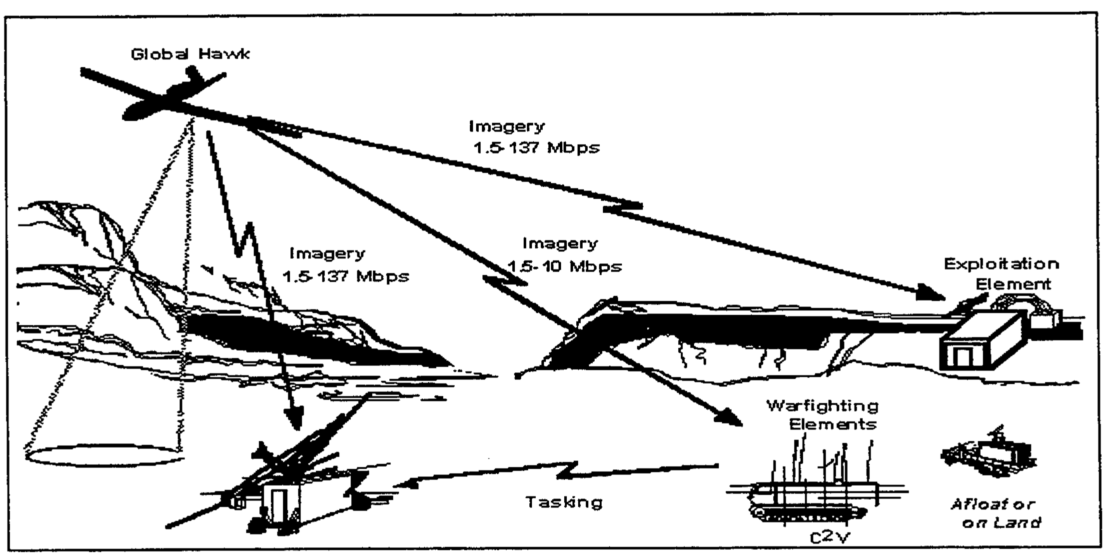

Figure 2-3. Line of Sight transmission

transmit sensor data at a rate of 137 Mbits/s through the Common Data Link (CDL). The CDL is a full-duplex link, available only in LOS mode, that offers the largest data throughput. The MCE is capable of receiving imagery at the full 137 Mbits/s, but other users may be constrained by the capacity of their equipment. Most of these tactical users will have communications equipment that is limited to T-1 data rates and will be able to receive the data at rates from 1.5 to 10 Mbits/s. A limitation of LOS mode is that multiple ground locations can not simultaneously receive the imagery. The author believes that LOS communications will be limited to the MCE, due to its capacity to handle the full data capacity, processing capability, and connectivity with C4I nodes.

Figure 2-4 shows how the air vehicle will transmit sensor data utilizing UHF and SHF SATCOM while operating in OTH mode. Any Ku-band commercial satellite is suitable for this use, including PANAMSAT and INTELSAT. Data rates are limited to 50 Mbs for Global Hawk due to satellite bandwidth limitations and 1.544 Mbs for DarkStar due to a smaller, stealthier air vehicle antenna. Any ground station with

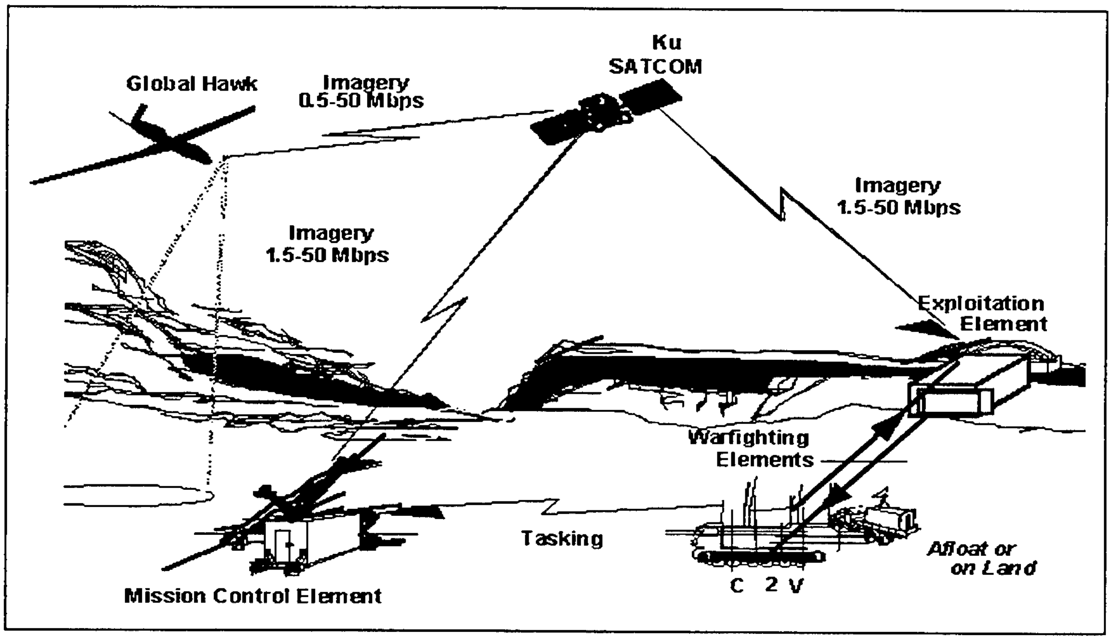

Figure 2-4. Over the Horizon transmission

suitable equipment that is in the satellite's footprint can simultaneously receive this imagery with other ground stations. OTH data rates are much lower than LOS data rates, and the air vehicle effective radius will most likely place most communications in the OTH realm.

The airborne sensor suites for the endurance UAVs and their ground-segment components interact through OTH satellite relay and LOS links to maintain sensor data dissemination communications paths. According to the HAE UAV CONOPS, the GCE has limited capabilities to disseminate collected intelligence directly to an exploitation ground system or battlefield customer, including the fleet. The emerging Global Broadcast Service (GBS) concept is expected to form the foundation for near-real-time dissemination of UAV intelligence products to the fleet. [Ref 8: p. 6.1]

B. VTUAVs

The last section discussed HAE UAVs, which are theater level assets. This section discusses VTUAVs, which are designed to be employed tactically at the unit level.

1. Background

The deployment of the Pioneer UAV system starting in the late 1980's showed the utility of a sea based UAV system. The increased mobility of naval forces, the extended range of operations and the variety of missions confronting the naval task forces are all factors driving the need for an integrated reconnaissance asset. As this requirement for organic reconnaissance collection capability grows UAVs must be capable of being operated from a range of ships with limited impact on flight deck operations. Operational Maneuver from the Sea (OMFTS) will require increased dexterity for the organic collection of reconnaissance and the precision targeting of weapons for OMFTS to reach its full potential. These factors drove the requirement for a VTOL UAV (VTUAV) to replace the Pioneer system.

VTUAV upgrades the Pioneer system, which has deficiencies with limited shipboard compatibility, limited payload capacity, obsolete and system-unique GCS and inadequate speed. The Defense Advanced Research Projects Agency (DARPA), in partnership with the Defense Airborne Reconnaissance Office (DARO), have formulated a program to explore two new vertical take-off and landing (VTOL) concepts to fill the required need. Final physical design has not been determined, but performance objectives have been established.

VTUAV is more than just a replacement for the Pioneer, it is a Naval Warfare enabler necessary for the strike weapons envisioned for the 21st century. For surface combatants the VTUAV will become an integral part of the suite of precision weapon systems. The VTUAV will provide real-time targeting for long-range naval guns and will support targeting for the full range of air delivered weapons.

The VTUAV will provide the ability to operate from all ships capable of conducting helicopter operations. According to the VTUAV CONOPS, three surface combatants are viewed in the near term: DDG-51, CG-47 and DD 963. FFG-7 could support UAV operations but it would not be in support of any shipboard weapons. CV/CVNs will not host or embark VTUAVs, however, they will have TCS for receive and control capability.

2. Organization

The VTUAV system will be located in Unmanned Aerial Vehicle (UAV) squadrons which will be organized and operate similar to LAMPS Mk III squadrons. UAV detachments will be available to deploy with VTUAV systems on a rotating basis. Two of these detachments will be in a deployed status at all times aboard the deployed LANTFLT and PACFLT ships. [Ref 9: p. 29]

A UAV detachment will be embarked under the command of an Officer-In-Charge (OIC). The detachment will be stationed on the ship with the UAVs and include personnel responsible for operation and maintenance of the system. The system can be deployed as the sole air asset or in combination with other aircraft such as the SH-60B Seahawk. [Ref 9: p. 27]

3. Missions Capabilities

The VTUAV system will be assigned to a range of missions, and any one mission may include a number of mission objectives from different areas. The VTUAV is expected to provide primary support to the unit operating the UAV, but will directly or indirectly support other ships. The VTUAV will also support additional missions as the payloads are developed.

The VTUAV employment extends the effective range of the weapons and sensors of the ship, promotes unity of effort, and increases mission effectiveness. According to the VTUAV CONOPS, some of the potential missions of the VTUAV include: [Ref 9: p. 11]

- **Reconnaissance.** The system supports a wide range of reconnaissance requirements for amphibious maneuver operations including the full spectrum of combat operations. The reconnaissance will be conducted to support a broad range of intelligence collection objectives.

- **Naval Surface Fire Support.** VTUAV imaging data will allow ships to fire on targets beyond line-of-sight, increasing the maximum effective range of shipboard guns. The VTUAV spotting will reduce rounds required per target by 50% due to increased first round accuracy and improved spotting data.

- **Battle Damage Assessment.** The VTUAV can provide long term staying power to conduct Battle Damage Assessment (BDA) in the objective area. The VTUAV may be employed to determine damage inflicted by units outside the battle group. The data will be critical to accurately determine the status of hostile forces and to plan re-targeting.

- **Close Air Support.** The VTUAV can be deployed to assist in the direction of Close Air Support. In this role the UAV can assist in performing the functions of the Forward Air Controller (FAC). During this mission the UAV operator would communicate directly with the strike aircraft.

- **Communications Relay.** The VTUAV will have the capability through a communications relay package to provide network connectivity between forces ashore and at sea and to provide communications relay services for CSAR or FAC.

While a specific VTUAV air vehicle has not been chosen, the operational characteristics have been determined. These performance characteristics are intended to align the operational capabilities of the VTUAV to the mission needs of the fleet while limiting the impact of flight deck operations. These performance characteristics are listed in Table 2.3.

Table 2-3. VTUAV system characteristics. From Ref [9]

Characteristic	VTUAV
Operating Radius	110 nautical miles
Operating Altitude	Up to 15,000 feet
True Air Speed	110 Knots with 25knot headwind
Time on Station	3 hours at 110 nm with full payload
Fuel	JP-5s
Survivability Measures	Low radar signature and muffled exhaust
Sensors	Forward Looking Infrared (FLIR) Real-time TV
Limits for shipboard recovery	+/- 3 degrees pitch, +/- 8 degrees roll

A potential platform for selection as the VTUAV is the Eagle Eye. The Eagle Eye is a tiltrotor aircraft whose proprotors permit it to take-off and land vertically. In transition to airplane mode, the counter-rotating proprotors mounted on each wing tip nacelle are rotated 90 ° forward, thus converting the Eagle Eye into a highly efficient turboprop airplane. Figure 2-5 illustrates the physical characteristics of a VTUAV.

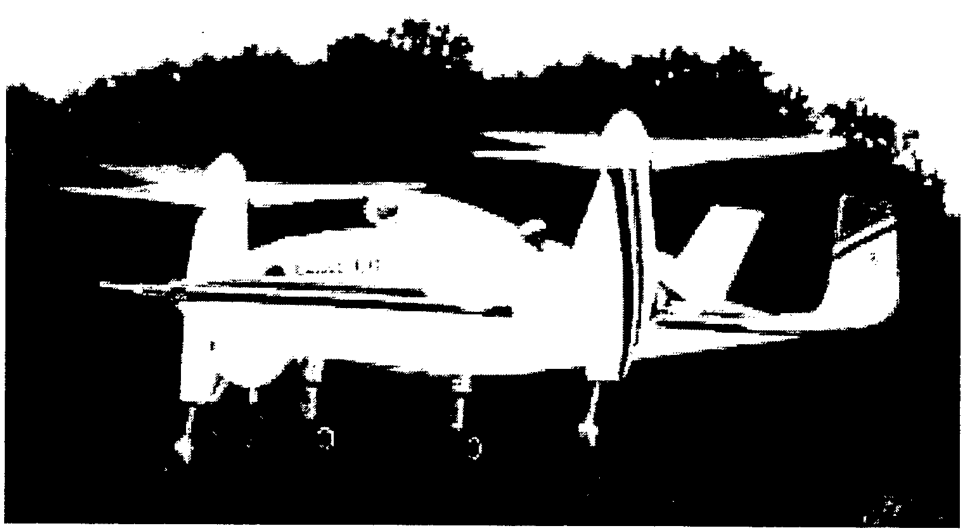

Figure 2-5. Eagle Eye VTUAV

4. Command and Control

The VTUAV command and control structure is only briefly discussed in the VTUAV CONOPS and requires documentation. However, the most likely structure will be similar to the LAMPS Mk III structure. The ship's Commanding Officer will exercise supervisory command of the VTUAV in accordance with the battle group warfare commander's intentions.

According to the VTUAV CONOPS, the UAV Mission Commander, a flight qualified officer able to execute positive control over a mission, oversees the operations at the control consoles and serves as the primary point of contact with the ship's CIC. The Tactical Action Officer will take directions from the CO and change the VTUAV mission profile as the tactical situation develops. The TAO will also receive VTUAV tasking from the battle group warfare commander and will relay these intentions to the UAV mission commander for execution. [Ref 9: p. 20]

There are also several alternatives for physically controlling the VTUAV during a mission. The normal mode of control will be for the air vehicle to be controlled throughout the mission by the ship that launched it. However, the VTUAV may also be controlled by a second control station on a ship or at a land site. During a hand off, the launching ship passes control to another ship, or shore station, for the direction of the VTUAV during a portion of the mission. The launching ship will resume control over the VTUAV for recovery. VTUAV operational command may also be passed when control is transferred.

5. Tasking

The VTUAV will be operated by and in direct support of the operational commander. The VTUAV is a tactical asset- not theater or strategic- and is designed to directly support the tactical war fighter. Sorties will be launched in accordance with a UAV schedule via the ATO, these prearranged missions are planned in advance, around intelligence or fire support requirements, and executed at a predetermined time. An example of prearranged sorties is the scheduling of consecutive sorties on the daily air plan with set launch and recovery times to provide 24 hour surveillance in an area of interest. In addition to pre-arranged sorties, On Call UAV sorties can be scheduled in the ATO to allow the UAVs to be launched on short notice from specific ships as required.

Pre-arranged VTUAV sorties in the ATO must be planned to include at least the following items:

- Launch and recovery times.
- Ingress and egress routes.
- On-station times and altitude blocks.
- Operational areas.
- Mission objectives.
- Hand-off information.

The degree of pre-arrangement of VTUAV sorties will vary depending on the level of intelligence of the threat in the objective area. Some sorties may be prearranged to accomplish a set of tactical objectives. However, flexibility is also necessary to provide On Call and opportunity sorties during an engagement to meet emerging requirements. On Call sorties will have a published ready condition of 5-30 minutes. [Ref 9: p. 31]

VTUAV sorties of opportunity will consist of flights scheduled on an ad hoc basis given the availability of a flight deck for launch, and a ready VTUAV system to support an emerging requirement. The VTUAV operational support plan must indicate which elements of the task force can request a sortie of opportunity for each phase of the operation. [Ref 9: p. 32]

6. Imagery Dissemination

The key to the success of the VTUAV as a tactical asset rests with the dissemination and analysis of its sensor data. VTUAV generated video will be exported to other systems by supplying a general use RS-170 video feed from the VTUAV system. The onboard CCTV system and onboard secondary imagery systems will utilize this video. The secondary imagery systems will frame grab the video, digitize the video frame, display and store the freeze frame video. This will provide an off-line freeze frame video exploitation capability for VTUAV video.

The ship's secondary imagery systems will also provide access to exterior communications circuits to distribute the exploited freeze frame imagery off board to other secondary imagery systems both afloat and ashore. The capabilities for any controlling ship to transmit live video has not been established, but will most likely occur indirectly through TCS multicast satellite transmission.

C. TCS

1. Background

The Tactical Control System (TCS) is a subsystem of VTUAV. It is the software, firmware, hardware, and the extra Ground Support Equipment (GSE) (antennae, cabling, etc.) necessary for the control of Tactical and MAE UAVs. Additionally, TCS will receive and disseminate data from High Altitude UAVs. [Ref 10: p. 1]

Current tactical UAV systems were initially procured using the Advanced Concept Technology Demonstration (ACTD) acquisition approach. Software and data links of current tactical UAV systems are not compatible or interoperable. Their ground control stations do not have the required capabilities or the architectural room for growth to satisfy all the Joint Service operational requirements. Each UAV ground control system is unique and not interoperable with other UAV ground control systems.

The TCS program provides joint warfighter commanders with interoperable and scalable command, control, communications and data dissemination systems for the family of present and future UAVs. TCS will eliminate the current approach of a unique control system for each type of UAV. TCS is a subsystem of VTUAV, and will be interoperable with all UAVs, including Predator, Outrider, and Pioneer, and will be capable of disseminating critical data for planning, targeting, and combat assessment to support Joint services at multiple echelons. [Ref 10: p. 1]

TCS will allow the tactical UAV operator to communicate, receive mission tasking, conduct mission planning, execute the mission, and collect and disseminate data from tactical UAVs, including the VTUAV.

2. System Capabilities

The TCS will be interoperable with different types of UAVs and UAV payloads across five levels of UAV interaction to the extent that it is transparent who is operating the air vehicle. This will give the shipboard operator the ability to interact with a variety of UAV platforms with different levels of functionality. The levels of interaction are listed below and illustrated in figure 2-6 [Ref]:

- **Level 1**--Receipt and transmission of secondary imagery and/or data.
- **Level 2**--Direct receipt of imagery and/or data.
- **Level 3**--Control of the UAV payload in addition to direct receipt of imagery/data.
- **Level 4**--Control of the UAV, less launch and recovery, plus all the functions of level 3.
- **Level 5**--Full function and control of the UAV from takeoff to landing

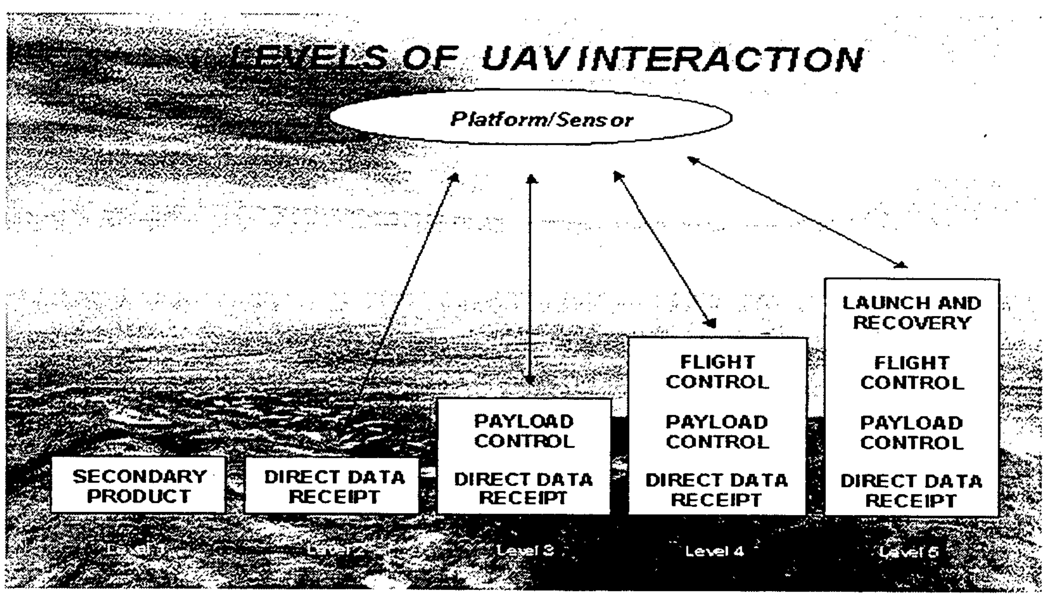

Figure 2-6. TCS levels of interaction. [Ref 10: p. 24]

The ultimate operational goal of TCS is to maximize interoperability and commonality among existing and future UAV systems. By establishing protocols for air vehicles and interfaces for ground data terminals TCS will provide the shipboard operators a common set of screen menus and displays to operate any air vehicle. It will be transparent to operators what air vehicle is providing the imagery. The directions for air vehicle and payload control will also be the same for all UAV systems. Thus the ability to operate UAVs in any operation, conducted by one or multiple services, will dramatically increase their military utility.

3. Command and Control

The TCS will be the control system for future ship-based UAVs and UAV operations. Since ships already provide the necessary infrastructure to support a computer-based system (electrical power, environmental control, radio networks, etc.), the TCS is virtually the GCS for the Navy.

TCS will interface to the existing user infrastructure by accommodating user platform interface requirements. TCS provides dynamic mission and sensor retasking during operational mission execution. TCS has the capability to receive and control payloads on a UAV that is being controlled from another TCS, and it has the ability to pass control of the UAV from one TCS to another.

TCS also has the capability to directly interface with the JMCIS, therefore allowing full awareness of its position among all ships through JOTS track symbology. This enables track de-confliction and allows commanders to accurately assess utilization and direction of VTUAVs.

4. Imagery Dissemination

The operational objective of the TCS is to get UAV products/ imagery to the warfighter. The warfighter ranges from the troops in the trenches who are fighting today's battle to the commanders at all levels that are planning for the successful outcome of the operation. The TCS supports this effort by providing real time information to enhance the warfighters situational awareness. [Ref 9: p. 23]

TCS has the ability to integrate with a spectrum of imagery dissemination and intelligence protocols. While the majority of these architectures will not be available at a shipboard TCS installation, most naval C4I architectures are compatible with TCS. Unfortunately, the capability for broadband connectivity between ships is currently limited and will not support direct broadcast of live video.

The ability for TCS operators to frame grab live video produces the best alternative for direct imagery transmission. The lower bandwidth required to transmit a single frame of imagery will allow direct transmission of the images between ships using current capabilities.

A second method for imagery transmission is multicast transmission from the air vehicle to each TCS equipped ship. This method does not enable non-TCS equipped ships to receive the imagery. However, multicasting will allow all TCS ships to directly receive sensor data from any compatible UAV using TCS level 2 interaction.

Finally, the TCS console provides aids such as artificial intelligence to alert operators that there is something of interest in the payload field of view and to assist the operators in determining what video segments or digital frames to store/pass on.

III. LIMITATIONS OF CURRENT UAV DOCTRINE

Chapter III uses the background information from Chapter II to develop a scenario to illustrate the limitations of current UAV command and control doctrine. Potential solutions to these limitations are proposed in Chapter IV.

A. BACKGROUND

Advances in UAV technology and the procurement of improved systems portend a radical shift in how these assets will be employed. While existing UAV doctrine is designed around UAVs with narrow missions, advances in capability will necessitate a corresponding change in tactics. Increasing inter-connectivity, decreasing cost and greater flexibility mark the advancing technology of UAVs. This will replace expensive systems with limited connectivity and narrow missions.

Current UAV systems were born largely from advanced technology demonstration projects. They were designed more to validate and test the technology than to operate in standardized command and control environments. While they proved successful operationally, as demonstrated by the Pioneer during the Gulf War and the Predator in Bosnia, they were tasked in a very narrow capacity with dedicated command and control, limited image dissemination, and restricted inter-connectivity.

In the Navy, operational UAV doctrine is based almost entirely on the Pioneer system. The Pioneer UAV has a narrow mission and a corresponding limited operational doctrine. This doctrine does not translate to the increased capabilities and expanded scope the Navy will enjoy with VTUAVs. Furthermore, the Navy must expand its doctrine to encompass HAE UAVs, since these will feed data into naval C4I systems.

The Navy's IT-21 and JV 2010 policy statements also indicate a paradigm shift towards increasing inter-connectivity and the concept of Network-centric Warfare. In this vision, data from all sensors is available across the network for utilization by war fighters that can parlay a narrow requirement for information into a tactical advantage. The growth in intelligence gathered by UAVs underscores the requirement to integrate them into the C4I environment.

The existing UAVs are all independent systems. They do not inter-connect easily with command and control systems, which isolates them from the lower echelons that need the information. The information is strictly in one form: processed data that is derived from the sensor data. This information must be filtered through a rigid dissemination process that limits the inherent flexibility of UAVs. Imagery to the tactical warfighter and real-time tracks will be important for modern UAVs.

A scenario will be developed to illustrate the limitations of current UAV operating procedures and doctrine. The doctrine will be applied to a simulated military crisis employing UAVs. The scenario will be developed in several stages to illustrate the manner in which HAE and tactical UAVs are employed using existing doctrine. The scenario will progress through a crisis in a distant third-world country where UAVs will be employed through each stage of the crisis.

B. TASKING SCENARIO

In the country of Orange, a coastal country located south of Liberia, a U.S. embassy dispatch indicates that rebel forces are attacking the capital and initial indications are that the ruling government has been thrown into exile. The president and his cabinet escaped and are safe.

The rebels are thought to have 100,000 troops and a supply of modern armor, including tanks, surface to air missiles, and attack aircraft. A country that is sponsoring socialist expansionism throughout the region supplied this armor, and the West views the rebels and their weapons as a significant threat to stability in the region. A communiqué from the rebel commander indicates that he has taken control of Orange and will rule a socialist government, all foreigners will be expelled. The exiled president appeals to the United States for military assistance.

The initial US military response is to dispatch a carrier battle group along with an amphibious ready group to the scene. In this instance, littoral operations are suitable since Orange is a coastal country. Assuming that the CBG is in the Mediterranean, transit to Orange will take 2 days. Transit from the Gulf, if ordered, could add up to 3 days.

Concurrent to the carrier deployment, the national command authority begins reconnaissance efforts to gather information about the rebel forces. Items of interest include the location and size of troop concentrations, the location of tanks, aircraft, and missile sites. Secondary intelligence concentrates on cartography and examining the existing database of intelligence data.

C. LIMITATIONS

The limitations of HAE UAVs and VTUAVs share a common theme: reducing the time directly related to proper command and control, and the integration of UAVs with operating forces.

1. HAE UAV Imagery Dissemination

The initial reconnaissance is important because it aids military planning. The information flows to the National Command Authority (NCA), which uses it to formulate strategy for the impending arrival of the battle group, among other things. The strategic reconnaissance centers around three assets: satellites, RSTA platforms, and HAE UAVs. All are considered national reconnaissance assets and tasked accordingly. For the HAE UAV, this implies a rigid decision chain and latency in tasking through the Air Tasking Order (ATO).

The latency of initial satellite employment results mostly from the time required for shifting orbits. RSTA platforms such as the U-2 or JSTARS could respond more quickly, but a delay is imposed on photo imagery by aircraft recovery and film development. Only HAE UAVs can respond relatively quickly and provide continuous real-time imagery. The initial response may be slower than the U-2, but the HAE UAV has the advantage of extended loiter times and real-time imagery dissemination. In our scenario, Tier II plus Global Hawk HAE UAVs are deployed to NAS Rota, Spain. They self-deploy and are ready for tasking within 24 hours.

HAE UAV sensor data transmission is sent via commercial satellite such as PANAMSAT or INTELSAT when the UAV is operating OTH. If the UAV were operating within LOS, the common data link (CDL) would be used. Either way, the sensor data is relayed to the Ground Control Element and subsequently an imagery exploitation site. The exploitation sites include the National Photographic Interpretation Center (NPIC) and theater Joint Intelligence Centers (JICs), if created.

At this point in our example, the CBG is steaming toward the crisis and preparing an action plan. Imagery from the HAE UAVs is flowing to the exploitation sites where it is being processed and disseminated in a useable form. Some examples of disseminated products are verbal reports, printed documents, photographs and video. The means by which these products can be disseminated are physical transfer, fax, and transfer through computer networks such as the Joint Deployable Intelligence Support System (JDISS), briefings, and tactical radio and satellite broadcasts such Global Broadcast Service (GBS) and Tactical Information Broadcast Service (TIBS).

The carrier receives the intelligence derived from the HAE UAV through the same channels from which it receives other intelligence data. The BG is hampered by the HAE UAVs classification as a virtual satellite and not as a tactical instrument. The final product the carrier receives is both time-late and diluted. The battle group has limited access to the real-time HAE UAV imagery and must plan using stale, text-based and still frame data.

2. HAE UAV Dynamic Retasking

In our scenario, the carrier battle group commander decides that he must have fresh imagery of a proposed amphibious landing site. Since no HAE UAV mission has yet overflown the proposed landing site and the battle group is not within range, he endeavors to task an HAE UAV with the mission.

A possible mechanism to achieve this tasking follows. The theater J-2 assigned by the JFC is responsible for the collection management of the HAE UAV system. This involves accepting all Requests For Information (RFI), prioritizing these requests based on the JFC's objectives, and defining reporting requirements. The J-2 and his staff make recommendations concerning mission and target priority for reconnaissance assets. RFIs are handled using existing architecture for collection management and are prioritized by the J-2 based on the CINC's essential elements of information (EEI).

Once the J-2 fulfills these responsibilities, the Joint Force Air Component Commander (JFACC) schedules sorties for the HAE UAV based upon the requirements given him by the J-2. The JFACC is responsible for integrating the HAE UAV into the Air Control Plan (ACP) so as to deconflict manned and unmanned operations in the same airspace. All HAE UAV sorties are tasked in accordance with the ATO. The ATO cycle is currently a 72-hour cycle that includes these steps. Because of the long time required for planning and coordinating all air operations through the ATO, it inhibits dynamic HAE UAV tasking.

This describes a process, which according to the HAE UAV CONOPS will successfully task the UAV, but will not support true dynamic collection requirements. Since the battle group commander's request must pass through a number of "wickets" to be integrated with other collection requirements and then written into the ATO, the chance of timely execution is nil.

UAVs, however, are inherently flexible intelligence gatherers. Since they are remotely flown from the ground, they can be instantly steered, whereas a manned aircraft must first be contacted and satellites are inherently difficult to dynamically retask. Clearly, a mechanism must be developed to ensure responsive HAE UAV dynamic retasking outside the normal ATO cycle.

3. HAE UAV Sensor to Shooter

Given that the battle group has arrived at the area of operations, it is now in a position to exercise force. The air defenses, however, have not yet been neutralized and fleet aircraft are kept "feet wet" until successful Suppression of Enemy Air Defenses (SEAD) occurs. The first strikes are planned for the evening and will consist of Tomahawks and strike aircraft. Only the high-flying, stealthy HAE UAVs are considered an acceptable risk for flight until then. Destroyers will remain within 10 miles of shore to neutralize mobile targets of opportunity with Naval Gunfire Support (NGFS).

A target of opportunity occurs when an analyst at the Joint Information Center detects a Silkworm anti-ship missile being transported to the coast. Further intelligence indicates that the Silkworm will be fired towards the battle group. This information is passed to the carrier battle group via flash message traffic. The order is given to a Destroyer to "take" the Silkworm with Naval Gunfire and the target coordinates from the flash message are given.

Since the Destroyer does not see the target, it must rely on external spotting to adjust its fire. Normally, a spotter on the ground providing corrections over an UHF radio net would accomplish this. The ship would receive the report, make corrections according to the spotter, and fire a salvo until the spotter indicated the fire was accurate by requesting "fire for effect".

The HAE UAV imagery dissemination is essentially a stovepipe system, no mechanism exists to deliver the imagery to tactical endusers. The carrier has the capability to receive the imagery time-late, but the Destroyer has no capability to receive the imagery at all. This means that the Destroyer can't use the imagery directly to make fire corrections.

The possibility exists for the HAE UAV to handoff the target to the Destroyer, which could utilize its organic VTUAV as the sensor to shooter platform. This is a viable solution, but a procedure to transfer a target from the HAE UAV to a VTUAV must also be developed to make it effective.

A final alternative is for the Destroyer to receive the imagery directly from the HAE UAV. This is described in the TCS CONOPS as level II reception; direct reception from the HAE UAV. This method, however, will be shown to be inappropriate.

4. HAE UAV Deconfliction

In our scenario, the battle group is on station near the country of Orange. The battle group is tracking all air contacts, including the HAE UAVs, with SPY phased-array radar. According to the HAE UAV CONOPS, the battle group does not have JMCIS track information on the HAE UAVs to de-conflict them from radar tracks. The HAE UAV CONOPS does not address the dissemination of real-time air vehicle track information from the ground control element to the fleet. Therefore, the battle group must assume that any airborne track is hostile if it does not hold a JMCIS track to merge it with.

The HAE UAV must be de-conflicted from battle group aircraft, gunfire, and missiles through coordination with the Joint Commander. The Joint Commander will promulgate a plan to apportion the airspace. The battle group must ensure the coordinated use of airspace with the HAE UAV before any strike. With its altitude capabilities, the HAE UAV can loiter at 60,000 feet while strike aircraft and missiles pass below it. This vertical apportionment of airspace gives the HAE UAV the ability to provide real-time Battle Damage Assessment (BDA). [Ref 11: p. II-6]

5. VTUAV Command and Control

Tactical UAVs are now introduced to our scenario. The VTUAV CONOPS envisions that these UAVs will be flown from air capable ships to support battle group operations whenever necessary. This scenario affords the battle group an excellent opportunity to utilize the capabilities of the embarked VTUAVs. The VTUAVs are initially tasked to remain clear of Orange until the risk of loss to anti-aircraft fire is acceptable. At that point, VTUAVs are tasked to fly over Orange.

The mission of any particular flight is determined by the objectives of the battle group commander. The flight, along with the mission and operating area, is scheduled in the ATO. The goal of the ATO is to coordinate the VTUAVs from the various ships to maintain continuous coverage over the areas of interest. The author believes that the areas of interest will be delineated in the Special Instructions (SPINS). A VTUAV launches to execute a swap with another VTUAV on-station. The relieved VTUAV recovers, refuels, and is prepared for its next flight.

The battle group commander, and every ship in the battle group, has continuous real-time tracks of the VTUAVs. This track information is taken from the TCS of the airborne vehicle's controlling ship and relayed throughout the fleet with JMCIS. Ships will individually merge a radar track with the JMCIS track to maintain an accurate picture.

This real-time track information allows the battle group commander to monitor VTUAVs positions to effectively direct them. Although the SPINS contains route information and way point coordinates, it does not provide tactical direction for each mission. Modifications to the route are directions that must be promulgated while the VTUAV is in flight and the tactical situation unfolds.

These directions to the VTUAVs may occur to clear a lane of fire for NGFS, to clear airspace for Close Air Support (CAS), or to proceed to another area of interest. In such a situation, the VTUAV CONOPS does not address how the actual command will reach the operator at the TCS.

Given the need to direct a VTUAV to an ammunition dump for surveillance, the battle group commander examines the positions of all VTUAVs and their status. He directs one from a lower priority target to the ammunition dump. The present manner to accomplish the command is to direct it over a voice net to the host ship's Combat Information Center (CIC) and then relay it to the operator at the TCS. This method is subject to error and delay. A mechanism must be developed to graphically convey the command directly to the TCS console.

6. VTUAV Imagery Interpretation and Exploitation

After a VTUAV is directed to the ammunition dump, the imagery must be interpreted to yield intelligence. For the HAE UAVs, the imagery is forwarded to a national exploitation facility where photo interpretation experts analyze the imagery. In the battle group environment, each air capable ship has the ability to embark and launch VTUAVs. These ships must also ensure the exploitations of the imagery.

Since the manning of these ships does not normally include photo interpretation personnel, the imagery must be forwarded to a site with suitable interpretation capabilities. Ship personnel undoubtedly have the ability to perform basic photo interpretation, but valuable, additional information can be gained from the imagery with appropriately trained personnel.

The TCS CONOPS indicates that the imagery has connectivity both within the ship and off the ship. Neither the TCS CONOPS nor VTUAV CONOPS, however, indicates where the imagery should be routed for proper analysis or how it should get there. Although the ammunition dump is used for purpose of example, the VTUAV will almost continuously provide imagery that is worthy of proper interpretation. If it is not worthy of interpretation, a trained interpreter should make that decision.

7. VTUAV Imagery Dissemination

According to the TCS CONOPS, the ammunition dump imagery received in the scenario has the potential for connectivity both on and off the host ship. The CONOPS describes connectivity to a host of standard architectures but does not describe which of these C4I architectures will be employed in the fleet. TCS connectivity to the standard C4I nodes is limited at sea due to limitations in shipboard space, separation from terrestrial networks, and technical difficulty of maintaining satellite links. The nature of the connectivity is important for several reasons.

As previously stated, the imagery should be routed to a suitable exploitation site. Although live video is not required for imagery analysis, the throughput should have the capacity for live video. Video has advantages over still frame imagery in some situations. Since the ship doesn't have properly trained analysts, it may also not capture the most suitable still frames for transmission to the exploitation site. By sending full video, the exploitation site can chose the best frames to analyze.

The nature of the imagery dissemination must also be considered for the sensor to shooter problem. Targets under surveillance by one ship's VTUAV may be assigned to a different ship for destruction by naval gunfire. Since ships will launch VTUAVs in accordance with the ATO, the position of ships controlling a VTUAV will change throughout the day and have no correlation with the position of the target. When the battle group commander decides to fire upon the target, a different ship than the one controlling the VTUAV could be in a better position to direct gunfire on the target.

The problem with this scenario is that the sensor to shooter loop IAW NCW doctrine has not been established. Ultimately, the firing ship must have feedback on the accuracy of its fire. The VTUAV will produce the imagery that is interpreted for this feedback. However, where the imagery gets interpreted and how the feedback reaches the firing ship needs to be established. This problem must be resolved for effective VTUAV operations.

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IV. UAV EMPLOYMENT MODEL

The last chapter exposed limitations of current UAV operational employment. This chapter further addresses the issues and offers potential solutions. First, HAE UAV CONOPS are addressed followed by VTUAV CONOPS.

A. BACKGROUND

The purpose of this chapter is to develop a model that could be used to overcome the demonstrated limitations of current UAV doctrine. Alternatives must be examined and, if possible, modeled to arrive at solutions that provide the greatest utility.

The difficulty in arriving at a solution is recognizing that the technology of UAVs is developing quicker than the underlying "intelligence machine" and more importantly, is outpacing the advancement of naval C4I systems. While the bandwidth capacity and technical capability of warships is increasing, the challenge is to develop the CONOPS that will weave the capabilities of UAVs into this technological fabric.

System capabilities due to the technological revolution are rapidly increasing which is expanding the ways to harness and exploit them. This new technology has spawned such names as IT21, NCW and so on. The rapid introduction of large numbers of UAVs into the operating forces has the potential to become another force multiplier. We need to find ways to use UAVs in an intelligent, integrated manner that is capitalizes on this technological revolution.

Doctrine is often developed after accompanying equipment is installed and operational, so assumptions must therefore be made about future C4I capabilities. The UAVs described herein have not yet achieved operational maturity. Accordingly, the HAE UAV CONOPS bills itself as a "living document to be updated." Likewise, this is a conceptual thesis based on current information and the anticipated continuation of existing trends.

B. HAE UAV CONOPS

This section addresses three HAE UAV CONOPS issues: dynamic retasking, imagery to the tactical warfighter and HAE target hand off to VTUAVs.

1. Dynamic Retasking

Current HAE UAV CONOPS aims to support the warfighter's immediate intelligence needs through a process called dynamic retasking [Ref 8: p. 4.6.2]. Dynamic retasking is defined as the process of altering the HAE UAV's mission plan in real time to satisfy immediate requirements. The process of dynamically tasking the HAE UAV as described in the HAE UAV CONOPS does not support the required response to these immediate requirements.

The HAE UAV is considered a surrogate satellite, and theater-level Joint tasking is the norm. ATO tasking can continue to be the norm because the ATO allows for pursuing targets of opportunity. A reach-back mechanism must, however, be included to allow for direct tasking by tactical war fighters. This process must be efficient enough to respond to time sensitive targets.

Revisiting our scenario, the battle group commander has decided that he requires airborne imagery of the intended amphibious landing site. He must have the imagery within one hour because it is critical to the successful planning of an amphibious landing at the beach. He knows that a HAE UAV is operating in the vicinity and endeavors to task it with his mission.

A standard procedure must be developed that will facilitate the timely processing of similar real-time collection requirements. This procedure must ultimately connect the requestor of collection support to the actual collector operator. The request must also be dynamically evaluated and prioritized against similar requests and the scheduled mission objectives.

The dynamic tasking process begins with the requestor. In this case we have cast the battle group commander as the requestor, but the request could be initiated at any level. Assuming that the request initiated at a subordinate level, a standard request format must be utilized. According the HAE UAV CONOPS, standard requests for immediate support should be submitted using normal air request procedures, such as

AIRREQSUP and AIRREQRECON messages. For purpose of example, the format will be the AIRREQRECON message. This message is forwarded to the commander over standard tactical fleet circuits for action. The battle group commander forwards the message to the Joint Task Force Commander's staff and further up the Chain of Command to the command responsible for the effective dynamic tasking of the HAE UAV.

The overall responsibility for dynamic retasking of the HAE UAV rests with the theater CINC or his designated Joint Force Commander. According to Joint Pub 2.0, the JFC's guidance and directives will determine the way in which the intelligence system operates during the type of crisis described in Chapter III.

> Intelligence requirements are identified based on the JFC's guidance and direction, estimate of the situation and objectives. The commander's requirements must be the principal driver of intelligence system components, organization, services, and products [Joint Pub 2.0]

Since the JFC carries the responsibility of being the principal driver of the intelligence system, he may provide guidance on how he wants his J-2 to handle requests for immediate support. The JFC decides which tasking is more urgent, the ATO tasking or time-critical imagery tasking, and directs the HAE UAV at his discretion. These directives ensure that his staff knows that he gives the dynamic retasking collection missions particular priority with regards to other collection missions.

Furthermore, the JFC has the option of dictating how he wants the time-critical imagery requests routed. The author believes that the standard fleet request should be via AIRREQRECON flash message traffic. The JFC must also follow-up his decision on a specific immediate intelligence support request with a reply indicating the disposition of the request.

2. Imagery to the Tactical Warfighter

A related issue to dynamic tasking is the dissemination of HAE UAV imagery to the tactical war fighter. The existing dissemination of HAE UAV video is composed of raw imagery to analysis centers, GBS capable ships, and TCS capable ships. This raw imagery is of limited use to the tactical warfighter.

> Raw imagery, even when comprehensive and unquestionably accurate, is of little use to the war fighter. It may be a wonderfully clear photographic image of some location, but without additional, vital information, such as the location of the photo, its orientation to true north, and its time and date of origin, the image might be useless. [Ref 12: p. 21]

Imagery to the war fighter should be processed by an analysis center to be useful. The imagery analysis can be performed at two places, the theater Joint Intelligence Centers (JICs), and the National Photographic Interpretation Center (NPIC). The Ground Control Element can also perform limited annotation of received imagery before forwarding it. The problem with utilizing the stateside analysis center for imagery to the war fighter is the disconnection between the analysis and the customer. The war fighter request for imagery must be routed to the states and the response will suffer.

The better alternative is to utilize the theater analysis center or the Ground Control Element, when feasible. This approach keeps the analysis closer to the decision center where the imagery requests are handled. The stateside capability is also not needed since much of the analysis will only comprise of annotating the imagery with date of origin, time and true north.

In any case, the performance of the system can be evaluated as the time it takes the tactical warfighter to receive properly analyzed and annotated imagery. Since part of the imagery analysis problem involves deciding which imagery the warfighter requires, the analysis system must be developed to process the imagery for targets in real-time.

Alternatives for connectivity after annotation depend on the quality of the images required by the war fighter. The instances where still imagery is sufficient must be differentiated from a justifiable need for streaming video. The sensor to shooter problem, for instance, requires moving video while the battle group commanders reconnaissance of the beach only requires a still photo to examine the location of defenses or obstacles.

> The emerging GBS concept is expected to form the foundation for near real-time dissemination of UAV intelligence products to exploitation systems and battlefield customers. [Ref 8: p. 6.1]

The nature of the imagery delivered to the naval war fighter depends largely on improvements in broadband, namely satellite, communications capability. To date, only the High Value Units (HVU) have the broadband access necessary to receive streaming video. Still imagery, however, can be transmitted over conventional communications channels, such as UHF and IMMARSAT. Ultimately, full access to streaming video should be available to all tactical users, independent of location. GBS on the smaller units would provide the bulk of this capability.

3. HAE UAV Target Hand-off to VTUAV

In the scenario, an analyst at the Joint Information Center detects a Silkworm anti-ship missile being transported to the coast. The problem is how to use this intelligence gained from the HAE UAV to direct force against the Silkworm missile. The answer is that HAE UAVs are considered surrogate satellites and are not intended, nor should they be employed, as a direct sensor to shooter platform. They operate within a matrix of intelligence platforms and provide vital cueing information to sensors directly supporting the shooters.

> Normally intelligence collectors do not have training in directing force application. Their training, organizational structure, and communications systems provide information to the decision maker who directs forces against the enemy. Targeters, on the other hand, are not normally as well versed in the collection management field. As military forces field more and more surveillance systems such as UAVs, it is extremely important to develop concepts of operations that take full advantage of available near-real-time combat information to direct fires. [Ref 13: p. 14]

According to the HAE UAV CONOPS, the intention is to place the value added that exploitation provides in direct contact, whether physically or electronically, with the tactical element which can best use the information to either retask the platform and collect more information, or use the intelligence to nominate a high value target [Ref 8: p. 5.4.2]. This agrees with the concept of network-centric warfare and implies that the HAE UAV will act as a cueing mechanism for the war fighter to utilize a tactical UAV or other tactical sensors as appropriate. The solution that passes targets from the HAE UAV to the VTUAV is ideally suited for sensor to shooter.

An alternative to handing the target off to a tactical UAV is to utilize the level II (direct receipt of imagery) capabilities of the shipboard TCS to allow the ship to receive imagery directly from the HAE UAV. A sensor to shooter link could then be established. This, however, violates the presumption that the HAE UAV is primarily a strategic theater level asset. Larger coverage area, deeper penetration and better imagery/analysis make HAE UAVs ideal for target identification. If the HAE UAV is occupied with a single target for a sensor to shooter engagement, it could miss detecting other targets. The sensor to shooter mission when tasked to tactical a UAV, frees the HAE UAV for continued search. This handoff employs all assets more effectively.

If a target handoff from the HAE UAV to a VTUAV is the solution, then a process must be developed for a quick and efficient handoff. The goal is to minimize the time from when the HAE UAV acquires a potential target to when that target is acquired by a VTUAV. This process includes identifying a target and handing it off to the VTUAV.

The limiting factor in this process is the man in the loop. The sensor data received from the HAE UAV must currently be interpreted by analysts to yield information about targets. This interpretation is time consuming and prone to error. A potential solution is to integrate software into the process to alert the analysts to potential targets. Software products such as ICE enhance characteristics of imagery to aid the recognition of valid targets by analysts.

A method for the handoff is to utilize the capabilities of JMCIS. Since a flight track of the HAE UAV can be monitored throughout the fleet in near real time, the same network can be used to indicate a potential target. Once an analyst has resolved a target from the HAE UAV sensor data, a target track can be created in the Common Operating Picture (COP) of JMCIS. The target track can also contain amplifying data such as the classification, time of last fix, and priority. This target track can then be used locally within the battle group to cue a VTUAV to the target.

C. VTUAV CONOPS

The focus will now shift from HAE UAVs to VTUAVs. Tactical UAVs are envisioned to be employed from any air capable ship to support battle group operations whenever necessary. The command and control challenge is to task the VTUAVs from different ships to maintain required presence over areas of interest. Multiple UAVs could also simultaneously cover several areas of interest.

While tasking the VTUAVs could be accomplished with the ATO and SPINS, command and control must also be able to efficiently re-direct VTUAVs, analyze and disseminate imagery, and perform sensor to shooter to direct force. Several options exist that provide a solution to these problems. These include the LAMPS model, imagery dissemination and analysis, and VTUAV sensor to shooter.

1. VTUAV Tasking and Direction

A model currently exists that could be used to task VTUAVs. The LAMPS Mk III helicopter is operationally similar to the VTUAV because it is launched from air capable ships and controlled via data link. Many of the issues that are pertinent to VTUAVs are addressed in the LAMPS operational model. The LAMPS model could therefore be used as a basis for a VTUAV tasking.

The premises of the LAMPS model is that each ship is free to task the helicopter when the battle group has no tasking. This allows ships the flexibility to conduct training and to support its own missions. When the battle group requires LAMPS support, this is published in the ATO. The helicopter is then launched and controlled from the host ship to support the battle group mission. The helicopter track is monitored by the battle group staff, and adjustments to the tasking are relayed through the host ship Combat Information Center (CIC). These mission changes are relayed to the pilots through a microwave datalink.

This model would also work well with VTUAVs. A ship would be free to fly its VTUAV as necessary to support the ship's mission. It would be controlled entirely by the Tactical Action Officer (TAO) from CIC. The VTUAV could be tasked by the battle group via the ATO and launched and controlled by the host ships. Since each VTUAV track is linked throughout the battle group by TCS connectivity to C4I nodes, the battle group staff is able to monitor tracks in real time. Decisions to retask the VTUAV, such as response to a target cued by a HAE UAV, must then be communicated to the host ship and ultimately the remote pilot at the TCS console. Since TCS is in the host ship, the voice commands can be relayed from CIC to the TCS operator through internal ship's circuits.

Voice commands, however, are not the best alternative for directing the VTUAV. Voice is not efficient and leaves room for error and misinterpretation. The solution is that commands to redirect the VTUAV must be electronically transmitted from the battle group staff to the host ship and appear on the TCS console as fly-to points. This method is quicker because it eliminates the delay inherent to relaying voice communications and allows the TCS operator to directly utilize the fly-to points for VTUAV direction.

2. Imagery Dissemination and Analysis

An issue related to controlling the VTUAV is the dissemination and analysis of the imagery. Although the VTUAV can be tasked for missions such as SIGINT and COMREL, proper imagery dissemination and analysis will be central to the effectiveness of the VTUAV. Host ships are not planned to have embarked imagery analysts nor does the VTUAV CONOPS anticipate having analysts. The imagery must therefore be routed elsewhere for imagery analysis. Additionally, the imagery must have the capability to be routed throughout the battle group for sensor to shooter engagements utilizing the VTUAV sensor data.

A solution to this problem is that the aircraft carrier, when present, could be used as a central node for all VTUAV imagery dissemination and analysis. Although there are no plans to operate VTUAVs from carriers, the VTUAV CONOPS anticipates that aircraft carriers will have TCS installed. The TCS will be installed solely for the ability to receive imagery from and to control VTUAVs. TCS has the ability to multi-cast the imagery from any VTUAV to each TCS station in the battle group. This multi-cast transmission path is only possible when the VTUAV is operating in the OTH mode with the imagery being transmitted via satellite. Any TCS equipped ship in the satellite's footprint can then receive the imagery.

Since the communications path of VTUAVs that are operating in line of sight mode is through a data link to the controlling ship, the aircraft carrier does not have access to this imagery. The aircraft carrier only has the capability to receive imagery from any VTUAV that is operating in OTH mode. In LOS mode, the beam is too narrow for more than one ship. Therefore, any VTUAV operating in LOS mode must switch to a satellite transmission path to solve the problem of how to get the imagery from the VTUAV to the carrier.

Once the imagery has been received at the carrier, it can be interpreted by a properly equipped imagery analysis center. This would include the software, computers, and personnel to fully exploit the received imagery for information. In the analysis center, imagery data becomes information to effect further action. This aligns well with maintaining centralized VTUAV command and control at the carrier because the battle group staff has the best picture of what each VTUAV is doing and can most effectively direct them.

In addition to the advantages gained in imagery analysis, the battle group central node also allows for increased coordination of VTUAVs with other battle group assets, such as tactical air. The fusion of VTUAV control with tactical air allows for positive airspace control during dynamic situations. Although airspace allocation for VTUAVs is delineated for all phases of the flight, dynamic situations may require the close use of airspace by both tacair and VTUAVs.

With a central node at the carrier, the battle group staff is in a better position to effectively synchronize VTUAV tasking and targeting. The alternative is to allow each ship to individually analyze the imagery and to de-centralize control, which results in a division of effort. The battle group central node, however, leverages the effectiveness of multiple VTUAVs by coordinating their actions and allowing a unity of effort. The central node also allows the battle group staff to direct VTUAV imagery for sensor to shooter and to ensure clear lanes of fire for naval gunfire.

3. VTUAV sensor to shooter

After VTUAV imagery has been analyzed to reveal a target, such as the Silkworm anti-ship missile in the scenario, the imagery can be further utilized for a sensor to shooter engagement. This may occur after the target is cued to the VTUAV from a HAE UAV, as discussed earlier, or if the target is found during a search by battle group assets. In either case, the VTUAV must acquire the target. The VTUAV imagery can then be interpreted for fire control corrections that are utilized by the shooter as appropriate.

A central VTUAV node is important for the sensor to shooter problem because the ship receiving the VTUAV target imagery may not be in the best position for an engagement. For example, a ship on the opposite end of the battle group may be in the best position to engage the target while the VTUAV host ship is poorly positioned. In addition, the shooter may be an aircraft. A central node will be best to determine host ship to shooter relationships and to clear a lane of fire for engaging ships. Targeting information must then flow from the host ship, which controls the VTUAV and is receiving the imagery, to the shooter ship, to complete the sensor to shooter loop.

A sensor to shooter loop is more accurately described as a sensor to processor to shooter loop, because the imagery must at some point be interpreted for the data. The raw imagery is worthless to the shooter unless it can be interpreted for the data which is used for the gunfire corrections. The point at which the imagery is interpreted for data marks the difference between any two solutions. The best solution, however, minimizes the overall latency of the sensor to shooter loop.

Several options exist for completing this sensor to processor to shooter link. The first option is for the VTUAV control ship to interpret the imagery and relay fire control data to the firing ship over a voice network. This solution is essentially similar to the present solution of using field spotters. The limitation is that rate of fire is constrained by the latency inherent with voice communications. With this system, the time to first round is slower, more rounds are required to destroy the target, and the total time to destroy the target is longer.

A second problem with this approach is that assumptions are made about the qualification of spotters on each ship. An FFG, for instance, may observe the target on its VTUAV imagery but may not have a spotter qualified to interpret the imagery for gunfire correction calls. The best solution for this method would be to utilize the central node for gunfire corrections. Since the carrier has the capability to receive all OTH

VTUAV imagery, it could standardize sensor to shooter by generating all gunfire corrections.

The inherent limitation of relaying gunfire corrections over voice networks can be solved by allowing the engagement ship to judge its own gunfire corrections. This can be achieved by routing the VTUAV imagery from the host ship to the engaging ship. This solution moves the processing towards the engaging ship and away from the imagery source. The advantage with this solution is that latency is reduced, but the difficulty is that transferring imagery instead of data to the engaging ship requires greater communications capacity.

The ultimate solution to any sensor to shooter loop would be to automate the imagery interpretation and move it as close to the UAV as possible. For instance, if the processing were performed by the UAV, then only a relatively small amount of data would be forwarded to the shooter, greatly reducing the demand on communications networks and increasing responsiveness.

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V. CONCLUSIONS AND RECOMMENDATIONS

The purpose of this Thesis is to demonstrate the increasing sophistication and growing utility of modern UAVs and the underlying problem with command and control, which is unprepared to leverage these capabilities into combat effectiveness. The problem can be summarized as a strategic imagery analysis structure that cannot meet the dynamic requirements of tactical reconnaissance and under-developed CONOPS that do not address necessary requirements.

A. CONCLUSIONS AND RECOMMENDATIONS

This section will develop a conclusion and recommendation for each issue developed in Chapter IV.

1. HAE UAV Dynamic Retasking

A standard procedure must be developed that will facilitate the timely processing of real-time collection requests by tactical end users. This procedure must ultimately connect the requestor of information to the actual collector operator. These requests must also be dynamically evaluated and prioritized against similar requests and scheduled mission objectives.

Recommendation- Develop a HAE UAV CONOPS that provides a standardized methodology for the submission and evaluation of immediate imagery requirements by tactical users. This should be exercised by actively integrating UAV operations into routine exercises and peacetime training.

2. HAE UAV Imagery to the Tactical Warfighter

The existing dissemination of HAE UAV video is composed of raw imagery to analysis centers and GBS capable ships. TCS equipped ships may also receive raw imagery directly from the HAE UAV when within line of sight. Video imagery processed by an analysis center, however, is only available to the fleet through GBS. In addition, the imagery analysis process is not responsive to tactical requirements.

Recommendation- Develop an imagery analysis system that has the capability to provide responsive service for tactical users. The processed imagery should be made available to all fleet users through GBS or similar high-bandwidth solution.

3. HAE UAV Target Hand-off to VTUAV

The HAE UAVs large coverage area, deep penetration and better imagery make it ideal for target identification. Once a target is identified, the HAE UAV will act as a cueing mechanism for the war fighter to utilize tactical UAVs and tactical weapons as appropriate. The HAE UAV is then free to continue searching for other targets. A process must be develop for quick and efficient handoff of these targets to VTUAVs.

Recommendation- Develop a process that can efficiently hand HAE UAV targets off to VTUAVs. The goal of this process is to minimize the time for a VTUAV to acquire a target from when it is handed-off.

3. VTUAV Tasking and Direction

VTUAVs will be employed and controlled from air capable ships such as Cruisers and Destroyers. No plan exists to deploy VTUAVs onto carriers, but the carrier will have the option to maintain operational control over these VTUAVs. At other times, the VTUAV organic ship will maintain operational control. A method must be developed to task VTUAVs in each situation.

Recommendation- Utilize the LAMPS Mk III model for tasking VTUAVs. This model stipulates that the host ship is free to exercise and task its VTUAV to support the ship's mission as long as the battle group has no underlying requirements. If the battle group assumes operational control, then a method must be developed to relay flight directions to the VTUAV operator on the host ship. Voice directions should be avoided in favor of electronically transmitted fly-to points directly to the operator's console.

5. VTUAV Imagery Dissemination and Analysis

Proper imagery analysis and dissemination will be the central to the effectiveness of the VTUAV. The host ships, due to manning and equipment constraints, will not be able to effectively analyze VTUAV imagery. An aircraft carrier would can be better equipped to analyze and distribute the imagery, but the capability does not exist to transmit streaming video imagery to an aircraft carrier.

Recommendation- Equip aircraft carriers to act as a central node for VTUAV imagery analysis and dissemination. Develop the software and firmware to streamline the imagery analysis process. Utilize the capabilities of TCS to transmit VTUAV imagery to the aircraft carrier.

6. VTUAV Sensor to Shooter

After VTUAV imagery has been analyzed to reveal a target, the imagery can be utilized for a sensor to shooter engagement. The imagery can be interpreted for fire control corrections that are utilized by the shooter as appropriate. Since the VTUAV host ship may not be the shooter, this information must be interpreted and relayed from the host ship to the shooter.

Recommendation- Utilize the aircraft carrier when it is available as a central node for VTUAV sensor to shooter engagements. Maintain Air Naval Gunfire Liaison Company (ANGLICO) personnel onboard the carrier in order to provide expert, centralized gunfire support capability.

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