JOINT SHIPBOARD HELICOPTER OPERATIONS: HUMAN FACTORS ISSUES AND INTERVENTION OPPORTUNITIES IN A COMPLEX SOCIO-TECHNICAL SYSTEM

John W. Ruffner and Jim E. Fulbrook
DCS Corporation
Alexandria, VA 22314

Military helicopters of all types routinely conduct operations on Navy ships. Consequently, shipboard helicopter interoperability is a requirement for all the military forces. Shipboard helicopter operations include landings and takeoffs, launch and recovery support activities, and external load operations. These operations involve a variety of helicopter types on all aviation-capable Navy ships, in different sea states, and under changing visibility and environmental conditions. Shipboard operations involve a complex socio-technical system of individuals with various skills and experience levels, complex equipment, and a working environment that allows little margin for error. Key personnel include the bridge team, the Helicopter Control Officer, the Landing Signal Enlisted crewmenber, and flight deck crews. The requirement for shipboard helicopter interoperability involves several unique human factors and human-system integration issues. We describe our recent work for the Navy to develop human factors and training solutions for shipboard helicopter operations, with emphasis on the individual, equipment, and group components and their interactions. We focus on key training, procedures, and compatibility issues, and make comparisons to the air traffic control domain. Finally, we identify human factors and training contributions and opportunities for future constructive interventions.

INTRODUCTION

Military helicopters are routinely required to conduct operations on Navy ships. Shipboard helicopter interoperability has become a requirement for all the military forces. Shipboard helicopter operations include landings and takeoffs, launch and recovery support activities, and external load operations. These operations involve different helicopter types on aviation-capable Navy ships, in a variety of sea states, and under changing visibility and environmental conditions. Thus, shipboard operations involve a complex socio-technical system of individuals with various skills and experience levels, complex equipment, and a hazardous working environment.

Organization of the Paper

This paper is organized into four sections. In the first section, we provide an overview of shipboard helicopter operations. In the second section, we discuss operational procedures and training requirements. We then discuss critical Human Factors/Human Systems Integration (HF/HSI) issues and problems in shipboard helicopter operations where HF/HSI principles and guidelines can be applied. In this section we include examples of problems resulting from inadequate attention to these principles and guidelines. In the final section we discuss our findings and observations and identify avenues for future work.

SHIPBOARD HELICOPTER OPERATIONS

Conducting Naval as well as joint helicopter operations on Navy ships, particularly landings and takeoffs, requires a high degree of planning, coordination, situation awareness, and communication among pilots, crew chiefs, and ship personnel, and presents many unique HF/HSI challenges. The coordination and communication requirements between the aircrew and shipboard personnel responsible for directing landings and takeoffs and handling helicopters on ships are very demanding and leave little margin for error. This is especially true for smaller air capable ships such as destroyers, frigates, or guided missile cruisers that have only one or two landing spots and small working areas.

Key Shipboard Personnel

Shipboard personnel involved in helicopter operations must interact in a well-orchestrated and coordinated manner. Two key individuals are the Helicopter Control Officer (HCO) and the Landing Signal Enlisted (LSE) crewmember.

Helicopter Control Officer. The Helicopter Control Officer (HCO) is the overall safety observer who supervises all flight operations on and in the vicinity of the ship's deck. The HCO ensures safe flight deck procedures are observed. He/she is responsible for exercising positive control over the helicopter during launch, recovery, and "over the deck" operations (see Figure 1).

The HCO coordinates all helicopter movement, obtains permission from the officer of the deck to start up and shutdown engines, engage and disengage rotors to launch and recover a helicopter, and to communicate with the LSE. Other supervisory ship personnel involved in helicopter operations are the bridge team and the "Air Boss" who directs and oversees all of the activity on the flight deck.

Figure 1. Helicopter Control Officer.

Landing Signal Enlisted. The LSE is responsible for visually assisting the pilot with the proper guidance of the helicopter for safe launches, landings, and over-deck hovering using standardized hand signals (see Figure 2). These are listed in NAVAIR 00-80T-113, *Aircraft Signals NATOPS Manual* (Department of the Navy, 1998a) and in Joint Pub 3-04-1, *Joint Tactics, Techniques, and Procedures for Shipboard Helicopter Operations* (Department of the Navy, 1997).

Figure 2. Landing Signal Enlisted.

There are over 100 hand signals organized in five categories: (1) mandatory (e.g., wave off, hold position), (2) general aircraft signals (e.g., stop, apply brakes), (3) startup and shutdown (e.g., start engine, cut engine), (4) directional flight (e.g., slow down, move ahead), and (5) flight deck evolution (e.g., release load, cut cable). The LSE's signals are advisory in nature, with the exception of mandatory wave-off and hold signals, which are used when an emergency condition exists, or when an unsafe situation arises. All pilots must comply with the mandatory hand signals.

The LSE directs the aircraft to the desired deck spot, positions the helicopter properly, and ensures that the flight deck is safe. He/she is also responsible for supervising the flight deck crews, including the chalk and chain personnel (see Figure 3). The LSE must accurately observe the helicopter, the aircrew, and the flight deck personnel to coordinate their activities and ensure safety.

Figure 3. Helicopter chalk and chain crew.

The LSE must also observe the aircraft carefully for signs of malfunctions (e.g., oil/hydraulic leaks), or unsafe conditions (e.g., hung landing gear, fires). He or she ensures that the helicopter is safely started, launched, recovered, and shut down, and that all tie-downs are removed before liftoff and properly secured after landing. The HCO, LSE, and flight deck crews must be proficient in conducting these procedures during the day, and at night using signal wands under unaided or aided conditions (i.e., using night vision goggles, NVGs). See Figure 4.

Figure 4. Shipboard NVG operations**.**

OPERATIONAL PROCEDURES AND TRAINING REQUIREMENTS

Navy/USMC Publication NWP 3-04-1 *Shipboard Helicopter Procedures For Air-Capable Ships*, (Department of the Navy, 1998b) sets forth the operational procedures and training requirements for helicopter operations from air-capable ships, and provides shipboard personnel with a standard reference. It lists operations and training requirements for Navy/USMC helicopter pilots, HCOs, LSEs, and other shipboard personnel. The operational procedures and requirements for Army and Air Force helicopter shipboard operations are listed in Joint Publication 3-04-1(Department of the Navy, 1997).

Pilot Training

The Navy conducts ground school training in shipboard helicopter operations as part of the pilot training program used by the Helicopter Fleet Replacement Squadrons. Ground school (orientation training) is mandatory for all aircrew assigned to units requiring deck landing qualification. Annual refresher training is required thereafter, if the aircrew are unable to maintain deck landing currency.

During pilot training, emphasis is placed on aircrew coordination using standardized voice and hand signal communications between the pilots, the crew chiefs, the LSE, and the HCO. Pilot training includes several mandatory areas critical to the pilot-LSE-HCO interaction: launch and recovery; aircraft landing and handling signals; and deck markings, lighting, and visual landing aids (see Figure 5).

Figure 5. Helicopter pilot training.

Shipboard Personnel Training

HCO and LSE formal training consists of classroom (schoolhouse) and shipboard training. The schoolhouse training provides instruction in the basic knowledge and skills required for conducting safe helicopter operations aboard Navy ships. LSE schoolhouse training currently consists of classroom instruction and “hands-on” field training periods. The classroom instruction includes lessons on several topics: helicopter capabilities, limitations, and special characteristics; flight deck visual landing aides; visual hand signals; start-up, shut-down, and aircraft handling procedures; helicopter emergencies; and NVG operations.

The “hands-on” training periods consist of helicopter pad periods for training LSE/helicopter interaction skills using hand signals (see Figure 6), and NVG familiarization. Typically, an LSE receives less than two minutes of live interaction with a helicopter during shore-based training. Furthermore, the opportunity to develop coordination and communication skills with the HCO is largely limited to on-the-job-training (OJT) during shipboard operations.

Figure 6. Schoolhouse helicopter pad training.

SHIPBOARD HELICOPTER INTEGRATION ISSUES

The Navy undertook the Joint Shipboard Helicopter Integration Process (JSHIP) Program during 1997 - 2003 to understand issues and potential problems involved in integrating Army and Air Force helicopters on board Navy ships, and to develop appropriate tactics, techniques, and procedures for these aircraft. The JSHIP Program objectives were to improve (1) shipboard helicopter interoperability for all services, (2) the compatibility of helicopters with ships, (3) procedures and training for both ship's company and embarked units, and (4) operational safety (Ruffner, Padukiewicz, and Meier, 2002; 2003). There are several issues and problems addressed during this program that may be solved using HF/HSI tools and techniques. These are in three areas: (1) helicopter ship interoperability *procedures*, (2) aircrew and ship personnel *training*, and (3) helicopter-ship physical *compatibility*. Examples of problems, along with recommended solutions, are provided below.

Procedures

Several service-specific procedures exist that may result in mishaps and accidents. For example, saying that a deck status is “red” may mean one thing to the deployed aircrew (deck is cleared for ordnance delivery) but a completely different thing to ship personnel (deck is unusable). A potential HF/HSI solution to this problem is to perform a communications protocol analysis to identify problems between helicopter crews and ship personnel that can arise due to a lack of standardized communications.

Training

Unlike many socio-technical systems in which participants interact frequently and on a consistent basis, the first time an Army or Air Force helicopter aircrew interacts with Navy ship landing personnel often is after they have been tasked to conduct shipboard helicopter operations at sea, and the helicopter is approaching the ship.

In many instances, this tasking comes at the last minute with limited time for crews to prepare for the deployment.

Therefore, the Navy recognized a need to provide skills training for individual and collective aircrew, as well as the ships crew, that can be effectively and economically delivered *prior* to aircrew deployment. This training includes topics such as aircraft and ship familiarization, flight deck personnel responsibilities, landing markings and signals, and LSE visual signals.

Potential HF/HSI technologies that can be leveraged to deliver this type of training quickly and efficiently are computer/web-based training (e.g., for helicopter signaling skills) and virtual reality simulation. Figure 7 shows a prototype screen from an LSE Signaling computer-based trainer (CBT) we recently developed for the Navy (Ruffner, Titley, Fulbrook, and Franz, 2004).

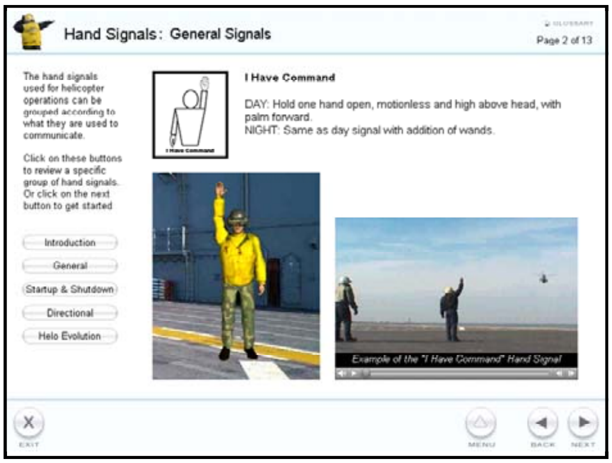

Figure 7. Screen from Helicopter Signaling CBT/WBT.

The trainer integrates newly developed multimedia material, content from the LSE course and the JSHIP Program, and digital videos of shipboard helicopter operations. The trainer has a broad spectrum of applications in that it can be used for both LSE and pilot computer-based and web-based training, and can be adapted to be used in multimedia classroom presentations. Figure 8 shows a scene from the Vertical Flight Deck Training System (VFDTS) a virtual reality signaling trainer developed for the Navy by CATI (Holmes, Franz, Struckhoff, and Salva, 2004). We are currently collaborating with CATI and the Navy to integrate the LSE CBT/WBT with the VFDTS, and to automate the recognition of selected hand signals using computer-vision and image processing technology.

Compatibility

Shipboard helicopter problems often arise due to physical incompatibility between the helicopter footprint (the space the aircraft takes up on the deck), and the available landing area, to deck space limitations restricting blade folding, and to on-deck aircraft movement. Many of these compatibility problems involve a poorly conceived human-system interface.

Figure 8. Screen from the VFDTS simulator.

Figure 9 shows an example of a type of physical compatibility problem commonly faced in shipboard helicopter operations. This represents a situation in which the use of HF/HSI tools, such as human performance and task network modeling techniques, could be used to predict the effects of a mix of factors on helicopter handling operations aboard different types of ships ahead of time.

Figure 9. Example of a shipboard compatibility problem.

Many HF/HSI-related incompatibility problems are marginally workable under favorable conditions (e.g., sufficient crew size, low workload, ample deck space, and low wind conditions). These problems may be exacerbated to the point of becoming dangerous with reduced manning, increased workload and fatigue, a crowded flight deck, and inclement weather (which at sea is the normal condition!). These problems, which reflect several HF/HSI domains (e.g., manpower, human factors, system safety), can often be identified ahead of time. This would allow time to explore potential solutions prior to deployment.

DISCUSSION AND CONCLUSIONS

Conducting joint shipboard helicopter operations during the day, night, and all weather conditions is a critical requirement for US military forces, especially with the nature of the current and future asymmetrical threats from terrorism. Understanding the nature of helicopter operations in a ship environment, identifying critical HF/HSI issues, and finding solutions for challenges in shipboard helicopter operations are critical requirements for enhancing human and system performance.

Shipboard operations involve a complex socio-technical system of individuals with various skills and experience levels, complex equipment, and a demanding working environment that allows little margin for error. There are many parallels to terminal area air traffic control operations in terms of mission requirements and socio-technical system issues involving personnel, equipment, and environmental factors. In this paper we discussed critical aspects of shipboard helicopter operations for which adopting HF/HSI principles and "best practices" are likely to improve operational effectiveness and safety.

This ability to work together as part of a complex socio-technical system during contingency operations leverages the best capabilities of each respective service into a cohesive joint team that, when combined, can more effectively project combat capability where needed. As noted previously, conducting helicopter operations on Navy ships requires a high degree of planning, coordination, situational awareness, and communication among pilots, mission aircrew, and shipboard personnel. In a sense, the participants become members of short-term "ad hoc" teams who are assembled quickly and who must perform successfully together with little or no opportunity for significant prior interactions, rehearsals, or opportunities for team building, and then are dispersed.

In addition, deployments force the aircrews to cope with difficult issues that have some basis in the nature of the socio-technical system (Ruffner, Padukiewicz, and Meier, 2002). Examples are:

- The proper preparation of both the aircraft and crew members for over-water operations (i.e. tie-down rings for aircraft, compatible fuel nozzles & adapters, dunker training for the pilots as well as over-water survival gear and clothing).
- The need for aircrews to deal with a foreign environment (at sea on a ship) that brings with it associated HF/HSI issues (sea-sickness, crew feeding and berthing, medical, and fitness).
- The exposure by the ship environment of the aircrew to new hazards, such as electromagnetic, water, weather, confined deck areas, proximity to large numbers of aircraft, machinery, ordnance, & weapons operations.

The shipboard helicopter integration process involves several unique issues and presents many challenges that need to be addressed by HF/HSI practitioners:

- Identifying error-prone shipboard helicopter interoperability procedures that contribute to mishaps and accidents, and developing recommendations for reducing errors
- Developing training for the required individual and collective aircrew and ship crew skills that can be effectively delivered prior to aircrew deployment or once aboard ship.
- Identifying shipboard helicopter compatibility problems involving human-system interactions and developing recommendations for avoiding or resolving these problems.

The lessons learned thus far, as well as from future work, are of interest to HF/HSI practitioners in both the aviation and shipboard communities, to students of complex socio-technical systems, as well as to acquisition professionals who can benefit by realizing the tangible benefits and value added by integrating HF/HSI into current and future programs.

REFERENCES

Department of the Navy. (1997). *Joint tactics, techniques, and procedures for shipboard helicopter operations* (Joint Pub 3-04-1). Department of the Navy.

Department of the Navy. (1998a). *Aircraft Signals NATOPS Manual.* Washington, DC: Deptartment of the Navy.

Department of the Navy. (1998b). *Helicopter operating procedures for air-capable ships*. (NWP 3-04-1). Washington, DC: Department of the Navy.

Holmes, B. J., Franz, T. M., Struckhoff, A. D., and Salva, M. (2004). *Vertical Flight Deck Training System*. Paper presented at the July 2004 Image Conference, Scottsdale, Arizona.

Ruffner, J. W., Fulbrook, J. E., Struckhoff, A. D., Morey, P. M., and Franz, T. M. (2004). What comes down must go up: Training shipboard helicopter signaling skills. *Proceedings of the 48th Annual Meeting of the Human Factors and Ergonomics Society* (p. 2548-2552). Santa Monica, CA: Human Factors and Ergonomics Society.

Ruffner, J. W., Padukiewicz, J. E., and Meier, J. D. Jr. (2003). Human systems integration issues in joint shipboard helicopter operations. *Proceedings of the Human Systems Integration Symposium: Enhancing Human Performance in Naval & Joint Environments,* Vienna, VA: June 23 – 25, 2003.

Ruffner, J. W., Padukiewicz, J. E., and Meier, J. D. Jr. (2002). Joint shipboard helicopter operations: Human factors issues and challenges. *Proceedings of the 46th Annual Meeting of the Human Factors and Ergonomics Society* (pp. 46-50). Santa Monica, CA: Human Factors and Ergonomics Society.

Ruffner, J. W. Titley, K. D., Fulbrook, J. E., and Franz, T. M. (2004). Integrating technologies for shipboard helicopter signaling skill training. *Proceedings of the Interservice/Industry Training, Simulation and Education Conference* (p. 223-234). Orlando FL: December 6 - 9 2004.