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FLIGHT INFORMATION PRIORITY BY PHASE

Brimner, Stuart S.; Cochran, Sean P.; Colvin, Jared D.; Durfee, Andrew F.; Page, Eric M.; Street, Terence D., Jr.

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SYSTEMS ENGINEERING CAPSTONE REPORT

FLIGHT INFORMATION PRIORITY BY PHASE

by

Stuart S. Brimner, Sean P. Cochran,
Jared D. Colvin, Andrew F. Durfee, Eric M. Page,
and Terence D. Street Jr.

December 2022

Advisor: Lawrence G. Shattuck
Co-Advisor: Matthew C. Nicholson
Second Reader: Panagiotis Matsangas (contractor)

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Military helicopter pilots must receive, analyze, communicate, and react to large amounts of information during a flight. Pilots continuously filter through information to identify what is relevant at the current point in their mission based on the operational and flight-specific situation. While fusing information, pilots may experience cognitive overload that results in degraded performance and contributes to catastrophic events. This report investigates whether pilots require different information during different phases of flight, what specific information pilots need during these phases, and how pilots want to receive different types of information. A survey was sent to 3600 U.S. Army UH-60 pilots (362 completed at least one portion of the survey; response rate of ~10%) asking them to prioritize 31 information items (very important, important, somewhat important) by phase of flight. The survey was followed by UH-60 pilot focus groups conducted at Fort Drum, NY. The research team found that desired information varies by phase, identified the specific information needed in each phase, and determined that pilots prefer most information to be presented visually. The conclusions of this study can inform future cockpit designs that integrate emerging technologies while reducing pilot cognitive load and increasing operational efficiency and safety.

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FLIGHT INFORMATION PRIORITY BY PHASE

CPT Stuart S. Brimner (USA), CPT Sean P. Cochran (USA), CPT Jared D. Colvin (USA), CPT Andrew F. Durfee (USA), CPT Eric M. Page (USA), and CPT Terence D. Street Jr. (USA)

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Lead Editor: Eric M. Page

Reviewed by:
Lawrence G. Shattuck
Advisor

Matthew C. Nicholson
Co-Advisor

Panagiotis Matsangas
Second Reader

Accepted by:
Oleg A. Yakimenko
Chair, Department of Systems Engineering

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ABSTRACT

Military helicopter pilots must receive, analyze, communicate, and react to large amounts of information during a flight. Pilots continuously filter through information to identify what is relevant at the current point in their mission based on the operational and flight-specific situation. While fusing information, pilots may experience cognitive overload that results in degraded performance and contributes to catastrophic events. This report investigates whether pilots require different information during different phases of flight, what specific information pilots need during these phases, and how pilots want to receive different types of information. A survey was sent to 3600 U.S. Army UH-60 pilots (362 completed at least one portion of the survey; response rate of ~10%) asking them to prioritize 31 information items (very important, important, somewhat important) by phase of flight. The survey was followed by UH-60 pilot focus groups conducted at Fort Drum, NY. The research team found that desired information varies by phase, identified the specific information needed in each phase, and determined that pilots prefer most information to be presented visually. The conclusions of this study can inform future cockpit designs that integrate emerging technologies while reducing pilot cognitive load and increasing operational efficiency and safety.

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LIST OF ACRONYMS AND ABBREVIATIONS

1LT	First Lieutenant
2LT	Second Lieutenant
ACP	air control point
AC	air corridor
APR-39	APR-39 Digital Radar Warning Receiver
AH	attack helicopter
AHB	Assault Helicopter Battalion
AMC	Air Mission Commander
AR	augmented reality
ANOVA	analysis of variance
AvMC	Aviation and Missile Center
ATP	Army Training Publication
CAB	Combat Aviation Brigade
CAC	Command Aviation Company
Co	Company
COL	Colonel
Commo	communication
CPT	Captain
CW2	Chief Warrant Officer 2
CW3	Chief Warrant Officer 3
CW4	Chief Warrant Officer 4
CW5	Chief Warrant Officer 5
C2	command and control

DEVCOM	Development Command
DMN	Default Mode Network
DoDI	Department of Defense Instruction
EMS	emergency medical services
Eng	engine
ExCheck	execution checklist
FAA	Federal Aviation Administration
FARP	forward arming and refuel point
FIPP	Flight Information Prioritization by Phase
FMS	Flight Management System
FVL	Future Vertical Lift
GPS	Global Positioning System
HLZ	helicopter landing zone
HRC	Human Resources Command
HSA-DM	Holistic Situational Awareness Decision Making
HUD	heads up display
IRB	Institutional Review Board
JVMF	Joint Variable Message Format
LTC	Lieutenant Colonel
LZ	landing zone
MAJ	Major
MEDEVAC	medical evacuation
MFD	multi-function display
MSE	mean square error

MRT	multiple resource theory
MSTr	mean square for treatments
NPS	Naval Postgraduate School
NR	rotor revolutions per minute
NG	gas producer
PEO	Program Executive Office
PPC	performance planning card
PZ	pickup zone
RL	readiness level
ROZ	restricted operating zone
RP	release point
RPM	revolutions per minute
SP	start point
TDH	time distance heading
TGT	turbine gas temperature
TQ	torque
UAS	unmanned aerial system
UH	utility helicopter
WO1	Warrant Officer 1
XMSN	transmission

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EXECUTIVE SUMMARY

Military helicopter pilots must receive, analyze, communicate, and react to large amounts of information during a flight. This information includes everything from aircraft performance data, such as rotor RPM, to mission data, like landing zone diagrams or friendly force locations. Pilots continuously filter through information to identify what is relevant at the current point in their mission based on the operational and flight-specific situation. While fusing this information, pilots may experience cognitive overload that results in degraded performance and contributes to catastrophic events. The main goal of this research was to determine whether pilots need different information in each phase of flight, and to develop and validate a comprehensive list of information that pilots require during different phases of flight. Additionally, the research intended to identify what modality of information was preferred to be presented to pilots. With this information, follow-on research and development can determine how to tailor information to pilots by phase in order to optimize operational decision-making. This report investigates three research questions: (1) Do pilots need different information during different phases of flight? (2) What specific information do pilots need during these specific phases? (3) How do pilots want to receive information?

After conducting a literature review to understand better the root cause of the problem and engaging stakeholders at FVL and HSA-DM, the researchers surveyed 362 qualified UH-60 pilots in the Army. A survey request was generated and sent to the Army Survey Office, as well as Army Human Resources Command. The survey was subsequently approved and distributed to participants via an email with an embedded Qualtrics link. The researchers modified an Air Assault scenario in Army Training Publication (ATP) 3–04.1, removing several aspects and changing it from an air assault to a tactical air movement. The literature review showed that the most demanding phases of flight are landing and takeoff, which were incorporated in the survey phases and react-to-radar phase. The survey was designed to accommodate an average completion time of 14 minutes. The survey captured demographics and included 31 flight information items the respondents were asked to assign to one of three categories (very important, important, somewhat important) for each phase of flight. Within each phase, respondents were also asked to prioritize information within the "very important" category. Finally, respondents were asked how they would prefer the information to be presented in the cockpit with visual, auditory, and tactile modality selection options.

To gain additional insight into the survey data and validate data collected from the survey, members of the research team conducted focus groups with pilots assigned to 10th Combat Aviation Brigade at Ft. Drum, N.Y.

Using survey methodology and the implementation of focus groups, the research team found that desired information varies by phase, and identified the specific information needed in each phase. The three most important pieces of information by phase were:

Phase 1: Rotor RPM, GPS, and Threat Update (UAS)

Phase 2: Radar Warning Indicator, Rotor RPM, and Vertical Situation Indicator

Phase 3: LZ Diagram, Rotor RPM, and GPS

The three focus groups consisted of the battalion aviation maintenance officer, six junior pilots, and six senior pilots.

Researchers also discovered that pilots primarily prefer information presented visually (70.5% of pilots chose visual as the preferred modality to receive information across all phases of the mission), with almost no pilots preferring tactile presentation of information. Of note, pilots preferred the auditory modality for only four pieces of information across all three phases: Cherry/Ice Call, Radar Warning Indicator, and Threat Update (UAS).

In addition to answering the research questions, the team found a relationship between the demographics of pilots and desired information. There may be a difference in how and when commissioned officers and warrant officers prefer certain pieces of information, affected by the type of flight responsibility and flight hours. Further research is needed to explore this relationship and its contributing factors. Additionally, pilots desire a heads-up display containing critical information that minimizes the need for pilots to look inside the cockpit.

These findings will allow the Holistic Situational Awareness and Decision-Making project team to develop systems to support the Future Vertical Lift program and ultimately reduce the cognitive load pilots experience, creating a more effective warfighting system. The conclusions of this study should be used to inform a more human-centric design in future cockpits that integrate emerging technologies, reduce pilot cognitive load, and increase operational efficiency.

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I. INTRODUCTION

A. PROBLEM STATEMENT

Military helicopter pilots must receive, analyze, communicate, and act/react to large amounts of information during a flight. This information includes everything from aircraft performance data, such as rotor RPM, to mission data, like landing zone diagrams or friendly force locations. The pilots receive the information through multiple modalities, including auditory, visual, and proprioceptive. While fusing all these data, pilots must simultaneously maintain control of the aircraft and fly it to the destination. Pilots continuously filter through information and find what is relevant to them at the current point in their mission. As one can imagine, pilots are very vulnerable to cognitive overload every time they fly. This research will investigate if pilot cognitive overload can be reduced by tailoring presented information to the current phase of flight.

The cognitive overload experienced by the pilot can result in degraded performance and contribute to catastrophic events. According to the U.S. Army Combat Readiness Center (2022), 11 fatalities were caused by helicopter crashes and 27 helicopter mishaps occurred in the fiscal year 2021 alone. Rempfer (2021) described a fatal crash of a UH-60 Blackhawk in 2020 in the Sinai Peninsula. Before the crash, during a routine reconnaissance flight, the aircraft's stabilator failed and had to be controlled manually. (The stabilator is an airfoil at the end of the tail boom that helps maintain horizontal stability and automatically adjusts position when operating correctly.) The crew elected to continue the mission and manually control the stabilator position throughout the rest of the flight. Following an approach to a high hover, the crew transitioned to forward flight but failed to adjust the stabilator position, resulting in an unrecoverable attitude, crashing and killing seven on board, with only one survivor. This crash was categorized as "human error" and is one of many examples of how pilots must process vast amounts of information and quickly become overloaded.

The aircraft provides both relevant and irrelevant data, which can lead to pilots forgetting the most important information for their current situation. To properly understand cognitive overload, it is essential to identify what types of information are received, the importance of those data, the modality in which that information is conveyed to the pilot, and the pilot's effectiveness at fusing the information promptly to make sound decisions.

United States Army rotary-wing pilots risk cognitive overload due to the mission information and aircraft information required to aviate, the communications information required to communicate, and navigation information required to navigate. These factors change depending on the phase of flight in which the aircraft is operating. Several studies have shown that certain phases of flight are more demanding than others. One such study from the *International Journal of Aviation Psychology* suggests that take-off and landing are the most demanding phases of flight (Wilson 2009, 8). Another study from the Federal Aviation Administration (FAA) found that visibility and environmental factors can increase the risk during any phase of flight. In 2021, the FAA conducted research showing Emergency Medical Services (EMS) helicopters suffered twice as many fatal crashes as non-EMS helicopters. Visibility/darkness and pilot judgment were shown to be the causes of this higher fatality rate (Greenhaw and Jamali 2021, 23). EMS helicopter missions are similar to U.S. Army Blackhawk missions because they often fly in poor weather and land in unimproved landing zones such as in open fields or on the side of a road.

Very little mission information is provided to pilots in legacy aircraft such as the UH-60 Blackhawk or the AH-64 Apache, forcing pilots to make decisions from analog kneeboard packets. Conversely, the helicopter provides real-time performance data, but it gives the same information during all phases of flight unless the pilot manually changes the display configuration. This can lead to unnecessary and distracting information being provided while needed information is not provided. Communications might be the most common cause of cognitive overload due to pilots monitoring five radios, communicating with their co-pilot, communicating with other aircraft, and, if needed communicating with non-rated crew members such as crew chiefs or flight medics. Environmental factors such as dust or poor visibility force pilots to focus their attention outside the aircraft more and focus less on other factors such as mission information or communications. All these factors contribute to cognitive overload in pilots and directly lead to aircraft accidents.

All Army aircraft have two pilots, the pilot and the pilot-in-command. The pilot-in-command is responsible for safely operating the aircraft, designating roles and responsibilities for the pilot, and making all decisions to accomplish the mission. The pilot-in-command must understand and rapidly process all the information provided by the aircraft and then communicate the plan of action to all crew members. When multiple aircraft are executing a mission, the Air Mission Commander is not only responsible for their aircraft but also to coordinate the mission with the other aircraft and other elements such as the ground force or artillery. Today, the aircraft presents the same information to these pilots no matter what their role (pilot, pilot-in-command, or air mission commander) and no matter what phase of flight they are in. The aircraft should aid pilots in making rapid and correct decisions by presenting needed information at the correct time.

B. OBJECTIVES

The purpose of this research is to identify what information pilots need and when to present that information based on the phase of the mission. This filtered information will allow the Holistic Situational Awareness and Decision-Making project team to develop systems to support the Future Vertical Lift program that ultimately reduces the cognitive load pilots experience, creating a more effective warfighting system. Designing a crew station or building a system to present information at the correct time is outside the scope of this research. This research will lay the foundation on which future projects can build and expand. The main goal of this project is to develop and validate a comprehensive list of information pilots require during different phases of flight. With this list of needed data, follow on research can determine how to automatically present that information to the pilots.

Perhaps more important than knowing what information pilots need is learning what information pilots do not need. Knowing what information the aircraft does not need to provide the pilots during a given phase of flight is the second objective of this research. Identifying what information pilots think is less important can help subsequent research discover how to not provide that information to pilots. By eliminating irrelevant information which must be sorted and disregarded, pilots can focus on important mission information and safely accomplish their mission.

The third objective of this project is to discover in what modality pilots prefer to receive important data. This information will be used by stakeholders to build aircraft displays that present the correct data, at the correct time, and in the correct modality. Ultimately, future research can discover how to automate presenting the correct information during the correct phase of flight. This project lays the foundation for understanding how to safely conduct tactical air movements in the UH-60 Blackhawk and future aircraft by decreasing the likelihood of cognitive overload.

C. RESEARCH QUESTIONS

After conducting a comprehensive literature review to better understand the root cause of the problem, we developed three research questions. Answering these questions will aid the HSA-DM project team in better designing aircraft and crew stations to reduce pilot cognitive workload.

- Question 1: Do pilots need different information during different phases of flight?
- Question 2: What specific information do pilots need during these specific phases?
- Question 3: How do pilots want to receive information, i.e., visually, audio, tactile?

D. HYPOTHESES

Reading and studying past research informed what we believe to be the answers to these research questions. Our hypotheses are as follows:

- Question 1 H0: Pilot’s prioritization of information that facilitates mission success does not change throughout phases of flight.

- Question 1 HA: Pilot’s prioritization of information that facilitates mission success will change throughout phases of flight.
- Question 2 H0: Pilots will not have prioritization of information in a specific phase of flight.
- Question 2 HA: Pilots will have prioritization of information in a specific phase of flight.
- Question 3 H0: Pilot’s modality preference for receiving information does not change throughout phases of flight.
- Question 3 HA: Pilot’s modality preference for receiving information changes throughout phases of flight.

E. THESIS ORGANIZATION

The remainder of the capstone report is organized into the literature review, methodology, results and information analysis, discussion, conclusion, and recommendations. Chapter II provides the literature used as the basis for discovering information. Chapter III explains the methodologies and approaches used for research collection. Chapter IV provides the results and information analysis of the study while Chapter V includes the discussion, conclusion, and recommendations for future research efforts based on the information from this study.

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II. LITERATURE REVIEW

After talking with the HSA-DM project leader and other stakeholders about the problem of cognitive overload in military rotary wing pilots, we began researching previous literature which could help guide our project. This chapter explains the cognitive demands placed on U.S. Army pilots, executing tactical air movements, overload experienced by pilots, and what can happen when they are overloaded. We began our research by ensuring we understood the problem our stakeholders asked us to solve. Our literature review suggests that certain phases of flight are more demanding than others and pilots need specific information during these phases. Our goal with this project is to reduce the cognitive workload of pilots so they can focus on flying the aircraft and accomplishing their mission efficiently and safely.

A. COGNITIVE WORKLOAD

Every task a pilot performs requires mental effort or cognitive workload. But some tasks require more mental effort than others. To better understand the cognitive work performed by pilots, we looked at the work done by Wilson (2009), which examined which phases of flight are the most demanding. Wilson shows that takeoff and landing are the most demanding phases of any flight and require a higher level of cognitive workload. Wilson suggests that the mode of flight—Instrument Flight Rules or Visual Flight Rules—does not change which phase of flight induces more stress. The physiological changes, such as increased heart rate, during different phases of flight suggest it is critical to present only relevant information to the pilot during takeoff and landing to reduce cognitive load. This study shows the need to determine which information is important in each phase of flight.

In addition to phases of flight, research shows that night conditions also increase the cognitive workload of pilots. Greenhaw and Jamali (2021) conducted a study to determine if EMS helicopters are more likely to suffer fatal crashes. They found that between 1999 and 2018, EMS helicopters suffered roughly twice as many fatal crashes as non-EMS helicopters. During this time, 14% of non-EMS crashes were fatal while 34% of

EMS crashes were fatal. While this study did not attempt to answer why EMS helicopters have a higher fatal crash rate than non-EMS helicopters, it did make several discoveries. Greenhaw and Jamali suggest that the two most likely causes of increased fatalities are visibility/darkness and pilot decision-making/judgment. Combined with the work of Wilson (2009), Greenhaw and Jamali's findings indicate that not only are different phases of flight more demanding but also operating during different light conditions can be more demanding.

B. COGNITIVE OVERLOAD

Most military operations are conducted at night, under low illumination conditions, meaning the pilots who support them are more likely to encounter a high cognitive workload. Galant et al., found that a large amount of information reaching the pilot through several onboard systems can lead to cognitive overload (Galant et al. 2020, 330). The American Psychological Association defines cognitive overload as "the situation in which the demands placed on a person by mental work (the cognitive load) are greater than the person's mental abilities can cope with" (Galant et al. 2020, 330). This overload causes fatigue and stress in pilots. They stated, "to successfully manage an emergency situation, flawless perception and fast analysis of information from many different sources are necessary" (Galant et al. 2020, 330). Their research found that pilots can inadvertently omit vital information due to cognitive overload. Omissions occurred when the pilot was stimulated with a large amount of information flow from at least two different sources.

C. MODALITIES

Modality refers to the medium in which information is passed and received by the user. There are generally three types of modalities in which information is passed: visual, auditory, and tactile. Mental imagery is our ability to "perceive with the mind's eye and ear" information that occurs in the world around us (Daselaar et al. 2010, 677). External stimulation occurs, and the human must synthesize information in working memory and in a framework that allows effective reaction (Daselaar et al. 2010). To ascertain how the brain synthesizes information, recent fMRI studies focused on monitoring brain regions associated with auditory and visual reception. A working hypothesis for areas that support multi-modality integration is the "Default Mode Network" (DMN). The DMN is a network of brain regions that are more active during rest and activities associated with non-cognitive load. The DMN facilitates the integration of multiple modalities (Daselaar et al. 2010, 678). An experimental "workaround" to assess the ability of internal synthesis is to provide different stimuli in different modalities and evaluate recall ability. Recent MRI studies identified a "core imagery network" (Daselaar et al. 2010, 684) that corresponded with the previously identified DMN. This core imagery network seemed to allow subjects to hold mental images and synthesize them across modalities. The theory is that to allow the DMN and "core imagery network" to synthesize and manipulate information, the brain blocks additional external stimuli to prevent cognitive overload. This theory suggests the shutdown of active external input when the brain is at maximum capacity. Potentially in the future, a pilot will have the ability, based on the phase of flight and ongoing contingencies, to prioritize what information is displayed to allow more relevant, lifesaving information to take priority. To do this, we must first know what information pilots prioritize during different phases and situations of flight. Our second research question attempts to discover what information pilots prioritize.

Along with the arrangement of information through the lens of modality presentation, inferential reasoning will heavily affect how an individual makes decisions. If certain types of information are presented in a specific order, the information may anchor an individual to more inferential decisions rather than valid probabilistic decisions (Hinterecker and Johnson 2016). In the world of a rotary wing pilot, the order and relevance of information presented may affect intuition and subsequent decisions. For example, if fuel levels are low (20%), and later in the mission, a warning light that indicates an engine failure is activated, the pilot may link the two. Linking the two pieces of information is not useful or correct if the low fuel is not the reason for the engine failure. Along with reducing cognitive overload and determining workload drivers, our research question is inevitably related to understanding decisions based on cognitive management capabilities. As an example, if certain non-essential warning indicators are displayed in the cockpit and create a judgment anchor within a pilot's decision framework, the negative results may create an unnecessary increase in cognitive load and affect the pilot's ability to operate during subsequent mission phases.

D. PHASES OF FLIGHT

To reduce the cognitive workload of Army aviators, we must understand how they plan and execute their missions. Army aviation doctrine dictates how Army aviators plan and execute highly complex missions. Air assaults use a five-step, reverse planning process: ground tactical plan, landing plan, air movement plan, loading plan, and staging plan (Department of the Army 2020, 8–6). Each of these phases requires its own in-depth planning, and the standard planning window is 96 hours (Department of the Army 2020). Pilots are expected to understand and, at times, recall copious amounts of information from memory.

The planning manuals show how much information pilots need to execute their mission safely and effectively. Figure 1 shows the various meetings and planning conferences required for an air assault, each with its own outputs. Pilots must understand and quickly recall or reference this information planned over 96 hours. Currently, Army aircraft do not display any of the mission data planned and produced for different phases of flight.

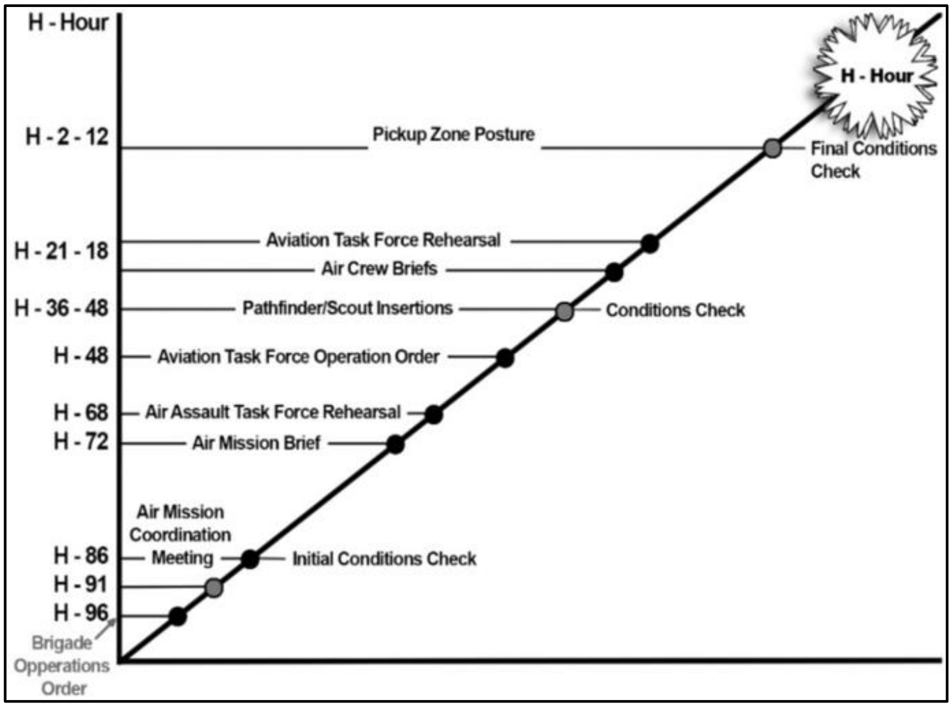

Figure 1. 96-hour air assault process. Source: ATP 3-04 (2022), 8–2.

In addition to these five phases, air routes are planned using start points (SP), air control points (ACP), release points (RP), and landing zones (LZ). Figure 2 shows how these different measures are related to the five-phase, reverse planning process. The SP is the beginning point of the tactical mission and the aircraft should be in the correct formation prior to reaching this point and stay in the correct formation until reaching the RP. ACPs along the route aid in navigation and staying on timeline. The lead aircraft navigates the formation to each subsequent ACP and adjusts the speed as necessary to stay on the planned timeline. Upon reaching the RP, the aircraft begin preparation for landing at the LZ. Because of Wilson’s (2009) research, we determine the flight from the RP to the LZ is the most stressful phase of the mission.

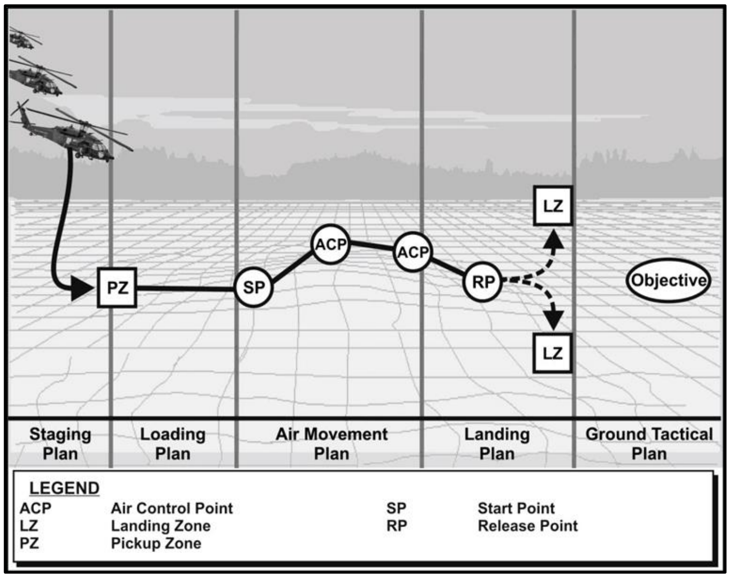

Figure 2. Air assault planning stages. Source: Department of the Army (2015), 9–2.

To plan and execute these complex missions requires two key leadership positions: air mission commander (AMC) and flight lead. Army aviation doctrine states: "An AMC is assigned to an aviation mission to lead the overall air mission and has decision-making authority for elements under his or her command. He or she must thoroughly understand the commander's intent and execute the mission with disciplined initiative. The AMC must demonstrate the ability to make sound decisions, possess proficiency in aviation operations, and provide leadership and an understanding of the mission to ensure mission accomplishment" (Department of the Army 2020, 1–9). The AMC is responsible for accomplishing the mission and is ultimately responsible for mission success or failure. AMC selection is "based on demonstrated leadership, proficiency, judgment, and tactical decision-making skills, not exclusively upon rank alone" (Department of the Army 2020, 1–9). However, high-ranking pilots have more experience and are more likely to be selected to serve as the AMC.

The flight lead is the lead planner for the air assault and flies in the lead aircraft. Army doctrine states "Whereas the AMC manages the overall conduct and flow of the mission, the flight lead is responsible for leading the flight according to the mission brief and commander's intent" (Department of the Army 2020, 1–10). This is a demanding position that requires detailed mission planning and efficient mission execution. A key duty is to “Execute selected contingencies without delay (inadvertent instrument meteorological conditions, threat avoidance) during mission execution” (Department of the Army 2020, 1–10). The flight lead should be an experienced pilot who can not only fly the aircraft but also execute the mission.

E. WICKENS’ MULTIPLE RESOURCE THEORY

Situational awareness is an important factor in reducing cognitive overload among pilots. Wickens’ Multiple Resource Theory (MRT) asserts that “tasks are assumed to demand resources for their performance and these resources are limited in their availability; therefore, when the joint demand of two tasks exceeds the available supply, time-sharing efficiency drops and will be more likely to do so as the difficulty of either component tasks increases” (Wickens 1991, 1). Another study investigated individual differences in situational awareness amongst a sample of 25 experienced single-seat air-to-air fighter pilots (Endsley and Bolstad 1994, 254). In their research, the authors determined five areas of individual difference to test: spatial, attention, memory, perception, and cognitive functions (cognitive complexity, field independence, and locus of control). A “set of air-to-air engagements was conducted in a real-time, manned, multi-engagement simulator facility,” Endsley and Bolstad determined that spatial and perceptual skills are the most important for pilot situational awareness. This research aligns with rotary wing flight operations as well. Given a helicopter’s lower ceiling of roughly 10,000 feet in comparison to a standard fighter jet’s altitude of 40,000 feet, spatial, perceptual, and pattern-matching skills are vital to rotary wing pilots who use terrain and manmade features to navigate and safely accomplish their mission. In other words, helicopter pilots need to remain focused on their surroundings to ensure a safe flight.

Pilots are constantly dividing their attention between many different sources of information, including avionics, the surrounding environment, and radios. Research shows that the modality in which information is presented affects pilots’ ability to divide their attention. Low et al. (2014) discuss the effect of the modality principle on working memory capacity. Low et al. explain that the modality principle refers to the cognitive load learning effect when a subject is presented with information in a mixed mode (visual and auditory) or single mode (visual or auditory). Low et al. also discuss the relationship between types of attention and their impacts on working memory. For example, when two or more sources of information need to be processed simultaneously, split attention will occur and negatively impact the subject's working memory load.

Along with MRT, this research suggests that pilots' cognitive workload can be reduced by providing the correct information in the correct modality. By providing pilots with only the correct information and eliminating irrelevant information, we can reduce how much they are splitting their attention and allow them to remain focused on their surroundings. MRT shows that when given too much information in the incorrect modality, a pilot is far more likely to experience cognitive overload and miss critical information. The missed information could be as simple as a routine radio call, or it could be that the aircraft is in a slow descent. We can help pilots accomplish their mission more efficiently and safely by providing them with the correct information, at the correct time, in the correct modality.

F. COGNITIVE TUNNELING

Army doctrine discusses task saturation which can happen when pilots experience cognitive overload. The U.S. Army Aeromedical manual defines task saturation: "Task saturation occurs when crewmembers become so engrossed with a problem or task within the cockpit that they fail to properly scan outside the aircraft" (Department of the Army 2018, 9–14). A negative coping mechanism for task saturation is cognitive tunneling. Cognitive tunneling is "the effect where observers tend to focus attention on information from specific areas of a display to the exclusion of information presented outside of these highly attended areas" (Wickens 2001, 1). As pilots receive more information through traditional heads-down displays and aircraft instrumentation, information received outside the cockpit is minimized (Jarmasz, Herdman, and Johannsdottir 2005, 1). For example, UH-60M pilots navigate by looking at their map displayed on one of two multi-function displays (MFD) shown in Figure 3. While looking down at their displays, pilots are not looking outside the aircraft to ensure terrain and obstacle avoidance. If pilot become too focused on a single display, or a single source of information, they can experience cognitive tunneling and miss critical information from other sources.

Figure 3. UH-60 M crew station. Source: Leipold (2017).

G. CONCLUSION

Pilots continuously receive data during a flight, which they must then process into information and use to make decisions. Simultaneously, pilots perform complex tasks which require focused attention, especially during the most demanding phases of flight. Because of the demands placed upon them, pilots are susceptible to cognitive overload which can lead to mistakes, accidents, or even death. When pilots are overloaded with information, they can become engrossed in an information source and experience cognitive tunneling, missing critical information from other sources. Because of these dangers, it is important to reduce Army rotary wing pilots' cognitive workload. After discussions with our stakeholders, and having reviewed the relevant literature, we determined that an initial step to solving cognitive overload, is to understand if pilots need different information at different times and if they want that information in different modalities.

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III. METHODS

A. OVERVIEW

This chapter addresses the methods we used for answering the research questions stated in Chapter I. Through discussion with our stakeholders and with previous capstone researchers, we identified the need to:

- understand how pilots prioritize information through different phases of flight
- to ascertain what information pilots need during specific phases, and
- to understand how pilots want to receive information.

Through our literature review, we explored research surrounding the issues that contribute to cognitive overload in pilots. Our primary stakeholder, Holistic Situational Awareness-Decision Making (HSA-DM), has two main objectives. The first objective is to determine cognitive workload drivers. The second objective is to develop cognitive workload management capabilities. The results of this capstone will aid in future acquisition decisions within Future Vertical Lift (FVL) and provide the HAS-DM project team the data to understand the UH-60 pilot informational and modality needs through various phases of flight.

B. PROCEDURES

After conducting a literature review to better understand the root cause of the problem and engaging stakeholders at FVL and HSA-DM, the researchers decided to survey all qualified UH-60 pilots in the Army. After the Institutional Review Board determined the survey did not meet the criteria for human subject research, an Army survey request was generated and sent to the Army Survey Office for review. The survey was approved and distributed to participants via an email with an embedded Qualtrics link. The email list of qualified UH-60 pilots was provided by the Army Human Resource Command (HRC).

C. SCENARIO DESIGN

We tailored our scenario from the Air Assault example given in Army Training Publication 3-04.1, removing several aspects, and changing it from an air assault to a tactical air movement. According to Army doctrine, the difference between an air assault and a tactical air movement is having a ground tactical plan. Our literature review showed the most demanding phases of flight are landing and takeoff, so we chose to include the landing phase in our scenario. To ensure applicability to our stakeholders we included a react-to-radar phase to learn if military pilots need different information when encountering hostile fire. Finally, we chose to include the air movement phase because it is the longest phase of an air movement. We chose to not include the loading phase or staging phase because they take place on the ground and would add little value to the survey while adding additional time.

D. SURVEY DESIGN

The survey was developed with support and recommendations from Combat Capabilities Development Command (DEVCOM) Aviation and Missile Center (AvMC) and various Naval Postgraduate School (NPS) faculty members to ensure that data captured both answered HSA-DM's main objectives and satisfied the three research questions posed. During the test and validation, the survey was adjusted to an average completion time of 14 minutes. The survey captures basic demographics and includes 31 pieces of information the respondents were asked to assign to one of three categories (very important, important, and somewhat important) for each phase of flight. The three phases of flight consisted of Movement, React to Contact, and Release Point to Landing Zone. For items that were identified as very important in each phase of flight, respondents were asked to rank order them. The pieces of information are following and are further defined in Appendix A:

- NR (Rotor Revolutions per Minute)
- GPS (Global Positioning System)
- Threat Updates (UAS)

- Cherry/Ice Call
- Radar Warning Indicator
- Master Warning Panel
- Mission Timeline
- Vertical Situation Indicator
- Horizontal Situation Indicator
- Route Data (TDH, Checkpoints)
- LZ Diagram (headings, go-arounds, grids, hazards)
- TQ
- Radar Altimeter
- Airspeed Indicator
- Clock
- Fuel Quantity
- Friendly Unit Locations (B Co, C Co, UAS)
- Abort Criteria
- Minimum Force
- PPC Data
- ExCheck
- Status Updates from Serial
- Eng Oil Temp and Pressure

- TGT
- Caution/Advisory Panel
- XMSN Temp and Pressure
- NG
- Barometric Altimeter
- Stabilator Indicator
- Commo Card
- UAS Video Feed

To account for information not included in these 31 pieces of information, respondents were asked for any additional information items they deemed important that were not listed. Additionally, respondents were asked how they would prefer the information to be presented in the cockpit with visual, auditory, and tactile selection options. A scenario involving a radar indication on the radar warning indicator was included in the survey to solicit pilots' priority of information during contingency execution. Data captured by the questionnaire were used to conduct both descriptive and inferential statistical analysis during the data analysis phase.

E. FOCUS GROUPS

To gain additional insight into the survey data, members of the research team conducted focus groups with pilots assigned to 10th Combat Aviation Brigade (CAB) at Ft. Drum, NY. The purpose of the focus groups was to validate data collected from the survey, determine the rationale behind the prioritization of information by phase, and generate options about how information can be presented. The focus group team included one researcher with aviation experience and two additional officers to help moderate and take notes. Focus group rehearsals were conducted with faculty members at NPS.

Team members were assigned the responsibilities of moderator, assistant moderator, and recorder. The moderator was responsible for the overall facilitation of discussion and ensuring the planned focus group questions were covered. The assistant moderator was responsible for identifying emergent paths for exploration based on how the discussions evolved. The recorder was responsible for capturing audio recording and written data collection, as well as identifying bins based on response themes and tendencies. The data captured in the focus groups were divided into individual data, group data, and group interaction data (Duggleby 2005).

The team was at Fort Drum, NY for two days and conducted a one-on-one interview with a senior maintenance test pilot, a focus group with six junior pilots, and a focus group with six senior pilots. Using the focus group plan of action in Appendix A, the team discussed what information pilots want during different phases of a tactical air movement. The moderator began the discussion while the recorder took notes. The assistant moderator facilitated the conversation by identifying potential emergent paths and allowing pilots to speak their minds and expand the conversation. After completing the focus groups, the team compiled the collected data and compared the information to survey data to determine whether focus group data aligned with survey findings.

F. DATA ANALYSIS

We used descriptive statistics to answer our three research questions. First, we ordered the pieces of information according to how frequently they were selected as “very important.” This allowed us to answer our first research question and determine if pilots need different information during different phases of flight. Next, we examined how often pilots prioritized a piece of very important information as the number one priority. We compared the five highest prioritized pieces of information to determine what information pilots need during different mission phases. Finally, we examined how frequently pilots selected a certain modality for each piece of information. This allowed us to determine the modality in which pilots want to receive information.

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IV. RESULTS

This chapter presents the results from the survey of pilots from across the U.S. Army over three weeks in September 2022 and results from the focus groups conducted at Fort Drum, NY. The results are divided into five sections. The first section describes the demographic and occupational characteristics of the study sample. In the second section, we focus on the information variance by phase to examine the different information pilots need during each phase of the mission. In the third section, we focus on information prioritization by phase to identify what information pilots prioritize during different phases of flight. Next, the preferred information modality section analyzes the responses from the participants regarding the preferred modality for different types of flight information. The last section is focused on the significant unforeseen outcomes in which we examine how information needed differs between commissioned and warrant officers and pilots desiring heads-up displays.

A. INFORMATION LOCATION

To understand our results, it is important to understand where pilots receive different information. Pilots receive information from various sources, including but not limited to MFDs, radios, Flight Management Systems (FMS), crew members, and kneeboard packets. Table 1 shows where pilots receive all 31 pieces of information referenced in the survey. Figure 4 shows the location of the MFD 1–4 and FMS 1 and 2 in the cockpit. Each pilot uses two MFDs and one FMS to receive the information they need to fly and execute their mission. Kneeboard packets are paper packets with critical information that pilots wear on a knee for easier reference. The definition and explanation for each piece of information are provided in Appendix A.

Table 1. Information Source

Information	Location/Source
Cherry/Ice Call	Kneeboard
Radar Warning Indicator	MFD
Threat Updates (UAS)	Radio communication
Radar Altimeter	MFD
Route Data (TDH, Checkpoints)	Kneeboard
GPS	FMS
Airspeed Indicator	MFD
Fuel Quantity	MFD
LZ Diagram (headings, go-arounds, grids,	Kneeboard
Mission Time Line	Kneeboard
Master Warning Panel	MFD
Friendly Unit Locations (B Co, C Co, UAS)	Radio communication
TQ	MFD
Clock	MFD
Horizontal Situation Indicator	MFD
NR	MFD
Abort Criteria	Kneeboard
Vertical Situation Indicator	MFD
Caution/Advisory Panel	MFD
Commo Card	Kneeboard
ExCheck	Kneeboard
Minimum Force	Kneeboard
Status Updates from Serial	Radio communication
TGT	MFD
PPC Data	Kneeboard
Barometric Altimeter	MFD
Stabilator Indicator	MFD
NG	MFD
UAS Video Feed	not currently available
XMSN Temp and Pressure	MFD
Eng Oil Temp and Pressure	MFD

Figure 4. UH-60 M crew station. Adapted from Leipold (2017).

B. PARTICIPANTS

The population of interest for this research was all active-duty Army pilots that are qualified on any model of the UH-60 Black Hawk. The survey was sent to 3600 pilots. Of the 3600 pilots that met the initial requirements, 362 began the survey, 205 completed the entire survey, and 153 had a partially completed survey. From the 153 partially complete surveys, 84 were accepted for analysis because the participant completed the survey items of at least one phase of the mission scenario outlined later in this chapter. Given these differences in respondents in each phase, Tables 2 and 3 provide a breakdown of the occupational characteristics of the respondents for each phase. We determined there was not a substantive difference in respondents between the different phases.

Table 2. Respondents' Ranks by Phase

Rank	Phase 1	Phase 2	Phase 3
WO1	11 (3.81%)	8 (3.49%)	8 (3.81%)
CW2	86 (29.7%)	69 (30.13%)	63 (30.0%)
CW3	51 (17.7%)	37 (16.2%)	35 (16.7%)
CW4	24 (8.30%)	19 (8.30%)	16 (7.62%)
CW5	10 (3.46%)	10 (4.37%)	10 (4.76%)
2LT	0	0	0
1LT	14 (4.84%)	11 (4.80%)	10 (4.76%)
CPT	72 24.9%)	57 (24.9%)	51 (24.3%)
MAJ	21 (7.27%)	18 (7.86%)	17 (8.10%)
LTC	0	0	0
COL	0	0	0

Results presented as number of respondents (percentage).

Table 3. Hours of Flight Experience by Phase

Flight experience in hours	Phase 1	Phase 2	Phase 3
0-250	29 (10.0%)	20 (8.73%)	19 (9.05%)
251-500	76 (26.3%)	60 (26.2%)	53 (25.2%)
501-750	43 (14.9%)	35 (15.3%)	31 (14.8%)
751-1000	43 (14.9%)	37 (16.2%)	35 (16.7%)
1001-1250	26 (9.00%)	19 (8.30%)	18 (8.57%)
1251-1500	11 (3.81%)	10 (4.37%)	9 (4.29%)
1501-1750	8 (2.77%)	2 (0.87%)	2 (0.95%)
1751-2000	15 (5.19%)	11 (4.80%)	11 (5.24%)
2001-2250	5 (1.73%)	3 (1.31%)	3 (1.43%)
2251-2500	9 (3.11%)	8 (3.49%)	8 (3.81%)
>2500	24 (8.30%)	24 (10.5%)	21 (10.0%)

Results presented as number of respondents (percentage).

C. INFORMATION VARIATION BY PHASE

In this section, we discuss the findings related to our first research question: Do pilots need different information during different phases of flight? Table 4 shows the top five pieces of information in each phase with the rank in parentheses. The information is arranged alphabetically. Items highlighted in gray are not needed in the indicated phase. It is clear that pilots need different information depending on the mission phase. The rest of this chapter goes into detail about what information pilots need.

Table 4. Top Five Pieces of Information Needed by Phase

Phase 1		Phase 2		Phase 3	
Information	**Rank**	**Information**	**Rank**	**Information**	**Rank**
Air Speed Indicator		Air Speed Indicator	4	Air Speed Indicator	3
Cherry/Ice Call	1	Cherry/Ice Call		Cherry/Ice Call	
Horizontal Situation Indicator		Horizontal Situation Indicator	5	Horizontal Situation Indicator	
LZ Diagram		LZ Diagram		LZ Diagram	1
Radar Altimeter	4	Radar Altimeter	2	Radar Altimeter	2
Radar Warning Indicator	2	Radar Warning Indicator	1	Radar Warning Indicator	5
Route Data	5	Route Data		Route Data	
Threat Updates (UAS)	3	Threat Updates (UAS)	3	Threat Updates	
TQ		TQ		TQ (4)	4

1. Phase 1

Phase 1 of the mission scenario is air movement to the RP with no malfunctions or emergencies, and pilots were asked what information they needed to accomplish their mission safely. After we organized the data into a useful Microsoft Excel spreadsheet, we examined if pilots listed different information as very important, important, or somewhat important by phase. Table 5 shows information ranked as most important in descending order of frequency. Cherry/Ice Call was listed as very important 170 times, the most of all information. Radar Warning Indicator was second, Threat Updates (UAS) was third, Radar Altimeter was fourth, and Route Data was fifth.

Table 5. Phase 1 Information Ranked as Very Important Ordered from Most Frequent to Least Frequent

	Somewhat Important	Important	Very Important
Cherry/Ice Call	42	77	170
Radar Warning Indicator	37	88	164
Threat Updates (UAS)	27	102	160
Radar Altimeter	36	102	151
Route Data (TDH, Checkpoints)	30	113	146
GPS	32	113	144
Airspeed Indicator	36	113	140
Fuel Quantity	55	97	137
LZ Diagram (headings, go-arounds, grids, hazards)	39	114	136
Mission Time Line	48	111	130
Master Warning Panel	66	97	126
Friendly Unit Locations (B Co, C Co, UAS)	37	131	121
TQ	55	116	118
Clock	56	117	116
Horizontal Situation Indicator	87	87	115
NR	92	87	110
Abort Criteria	94	103	92
Vertical Situation Indicator	110	93	86
Caution/Advisory Panel	109	108	72
Commo Card	85	134	70
ExCheck	97	127	65
Minimum Force	148	81	60
Status Updates from Serial	78	160	51
TGT	157	89	43
PPC Data	138	110	41
Barometric Altimeter	164	84	41
Stabilator Indicator	193	70	26
NG	202	63	24
UAS Video Feed	195	73	21
XMSN Temp and Pressure	204	65	20
Eng Oil Temp and Pressure	206	63	20

When the information is reorganized based on what pilots ranked as either Important or Very Important, the information changes as shown in Table 6. Threat Updates

(UAS) is ranked as either Important or Very Important 262 times, followed by Route Data second, GPS third, Radar Altimeter fourth, and Airspeed Indicator fifth. In focus groups, pilots explained they need both mission data and aircraft data to enable shared understanding and rapid decision-making. Threat Updates from UAS, Radar Altimeter, and GPS are all in the top five most important pieces of information using either method to sort the data. Focus group participants listed radar altimeter, threat updates, route data, and the clock as some of the most important information during Phase 1. When asked why they want this information, pilots explained that during this phase, pilots are constantly making decisions about how to continue the mission and achieve the ground force commander's intent. They need to know where to fly, how long it will take to get there, and how much power and fuel are required to get there.

Table 6. Phase 1 Information Ranked Either Important or Very Important Ordered from Most Frequent to Least Frequent

	Somewhat Important	Important	Very Important	Important/ Very Important
Threat Updates (UAS)	27	102	160	262
Route Data (TDH, Checkpoints)	30	113	146	259
GPS	32	113	144	257
Radar Altimeter	36	102	151	253
Airspeed Indicator	36	113	140	253
Radar Warning Indicator	37	88	164	252
Friendly Unit Locations (B Co, C Co, UAS)	37	131	121	252
LZ Diagram (headings, go-arounds, grids, hazards)	39	114	136	250
Cherry/Ice Call	42	77	170	247
Mission Time Line	48	111	130	241
Fuel Quantity	55	97	137	234
TQ	55	116	118	234
Clock	56	117	116	233
Master Warning Panel	66	97	126	223
Status Updates from Serial	78	160	51	211
Commo Card	85	134	70	204
Horizontal Situation Indicator	87	87	115	202
NR	92	87	110	197
Abort Criteria	94	103	92	195
ExCheck	97	127	65	192
Caution/Advisory Panel	109	108	72	180
Vertical Situation Indicator	110	93	86	179
PPC Data	138	110	41	151
Minimum Force	148	81	60	141

	Somewhat Important	Important	Very Important	Important/ Very Important
TGT	157	89	43	132
Barometric Altimeter	164	84	41	125
Stabilator Indicator	193	70	26	96
UAS Video Feed	195	73	21	94
NG	202	63	24	87
XMSN Temp and Pressure	204	65	20	85
Eng Oil Temp and Pressure	206	63	20	83

2. Phase 2

Information required during Phase 2, react to contact, is like Phase 1, but now the Horizontal Situation Indicator is one of the top five pieces of information pilots need. Table 7 shows what information pilots listed as Very Important most frequently, with Radar Warning Indicator being the most frequent.

Table 7. Phase 2 Information Ranked as Very Important Ordered from Most Frequent to Least Frequent

	Somewhat Important	Important	Very Important
Radar Warning Indicator	8	10	211
Radar Altimeter	30	41	158
Threat Updates (UAS)	30	65	134
Airspeed Indicator	40	77	112
Horizontal Situation Indicator	82	50	97
TQ	60	76	93
Vertical Situation Indicator	89	55	85
Friendly Unit Locations (B Co, C Co, UAS)	40	105	84
NR	94	52	83
GPS	58	97	74
Master Warning Panel	82	81	66
Status Updates from Serial	82	81	66
Fuel Quantity	89	83	57
Abort Criteria	101	82	46
Route Data (TDH, Checkpoints)	78	109	42
Caution/Advisory Panel	97	90	42
Cherry/Ice Call	128	65	36
TGT	127	76	26
PPC Data	146	60	23

	Somewhat Important	Important	Very Important
Barometric Altimeter	149	57	23
Mission Time Line	142	67	20
LZ Diagram (headings, go-arounds, grids, hazards)	148	63	18
Clock	158	55	16
Minimum Force	163	51	15
Commo Card	146	72	11
UAS Video Feed	165	54	10
ExCheck	168	51	10
NG	175	45	9
XMSN Temp and Pressure	190	32	7
Eng Oil Temp and Pressure	192	30	7
Stabilator Indicator	181	44	4

When the information is arranged based on how often pilots ranked them as either Important or Very Important, the top five most important pieces of information change only slightly, with Friendly Unit Locations now the fifth most important piece of information instead of the Horizontal Situation Indicator. The complete list of Phase 2 data ranked as Important and Very Important is shown in Table 8.

Table 8. Phase 2 Information Ranked Either Important or Very Important Ordered from Most Frequent to Least Frequent

	Somewhat Important	Important	Very Important	Important/ Very Important
Radar Warning Indicator	8	10	211	221
Radar Altimeter	30	41	158	199
Threat Updates (UAS)	30	65	134	199
Airspeed Indicator	40	77	112	189
Friendly Unit Locations (B Co, C Co, UAS)	40	105	84	189
GPS	58	97	74	171
TQ	60	76	93	169
Route Data (TDH, Checkpoints)	78	109	42	151
Horizontal Situation Indicator	82	50	97	147
Master Warning Panel	82	81	66	147
Status Updates from Serial	82	81	66	147
Vertical Situation Indicator	89	55	85	140

	Somewhat Important	Important	Very Important	Important/ Very Important
Fuel Quantity	89	83	57	140
NR	94	52	83	135
Caution/Advisory Panel	97	90	42	132
Abort Criteria	101	82	46	128
TGT	127	76	26	102
Cherry/Ice Call	128	65	36	101
Mission Time Line	142	67	20	87
PPC Data	146	60	23	83
Commo Card	146	72	11	83
LZ Diagram (headings, go-arounds, grids, hazards)	148	63	18	81
Barometric Altimeter	149	57	23	80
Clock	158	55	16	71
Minimum Force	163	51	15	66
UAS Video Feed	165	54	10	64
ExCheck	168	51	10	61
NG	175	45	9	54
Stabilator Indicator	181	44	4	48
XMSN Temp and Pressure	190	32	7	39
Eng Oil Temp and Pressure	192	30	7	37

Focus group discussions further validated these findings and add context to why pilots need this information. During the focus groups, pilots stated they need Radar Warning Indicator, Radar Altimeter, and attitude readings from the Horizontal Situation Indicator to safely operate the aircraft and not induce another emergency. Pilots discussed their concerns about flying into terrain or flying into other aircraft while executing classified maneuvers to break radar contact. These maneuvers must be executed within seconds of receiving radar indications, and the pilot must determine what heading and altitude to fly based on the threat location and surrounding terrain. The rapid fusion of data to make the correct decision in such a high-stress environment can quickly lead to cognitive overload. Information that helps ensure the safe operation of the aircraft must be displayed to ensure pilots are aware of their altitude, attitude, and location in relation to terrain and other aircraft.

3. Phase 3

Survey responses for Phase 3, RP inbound, show pilots need different information than Phase 1 or 2. Landing Zone Diagram was ranked very important more than any other piece of information, followed by the Radar Altimeter, Airspeed Indicator, TQ, and Radar Warning Indicator. The complete list of Phase 3 information ranked according to how often they were rated Very Important is shown in Table 9.

Table 9. Phase 3 Information Ranked as Very Important Ordered from Most Frequent to Least Frequent

	Somewhat Important	Important	Very Important
LZ Diagram (headings, go-arounds, grids, hazards)	16	44	150
Radar Altimeter	22	59	129
Airspeed Indicator	14	68	128
TQ	35	76	99
Radar Warning Indicator	31	87	92
GPS	46	74	90
Horizontal Situation Indicator	60	64	86
Vertical Situation Indicator	65	61	84
NR	67	65	78
Clock	60	77	73
Cherry/Ice Call	90	52	68
Threat Updates (UAS)	47	100	63
Route Data (TDH, Checkpoints)	62	88	60
Master Warning Panel	64	88	58
Abort Criteria	85	67	58
PPC Data	59	97	54
Friendly Unit Locations (B Co, C Co, UAS)	50	109	51
Mission Time Line	69	100	41
Fuel Quantity	106	64	40
Status Updates from Serial	65	114	31
Minimum Force	114	67	29
ExCheck	82	100	28
Caution/Advisory Panel	93	94	23
TGT	130	60	20
Commo Card	112	78	20
Barometric Altimeter	119	72	19

	Somewhat Important	Important	Very Important
UAS Video Feed	129	64	17
NG	160	40	10
Stabilator Indicator	143	57	10
Eng Oil Temp and Pressure	182	24	4
XMSN Temp and Pressure	183	24	3

When information is ranked according to what pilots said is either Important or Very Important, the ranking changes. Airspeed Indicator was ranked as Important or Very Important, the most frequent, followed by LZ Diagram, Radar Altimeter, Radar Warning Indicator, and TQ. Table 10 shows all the information ranked by what pilots rated as Important or Very Important.

Table 10. Phase 3 Information Ranked Either Important or Very Important Ordered Most Frequent to Least Frequent

	Somewhat Important	Important	Very Important	Important/ Very Important
Airspeed Indicator	14	68	128	196
LZ Diagram (headings, go-arounds, grids, hazards)	16	44	150	194
Radar Altimeter	22	59	129	188
Radar Warning Indicator	31	87	92	179
TQ	35	76	99	175
GPS	46	74	90	164
Threat Updates (UAS)	47	100	63	163
Friendly Unit Locations (B Co, C Co, UAS)	50	109	51	160
PPC Data	59	97	54	151
Horizontal Situation Indicator	60	64	86	150
Clock	60	77	73	150
Route Data (TDH, Checkpoints)	62	88	60	148
Master Warning Panel	64	88	58	146
Vertical Situation Indicator	65	61	84	145
Status Updates from Serial	65	114	31	145
NR	67	65	78	143
Mission Time Line	69	100	41	141
ExCheck	82	100	28	128
Abort Criteria	85	67	58	125

	Somewhat Important	Important	Very Important	Important/ Very Important
Cherry/Ice Call	90	52	68	120
Caution/Advisory Panel	93	94	23	117
Fuel Quantity	106	64	40	104
Commo Card	112	78	20	98
Minimum Force	114	67	29	96
Barometric Altimeter	119	72	19	91
UAS Video Feed	129	64	17	81
TGT	130	60	20	80
Stabilator Indicator	143	57	10	67
NG	160	40	10	50
Eng Oil Temp and Pressure	182	24	4	28
XMSN Temp and Pressure	183	24	3	27

These findings were supported, and further explained in focus group discussions about Phase 3, RP to LZ. Pilots in both focus groups discussed how difficult it is to identify the LZ when flying at high airspeeds and low altitudes, which is why the LZ diagram is so essential. The LZ diagram allows pilots to see a two-dimensional representation of the LZ. Still, the pilot must mentally picture the LZ's appearance based on their inbound heading and altitude. This two-dimensional depiction also displays structural hazards and assessed enemy locations. This LZ diagram is a paper printout that pilots must reference by shifting their attention from outside the aircraft to their kneeboard packet. At night and with high airspeeds, this task requires a high cognitive workload and is done numerous times during this phase.

TQ is another piece of raw data that pilots need to land at an LZ and execute the mission safely. Pilots must shift their attention from looking outside the aircraft to the Flight Management System in the center console to reference the projected TQ required to land at the LZ. Pilots need to know several types of TQ, including single engine max TQ, dual engine max TQ, TQ required to land with passengers, and TQ required to take off with or without passengers. Calculating all these different TQ requirements requires time and cognitive work in addition to shifting attention from outside the aircraft to the center console.

D. INFORMATION PRIORITIZATION BY PHASE

In this section, we discuss how pilots prioritized information by phase and answer the second research question: What specific information do pilots need during each phase?

1. Phase 1

After classifying each piece of information as Somewhat Important, Important, or Very Important, participants were asked to rank their Very Important information by priority. Table 11 shows what information pilots ranked number one most frequently. NR is the most frequent number one, followed by GPS, Threat Update (UAS), Cherry/Ice Call, and Radar Warning Indicator.

Table 11. Phase 1 Information Selected as the Number 1 Priority Ordered Most Frequent to Least Frequent

Information	Number of times listed Very Important	Prioritization				
		1	2	3	4	5
NR	110	29	5	5	4	8
GPS	144	20	7	14	3	10
Threat Updates (UAS)	160	19	20	12	14	8
Cherry/Ice Call	170	18	14	16	12	18
Radar Warning Indicator	164	17	13	14	21	7
Master Warning Panel	126	16	12	9	9	8
Mission Time Line	130	14	9	13	11	9
Vertical Situation Indicator	86	13	9	5	10	7
Horizontal Situation Indicator	115	13	19	14	11	7
Route Data (TDH, Checkpoints)	146	13	21	13	11	16
LZ Diagram (headings, go-arounds, grids, hazards)	136	11	7	7	12	14
TQ	118	8	10	13	6	6
Radar Altimeter	151	8	10	16	14	10
Airspeed Indicator	140	7	17	13	22	9
Clock	116	6	9	14	8	11
Fuel Quantity	137	5	12	9	6	9
Friendly Unit Locations (B Co, C Co, UAS)	121	5	9	7	12	13
Abort Criteria	92	5	7	10	3	8
Minimum Force	60	5	3	2	6	4
PPC Data	41	2	1	1	4	1
ExCheck	65	2	3	2	4	2

Information	Number of times listed Very Important	Prioritization				
		1	2	3	4	5
Status Updates from Serial	51	2	1	4	4	2
Eng Oil Temp and Pressure	20	1	0	0	1	1
TGT	43	1	3	3	4	3
Caution/Advisory Panel	72	1	6	6	2	4
XMSN Temp and Pressure	20	0	1	1	0	0
NG	24	0	1	1	2	2
Barometric Altimeter	41	0	0	1	3	8
Stabilator Indicator	26	0	1	1	3	1
Commo Card	70	0	6	5	5	4
UAS Video Feed	21	0	1	0	3	1

This ranking suggests that pilots who want to see their NR wish to see it more than any other piece of information. NR was ranked Very Important by only 110 pilots, but of the 110 pilots, 29 believed it to be the highest priority piece of information. This was explained during focus group conversations when less experienced pilots said they wanted to see NR while more experienced pilots said they did not want to see NR. This difference of opinion between experienced and less experienced pilots is discussed further in Section D of this chapter.

2. Phase 2

In Phase 2, react to contact, participants were again asked to prioritize the information they rated as Very Important. Table 12 shows how frequently pilots prioritized each piece of information as the highest priority. In Phase 2, pilots overwhelmingly ranked Radar Warning Indicator as the highest priority information, followed by NR, Vertical Situation Indicator, Threat Update (UAS), and Radar Altimeter. These results were verified and explained by focus group participants who discussed the importance of knowing the location of the threat and not inducing another emergency while executing evasive maneuvers. Radar Warning Indicator and Threat Update from the UAS provide location and information about the threat, while NR, Vertical Situation Indicator, and Radar Altimeter provide the necessary information to execute aggressive maneuvers safely. GPS is the next highest priority piece of information pilots want and focus group participants discussed the need for route information to continue the mission. Pilots must quickly decide if they will continue the mission along a new route avoiding the threat or if they will abort the mission and return to base.

Table 12. Phase 2 Information Selected as the Number 1 Priority Ordered Most Frequent to Least Frequent

Information	Number of times listed as Very Important	Prioritization				
		1	2	3	4	5
Radar Warning Indicator	211	144	17	6	13	14
NR	83	15	7	14	5	11
Vertical Situation Indicator	85	13	10	16	9	7
Threat Updates (UAS)	134	10	34	17	9	17
Radar Altimeter	158	7	49	27	25	18
GPS	74	7	3	10	10	11
Horizontal Situation Indicator	97	6	24	21	16	7
Master Warning Panel	66	5	6	6	4	5
TQ	93	4	18	18	13	15
Route Data (TDH, Checkpoints)	42	3	3	5	4	5
Friendly Unit Locations (B Co, C Co, UAS)	84	2	9	13	13	10
Fuel Quantity	57	2	5	5	6	5
Mission Time Line	20	2	0	2	3	0
Airspeed Indicator	112	1	12	23	28	17
Status Updates from Serial	66	1	2	9	12	12
Caution/Advisory Panel	42	1	1	4	3	0
XMSN Temp and Pressure	7	1	0	0	2	1
Commo Card	11	1	0	0	2	1
Abort Criteria	46	0	6	3	4	4
Cherry/Ice Call	36	0	6	4	3	3
LZ Diagram (headings, go-arounds, grids, hazards)	18	0	0	3	3	2
TGT	26	0	0	2	2	2
Barometric Altimeter	23	0	1	1	2	4
Clock	16	0	2	0	2	4
Eng Oil Temp and Pressure	7	0	0	0	2	1
ExCheck	10	0	0	0	2	2
PPC Data	23	0	4	1	1	1
UAS Video Feed	10	0	2	1	1	1
NG	9	0	0	0	1	1
Stabilator Indicator	4	0	0	0	1	0
Minimum Force	15	0	0	3	0	2

3. Phase 3

In Phase 3, RP to the LZ, pilots were again asked to prioritize the information they ranked as Very Important. LZ Diagram is the highest priority, followed by NR, GPS, Cherry/Ice Call, and TQ. The complete priority list for Phase 3 is displayed in Table 13 below. These findings were explained by focus group participants discussing the technical difficulties of landing at an LZ. Pilots said they need the LZ diagram to find the LZ, where they are landing and possible hazards, and the location of assessed threats. Along with GPS, the LZ diagram ensures pilots can complete the mission and safely land at the correct location. The Cherry/Ice Call ensures that the LZ is clear of any immediate enemy threats and that the mission can continue. NR and TQ are technical flying information required to operate and land the aircraft safely.

Table 13. Phase 3 Information Selected as the Number 1 Priority Ordered Most Frequent to Least Frequent

Information	Number of times listed as Very Important	Prioritization				
		1	2	3	4	5
LZ Diagram (headings, go-arounds, grids, hazards)	150	50	23	14	15	5
NR	78	18	10	13	9	6
GPS	90	18	10	11	7	5
Cherry/Ice Call	68	18	7	5	1	6
TQ	99	11	20	19	15	9
Vertical Situation Indicator	84	9	9	8	11	15
Airspeed Indicator	128	9	23	26	13	10
Clock	73	9	6	2	7	13
Fuel Quantity	40	8	2	4	10	3
Master Warning Panel	58	8	2	6	5	6
Horizontal Situation Indicator	86	8	17	3	9	11
Radar Warning Indicator	92	8	13	8	5	9
PPC Data	54	7	8	7	7	1
Radar Altimeter	129	7	15	30	23	13
Threat Updates (UAS)	63	5	6	5	8	4
Route Data (TDH, Checkpoints)	60	3	4	7	6	8
Abort Criteria	58	3	3	7	3	4
TGT	20	2	1	1	3	5
Mission Time Line	41	2	4	4	6	9
Friendly Unit Locations (B Co, C Co, UAS)	51	2	8	2	4	5

Information	Number of times listed as Very Important	Prioritization				
		1	2	3	4	5
Status Updates from Serial	31	2	1	1	1	3
Commo Card	20	1	1	2	2	2
UAS Video Feed	17	1	1	1	0	1
XMSN Temp and Pressure	3	0	0	0	0	0
Eng Oil Temp and Pressure	4	0	1	0	0	0
NG	10	0	1	1	2	0
Caution/Advisory Panel	23	0	2	2	3	2
Barometric Altimeter	19	0	1	0	2	6
Stabilator Indicator	10	0	0	0	1	1
ExCheck	28	0	4	1	2	4
Minimum Force	29	0	2	3	4	3

E. PREFERRED INFORMATION MODALITY

In this section, we answer our third research question: How do pilots want to receive information, i.e., through visual, audio, or tactile means? Figure 5 illustrates that there is minimal variation in the preferred modality between phases. Due to this limited variation, we examine each modality according to the piece of information independent of the phase of flight.

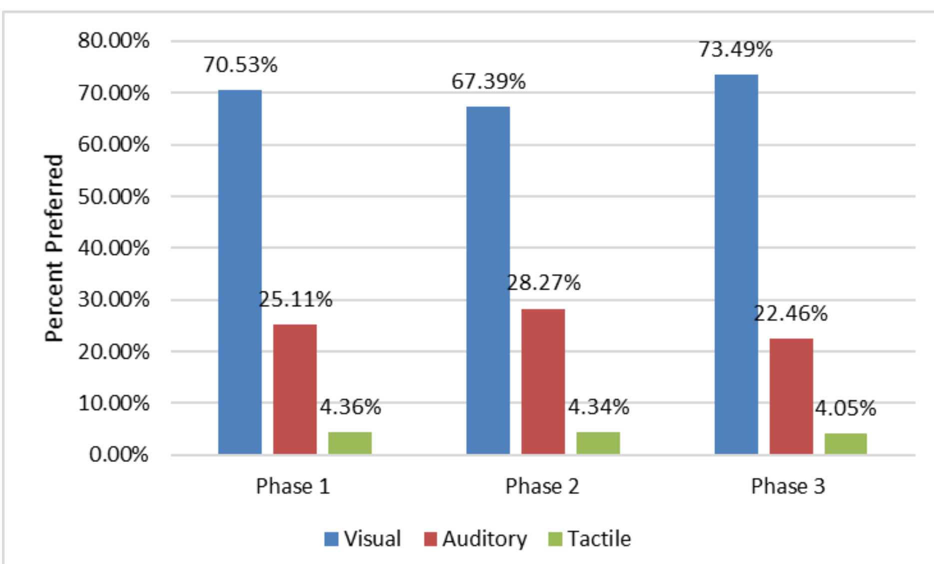

Figure 5. Preferred modality by phase

1. Visual

Overall, results show that 70.5% of pilots chose visual as the preferred modality to receive information across all phases of the mission. Figure 6 shows how often pilots chose each modality across all mission phases. These findings are consistent with responses from focus group participants who stated they wanted almost all information visually. Pilots can choose what they are visually looking at and, therefore, what information they are processing and using to make decisions.

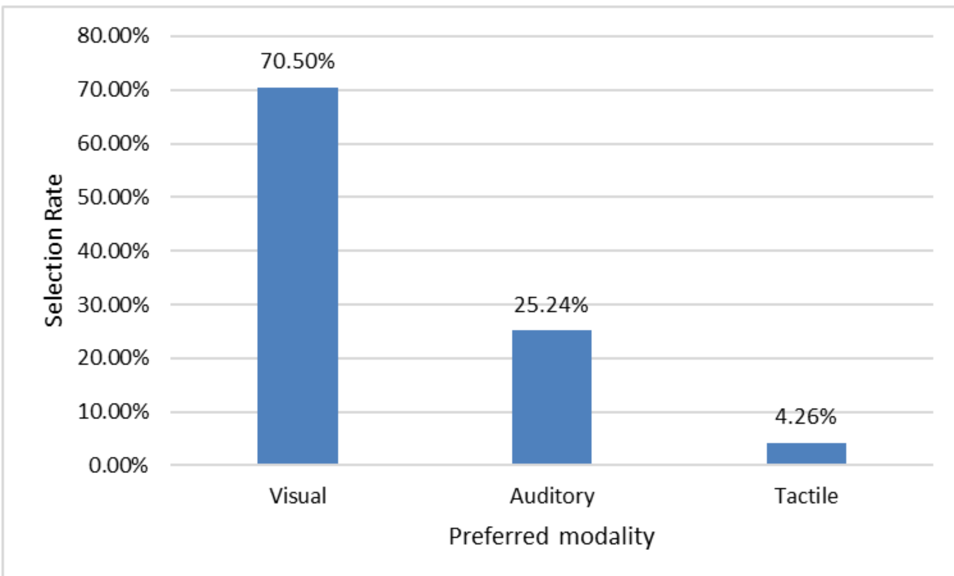

Figure 6. Preferred modality across all mission phases

2. Auditory

Pilots preferred the auditory modality for only four pieces of information: Cherry/Ice Call, Radar Warning Indicator, Threat Update (UAS), and Status Updates from Serial. Figures 7 through 10 show how pilots selected auditory for these four pieces of information across all mission phases. When asked about receiving information audibly, focus group participants said they only wanted specific pieces of information and didn't want any information from an automated, computerized voice.

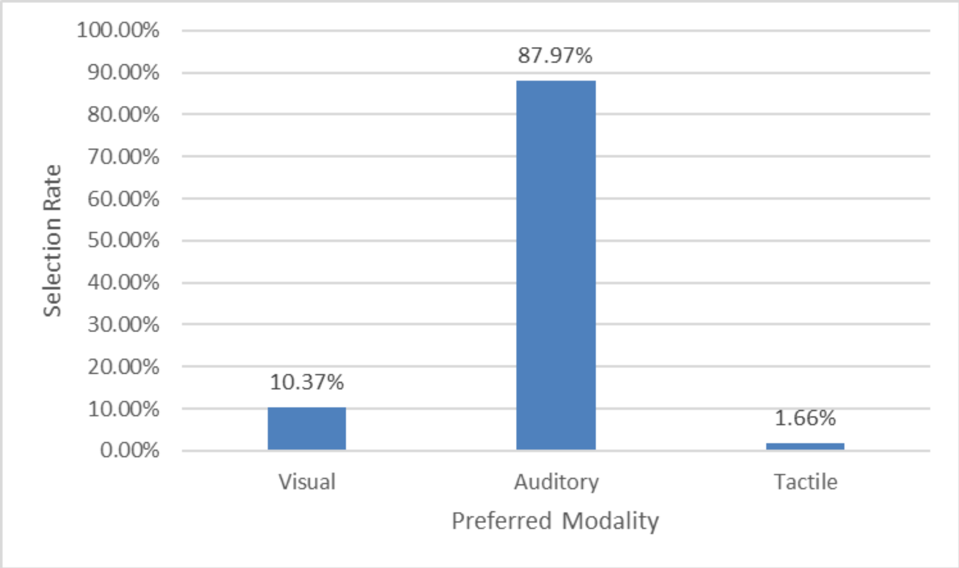

Figure 7. Preferred modality for Cherry/Ice Call

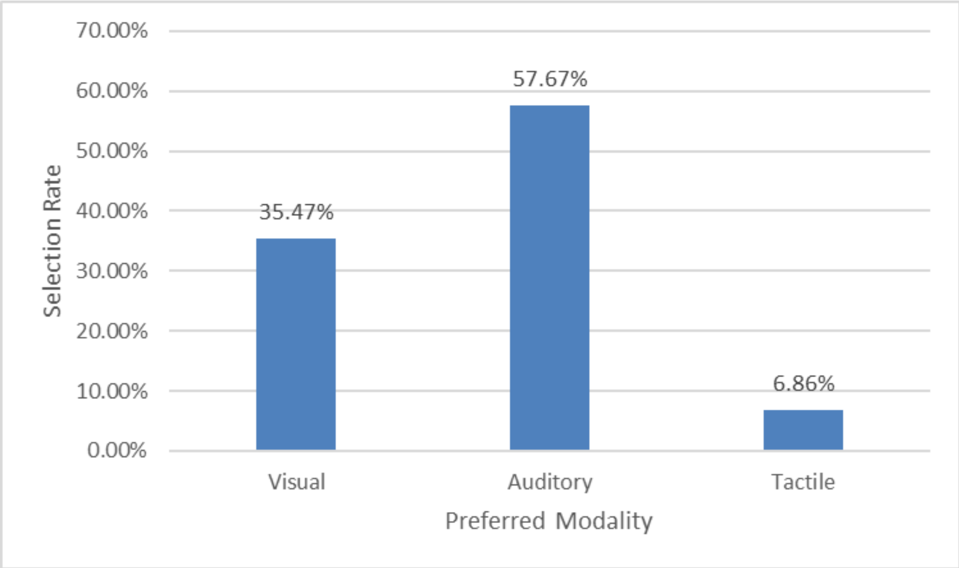

Figure 8. Preferred modality for Radar Warning Indicator

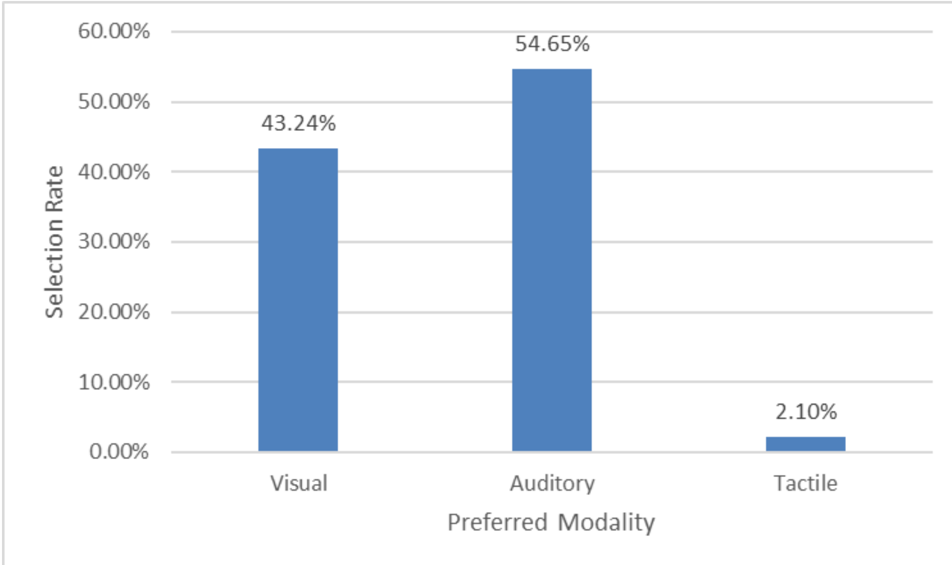

Figure 9. Preferred modality for Threat Update (UAS)

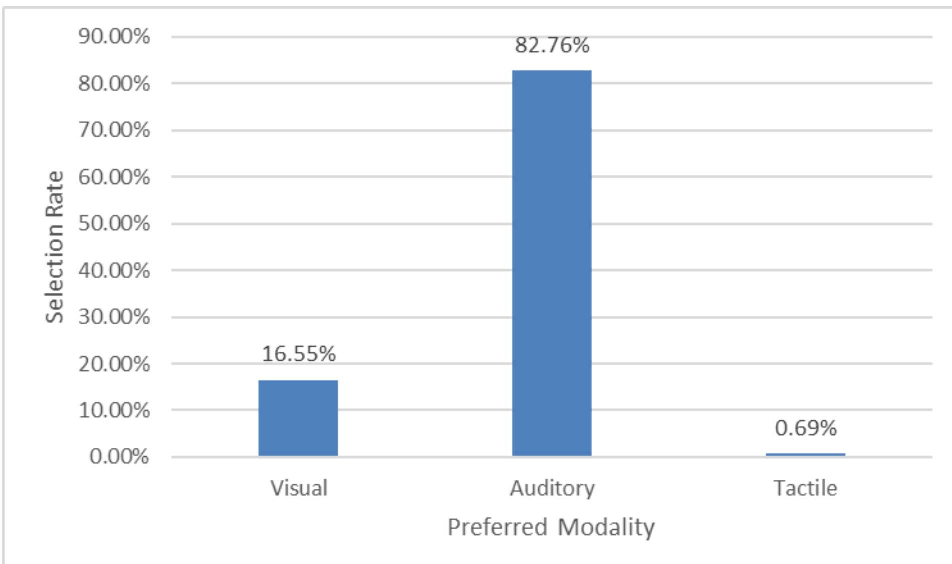

Figure 10. Preferred modality for Status Update from Serial

Tactile was not the preferred modality for any piece of information during any phase of the mission. Focus group participants talked about the difficulty in feeling a tactile alert in the aircraft with associated vibrations and movements. One pilot believed it would be helpful for the collective to vibrate when the aircraft is approaching engine temperature or torque limits. Receiving this tactile alert through the collective would allow pilots to decide how to proceed without bringing their eyes inside the aircraft.

F. ADDITIONAL FINDINGS

In this section, we discuss three outcomes not related to our research questions that we did not expect to discover. These findings were found from survey responses and focus group discussions, but the focus groups contextualized why pilots need different information.

1. Difference between Commissioned and Warrant Officers

Commissioned and warrant officers have different roles in Army aviation, and this may cause them to need different information while flying. Warrant officers are subject matter experts and spend their careers becoming tactical and technical professionals. Commissioned officers focus on leading organizations while planning and executing operations. As warrant officers gain experience, they choose a specialty to track: Instructor Pilot, Maintenance Test Pilot, Safety Officer, or Aviation Mission Survivability Officer. Each of these positions plays a key role in supporting the unit commander's accomplishment of the mission. Conversely, as commissioned officers gain experience, they are given leadership positions of increased responsibility eventually becoming commanders. Commissioned officers are responsible for leading organizations and ensuring the ground force commander is successful.

Survey data suggest that commissioned and warrant officers prioritize information differently. During Phase 1, 45.6% of warrant officers rated NR as Very Important, whereas only 25.23% of commissioned officers rated it as Very Important. As Figure 11 shows, this is a 20.37% difference between commissioned and warrant officers and an unexpected outcome. Focus group participants were all warrant officers, but they provided insight into a possible explanation of this difference. Focus group participants talked about how young and inexperienced pilots are focused on aircraft data to fly the aircraft safely. Just flying the aircraft can overwhelm young pilots who need aircraft health data to operate the helicopter safely. Senior, more experienced pilots have much more flight experience and are therefore given increased responsibility to ensure successful mission execution. Pilots with increased responsibility want mission data instead of aircraft health data to enable rapid decision-making related to mission accomplishment. This is validated when looking at ExCheck and Abort Criteria data for Phase 1, shown in Figures 12 and 13.

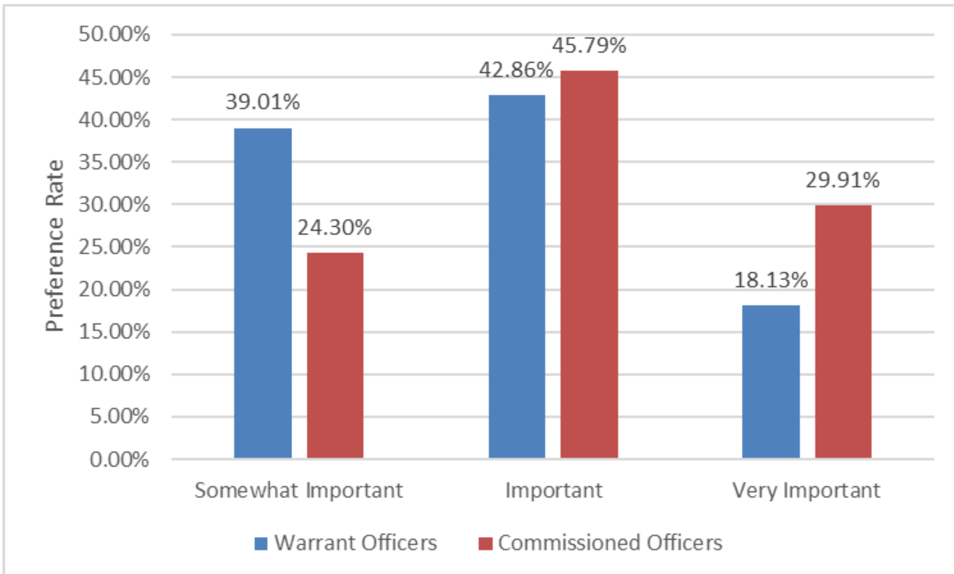

Figure 11. Phase 1 percentage of commissioned and warrant officers rating NR as Very Important

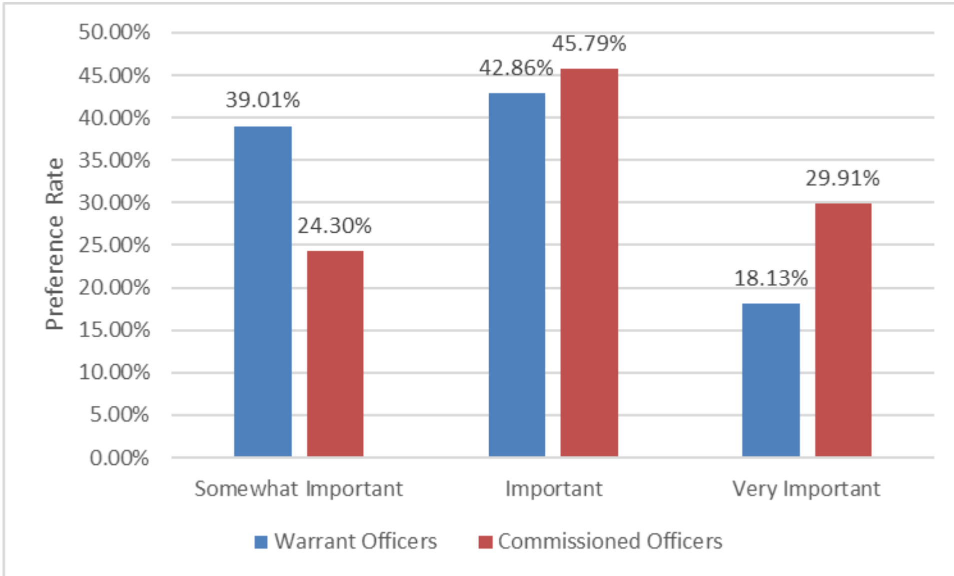

Figure 12. Phase 1 percentage of commissioned and warrant officers rating ExCheck as Very Important

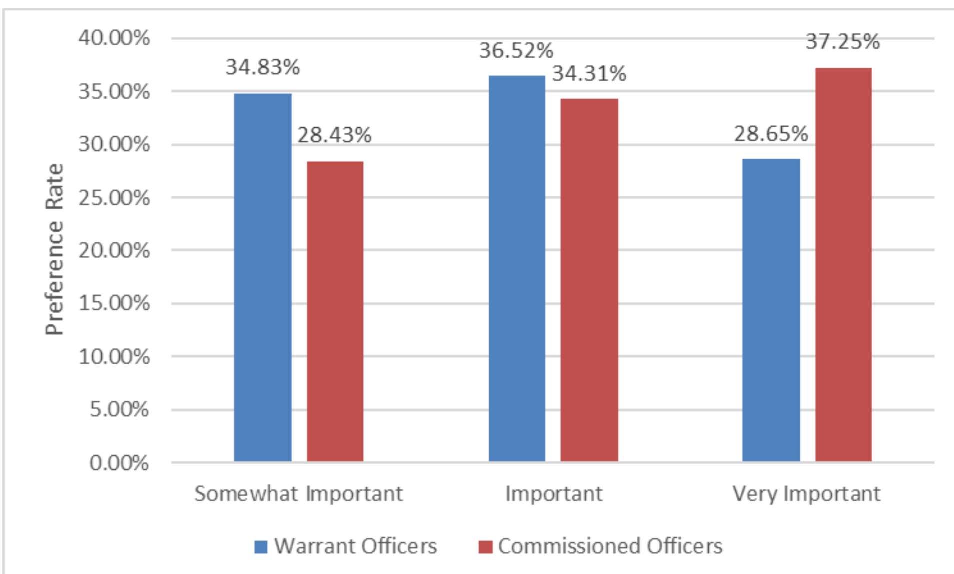

Figure 13. Phase 1 percentage of commissioned and warrant officers rating Abort Criteria as Very Important

During Phase 1, 29.91% of commissioned officers rated the ExCheck as Very Important compared to 18.13% of warrant officers. Abort criteria shows a similar pattern, with 37.25% of commissioned officers rating it as Very Important and only 28.65% of warrant officers. When asked about the ExCheck and Abort Criteria, focus group participants discussed how pilots with a low level of responsibility would often remove these items from their mission packet and never look at them. Low-responsibility pilots are focused on flying the aircraft and do not want additional information, leaving the decision-making to pilots assigned as air mission commanders or flight leads. This trend is also evident in Phases 2 and 3 of the mission (see Figures 14 through 17). During Phase 2, 47.18% of warrant officers rated NR as Very Important, whereas only 23.94% rated Status Update from Serial as Very Important. Conversely, only 18.82% of commissioned officers rated NR Very as Important, whereas 41.18% rated Status Update from Serial as Very Important.

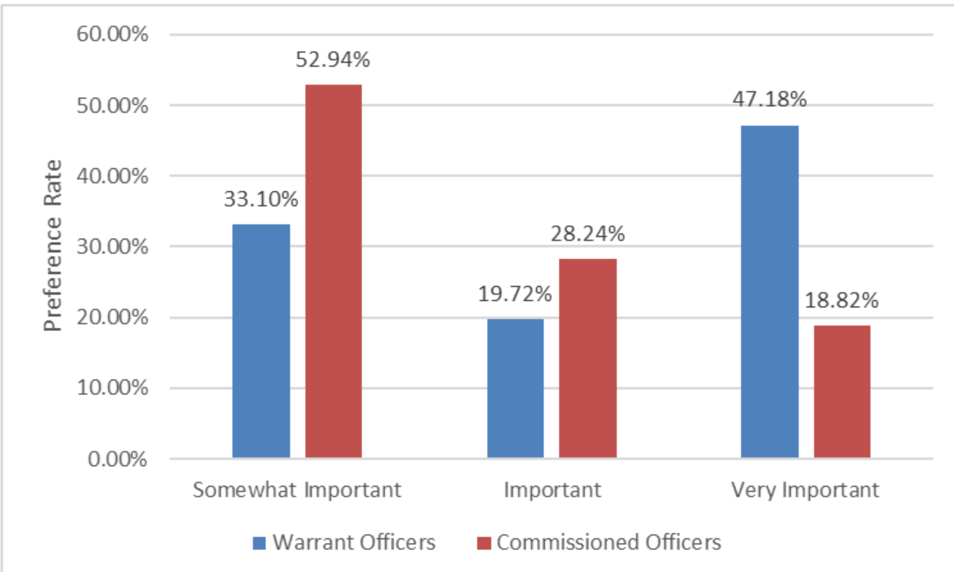

Figure 14. Phase 2 percentage of commissioned and warrant officers rating NR as Very Important

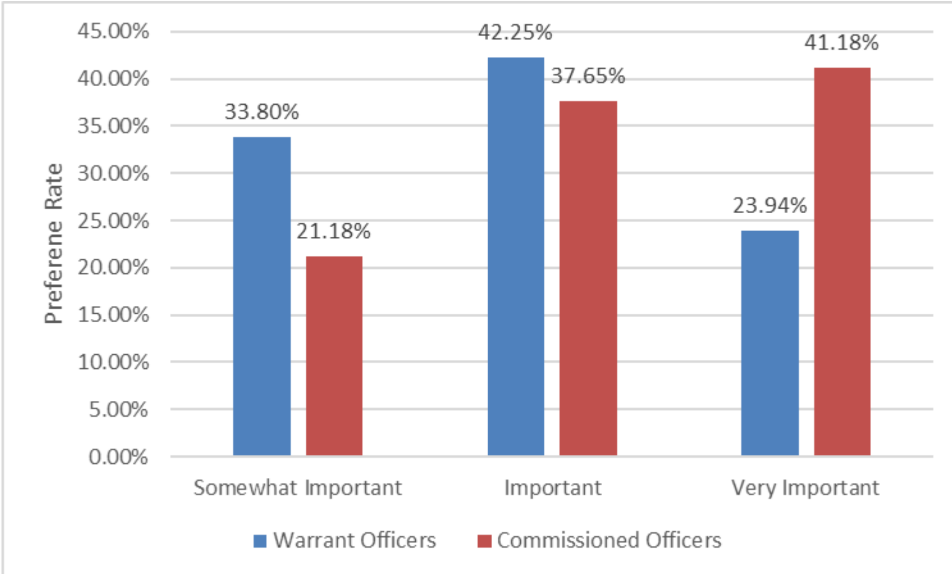

Figure 15. Phase 2 percentage of commissioned and warrant officers rating Status Updates from Serial as Very Important

Phase 3 showed a similar difference between commissioned and warrant officers: 40.15% of warrant officers rated NR Very Important versus only 32.05% of commissioned officers (Figure 16). Also, 20.51% of commissioned officers rated ExCheck Very Important, whereas only 9.09% of warrant officers rated it to be Very Important (Figure 17).

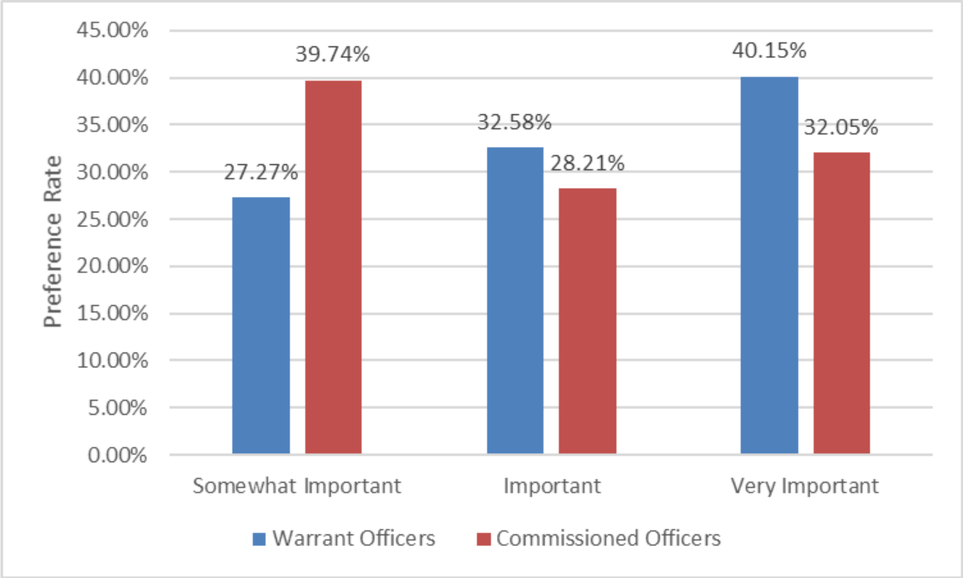

Figure 16. Phase 3 percentage of commissioned and warrant officers rating NR as Very Important

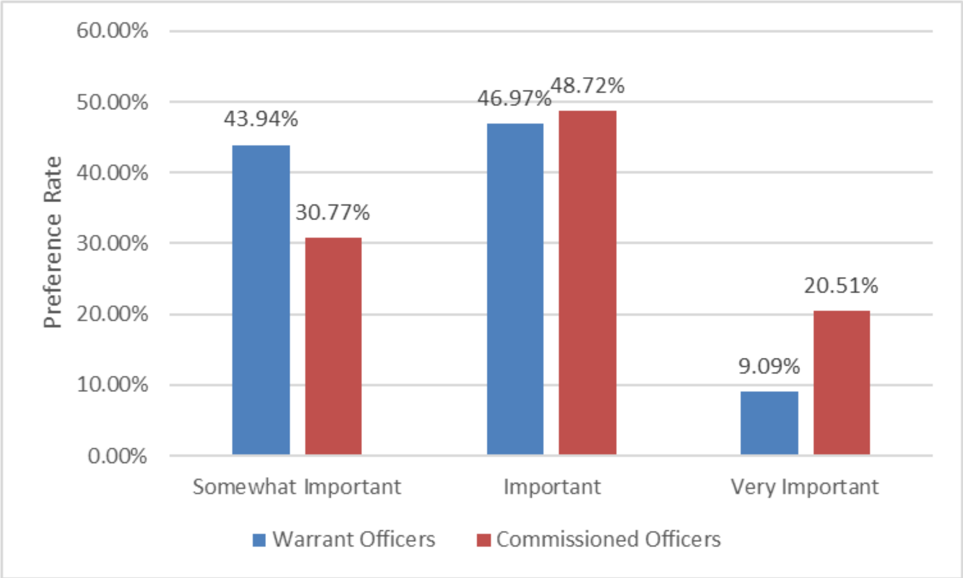

Figure 17. Phase 3 percentage of commissioned and warrant officers rating ExCheck as Very Important

2. Heads Up Display

Survey results show that pilots want to receive information visually and focus group participants confirmed these results. When asked what the ideal method to receive information is, pilots discussed wanting the ability to keep their eyes outside the aircraft. Currently, pilots must bring their eyes inside to see and process information. Pilots do not want to remove their eyes from the surroundings to check their route, the location of the LZ, or any information about their surroundings. Pilots also discussed the difficulty of locating and seeing the landing zone when flying fast and low at night. Specifically, a heads-up display with augmented reality showing route information and the location of the LZ was desired. A heads-up display (HUD) showing the location of friendly forces and the assessed location of enemy forces would provide pilots with increased situational awareness. A heads-up display with augmented reality showing route, LZ, and friendly force data would allow pilots to keep their eyes focused outside, with no need to reference a map or LZ diagram during high-stress phases of flight such as RP to LZ.

V. CONCLUSION

Our research focused on potential methods to make Army rotary wing operations safer by reducing the cognitive workload of pilots. After completing a literature review, we decided to develop a survey to identify the information pilots need during different phases of flight and how they prefer to receive that information. We developed three research questions, and in this chapter, we discuss our findings and how they answer those questions. We also discuss recommendations for how to analyze the data further and to understand what information pilots need and the preferred way to present it to them.

A. PRIORITIZATION OF INFORMATION

As Table 14 shows, pilots need different information during different phases of flight. Based on the survey results, we answered our first research question and reject our null hypothesis stated in Chapter I. Focus group participants helped explain why pilots need different information during these mission phases. Pilots constantly make quick decisions relating to safely flying the aircraft and accomplishing the mission and need relevant information. In all phases, pilots wanted their Radar Warning Indicator to ensure they were not being tracked by enemy air defense. During phase 1, pilots are flying to the objective and need information about their current status (Route and Radar Altimeter) and future actions needed at the LZ (Cherry/Ice Call and Threat Update). During phase 2, pilots only wanted information about their current situation to make immediate decisions and take immediate action. Airspeed Indicator, Radar Altimeter, and Horizontal Situation Indicator are all needed to fly safely and not induce an emergency while executing aggressive flight maneuvers. Radar Warning Indicator and Threat Update (UAS) ensure the pilot understands how to break contact and avoid subsequent enemy contact. During phase 3, pilots need the information to land safely while ensuring they are not being tracked by the enemy. Airspeed indicator, Radar Altimeter, TQ, and LZ Diagram are all needed to ensure a safe landing, while Radar Warning Indicator ensures the enemy is not tracking their movement.

B. INFORMATION PRIORITIZATION BY PHASE

The information from the survey and the focus groups shows that pilots want and need different information during different phases of a tactical air movement. Table 14 shows the five highest-priority pieces of information by phase and how they differ. Each phase has different information ranked as the highest priority, and no two phases have the same five pieces of information in the top five. This variation further validates our conclusion that pilots need different information during different phases of flight.

Table 14. Information Rated High Priority to Lowest Priority by Phase

Phase 1: Movement		Phase 2: React to Contact		Phase 3: Release Point to Landing Zone	
Information	**Rank**	**Information**	**Rank**	**Information**	**Rank**
Cherry/Ice Call	4	Cherry/Ice Call		Cherry/Ice Call	4
GPS	2	GPS		GPS	3
LZ Diagram		LZ Diagram		LZ Diagram	1
NR	1	NR	2	NR	2
Radar Altimeter		Radar Altimeter	5	Radar Altimeter	
Radar Warning Indicator	5	Radar Warning Indicator	1	Radar Warning Indicator	
Threat Updates (UAS)	3	Threat Updates (UAS)	4	Threat Updates (UAS)	
TQ		TQ		TQ	5
Vertical Situation Indicator		Vertical Situation Indicator	3	Vertical Situation Indicator	

The complete prioritization list answers research question 2: What specific information do pilots need during these specific phases? The survey and focus group results show that pilots need a combination of mission data and flight data to accomplish their mission safely. The mission and flight data pilots require changes according to the phase of the mission and what decisions needed to be made. During phase 1, movement, pilots want information about future decisions at the LZ along with route data to navigate correctly. During phase 2, react to contact, decisions are immediate and focused on mitigating the threat and not inducing an emergency while executing aggressive flight maneuvers. During phase 3, the landing phase, information is required to land the aircraft while avoiding obstacles and assessing threats safely. Pilots make continuous decisions about accomplishing the mission and operating the aircraft and need specific information to facilitate correct and timely decision-making.

C. MODALITY

The survey and the focus group results confirmed that pilots prefer to receive information visually, with a select few alerts received audibly. Our results answer our third question and confirm our null hypothesis. Pilots do not want information in multiple modalities and generally prefer the visual modality. Pilots talked about how much noise and vibration they experience in current aircraft, making additional audio and tactile inputs challenging to perceive or interpret. Focus groups discussed how the ideal method is receiving information through a heads-up display with augmented reality. Anything that keeps their eyes up and their focus outside the aircraft makes the operation safer. The only alerts that pilots want to receive audibly are immediate action emergencies such as a fire or enemy radar contact.

1. Auditory Modality

Pilots explained they only want to have a few audible alerts because current alerts are used for emergencies that require immediate action. These alerts include Master Caution, Low Rotor RPM, Fire, and Stabilator Malfunction. All these alerts require immediate action and take precedence over other actions. Pilots discussed how too many audible alerts would constantly cause pilots to believe an immediate action emergency is in progress. They want as few audible alerts as possible and only those for emergencies that require immediate action.

Survey results showed that most pilots only want to receive four additional pieces of information audibly: Cherry/Ice Call, Radar Warning Indicator, Threat Update (UAS), and Status Updates from Serial. These four pieces of information are currently received audibly in the aircraft, and the results indicate that pilots do not want that to change. Cherry/Ice Calls, Threat Updates (UAS), and Status Update from Serial are all radio calls that are not provided by the aircraft but rather by other humans on the battlefield. The Radar Warning Indicator is provided by the aircraft in the form of a voice alerting the pilots to the threat. Pilots discussed how difficult it is to understand the voice that alerts them and that they must divert their attention and focus on trying to understand what the voice is saying. This difficulty appears to have created a bias against using the auditory modality. Pilots were very skeptical that they would understand or even hear additional voice updates from the aircraft. Several pilots even indicated they want to receive as little information as possible audibly, including Cherry/Ice Call, Threat Update (UAS), and Status Update from Serial. Rotor noise in flight is a significant issue and makes virtually all audible updates difficult to understand.

We believe pilots distrust audible updates because of current technological limitations and need help to imagine clear and easily understood audible updates. To make the audible modality effective, the problem of ambient noise must be solved. Helicopters are loud, with noise coming from the rotor, two engines, the outside environment, and many more internal systems. Pilots quickly become overloaded when they must focus on understanding the audible signals they are receiving. The audible information is highly perishable. Once the message is communicated it resides only in the memory of those who heard it, whereas visual information lingers on a display until that display is updated. Additional research needs to be conducted to determine if reducing ambient noise reduces cognitive workload and makes the auditory modality effective.

2. Tactile Modality

Tactile was not the preferred modality for any information in the survey and focus group participants verified these findings. Like the auditory modality, pilots discussed how difficult it is to feel anything over the vibrations of the aircraft. They did not believe they would feel any tactile alerts in the aircraft. This is a limitation of current technology, and if systemic vibrations felt by pilots could be reduced, the tactile modality may become feasible. Additional research is needed to determine if the tactile modality would be effective if aircraft vibrations were mitigated.

One pilot discussed wanting the collective to vibrate when approaching TQ or turbine gas temperature (TGT) limitations. As shown in Figure 18, the collective is at the left-hand side of the pilot and, when pulled up, increases the aircraft's power. Increasing power increases TQ and TGT. If TQ or TGT increases too much, it will cause permanent damage to the aircraft and could result in an emergency. The current TQ and TGT are shown on the pilot's MFD, and the pilots must bring their eyes inside the aircraft to see them. Because of helicopter aerodynamics, takeoff and landing are common times when TQ and TGT limits can be exceeded. As already discussed, takeoff and landing are high-stress phases of flight. This pilot suggested having the collective vibrate when TQ or TGT limits are exceeded, alerting the pilot that an adjustment must be made but not requiring their eyes to come inside the aircraft. We recommend further research to determine if this is a feasible solution.

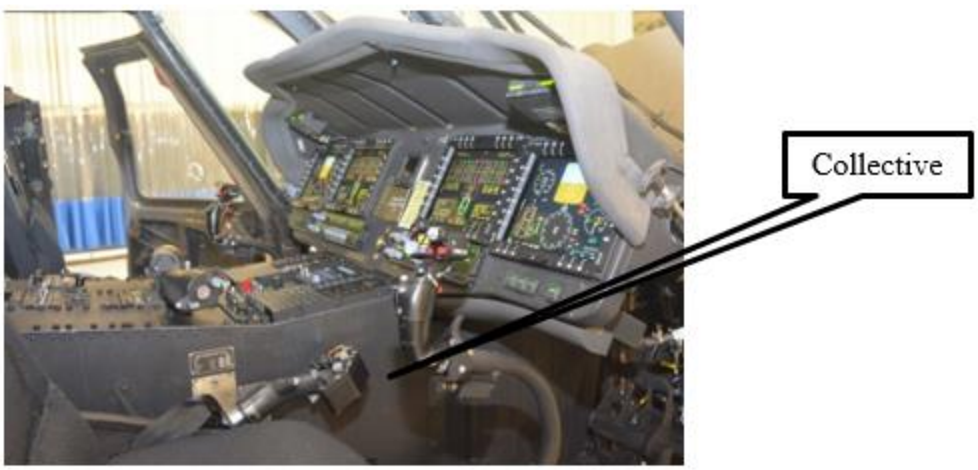

Figure 18. UH-60M collective. Adapted from Fort Indiantown Gap.

3. Heads-Up Display

We asked focus group participants about the optimal way to receive visual information and they discussed a heads-up display with augmented reality. A heads-up display showing the current route allows the pilot to keep their eyes outside the aircraft. Additional research must be conducted to determine what information should be shown on a heads-up display. Pilots discussed their desire for friendly unit positions and templated enemy locations to be shown. They discussed their desire for displaying information about other aircraft, such as altitude, distance, and airspeed. Following several minutes of discussion, they realized that the amount of information they wanted on the heads-up display would be too much and would negatively impact their ability to see the surrounding environment. Additional research must determine how much information rotary wing pilots need in a heads-up display and what information should be prioritized.

D. RECOMMENDATIONS

This research is meant to inform future work and help determine how prioritizing information can reduce the cognitive workload of pilots. We recommend additional experiments to verify the survey findings and focus groups by placing pilots in a simulator and providing them with only information needed during their phase of flight. This will show if the cognitive workload of pilots is reduced by limiting the information provided.

The amount of data collected from the survey was too much to be analyzed for this capstone report. The most interesting findings are not directly related to our research questions and may prove to be equally valuable. Our additional findings show that commissioned and warrant officers want different information. Focus group participants discussed how the information they need may change depending on their position and responsibilities within the flight, i.e., flight lead or AMC. The survey asks respondents if they are an AMC or not. Further analysis can be conducted to determine if AMCs want different information than other pilots within the flight.

Analyzing the data to determine what information pilots with different flight hours want should be conducted. This could inform future aircraft and mission planning systems to be designed for customizability. For example, if a low-flight-time pilot is flying, the aircraft may provide that pilot with more aircraft data and less mission data. Conversely, the aircraft may provide high flight time pilots with more mission data and less aircraft data. The data from this survey can serve as a foundation for future experiments and aircraft designs. The design of this survey is an example of how to collect data from the operational Army and determine what operational pilots want to accomplish their mission. Helping pilots make better, more accurate decisions will make Army aviation operations safer and more capable.

APPENDIX A. INFORMATION ITEM DEFINITIONS

Abort Criteria: Pre-planned conditions that, when met, result in aborting the mission

Airspeed Indicator: Displays aircraft's current airspeed.

Barometric Altimeter: Displays aircraft's current altitude above Mean Sea Level

Caution/Advisory Panel: displays all active cautions and advisories

Cherry/Ice Call: Radio call from a pre-determined source (often AH-64 Apache) about the enemy situation on the LZ. Cherry LZ has enemies too close to the LZ. Ice LZ does not have enemies close to the LZ.

Clock: Displays current Zulu time. Essential to executing mission on the timeline

Commo Card: Paper product showing the frequency of all units supporting and enabling the radio communication for the operation.

Eng Oil Temp and Pressure: Displays current engine oil temperature and pressure

ExCheck: Short for Execution Checklist. List of brevity codes indicating a key event in the mission. Example: 1st lift taking off: brevity code "Irene"

Friendly Unit Locations (B Co, C Co, UAS): Not currently displayed in the aircraft in a useful manner. Pilots must understand the battlefield and know where units are with radio call updates.

Fuel Quantity: Displays current fuel quantity on the MFD

GPS: Input coordinates through the FMS. When selected, GPS routes are displayed on the MFD

Horizontal Situation Indicator: Displays current attitude (left and right bank, pitch up or down) on the MFD

LZ Diagram (headings, go-arounds, grids, hazards): Physical printed kneeboard product showing hazards and all pertinent information about the LZ

Master Warning Panel: Panel above MFD that flashes "Master Caution," "Engine RPM Low" or "Fire"

Minimum Force: Physical printed kneeboard product that shows the minimum ground force required to execute the mission

Mission Time Line: Physical printed kneeboard product that shows what time each key event should take place

NG: Gas Generator Speed. Displays the current speed of the compressor section of the engine on the MFD.

NR: Displays current rotor speed on the MFD.

PPC Data: Performance Planning Card Data. Calculations completed before the flight to determine critical flight data such as fuel burn rate, maximum gross weight, and maximum torque for flight.

Radar Altimeter: Displays the altitude above ground level on the MFD.

Radar Warning Indicator: Displays a warning on the MFD of the presence of enemy radar in the vicinity of the aircraft.

Route Data (TDH, Checkpoints): Physical printed kneeboard document that shows key points along the aircraft's route to its destination. Typically, these points are also associated with some type of reporting requirement by the pilot.

Stabilator Indicator: Displays the current status of the aircraft stabilizer on the MFD.

Status Updates from Serial: Radio communication update between the serials (groupings of two or more aircraft) within the lift (grouping of multiple serials).

TGT: Displays turbine gas temperature on the MFD.

Threat Updates (UAS): Radio communication update from the UAS controller on enemy presence in the vicinity of the aircraft.

TQ: Displays the torque effect on the aircraft via the MFD. The torque effect causes the main rotor to turn the aircraft fuselage in the opposite direction of the rotor's spin.

UAS Video Feed: Live feed from Grey Eagle or Shadow unmanned aerial system. This feed is not readily available to the pilot and must be relayed from the GreyEagle/Shadow controllers (see Threat Updates).

Vertical Situation Indicator: Displays rate of climb or rate of descent of the aircraft on the MFD.

XMSN Temp and Pressure: Displays current transmission oil temperature and pressure on the MFD.

APPENDIX B. SURVEY

Flight Information Priority by Phase

Start of Block: Survey Introduction

The Holistic Situation Awareness and Decision-Making (HSA-DM) Project, in coordination with the Naval Postgraduate School Human Systems Integration Program, is seeking your feedback to help us evaluate what information needs to be presented to pilots, when pilots need that information, and in what modalities to present information to facilitate rapid data fusion and reduce pilot cognitive load.

This comprehensive, Army-wide, scenario-based survey takes approximately 20 minutes to complete and is geared towards RL-1 UH-60 pilots. The scenario features an air movement scenario with contingencies. Your answers are anonymous and will be used to improve HSA-DM efforts. There are no pre-determined correct responses, we want to know your preferences. The NPS IRB determined this activity does not constitute human subject research as defined by DoDI 3216.02.

If you have any concerns about the conduct of this work, please contact the principal investigator Professor Lawrence Shattuck at lgshattu@nps.edu or (831) 656–2473.

End of Block: Survey Introduction

Start of Block: Demographics

What is your rank?

- WO1 (12)
- CW2 (13)
- CW3 (14)
- CW4 (15)
- CW5 (16)
- 2LT (17)
- 1LT (18)
- CPT (19)
- MAJ (20)
- LTC (21)
- COL (22)

Display This Question:

If What is your rank? = WO1

Or What is your rank? = CW2

Or What is your rank? = CW3

Or What is your rank? = CW4

Or What is your rank? = CW5

Are you tracked?

- No (1)
- Yes (2)

Display This Question:

If Are you tracked? = Yes

What is your track?

- ○ Safety (1)
- ○ Instructor Pilot (2)
- ○ Maintenance Test Pilot (3)
- ○ Aviation Mission Survivability Officer (4)

What is your Readiness Level?

- ○ RL1 (1)
- ○ RL2 (2)
- ○ RL3 (3)

What position best describes you?

- ○ Pilot (1)
- ○ Pilot-in-Command (2)

Are you currently an Air Mission Commander?

- ◯ No (1)
- ◯ Yes (2)

---

*

How many years of military aviation experience do you have as a pilot?

____

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*

How many military flight hours do you have?

____

---

*

How many combat flight hours do you have?

____

Select the option that best describes you in your current assignment.

- ○ Serving in a MEDEVAC Company (1)
- ○ Serving in an Assault Company (2)
- ○ Serving in a CAC (3)
- ○ Staff supported Aviator on MEDEVAC Company ATP (4)
- ○ Staff supported Aviator on Assault Company ATP (5)
- ○ Staff supported Aviator on CAC ATP (6)
- ○ Other (7) ____

End of Block: Demographics

Start of Block: Scenario Part 1

The CAB has been tasked to conduct a tactical air movement for ground forces to stage for follow on operations. The CAB commander assigns the AHB to conduct simultaneous movements to three HLZs on the objective. The AHB's Alpha Company will maneuver into HLZ Wren as the main effort, while Bravo and Charlie Companies (supporting efforts) maneuver into HLZs Robin and Owl, respectively. See figure below.

In the event that HLZ Owl is untenable, the company plans HLZs Parrot and Rooster as alternate and contingency HLZs, respectively. A UAS is already overhead in a UAS ROZ and provides reconnaissance. See figure below.

As you continue your movement along AC Saturn, rank the following information in order of how important it is to you. Assume that only a limited amount of the information below can be displayed at one time. The aircraft's systems are in normal operating ranges and there are no active emergencies.

	Somewhat Important (1)	Important (2)	Very Important (3)
Fuel Quantity (1)	○	○	○
XMSN Temp and Pressure (2)	○	○	○
Eng Oil Temp and Pressure (3)	○	○	○
TGT (4)	○	○	○
NG (5)	○	○	○
TQ (6)	○	○	○
NR (7)	○	○	○
Master Warning Panel (8)	○	○	○
Caution/Advisory Panel (9)	○	○	○
PPC Data (10)	○	○	○
Radar Altimeter (11)	○	○	○
Barometric Altimeter (12)	○	○	○
Vertical Situation Indicator (13)	○	○	○
Horizontal Situation Indicator (14)	○	○	○
Airspeed Indicator (15)	○	○	○

Stabilator Indicator (16)	○	○	○
GPS (17)	○	○	○
Commo Card (18)	○	○	○
Mission Timeline (19)	○	○	○
Route Data (TDH, Checkpoints) (20)	○	○	○
LZ Diagram (headings, go-arounds, grids, hazards) (21)	○	○	○
Friendly Unit Locations (B Co, C Co, UAS) (22)	○	○	○
ExCheck (23)	○	○	○
Cherry/Ice call (24)	○	○	○
Abort Criteria (25)	○	○	○
Minimum Force (26)	○	○	○
Radar Warning Indicator (27)	○	○	○
Clock (28)	○	○	○
Threat Updates (UAS) (29)	○	○	○
UAS Video Feed (30)	○	○	○

Status Updates From Serial (31)	○	○	○

Is there another piece of information that you would want that isn't listed above?

○ No (1)

○ Yes (2)

Display This Question:

If Is there another piece of information that you would want that isn't listed above? = Yes

Please list all additional information you would want.

____

Carry Forward Selected Choices from "As you continue your movement along AC Saturn, rank the following information in order of how important it is to you. Assume that only a limited amount of the information below can be displayed at one time. The aircraft's systems are in normal operating ranges and there are no active emergencies."

X→

In the previous question you ranked the following items as "very important." Please rank order the following from the most important to least important. The most important item will be ranked #1.

_______ Fuel Quantity (1)
_______ XMSN Temp and Pressure (2)
_______ Eng Oil Temp and Pressure (3)
_______ TGT (4)
_______ NG (5)
_______ TQ (6)
_______ NR (7)
_______ Master Warning Panel (8)
_______ Caution/Advisory Panel (9)
_______ PPC Data (10)
_______ Radar Altimeter (11)
_______ Barometric Altimeter (12)
_______ Vertical Situation Indicator (13)
_______ Horizontal Situation Indicator (14)
_______ Airspeed Indicator (15)
_______ Stabilator Indicator (16)
_______ GPS (17)
_______ Commo Card (18)
_______ Mission Timeline (19)
_______ Route Data (TDH, Checkpoints) (20)
_______ LZ Diagram (headings, go-arounds, grids, hazards) (21)
_______ Friendly Unit Locations (B Co, C Co, UAS) (22)
_______ ExCheck (23)
_______ Cherry/Ice call (24)
_______ Abort Criteria (25)
_______ Minimum Force (26)
_______ Radar Warning Indicator (27)
_______ Clock (28)
_______ Threat Updates (UAS) (29)
_______ UAS Video Feed (30)
_______ Status Updates From Serial (31)

Carry Forward Selected Choices from "As you continue your movement along AC Saturn, rank the following information in order of how important it is to you. Assume that only a limited amount of the information below can be displayed at one time. The aircraft's systems are in normal operating ranges and there are no active emergencies."

Regardless of how this information is currently presented in the cockpit, how would YOU want to receive this information?

Visual - Via dash display, HUD, or other visual means
Auditory - Cues through your headset
Tactile - Using the sense of touch to receive information through haptic gloves, vibrations, etc.

	Visual (1)	Auditory (2)	Tactile (3)
Fuel Quantity (x1)	○	○	○
XMSN Temp and Pressure (x2)	○	○	○
Eng Oil Temp and Pressure (x3)	○	○	○
TGT (x4)	○	○	○
NG (x5)	○	○	○
TQ (x6)	○	○	○
NR (x7)	○	○	○
Master Warning Panel (x8)	○	○	○
Caution/Advisory Panel (x9)	○	○	○
PPC Data (x10)	○	○	○
Radar Altimeter (x11)	○	○	○
Barometric Altimeter (x12)	○	○	○
Vertical Situation Indicator (x13)	○	○	○
Horizontal Situation Indicator (x14)	○	○	○
Airspeed Indicator (x15)	○	○	○

Stabilator Indicator (x16)	○	○	○
GPS (x17)	○	○	○
Commo Card (x18)	○	○	○
Mission Timeline (x19)	○	○	○
Route Data (TDH, Checkpoints) (x20)	○	○	○
LZ Diagram (headings, go-arounds, grids, hazards) (x21)	○	○	○
Friendly Unit Locations (B Co, C Co, UAS) (x22)	○	○	○
ExCheck (x23)	○	○	○
Cherry/Ice call (x24)	○	○	○
Abort Criteria (x25)	○	○	○
Minimum Force (x26)	○	○	○
Radar Warning Indicator (x27)	○	○	○
Clock (x28)	○	○	○
Threat Updates (UAS) (x29)	○	○	○
UAS Video Feed (x30)	○	○	○

Status Updates From Serial (x31)	○	○	○

End of Block: Scenario Part 1

Start of Block: React to Contact

While moving to HLZ Owl, Alpha company aircraft receive radar indication from their APR-39. They execute their "react to radar" plan and return to PZ Elm to await follow-on instructions.

Immediately upon receiving radar indications on your radar warning indicator, rank the following information in order of how important it is to you. Assume that only a limited amount of the information below can be displayed simultaneously.

	Somewhat Important (1)	Important (2)	Very Important (3)
Fuel Quantity (1)	○	○	○
XMSN Temp and Pressure (2)	○	○	○
Eng Oil Temp and Pressure (3)	○	○	○
TGT (4)	○	○	○
NG (5)	○	○	○
TQ (6)	○	○	○
NR (7)	○	○	○
Master Warning Panel (8)	○	○	○
Caution/Advisory Panel (9)	○	○	○
PPC Data (10)	○	○	○
Radar Altimeter (11)	○	○	○
Barometric Altimeter (12)	○	○	○
Vertical Situation Indicator (13)	○	○	○
Horizontal Situation Indicator (14)	○	○	○
Airspeed Indicator (15)	○	○	○

Stabilator Indicator (16)			
GPS (17)			
Commo Card (18)			
Mission Timeline (19)			
Route Data (TDH, Checkpoints) (20)			
LZ Diagram (headings, go-arounds, grids) (21)			
Friendly Unit Locations (B Co, C Co, UAS) (22)			
ExCheck (23)			
Cherry/Ice call (24)			
Abort Criteria (25)			
Minimum Force (26)			
Radar Warning Indicator (27)			
Clock (28)			
Threat Updates (UAS) (29)			
UAS Video Feed (30)			

Status Updates From Serial (31)	○	○	○

Is there another piece of information that you would want that isn't listed above?

○ No (1)

○ Yes (2)

Display This Question:

If Is there another piece of information that you would want that isn't listed above? = Yes

Please list all additional information you would want.

____

Carry Forward Selected Choices from "Immediately upon receiving radar indications on your radar warning indicator, rank the following information in order of how important it is to you. Assume that only a limited amount of the information below can be displayed simultaneously."

In the previous question you ranked the following items as "very important." Please rank order the following from the most important to least important. The most important item will be ranked #1.

_______ Fuel Quantity (1)
_______ XMSN Temp and Pressure (2)
_______ Eng Oil Temp and Pressure (3)
_______ TGT (4)
_______ NG (5)
_______ TQ (6)
_______ NR (7)
_______ Master Warning Panel (8)
_______ Caution/Advisory Panel (9)
_______ PPC Data (10)
_______ Radar Altimeter (11)
_______ Barometric Altimeter (12)
_______ Vertical Situation Indicator (13)
_______ Horizontal Situation Indicator (14)
_______ Airspeed Indicator (15)
_______ Stabilator Indicator (16)
_______ GPS (17)
_______ Commo Card (18)
_______ Mission Timeline (19)
_______ Route Data (TDH, Checkpoints) (20)
_______ LZ Diagram (headings, go-arounds, grids) (21)
_______ Friendly Unit Locations (B Co, C Co, UAS) (22)
_______ ExCheck (23)
_______ Cherry/Ice call (24)
_______ Abort Criteria (25)
_______ Minimum Force (26)
_______ Radar Warning Indicator (27)
_______ Clock (28)
_______ Threat Updates (UAS) (29)
_______ UAS Video Feed (30)
_______ Status Updates From Serial (31)

Carry Forward Selected Choices from "Immediately upon receiving radar indications on your radar warning indicator, rank the following information in order of how important it is to you. Assume that only a limited amount of the information below can be displayed simultaneously."

Regardless of how this information is currently presented in the cockpit, how would YOU want to receive this information?

Visual - Via dash display, HUD, or other visual means
Auditory - Cues through your headset
Tactile - Using sense of touch to receive information through haptic gloves, vibrations, etc.

	Visual (1)	Auditory (2)	Tactile (3)
Fuel Quantity (x1)	○	○	○
XMSN Temp and Pressure (x2)	○	○	○
Eng Oil Temp and Pressure (x3)	○	○	○
TGT (x4)	○	○	○
NG (x5)	○	○	○
TQ (x6)	○	○	○
NR (x7)	○	○	○
Master Warning Panel (x8)	○	○	○
Caution/Advisory Panel (x9)	○	○	○
PPC Data (x10)	○	○	○
Radar Altimeter (x11)	○	○	○
Barometric Altimeter (x12)	○	○	○
Vertical Situation Indicator (x13)	○	○	○
Horizontal Situation Indicator (x14)	○	○	○
Airspeed Indicator (x15)	○	○	○

Stabilator Indicator (x16)	○	○	○
GPS (x17)	○	○	○
Commo Card (x18)	○	○	○
Mission Timeline (x19)	○	○	○
Route Data (TDH, Checkpoints) (x20)	○	○	○
LZ Diagram (headings, go-arounds, grids) (x21)	○	○	○
Friendly Unit Locations (B Co, C Co, UAS) (x22)	○	○	○
ExCheck (x23)	○	○	○
Cherry/Ice call (x24)	○	○	○
Abort Criteria (x25)	○	○	○
Minimum Force (x26)	○	○	○
Radar Warning Indicator (x27)	○	○	○
Clock (x28)	○	○	○
Threat Updates (UAS) (x29)	○	○	○
UAS Video Feed (x30)	○	○	○

Status Updates From Serial (x31)	○	○	○

End of Block: React to Contact

Start of Block: Scenario Part 2

Assume you did not receive the radar indication described in the previous question, and the mission is continuing as planned. The UAS displaces to a new ROZ to provide the AMC in the C2 aircraft an initial conditions check on the state of HLZ Owl prior to arrival. This is all done while the UH-60 crews are en route to determine whether the mission has to abort, delay, or proceed into the landing phase. See figure below.

The conditions at HLZ Owl, as determined by the UAS aircraft commander, are “Ice.” This allows the assault force to land on time in the primary HLZ. After landing in HLZ Owl, Alpha Company returns to PZ Elm and stages for follow-on operations as needed. See below.

You are now RP inbound, rank the following information in order of how important it is. Assume that only a limited amount of the information below can be displayed simultaneously.

	Somewhat Important (1)	Important (2)	Very Important (3)
Fuel Quantity (1)	○	○	○
XMSN Temp and Pressure (2)	○	○	○
Eng Oil Temp and Pressure (3)	○	○	○
TGT (4)	○	○	○
NG (5)	○	○	○
TQ (6)	○	○	○
NR (7)	○	○	○
Master Warning Panel (8)	○	○	○
Caution/Advisory Panel (9)	○	○	○
PPC Data (10)	○	○	○
Radar Altimeter (11)	○	○	○
Barometric Altimeter (12)	○	○	○
Vertical Situation Indicator (13)	○	○	○
Horizontal Situation Indicator (14)	○	○	○
Airspeed Indicator (15)	○	○	○

Stabilator Indicator (16)	○	○	○
GPS (17)	○	○	○
Commo Card (18)	○	○	○
Mission Timeline (19)	○	○	○
Route Data (TDH, Checkpoints) (20)	○	○	○
LZ Diagram (headings, go-arounds, grids) (21)	○	○	○
Friendly Unit Locations (B Co, C Co, UAS) (22)	○	○	○
ExCheck (23)	○	○	○
Cherry/Ice call (24)	○	○	○
Abort Criteria (25)	○	○	○
Minimum Force (26)	○	○	○
Radar Warning Indicator (27)	○	○	○
Clock (28)	○	○	○
Threat Updates (UAS) (29)	○	○	○
UAS Video Feed (30)	○	○	○

Status Updates From Serial (31)	◯	◯	◯

Is there another piece of information that you would want that isn't listed above?

◯ No (1)

◯ Yes (2)

Display This Question:

If Is there another piece of information that you would want that isn't listed above? = Yes

Please list all additional information you would want.

____

Carry Forward Selected Choices from "You are now RP inbound, rank the following information in order of how important it is. Assume that only a limited amount of the information below can be displayed simultaneously."

X→

In the previous question you ranked the following items as "very important." Please rank order the following from the most important to least important. The most important item will be ranked #1.

_______ Fuel Quantity (1)
_______ XMSN Temp and Pressure (2)
_______ Eng Oil Temp and Pressure (3)
_______ TGT (4)
_______ NG (5)
_______ TQ (6)
_______ NR (7)
_______ Master Warning Panel (8)
_______ Caution/Advisory Panel (9)
_______ PPC Data (10)
_______ Radar Altimeter (11)
_______ Barometric Altimeter (12)
_______ Vertical Situation Indicator (13)
_______ Horizontal Situation Indicator (14)
_______ Airspeed Indicator (15)
_______ Stabilator Indicator (16)
_______ GPS (17)
_______ Commo Card (18)
_______ Mission Timeline (19)
_______ Route Data (TDH, Checkpoints) (20)
_______ LZ Diagram (headings, go-arounds, grids) (21)
_______ Friendly Unit Locations (B Co, C Co, UAS) (22)
_______ ExCheck (23)
_______ Cherry/Ice call (24)
_______ Abort Criteria (25)
_______ Minimum Force (26)
_______ Radar Warning Indicator (27)
_______ Clock (28)
_______ Threat Updates (UAS) (29)
_______ UAS Video Feed (30)
_______ Status Updates From Serial (31)

Carry Forward Selected Choices from "You are now RP inbound, rank the following information in order of how important it is. Assume that only a limited amount of the information below can be displayed simultaneously."

Regardless of how this information is currently presented in the cockpit, how would YOU want to receive this information?

Visual - Via dash display, HUD, or other visual means
Auditory - Cues through your headset
Tactile - Using sense of touch to receive information through haptic gloves, vibrations, etc.

	Visual (1)	Auditory (2)	Tactile (3)
Fuel Quantity (x1)	○	○	○
XMSN Temp and Pressure (x2)	○	○	○
Eng Oil Temp and Pressure (x3)	○	○	○
TGT (x4)	○	○	○
NG (x5)	○	○	○
TQ (x6)	○	○	○
NR (x7)	○	○	○
Master Warning Panel (x8)	○	○	○
Caution/Advisory Panel (x9)	○	○	○
PPC Data (x10)	○	○	○
Radar Altimeter (x11)	○	○	○
Barometric Altimeter (x12)	○	○	○
Vertical Situation Indicator (x13)	○	○	○
Horizontal Situation Indicator (x14)	○	○	○
Airspeed Indicator (x15)	○	○	○

Stabilator Indicator (x16)	○	○	○
GPS (x17)	○	○	○
Commo Card (x18)	○	○	○
Mission Timeline (x19)	○	○	○
Route Data (TDH, Checkpoints) (x20)	○	○	○
LZ Diagram (headings, go-arounds, grids) (x21)	○	○	○
Friendly Unit Locations (B Co, C Co, UAS) (x22)	○	○	○
ExCheck (x23)	○	○	○
Cherry/Ice call (x24)	○	○	○
Abort Criteria (x25)	○	○	○
Minimum Force (x26)	○	○	○
Radar Warning Indicator (x27)	○	○	○
Clock (x28)	○	○	○
Threat Updates (UAS) (x29)	○	○	○
UAS Video Feed (x30)	○	○	○

Status Updates From Serial (x31)	○	○	○

End of Block: Scenario Part 2

Start of Block: Survey Request

If you would like to receive a copy of the final report, please enter your email address below:

____

End of Block: Survey Request

APPENDIX C. FOCUS GROUP PLAN OF ACTION

Facilitator Positions:

1. Moderator: Facilitate conversation
2. Assistant moderator: Manage timeline and facilitate follow-up questions
3. Scribe: Take notes on computer and record conversation

Resources

1. Printed list of information to hand out to respondents
2. Printed list of information ranked/ordered with data we have collected so far

Source of Data: Note-based analysis

Purpose:

1. Validate data collected from FIPP survey
2. Determine the rationale behind the prioritization of information by phase.
3. Generate options about how information can be presented

Background:

Information produced by the research will be used by the HSA-DM division of DEVCOM to help develop future helicopter cockpits. We believe pilots need different information during different phases of the mission and the aircraft should provide this information needed.

Ground Rules

1. Information communicated here stays here and it does not leave the group
2. Be respectful of others
3. Information will not be used against each other outside the group

Questions:

Movement phase:

1. Discuss the top 5 pieces of information
    a. Need to find out why for each piece of information
2. What did you list as your most important information and why?
    a. If there were no limits on technology, how would you want to receive this information?
3. Alternate: What information do you check most often during the movement phase? Or do you use this as an opportunity to check all information?
4. Optional: Is there one piece of information needed more than any other?
5. How is this information currently presented in the cockpit? Does it need to change?

6. Is there information the aircraft provides that you do not need during the movement phase? i.e is there information that gets in the way and you need to filter?
    a. Why is this information not needed?

React to contact:

1. Discuss the top 5 pieces of information
2. What did you list as your most important information and why?
    a. If there were no limits on technology, how would you want to receive this information?
3. Alternate: What information do you check most often during the movement phase? Or do you use this as an opportunity to check all information?
4. Optional: Is there one piece of information needed more than any other?
5. How is this information currently presented in the cockpit? Does it need to change?
6. Is there information the aircraft provides that you do not need during the movement phase? i.e is there information that gets in the way and you need to filter?
    a. Why is this information not needed?

RP to LZ:

1. Discuss the top 5 pieces of information
2. What did you list as your most important information and why?
3. If there were no limits on technology, how would you want to receive this information?
4. Alternate: What information do you check most often during the movement phase? Or do you use this as an opportunity to check all information?
5. Optional: Is there one piece of information needed more than any other?
6. How is this information currently presented in the cockpit? Does it need to change?
7. Is there information the aircraft provides that you do not need during the movement phase? i.e is there information that gets in the way and you need to filter?
8. Why is this information not needed?
9. Does receiving non-critical information impact your ability to manage the cockpit?
10. Would you like to receive critical information differently than non-critical information?

Extra:

1. What technology (emerging, commercial, and all others) do you wish the system had?

APPENDIX D. FOCUS GROUP RESPONSE SUMMARY

Q1: Do pilots need different information during different phases of flight?

> Yes, there was a clear indication that pilots, regardless of experience level, want different information during the different phases of flight.

Q2: What specific information do pilots need during these specific phases?

> The answer to this question had significant differences based on the pilot's experience level and leadership positions during the operation. Junior pilots were focused on the small piece of the mission, primarily aircraft performance. Senior pilots found aircraft performance metrics less important due to their proficiency and instead chose to focus on operation specific information, primarily mission timelines, EXCHECKs, and communications.

Q3: How do pilots want to receive information i.e., visually, audio, tactile?

> Pilots continued to indicate that they preferred visual information over all other modalities, particularly for routine information. Any emergency or high importance information was wanted audibly.
>
> Visual: Pilots indicated an interest in Augmented Reality views to see mission related information outside of the aircraft. Some of the ideas for use of AR in the cockpit included highlighting known friendly and enemy positions, visual display of route data (path, altitude, stacking, etc), indicating the LZ using a column of light through the AR, and highlighting location and status of FARP.
>
>> Audible: Pilots indicate that they are already on the verge of audible overload and wanted to ensure that any new audible indicators were reserved for emergency or highly important information. Though it was discussed, many of the pilots did not like the idea of an in-cockpit digital assistant (Siri, Alexa, etc.). The pilots that did express interest wanted to ensure that it was a physical cue, not a verbal one, to eliminate any potential miscommunication and alteration to mission or aircraft information. The most popular function of the audible digital assistant was to dictate JVMF messages.
>>
>> Tactile: Pilots were generally against any introduction of tactile modality in the cockpit due to the existing level of vibration and potential to miss any information. A popular idea for the use of tactile information was

having the aircrafts collective vibrate if there was a potential for torque overload.

Extra Question: Outside of technology and budgetary constraints, what do you want in the next generation aircraft?

> The two most common trends for this question were the introduction of AR or synthetic vision into the cockpit and to have overhauled helmet, suit, gloves, vest, etc to ensure that any new additions to the cockpit continue to lower the cognitive demand, not just make room for more work.

SUPPLEMENTAL

FIPP Survey Data: This supplemental information features the results of the FIPP survey administered to UH-60 pilots across the U.S. Army. It shows the responses to all questions administered during the survey including demographic information, responses to scenario-based exercise, text inputs for information preferences, and survey duration for each respondent. If you are interested in obtaining a copy of this supplemental information, please contact the Naval Postgraduate School's Dudley Knox Library (Archives).

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