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MQ-25A Manned/Unmanned Teaming

Miller, Scot A.; McGuire, Mollie R.; Boger, Dan C.

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MQ-25A MANNED/UNMANNED TEAMING EXECUTIVE SUMMARY

Principal Investigator (PI): CAPT Scot Miller, USN (ret), Information Sciences (IS)

Additional Researcher(s): Dr. Dan Boger, IS

Student Participation: Capt Andrew Benton, USMC, IS

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Topic Sponsor Name(s): MQ-25A Program Manager, PMA-268, CAPT Greg Machi, USN
Topic Sponsor Contact Information: Gregory.a.machi.mil@us.navy.mil; 301-757-3807

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Project Summary

The MQ-25 is an unmanned aircraft system (UAS) designed to operate from an aircraft carrier and perform air-to-air refueling (AAR) and intelligence, surveillance, and reconnaissance (ISR) for the carrier air wing (CVW). This will relieve manned platforms, such as the F/A-18, from conducting these missions, thereby preserving manned flight hours and extending F/A-18 service life. Current UAS operations rely predominantly on human teams connected through beyond line-of-sight communications (BLOS) links. This architecture is insufficient to ensure MQ-25 mission accomplishment in an operational environment characterized by uncertainty in the electronic magnetic spectrum (EMS). Manned aircraft have pilots in the cockpit making tactical, context driven decisions and must be complemented by competent unmanned teammates; the MQ-25 has the potential to be this teammate. To this end, we employed interdependence analysis (IA) and co-active design to examine the human-machine interface and identify areas for increasing instances and proficiency of human-machine teaming (HMT), especially through the consideration of observability, predictability, and directability.

From this analysis, recommendations in system design, employment, and other functional areas were made that enhance mission accomplishment and system performance and resilience in uncertain EMS environments. These include the creation of a common Joint Planning and After-Action System (JPAAS) digital mission planning system to enable semantic interoperability between manned and unmanned systems and a sense and detect capability on the UAS to generate better unmanned situational awareness and promote possible cognitive decision making, especially in contested EMS operations. Warfare is inherently a team enterprise, and the efforts to fully automate it are misplaced. The value to be gained in HMT comes from utilizing the strengths of each team member to maximize effectiveness.

Keywords: *MQ-25; human-machine teaming; HMT; interdependence analysis; IA; digital planning; unmanned aircraft systems; UAS; intelligence, surveillance, and reconnaissance; ISR; beyond line-of-sight; BLOS; observability, predictability, and directability; OPD; mission planning; Joint Planning and After-Action System; JPAAS; electromagnetic spectrum; EMS*

Background

In the early 2000s, the Navy sought an aircraft that would serve as an unmanned combat aircraft vehicle (UCAV). At a 2008 Naval Postgraduate School concepts wargame, UCAV participants raved about how it would serve as the predominant naval strike aircraft of the future. Other participants suggested that with its lengthy flight endurance, it could also serve as an ISR platform. While UCAV aircraft carrier operations development proceeded with successes, mission design faltered. In 2016, the Navy decided on making UCAV a primary mission and overhead tanker, with ISR capability as a secondary mission. Called the MQ-25, it extends the strike range of existing F/A-18 aircraft and relieves them of their tanker role.

While manned aircraft coordinate with voice, hand signals, and lights, coordination with the MQ-25 is accomplished through an air vehicle operator (AVO), connected through beyond line-of-sight communications. Degradation of that communications link inhibits operational capability.

Designing for human-machine teaming may reduce that degradation in MQ-25 missions. Further, advanced human-machine teaming capability will enable force multiplier mission support, increasing the carrier air wing's warfighting capabilities.

Co-active design and interdependence analysis (Johnson, 2014) are two proven methods for identifying human-machine teaming requirements and generate resilience, reliability, and potential pitfall considerations. Proper identification of these requirements enables focused research and development of human-machine paired systems that truly enhance mission effectiveness. With the desire to introduce additional capability to the MQ-25 platform and the increasing likelihood of contested EMS environments, the MQ-25 must perform its current and future missions of tanking and enhanced ISR in these environments.

During the co-active design phase, researchers developed an operational view to display the mission scenario and hybrid operational concepts between the MQ-25, receiver aircraft, and the AVO. Researchers first performed systems functional analysis to identify specific process steps then used the co-active design approach to develop HMT requirements in terms of observability, predictability, and directability to display the interdependency relationships between the three systems.

As mentioned, BLOS communication links are subject to being denied or degraded, making assured mission success problematic. Using the co-active design process enables recognizing what computational and decision capability must be pushed as close as possible to the tactical edge to minimize environmental effects on mission accomplishment. Strike and other manned aircraft have humans in the cockpit making tactical decisions and, therefore, ought to be complimented by competent, capable, and predictable unmanned teammates to maximize mission effectiveness from both manned and unmanned platforms.

The analysis leveraged sponsor-defined use cases, to include enhanced ISR and other aviation operations, in contested network and communications environments. These requirements are intended to be incorporated into the MQ-25 and subsequent type, model, series of the system, and are meant to focus and enhance subsequent efforts to allow the MQ-25 system to partner with human operators in the conduct of tanking, ISR, and other missions in support of fleet operations.

Findings and Conclusions

UASs have long been conceptualized as human capability extenders, increasing reach and staying power. While this valuable capability has served the force well, the time has come to move beyond. UAS operations need not be on either extreme end of a spectrum that spans from human-in-the-loop operations to purely autonomous systems operating in a fire and forget manner. Warfare is inherently a team enterprise, and the efforts to fully automate it are misplaced. The value to be gained in HMT comes from utilizing the strengths of each team member to maximize effectiveness.

The United States Navy needs a digital mission planning system (in this research, it is called the Joint Planning and After-Action System, or JPASS) with one ontology for all missions, that all air wing and other impacted mission platforms employ. JPAAS would enable semantic interoperability of all CVW systems, manned and unmanned, a critical component of any non-permissive teaming effort. This eases information exchange, since the data framework and structure would be common across platforms, increasing teaming among aircraft and surface ships. After mission completion, JPAAS would be included in the after-action review process so that the entire planning team can evaluate the effectiveness of their planning decisions.

Utilizing the AVO as an information conduit or as the primary source for cognition does not utilize the MQ-25 as an unmanned teammate but rather as a capability extension. The inclusion of a sense and detect (S&D) system to the MQ-25 will create opportunity for true human-machine teaming in permissive environments and enable successful mission completion by the unmanned teammate in non-permissive environments. The S&D system is envisioned to provide perceptive and cognitive capabilities to the MQ-25, where only limited performative characteristics currently exist. The ability for the MQ-25 to perceive its environment and make recommendations or decisions, depending upon the environment, is crucial to its ability to operate in the future environment.

For instance, in AAR, safety dictates only critical, relevant information be transmitted to enable refueling. The MQ-25's ability to prioritize and select the appropriate information is vital. Starting with doctrinal parameters, this S&D system would use machine learning (ML) to increase decision capability in permissive operations when teaming with human operators, building trust for when human teammates are unavailable. JPAAS integration allows planning iterations, including unexecuted missions, to contribute to the training of the S&D ML algorithm. The introduction of a system that interacts with the human teammate beyond displaying system status information is key to moving beyond human-human teaming with an unmanned intermediary.

Humans have the capacity to work with many different teammates. The MQ-25 should be given the ability to do the same. Allowing the MQ-25 to communicate directly with teammates, particularly in AAR, expands human-machine teaming opportunities, decreases associated delays, and builds system resilience during periods of AVO-UAS non-connectivity. This improves CVW resilience and increases system flexibility by opening alternative communications pathways.

Recommendations for Further Research

Four broad areas emerged that require further research. The Joint Planning and After-Action System (JPAAS) system would enable semantic interoperability at the system level for aircraft and systems fleetwide. Such a system also expands human-machine teaming potential to planning and after-action phases of operations, creating opportunities for increased trust and training the respective machine learning (ML) algorithms. A JPAAS system should be explored in greater detail to enable the key capabilities, particularly in the areas of underlying message structure, ML algorithms, and how the system would interface with its human teammates and other unmanned systems fleet-wide. The goals set forth in the Navy's Project Overmatch present a unique opportunity to bring a system, like the one posited here, to fruition.

A theme that emerged throughout this research was the reliance on the air vehicle operator (AVO) for many critical functions during execution. A non-permissive environment removes the AVO from the situation, meaning the MQ-25 must be capable of teaming with the receivers or any other aircraft relevant to its mission, necessitating communication between those entities. Examination of a direct communications link from MQ-25 to receiving aircraft would enable this teaming possibility, increasing the likelihood of safe mission accomplishment. A detailed interdependence analysis (IA) of this human-machine team could provide valuable insights as to precisely what cognitive capabilities should be included in the MQ-25. Additionally, examination of the technical aspects of this communications link, such as J-series message standardization, or other short-range communications methods should be examined to enable data communication. Air-to-air refueling (AAR) operations currently involve extensive use of voice communications, and technologies such as natural language processing should be explored to enable the MQ-25 to communicate in this manner as well.

Another theme that emerged in this research was the complexity of aviation command and control (C2) and the many entities involved. IA, or other analytical methods, should be applied to the C2 structure that surrounds the MQ-25 to include the many entities with which the AVO currently coordinates to understand how to better integrate the MQ-25 into this structure and improve communications efficiency. Additionally, this analysis would reveal insights as to how this structure may need to adapt to better support the types of operations desired in the future that may be data centric but where periods of non-permissibility are commonplace.

The recommended sense and detect system requires the inclusion of additional sensors and data processing capacity onboard the MQ-25. Among those discussed were environmental and navigation sensors, natural language processing, transmission media evaluation, and ISR data prioritization. Non-permissive electro-magnetic spectrum (EMS) environments will require pushing computational capability to the tactical edge, rather than retaining it at centralized stations connected by long-haul communications links. Mission accomplishment in these uncertain EMS environments will not be possible without increasing the processing capacity resident on the MQ-25 platform to perform these processes and requires additional study.

References

Johnson, Matthew. (2014). *Coactive design: Designing support for interdependence in human-robot teamwork* [PhD dissertation, Delft University of Technology-Mekelweg/Netherlands]. https://www.researchgate.net/publication/267393898_Coactive_Design_Designing_Support_for_Interdependence_in_Human-Robot_Teamwork.

Acronyms

AAR	air-to-air refueling
AVO	air vehicle officer
BLOS	beyond line-of-sight
CVW	carrier air wing
EMS	electromagnetic spectrum
HMT	human-machine teaming
ISR	intelligence, surveillance, and reconnaissance
IA	interdependence analysis
JPAAS	joint planning and after-action system
ML	machine learning
OPD	observability, predictability, and directability
S&D	sense and detect
UAS	unmanned aircraft systems
UCAV	unmanned combat aircraft vehicle