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MQ-25 MANNED/UNANNED TEAMING (MUM-T) EXECUTIVE SUMMARY

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Project Summary

The MQ-25A is an unmanned carrier-based aircraft designed to provide air-to-air refueling to the carrier air wing and, as a secondary mission, provide intelligence, surveillance, and reconnaissance (ISR) support. Initial operational capability (IOC) is scheduled for 2024. Current carrier air wing refueling is supported by organic, manned aircraft. This limits the number of strike mission sorties and burdens the air wing with a plethora of secondary missions. This research examined the human-machine teaming aspects of MQ-25A operations during air-to-air refueling and ISR missions only. Launch, recovery, and flight deck operations were not included.

To explore human-machine teaming between this new unmanned tanker and the air vehicle operator (AVO), this research employed interdependence analysis (IA), which is a systems engineering design technique that identifies interactions required between humans and machines to successfully complete a shared mission. This interaction between humans and machines occurs in three general areas: *observability*, *predictability*, and *directability*. IA assists analysts in defining all functional paths through a mission, which promotes *reliability*. IA also supplies a thorough "what if" audit, which identifies methods to increase system *resiliency*.

Two findings emerged: First, the MQ-25A operates in a permissive environment; that is, communications links and the global positioning system are expected to be operating during MQ-25A flights. This represents a significant assumption, as the Navy admits near-peer operations will occur in a denied, disrupted, intermittent, and limited (low-bandwidth) communications environment. Second, the upgraded precision landing mode (PLM) makes the nightmare known as night carrier recovery less hazardous and more reliable.

Recommendations are twofold: Explore potential human-machine teaming required in a nonpermissive communications environment; second, investigate the human-machine teaming needed for more advanced ISR capabilities embedded on the MQ-25A.

Keywords: *MQ-25A, ISR, AVO, GPS, PLM, air- to-air refueling, (non) permissive environment, unmanned, human-machine teaming, interdependence analysis*

Background

The MQ-25A is an unmanned, carrier-based aircraft designed to provide air-to-air refueling to the carrier air wing and, as a secondary mission, provide ISR support. IOC is scheduled for 2024. Current carrier air wing refueling is supported by organic, manned aircraft. This limits the number of strike mission sorties and burdens the air wing with a plethora of secondary missions. This research examined the human-machine teaming aspects of MQ-25A operations during air-to-air refueling and ISR missions only. Launch, recovery, and flight deck operations were not included. The topic sponsor is the engineering development lead for the MQ-25A program office.

With an IOC of 2024, the program office has an approach to provide a robust and capable platform to support the mission. Indeed, the first squadron is receiving assigned sailors now. This research, by providing a second set of eyes, was designed to identify any unidentified surprises. Defining human-machine teaming requirements, as described in the Co-Active Design process (Johnson, 2014), provides a rigorous approach to identifying the capacities required for humans and machines to complete the air-to-air refueling and ISR missions. The Co-Active Design approach has been used on more than a dozen prior NPS theses, exploring various manned and unmanned teaming situations. Consistently, the process has delivered keen insights and prioritized requirements.

The research approach was straightforward: learn as much as possible about air-to-air refueling, the new MQ-25A, and ISR, and also standard carrier operations. This approach included using the Navy's Naval Aviation Training and Operating Procedures Standardization manuals, known as NATOPS.
An element of Co-Active Design is IA, which is a systems engineering design technique that identifies interactions required between human and machines to successfully complete a shared mission. IA begins by capturing the specific capacities of the mission, which may be performed by either unmanned machine or human. The IA approach asks the analyst, "How good is the machine at performing the capacity, and how can the human assist?", and vice versa. This interaction between humans and machines occurs in three general areas: observability, predictability, and directability (OPD). The analyst then suggests how the OPD might be executed for this specific capacity. IA also assist analysts in defining all functional paths through a mission to understand system reliability. IA provides a thorough "what if" audit, which identifies possible methods to increase system mission resiliency.

The initial research hypothesis was that the MQ-25A would be operated in a nearly teleoperated mode and would be ripe for capacity automation recommendations.

Findings and Conclusions
The program office performed stellar engineering preparations. The MQ-25A is not teleoperated per se, just designed with a magnificent autopilot so that the AVO operates it by establishing altitudes, waypoints, and orbits. The emergence of the PLM (Eckstein, 2021) on F/A-18s makes their recovery rate high. In the past, there was a nightly occurrence of a jet running on fumes, waiting to tank. Such emergencies are rare now. This means that perilous night tanking operations, with new AVOs, does not appear likely.

The approach to fleet introduction is also interesting. While it appears the MQ-25A will perform well, there is no intent on the first couple of deployments to dismiss manned refueling operations. Carrier air wings will slowly grow the capability, first trying daytime air-to-air refueling with the MQ-25A, then eventually moving to nighttime air-to-air refueling. Mission critical tanking operations will remain the province of manned tankers to begin with. This aligns well with other human-machine teaming trust development techniques (Yurkovich, 2020).

Because the program office desired this research to serve as an outside look, researchers had little access to many program office events that would have provided deeper understanding of the MQ-25A. For instance, the first refueling of an F/A-18 by the MQ-25A occurred in June 2021 (NAVAIR, 2021), but researchers were not invited to the event or privy to the results.

In the near term, research found that the Navy has a competent airframe, a well-organized rollout, a training program for the AVOs, and perhaps most importantly, the Navy decided to attach the MQ-25A carrier detachment personnel to the E-2D squadron to provide guidance, insight, comradery, and professionalism. The AVOs are planned to be Warrant Officer Grade One, to start, with a high school education. Giving them a home aboard ship will help build confidence, instill team spirit, and produce an understanding of the importance of the tanking mission, for both strike missions and recovery operations. MQ-25A will begin carrier life with modest ISR equipment, including a low-end electro optic/infrared sensor, a mid-grade electronic support measures system, and an automatic identification system, the merchant ship equivalent to an airborne transponder. These passive systems make the MQ-25A, as an ISR platform, dependent on others' transmissions.

While the MQ-25A development is proceeding, two obvious recommendations emerged. First, the program office should research human-machine teaming requirements for operating the MQ-25A in a non-permissive environment, meaning little-to-no communications and positioning equipment are available. Aircraft carriers, for tactical purposes, often operate in emission control conditions, where radios are seldom used. It would be difficult to see the Navy deploying an unmanned system and then not using it much of the time. Second, so far, it appears that ISR capabilities are an afterthought. There are many possible improvements that could make the MQ-25A an ISR force multiplier, but that also requires defining the human-machine teaming needs to implement better sensors and processing capabilities.

Recommendations for Further Research

The MQ-25A is an unmanned carrier-based aircraft designed to provide air-to-air refueling to the carrier air wing and, as a secondary mission, provide intelligence, surveillance, and reconnaissance (ISR) support. Initial operational capability (IOC) is scheduled for 2024. Current carrier air wing refueling is supported by organic, manned aircraft. This limits the number of strike mission sorties and burdens the air wing with a plethora of secondary missions. This research examined the human-machine teaming aspects of MQ-25A operations during air-to-air refueling and ISR missions only. Launch, recovery, and flight deck operations were not included.

While the MQ-25A progresses apace, this is the first of its kind, so there will be a significant amount of learning and updates required. Several are emerging based on this research.

First, research is needed on the entire mission planning realm associated with the MQ-25A. If it is just a written plan for the AVO to follow, that might be fine for simple ISR and refueling missions. More complex operations, though, will need formal digital plans. The Navy already has the Joint Mission Planning System and is planning a next generation planning system for the E-2Ds and the F/A-18s. Should the MQ-25A be a part of this planning software? In the longer term, one might assume that other aircraft might take control responsibilities for the MQ-25A, and improved interoperability is more likely if all carrier air wing aircraft use the same planning software. This would help make system development to meet the OPD requirements easier to design and manage. Similarly, all carrier air wing aircraft ought to have a common digital debriefing system as well. Emerging artificial intelligence techniques and systems, perhaps installed on the MQ-25A, could leverage these historical data to discern enemy intent. Second, this author completed two cruises on an aircraft carrier, and other than carrier qualifications, strong effort was made to reduce or eliminate any radiated emissions. However, the MQ-25A right now is only required to operate in a permissive navigation and communication environment. This does not align with all the other air wing aircraft, which routinely operate in emission-controlled environments. The reason is obvious. Operating an unmanned aircraft in such an environment is hard! Future research should investigate the need to create interdependence in such an environment.

Current research explored reliability and resilience factors of the MQ-25A, and they were found to be well considered. However, in a nonpermissive environment, these factors will be much different, and therefore deserve another look.

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Acronyms

AVO	air vehicle operator
IA	interdependence analysis
IOC	initial operating capability
ISR	intelligence, surveillance, and reconnaissance
OPD	observability, predictability, and directability
NATOPS	Naval Aviation Training and Operating Procedures Standardization
PLM	precision landing mode