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Manpower Evaluation: U.S. Navy Future Vertical Lift Maritime Strike

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Abstract: The U.S. Naval Air Systems Command (NAVAIR) is looking to replace their current fleet of helicopters, consisting of both manned and unmanned aircraft, with helicopters implementing a new technology called Future Vertical Lift (FVL). FVL helicopter technology is expected to improve aircraft performance through increased speed and endurance. However, with aircraft parameter changes, the amount of aviation detachment personnel required to support the deployment of these aircraft will change as well. This project uses Mixed-Integer Linear Programming in MATLAB to output optimized mission schedules, and Microsoft Excel to create work schedules for each aviation detachment personnel group and track hours for flights, personnel, and maintenance. Based on the schedules and utilization data produced, the user can determine whether the manpower mix, or berthing space of the operating ship require changes for more efficient or cost-effective mission completion.

Keywords: Staffing, Future Vertical Lift Maritime Strike, Mixed Integer Linear Programming

1. Introduction

The U.S. Navy has continued be on the forefront of new age aircraft technology. Using a mixture of both manned and unmanned aircraft, the U.S. Navy can successfully carry out missions across the world. However, the U.S. Navy wants to replace their current MH-60R/S Seahawk and MQ-8 Fire Scout UAV helicopters by the 2030s and find more cost-effective alternatives through the newly developed Future Vertical Lift (FVL) Maritime Strike project (Jennings, 2021). The FVL family of helicopters will be required to produce greater speed, allow for longer mission durations, and incorporate more advanced technologies than current models to effectively prepare the U.S. Navy to further their accomplishments after successful integration and implementation (Cosner, 2021).

While designing, building, and testing these aircraft of the future is a large task on its own, a more significant problem that has arisen is the issue of workforce management regarding those operating, maintaining, and supporting the aircraft(s) aboard small and/or large surface vessels. This is specifically due to the capacity limits on board which only allow for 24-32 aviation detachment (AvDet) personnel on board at any given time. Personnel for the context of this project has been defined and sorted into three categories: Pilots, Aircrew, and Maintenance (Cosner, 2021).

To account for future staffing changes, a decision support tool has been designed to evaluate AvDet personnel allocation and ensure mission completion. This tool accounts for several constraints defined within NAVAIR's current staffing process, such as ship and mission specifications, aircraft parameters, flight operation duration, number and types of missions, and operational hour limits per personnel type and aircraft type. With a final output of personnel usage and a sample mission schedule for the flight operation period scheduled, this tool is ultimately able to account for the advances in aircraft technology for the U.S. Navy.

There are two mission variations that the simulation accounts for: Maritime ISR&T (Surveillance) and Logistics. Surveillance missions involve the deployment of aircraft to scan the sea as continuously as possible to gauge any possible threats or nearby threats. Logistics missions involve the transportation of cargo between the operating ship and a logistics ship containing all necessary cargo (Cosner, 2021).

2. Methodology

This simulation assists the user to determine whether changes can be made to the current manpower mix as it is able to predict whether there must be an increase (or decrease) in AvDet personnel. The simulation inputs are adaptable such that technological advancements can be taken into account for future staffing requirements. To illustrate, a 1-week long Flight Operations Duration (FOD) is optimized and simulated using a combination of MATLAB and Microsoft Excel. A mission schedule along with personnel allotment and their respective schedules are created. Conclusions regarding manpower mix and ship berthing utilization are drawn up by the simulation through further calculations such as maintenance hours, flight hours, and cumulative working hours per personnel type.

2.1 Modeling

Microsoft Excel is used, simultaneously, as the primary User Interface (UI) and Output Display (OD). The spreadsheet includes 11 sheets: Instructions, UI, Data Sheet, Day 1, Day 2, Day 3, Day 4, Day 5, Day 6, Day 7, Conclusions.

2.1.1 Data Sheet

The simulation is controlled by pre-existing data regarding 5 aircraft: MH-60R, MQ-8C, New Helo, Small UAV, Large UAV. Of these aircraft MH-60R and the New Helo are manned requiring 2 pilots and 1 aircrewman, while MQ-8C and both Small and Large UAVs are unmanned requiring 1 pilot and 1 aircrewman. Further information regarding the aircraft including endurance, speed, payload, maintenance hours per flight hour (MMH/FH), hangar size, and maximum distance that can be flown are shown in the last five rows of Table 1 (Cosner, 2021). The first three rows change based on the selected user inputs of notional configuration.

Table 1. Aircraft Specifications

Type	Aircraft Type	Max Endurance (hours)	Speed (knots)	Payload	MMH/FH	Hangar Size	Pilots	Aircrew	
Manned	New Helo	5	180	1000	10	1	2	1	
UAV	Small UAV 1	8	180	0	10	0.5	1	1	
UAV	Small UAV 2	8	180	0	10	0.5	1	1	
									Max distance can travel (NM)
	MQ-8C	10	110	0	10	1	1	1	1100
	MH-60R	3	120	1000	10	1	2	1	360
	New Helo	5	180	1000	10	1	2	1	900
	Small UAV	8	180	0	10	0.5	1	1	1440
	Large UAV	12	200	0	10	1	1	1	2400

Initial inputs require the user to choose from two ships: Guided-Missile Destroyers (DDG) or Guided-Missile Frigate (FFG). Both ships utilize the same notional configuration of aircraft on board given their similar hangar sizes and helipads. Notional configuration refers to which combination of manned and unmanned aircraft are on board the ships. Table 2 lists the variations from Alpha to Foxtrot with the second column being the manned aircraft and the third column denoting the unmanned aircraft for their respective configuration. It is crucial to have one manned and one unmanned aircraft on board due to mission purposes as certain missions can only be performed by manned aircraft. Additionally, given that the small UAVs only take up half of a hangar space, configurations Charlie and Foxtrot can have three aircraft with two of them being small UAVs.

Given that both DDG and FFG ships only have 1 helipad, only one aircraft can be operating in the air at any given time. This restriction is in place to ensure that the helipad is available for the operating aircraft to land at any time in case of emergency. To ensure that the optimization accounts for this constraint, a table for flight usability is created and set to have values of ‘1’ for further use. In the case of a larger ship, like an aircraft carrier, that has two or more helipads, the flight usability can be changed to match that number ensuring that the simulation can have multiple missions and aircraft in use at once.

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Table 2. Notional Configuration

Notional Configuration		
Alpha	MH-60R	MQ-8C
Bravo	MH-60R	Large UAV
Charlie	MH-60R	2 Small UAVs
Delta	New Helo	MQ-8C
Echo	New Helo	Large UAV
Foxtrot	New Helo	2 Small UAVs

2.1.2 User Interface

Inputs for this simulation include ship type, Notional Configuration, and mission sets for a 7-day FOD (divided in 24-hour periods). The Notional Configuration dictates which aircraft will be available for mission use as the model uses that information to ensure the user does not select an aircraft that is unavailable for their FOD.

Based on the mission type, the user can input distance parameters. Surveillance missions require inputs of minimum and maximum travel distance. Ideally, the Navy would like to do as much surveillance as possible at variable distances and times away from the ship. Logistics missions require inputs of travel distance (since the load must be dropped off at a predetermined location) and weight of cargo to transport. The user is then able to select the aircraft to use for each mission. Logistics missions are only allowed to be completed by manned aircraft as those planes are the only ones that can carry extra weight (up to 1000 lbs.).

Given the time needed prior to and following the mission for preflight and postflight activities, a maximum of 5 missions can be completed in one day. As a result, the user may select up to 5 missions and is not required to fill up each day with missions. These user-defined missions are then transferred to their respective sheets per day. 24 Free blocks are built into the mission schedule to account for hours that can be optimized throughout the day. Given that the missions are top priority, they are denoted with a 1, while the “FREE” blocks are denoted with a 2.

2.2 Mixed-Integer Linear Programming Model

The simulation is dependent on an optimization of the missions for each day. This is done in MATLAB using Mixed-Integer Linear Programming (MILP). For the case of this simulation, variable constraints included the MinHours/MaxHours columns as well as the Availability column which is used to indicate if certain missions needed to be run at certain times. Additionally, strict constraints of only one helicopter in use at any given time and each inputted mission can only be run once are added to ensure the model does not create unnecessary missions for any day. A custom MILP function (MATLAB & Simulink, 2016) along with the *intlinprog* algorithm takes inputs of aircraft, minimum mission hours, maximum mission hours, and priority of flight time as specified by the GUI, to create an optimal flight schedule for the given day. MATLAB, then, creates an output of an hours matrix which denotes when each mission will be completed during the day along with the flight for that mission. This is automatically downloaded to the Excel spreadsheet which conducts further calculations to create staffing, flight, and maintenance schedules.

2.3 Assumptions

There are various assumptions about personnel and aircraft functionality that were established in the development of this model. All AvDet personnel are assumed to be able to operate/maintain all aircrafts on board, therefore allowing them to be randomly assigned to all aircraft types. Required aircraft maintenance hours are calculated based on the assumption that all aircraft require 10 hours of maintenance man-hours per flight hour (Cosner, 2021). Based off the assumption that this model will be run prior to staffing and deployment, aircraft can continue to be scheduled for missions regardless of whether all maintenance hours have been completed from the previous day due to the nature of the randomization functions. If an aircraft has remaining maintenance hours from its first day of operation, those hours are included in the amount of remaining maintenance hours for the next day as well. Therefore, the summary of remaining maintenance hours can provide more insight to the user as it works to show how many maintenance hours can be completed versus how many hours need to be completed given the mission schedule.

3. Results and Analysis

3.1 Case Study

To provide a thorough review of the mission and staffing simulator, a case study was conducted using the inputs in Figure 1. Minimum and maximum distance inputs were converted to a rounded time value in hours by dividing the distance by the speed of the respective aircraft. MATLAB received inputs of the various necessary missions along with their respective aircraft, minimum and maximum mission duration, priority level, and availability. For this scenario, and specifically regarding the New Helo, the logistics mission needed to be carried out within the hours of 8:00 and 11:00, while the surveillance mission by the same aircraft could be completed any time after 13:00. "FREE" blocks were still built in and used by the simulation to ensure an optional solution schedule can be created for a full 24 hours.

Initial Inputs	
Ship Classification	DDG
Aircraft Configuration	Foxtrot

Day 1	
Mission 1	Logistics
Distance to move weight	300
Weight to move	800
Aircraft 1	New Helo
Mission 2	Surveillance
Minimum distance to travel	200
Maximum distance to travel	900
Aircraft 2	Small UAV 1

Mission 3	Surveillance
Minimum distance to travel	20
Maximum distance to travel	400
Aircraft 3	Small UAV 2

Mission 4	Surveillance
Minimum distance to travel	100
Maximum distance to travel	800
Aircraft 4	Small UAV 1
Mission 5	Surveillance
Minimum distance to travel	300
Maximum distance to travel	600
Aircraft 5	New Helo

Aircraft	MinHour	MaxHour	Priority	Availability
New Helo	2	2	1	8-11
Small UAV 1	2	5	1	
Small UAV 2	1	3	1	
Small UAV 1	1	5	1	
New Helo	2	4	1	13-23
FREE	0	1	2	
FREE	0	1	2	

Figure 1. UI Input of Case Study

3.1.1 Simulation Results

The initial result of this simulation was an hours matrix with values of 0 and 1 from MATLAB which translates to the mission schedule for the day as shown in the top table of Figure 2 where the 1s are denoted by blue squares. While this scenario had five user-input missions, in the case that all five are not allotted, the remaining rows would stay empty. Given that the aircraft are used for multiple missions during the day, a flight schedule has been created as shown in the bottom table of Figure 2. Flight hours are calculated by adding up each hour the flight is in use and maintenance hours are calculated by multiplying flight hours by 10.

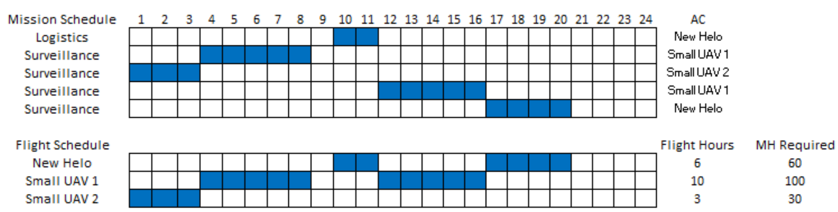

Figure 2. Mission and Flight Schedule Day 1 Output

This mission and flight schedules then dictate the maintenance schedule as shown in the top timetable of Figure 3. This schedule also calculates the completed and remaining Maintenance Hours. Maintenance personnel are set to work on the aircraft whenever they are not in use as shown in the bottom table of Figure 3. Maintenance staff work on 12 hour rotating schedules, unlike their counterparts who work in 18-hour shifts which is why they are split from 0:00 - 12:00 and 13:00 - 24:00. If available, maintenance personnel are randomly assigned to multiple aircraft at once. The three colors denote which aircraft they are working on for that hour to ensure that all aircraft are getting their required maintenance. The “MH remaining” column shows the remaining maintenance hours required given the flight hours from this FOD. For “New Helo" and “Small UAV 1” there are still 13 and 65 maintenance hours remaining respectively. For “Small UAV 2”, the hours remaining is -32, meaning that 32 extra hours were allotted over the required amount. Given the nature of the randomization required to create the schedule to staff maintenance personnel, the user will have to manually transfer 32 maintenance hours from Small UAV 2 to either of the two other planes.

Next, staffing schedules are created based on these schedules. Figure 4 has two tables, the first one randomizes which pilots and aircrew are randomly assigned to missions (but still in accordance with flight necessity). This table then translates to the second table by merging when the missions are being completed along with which personnel are assigned to that mission.

This moves the user into the Recommended Next Steps tab. This keeps track of which pilots/aircrew were not in use over the FOD, along with any maintenance man hour discrepancies and subsequent suggestions. Figure 5 shows the next steps for this FOD.

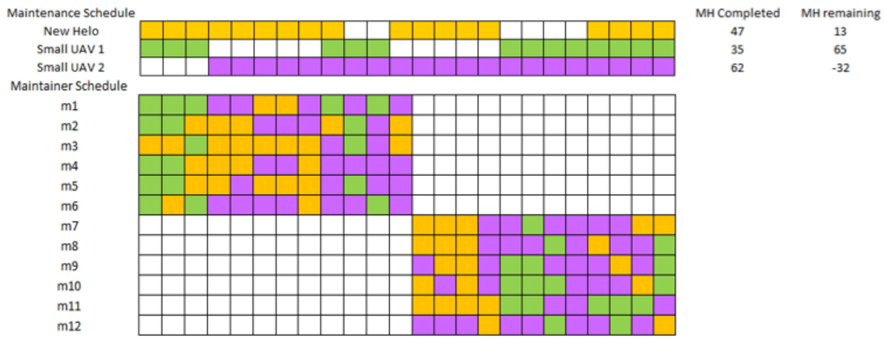

Figure 3. Maintenance Flight and Personnel Schedule Output

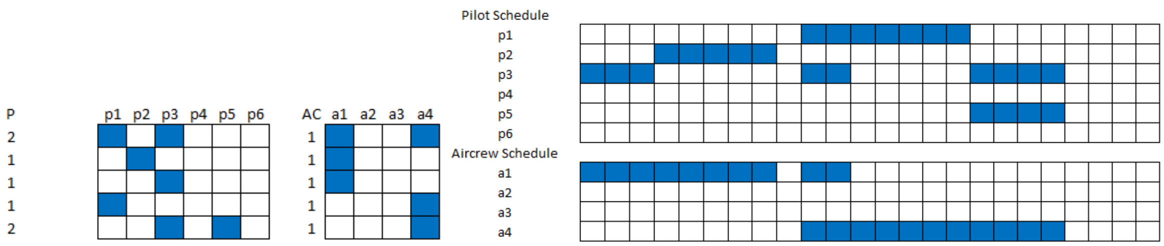

Figure 4. Pilot and Aircrew Schedules

Day 1 Summary

	Pilots Unused	PH > 18	Aircrew Unused	AH > 18	MH Remaining	Additional Maintenance?	Remove/Add	How Many?
					46	4	Pilots	
			Aircrew 2				Remove	2
			Aircrew 3					
	Pilot 4						Aircrew	
							Remove	2
	Pilot 6							
Total	2	0	2	0				

Figure 5. Case Study Recommendations

The simulator recommends adding 4 maintenance personnel and removing 2 pilots and aircrew for the current mission schedule.

3.1.2 Next Steps Recommendations

Re-running the simulation with the recommendations of fewer pilots and aircrew and increased maintenance staff gives the following outputs as seen below in the three tables of Figure 6. Seeing that all personnel are being used and finding the sum of the MH remaining (-2 MH required), the user can assume that this is the optimal manpower mix as there are no remaining personnel that aren't being used, personnel being used excessively, and absconding maintenance hours.

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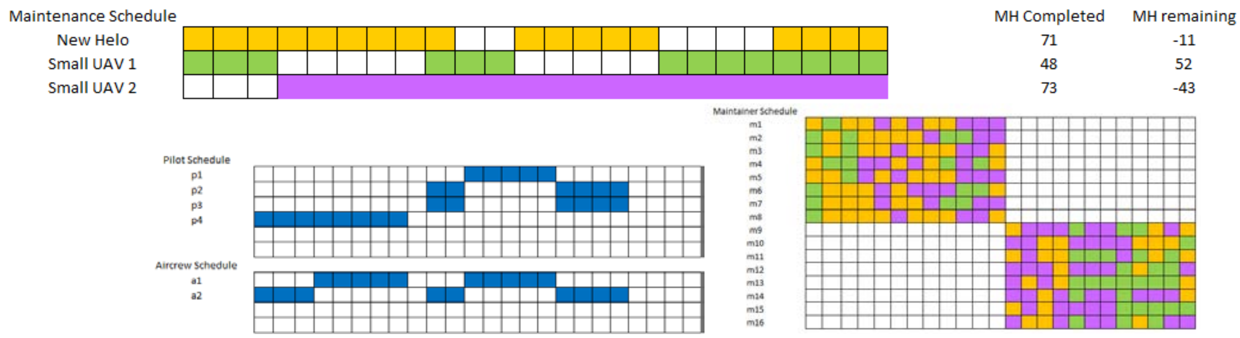

Figure 6. Case Study Rerun Results

3.2 Verification Testing

The primary verification method used for this model was the manual simulation of a schedule for missions, aircraft, and personnel. The case study detailed above will be used as the primary example to outline steps of this verification method. The resulting mission schedule was mapped by hand in a timetable format and was chosen to verify the preflight and postflight activities. However, for this specific case study, preflight and postflight activities were not explicitly plotted by hand because missions were scheduled consecutively. In Figure 7, it is assumed that Small UAV 2's preflight preparations were completed the day before because it was scheduled for a surveillance mission from 0:00 to 2:00. However, Small UAV 1's preflight activities for its surveillance mission were scheduled while Small UAV 2 was in operation (between 0:00 to 2:00). Because no pilots or aircrew have been scheduled to operate more than one aircraft within this 24-hour period (see Figure 7), it can be ensured that no aviation detachment personnel are being overscheduled. Through the repetition of the process described above, each mission schedule produced by this simulation was verified.

Figure 7. Manual Simulation of Mission Schedule

Conclusions

As new technology continues to develop, more efficient tools are required to ensure optimal personnel allocation and efficiency of mission completion. This manpower decision support tool is an essential component of the Future Vertical Lift technology as the aircraft and mission requirements continue to advance by the year 2030. This simulation allows the U.S. Navy to understand their current manpower utilization and make the best judgment call on design requirements for the new ships that the U.S. Navy will use. Future development to improve this model will include adding the capability to specify pilot qualifications and ensure that the outputted personnel schedules account for each crew members' skills level when assigning missions.

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