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Analyzing the Future of Army Aeromedical Evacuation Units and Equipment: A Mixed Methods, Requirements-Based Approach

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ABSTRACT We utilize a mixed methods approach to provide three new, separate analyses as part of the development of the next aeromedical evacuation (MEDEVAC) platform of the Future of Vertical Lift (FVL) program. The research questions follow: RQ1) What are the optimal capabilities of a FVL MEDEVAC platform given an Afghanistan-like scenario and parameters associated with the treatment/ground evacuation capabilities in that theater?; RQ2) What are the MEDEVAC trade-off considerations associated with different aircraft engines operating under variable conditions?; RQ3) How does the additional weight of weaponizing the current MEDEVAC fleet affect range, coverage radius, and response time? We address RQ1 using discrete-event simulation based partially on qualitative assessments from the field, while RQ2 and RQ3 are based on deterministic analysis. Our results confirm previous findings that travel speeds in excess of 250 knots and ranges in excess of 300 nautical miles are advisable for the FVL platform design, thereby reducing the medical footprint in stability operations. We recommend a specific course of action regarding a potential engine bridging strategy based on deterministic analysis of endurance and altitude, and we suggest that the weaponization of the FVL MEDEVAC aircraft will have an adverse effect on coverage capability.

INTRODUCTION

The Medical Evacuation Proponency Directorate (MEPD) Futures Study Team of the U.S. Army Medical Department (AMEDD) continues to analyze current shortfalls and future requirements to support the aeromedical evacuation (MEDEVAC) mission and specifically the Future of Vertical Lift (FVL). The FVL is a futures program focused on replacement of the aging military helicopter fleet. As such, it represents the future of Army MEDEVAC capability. This article discusses the relevant, previous findings of the MEPD study team (including existing capability shortfalls, data acquisition, and agnostic capability requirements). This study also details a discrete-event simulation (DES) of Afghanistan, provides additional insight regarding aircraft engine requirements based on proposed engine solutions (interim and future), assesses the notion of weaponizing MEDEVAC platforms, and discusses the future way ahead for cabin design and major combat operations. The study, funded by MEPD, begins with a review of the existing knowledge about the MEDEVAC fleet and the implications for FVL planning.

Study Background

In a 2009 study, MEPD evaluated the total number of Army MEDEVAC aircraft authorized as part of the total army analysis process.[1] Conclusions from this study indicated that estimating the number of MEDEVAC platforms requires both workload and geographic analysis. In addition, the study identified the distribution of patients by evacuation category for two aeromedical evacuation units with complete data (31% urgent, 21% priority, 48% routine), the distribution of the number of intratheater movements by patients (85% = 1 movement, 13% = 2 movements, 2% > 2 movements), and the number of patients per evacuation (57% = 1 patient, 43% > 1 patient). The importance of this study is that it not only provided an initial basis for future geographic and workload-based simulations, but also underscored the necessity to evaluate unique medical assets separately from grouped units (in this case aviation units). This finding underscores the need for medical involvement in the development of the FVL platform.

Linked to distributions and data of the 2009 study, MEPD developed a two-stage stochastic optimization model using realistic, historical data that allocated both treatment and evacuation (ground and air) assets across a mock operating area to minimize patient transport time in 2010.[2] This study provided a few important components necessary for simulating future scenarios in support of the FVL project, two of which were the stochastic casualty generator used by similar research[3] and the distribution of injury severity scores (ISS) based on real-world data. In addition, the study showed that the complexity of the problem would require more wide-scale use of simulation.

Beginning in 2011, MEPD began evaluating the design of the current MEDEVAC company based on doctrine,

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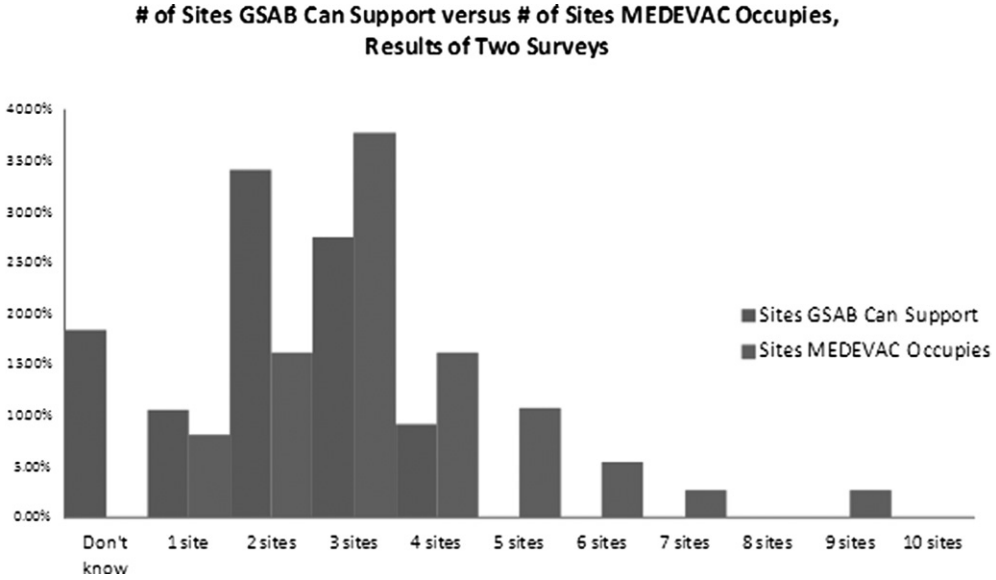


FIGURE 1. Aviation branch officers and enlisted were asked to estimate the number of geographically dispersed sites the General Support Aviation Battalion could reasonably support with maintenance given its current structure. Previously deployed MEDEVAC experts were asked to report on the number of remote sites their organization occupied on their last or current deployment. The difference in the distribution between the 2 response sets is shown.

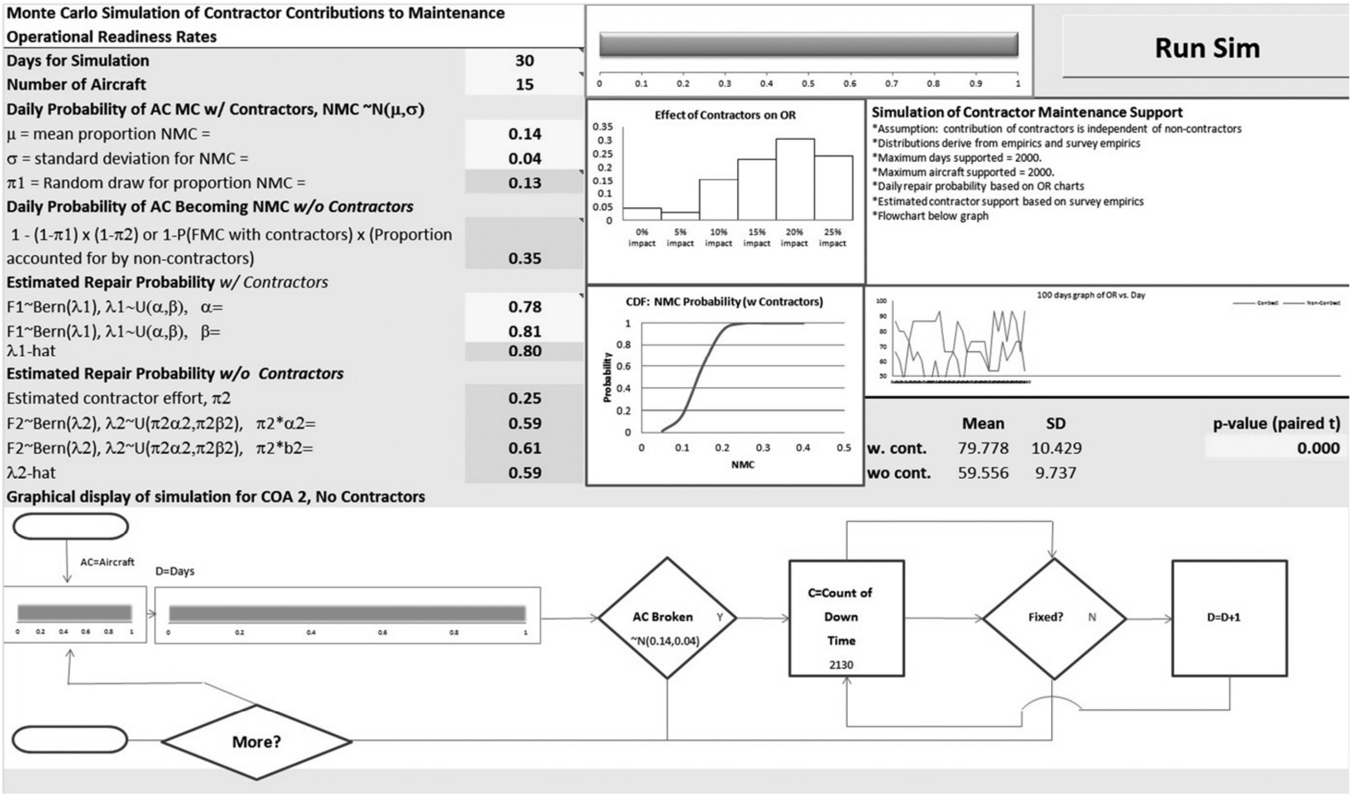
organization, training, maintenance, leadership, personnel, and facilities (DOTMLPF).[4] Results of this study identified widespread concurrence from 100 survey respondents of the shortages in enlisted personnel, maintainers, and maintenance equipment. All of these results were statistically significant ($\alpha = 0.05$). One of the major findings of this study is associated with Figure 1. The number of separate, geographically dispersed MEDEVAC sites supportable by the maintenance component of Army aviation, the General Support Aviation Battalion, is estimated to be different than the self-reported number of sites a MEDEVAC unit occupies in ongoing stability operations, resulting in shortages of capabilities. This finding was identical to separate analysis conducted by the Army Aviation Center[2] and is important to the development of the FVL platform. Aircraft with increased range and speed might be able to reduce the number of geographically separate locations required of MEDEVAC units. Such a reduction in geographic locations would reduce the maintenance footprint required. The study provided a basis for understanding the current MEDEVAC organization, as the Army plans the redesign of the Army helicopter fleet.

Also from this survey, comments from the field were collected and analyzed qualitatively for each DOTMLPF area. Analyzing these comments was more than revealing, as relevant themes emerged. These qualitative themes mirrored the statistical findings in that there was widespread discussion of maintenance issues associated with geographic dispersion.

In a separate 2011 survey and Monte Carlo simulation of daily operational readiness rates (percentage of the time aircraft are operational), the MEPD study team assessed the impact that contractors currently have on operational readiness in theaters of operation. One of the considerations was that the development and adoption of more capable aircraft might reduce the maintenance footprint by eliminating geographic dispersion requirements and/or reducing maintenance exposure by shortening mission time, eliminating the need for many contractors. Understanding the current contribution of contractors would help with future analysis of any potential cost savings associated with design and development of the FVL platform. Survey responses ($n = 90$) garnered from 600 aviators indicated that contractors had a significant effect on operational readiness rates as shown in Table I. Based on this table, the mean contribution of contractors was estimated to be about 14.8%. Using Monte Carlo simulation (Fig. 2), the study team mixed the survey results with actual operational readiness rates and estimated daily failure distributions coupled with repair rate distributions for both with and without contractor conditions. A 365-day run for one 15-aircraft company resulted in an estimated 17.6% contractor contribution with a 95% confidence interval of (16.1%, 19.1%). To eliminate the number of contractors required to support the future MEDEVAC force while

TABLE I. The Assessment of Contractor Contribution to Operational Readiness

Assessed Impact on Operational Readiness Rates	Percentage of Respondents
0% Impact	5
$0\% < p \leq 5\%$ Impact	3
$5\% < p \leq 10\%$ Impact	15
$10\% < p \leq = 15\%$ Impact	23
$15\% < p \leq = 20\%$ Impact	30
$20\% < p \leq = 25\%$ Impact	24



Monte Carlo Simulation of Contractor Contributions to Maintenance Operational Readiness Rates

Days for Simulation	30
Number of Aircraft	15
Daily Probability of AC MC w/ Contractors, NMC ~N(μ,σ)	
μ = mean proportion NMC =	0.14
σ = standard deviation for NMC =	0.04
π1 = Random draw for proportion NMC =	0.13
Daily Probability of AC Becoming NMC *w/o Contractors*	
1 - (1-π1) x (1-π2) or 1-P(FMC with contractors) x (Proportion accounted for by non-contractors)	0.35
Estimated Repair Probability *w/ Contractors*	
F1~Bern(λ1), λ1~U(α,β), α=	0.78
F1~Bern(λ1), λ1~U(α,β), β=	0.81
λ1-hat	0.80
Estimated Repair Probability *w/o Contractors*	
Estimated contractor effort, π2	0.25
F2~Bern(λ2), λ2~U(π2α2,π2β2), π2*α2=	0.59
F2~Bern(λ2), λ2~U(π2α2,π2β2), π2*b2=	0.61
λ2-hat	0.59

Graphical display of simulation for COA 2, No Contractors

Simulation of Contractor Maintenance Support
*Assumption: contribution of contractors is independent of non-contractors
*Distributions derive from empirics and survey empirics
*Maximum days supported = 2000.
*Maximum aircraft supported = 2000.
*Daily repair probability based on OR charts
*Estimated contractor support based on survey empirics
*Flowchart below graph

	Mean	SD	p-value (paired t)
w. cont.	79.778	10.429	0.000
wo cont.	59.556	9.737	

FIGURE 2. Screen snapshot of the Monte Carlo simulation for contractor contribution to operational readiness.

retaining current operational readiness rates, future fleets would need to be nearly 18% more reliable by a combination of less downtime, less exposure, less manpower requirements, quicker repair times, etc.

In 2012, MEPD deterministically analyzed requirements for speed and range based on specifications of the future brigade operating area and Secretary of Defense requirements for response time.[5] Findings associated with this study informed decision makers about the speed and range requirements for the future MEDEVAC platform along with possible doctrinal employment. The findings follow: (1) aircraft with ground speed capability of 350 knots can provide 100% coverage of the future brigade operating space (300 km^2) given simplifying assumptions; (2) aircraft with ground speed capability of 260 knots provide 100% coverage for future brigades projecting power in a circle of radius 150 km; (3) Colocating MEDEVAC assets and surgical elements when casualty distributions are uncertain (uniformly distributed over a circle) optimizes the one-hour coverage directed by the Secretary of Defense.

By 2011 and throughout 2012, the FVL project came to the forefront for MEPD, and the study team began looking at the problem using a variety of stochastic and deterministic techniques. A DES emerged as a reasonable solution to assessing future capabilities (platform agnostic) based on modeling an Afghanistan-like, stability operations scenario. The advantage of the DES is that it allows for flexible modeling of multiple parameters associated with aircraft design, unit employment, etc. Once a baseline model has been verified and validated, then excursions are readily conducted over an array of parameters, often using design of experiments (DOE) methods.

Through 2012, several other requirements for analysis emerged, including the need to address specific engine considerations. The YT706 General Electric (GE) Aviation engine adopted by the Special Forces community[6] was of interest to the aviation community as a potential bridging strategy to the FVL, and the Army's Improved Turbine Engine Program (ITEP engine) established capabilities for future engines important to analyze. The ITEP engine is supposed to achieve a 50% increase in power (3000 shaft horsepower [SHP]), a 25% reduction in fuel for a given SHP, and a 35% reduction in maintenance costs. Although still in the Science and Technology phase (expected to emerge for request for proposals in 2013), both GE Aviation and a 50/50 venture between Honeywell and Pratt & Whitney are actively seeking to build an engine with these capabilities.[7] The question important to the FVL MEDEVAC variant was the utility of acquiring the ITEP or YT-706 for the UH-60 Black Hawk before the fielding of the FVL platform as a bridging strategy for the current UH-60 fleet or waiting for the FVL with the proposed ITEP.

Another question that emerged during 2011 and 2012 was the possibility of arming current and future MEDEVAC aircraft, which made national news.[8] This issue ostensibly arose after delays in launch time, whereas MEDEVAC assets awaited armed escort to provide aerial security at the landing zone. Aside from the "con" arguments regarding the Geneva Convention and the use of unarmed aircraft emblazoned with the Red Cross to designate noncombatant status, other arguments against arming MEDEVAC platforms have included the negative effects of increased aircraft gross weight as well as the remaining MEDEVAC chase aircraft requirement (i.e., MEDEVAC aircraft must launch with a second escort aircraft). The MEPD Capabilities Study Team was asked to look at the weight factor directly.

Study Purpose and Research Questions

Given what the study team found in previous work, we had a reasonable basis and background to address three additional research questions for 2012. The first research question dealt with a capabilities assessment of the effects of speed and range on force structure in theater. The second research question surrounded engine capability for the bridging strategy to the FVL platform, adopt the YT706, or wait for the ITEP. The third research question addressed an analysis weaponizing the FVL platform. The research questions (RQs) follow:

- RQ1: What are the optimal capabilities of an FVL MEDEVAC platform given an Afghanistan-like scenario and parameters associated with the treatment/ground evacuation capabilities in that theater? Answering this question for Afghanistan provides a basis for modeling the FVL platform across multiple geographies, as different regions of the country vary in altitude, environmental conditions, and terrain.
- RQ2: What are the MEDEVAC trade-off considerations (range, endurance, altitude, etc.) associated with different aircraft engines operating under variable conditions? Answering this question is foundational to the FVL study, as it provides an assessment of bridging strategies before fielding of the FVL.
- RQ3: How does the additional weight of weaponizing the current MEDEVAC fleet affect range, coverage radius, and response time? Answering this question is important for both current operations and the FVL configuration.

RQ1: METHODS, RESULTS, AND DISCUSSION

Discrete Event Simulation of Afghanistan

For RQ1, the published studies to date provided the necessary framework for the development of a DES focused initially on Afghanistan. The problems with questions of this nature involve both the scenario and the definition of capabilities. The study team evaluated the nature of the problem and determined that flexible simulation (with the capability to change scenarios relatively rapidly) with post hoc optimization (design of experiments with a goal-programming optimization approach) would yield results suitable for analysis of the future, especially given the increasing complexity of analyzing a yet-to-be designed future aircraft. Unfortunately, scenarios are restricted often by what we know (the present) versus what we do not know (the future), at least for validating that the simulation is producing results congruent with the known. To address this issue, the study team selected an Afghanistan-like scenario to help with the validation process.

Selected capabilities of importance to the study team included the following: range of aircraft in nautical miles (NM), speed of aircraft in knots, altitude capability of aircraft (as estimated by path network), and cost of aircraft as a function of speed (estimated). These variables have a significant effect on the requirement for medical assets such as intensive care units (ICUs) and operating tables as well as the ability to move a patient from the point of injury to surgical treatment within the allotted time. Further, changing aircraft capability has an effect on maintenance (consider exposure to β-distributed downtime) as well as aircraft utilization (opportunity cost). As part of the simulation, the study team conducted post hoc analysis using DOE factors. By manipulating variables of interest, we were able to optimize objective functions in a goal-programming fashion based on weights of key decision makers.

Modeling Environment

MedModel was the primary programming and simulation environment for the simulation.[9] MedModel allows for flexible, rapid development of complex simulation problems. Although many simulation platforms exist, MedModel has been used by the military for various applications including unit rotation planning[10] and medical planning. The Center for AMEDD Strategic Studies (CASS) retains the site license associated with this simulation.

The Scenario

Understanding that the primary mission set for analysis was the collection of patients, the treatment of patients, and the evacuation of patients, the study team determined that an initial analysis of the Afghanistan Theater of Operations (which has a known casualty stream, real data, and concrete distances) would provide a reasonable scenario for initial evaluation. To set up the problem in an unclassified way, the team resorted to using open-source data for casualties[11] and distributing these casualties around population centers.

The Locations and Time Frame

The number of population centers selected was 24, throughout the country, as these population centers were of sufficient size to receive geographic attention from publicly available mapping sources (i.e., Google Maps). The time for the study was set to May 2009 to April 2011, 730 days. This period reflected a period of increased casualties.

The Entities

The primary entity in this simulation was the patient. Given the focus on evacuation times, all other objects were considered resources that the patient could demand. Even the FVL platform was considered a resource rather than an entity. The differentiation between entities and resources is important only to the coding available in MedModel. The primary resources in the model include the use of ground evacuation resources (medics and vehicles), fuel, mechanics, intensive care units (ICUs), operating rooms, and the FVL platform itself. The fuel and mechanic distributions are underdeveloped but exist to provide future refinement.

The total number of casualties estimated to be moved during this time was 9,293, which included 8,369 wounded-in-action (WIA), 889 killed-in-action (KIA), and an additional 35 disease nonbattle injury (e.g., heart attack victims). The WIA and KIA derived from an open-source database.[11] According to Karen Bagg, an operations research analyst and statistician at CASS, this source matches closely with the Department of Defense reports. These last 35 were calculated using a rate of 1.83 disease nonbattle injury admissions per 100,000 troops (provided by CASS) with the number of troops deriving from the Brooking's Institute Afghanistan Index.[12]

Patient Arrivals

Although exact locations of casualties are known, using these distributions would potentially classify this study. Instead, the study team chose to scatter the casualties randomly around the geographic casualty centers. The scenario selected included only two hospitals: one in Kandahar and one in Kabul. These locations currently provide out-of-theater evacuation capability, and so this site selection was logical. The team chose not to place any far-forward support for the initial analysis to test the robustness of the simulation and post hoc optimization for challenging scenarios.

Distributing the casualties appropriately was a function of using a Compound Poisson Process. In this process, patient groups arrived in Poisson distribution fashion with a fixed arrival rate. The number in the group was based on a triangular distribution derived from a previous MEDEVAC study.[1] The daily arrival rate was set to 1 every 70 hours for each of the 24 locations. This rate of arrival mimicked the number of daily casualties experienced during the time frame of May 2009 to April 2011. Initial arrival time was randomized uniformly over time using a β (1,1) distribution.

The patient priority for the MEDEVAC queuing process was determined by an empirically generated ISS, a measure of patient severity that is widely tracked by the U.S. military. The ISS effectively weighs the severity of a patient from 0 to 75, with higher numbers equating to more severe casualties. The queuing priority was based on this patient attribute.

Patient Processing

Because the simulation was designed to evaluate an entire health care evacuation and treatment system, the flow through the system was important to understand. Specifically, the study team wanted to establish a parsimonious model that captured the essential flowchart elements. Figure 3 depicts this flowchart.

Each patient arrival was triaged by a medic with treatment time distributed exponentially with a wait parameter of 15 minutes. Patients were initially categorized as a KIA (8% from CASS), a return to duty (RTD) (9% based on National Trauma Data Bank 2010 analysis),[13] a died of wounds (2.5% from CASS), or a non-RTD evacuee survivor requiring medical treatment (80.5%). Patients were also assigned to either litter or nonlitter status, ~Bernoulli(0.5), associated with a previous study.[1]

ISS for evacuated survivors were assigned based on the National Trauma Data Bank 2010 distributions.[13] Higher ISS scores indicate more severely injured patients with survival rates dropping rapidly. The ISS scores also link to surgical and ICU demand as shown in Table II.

The FVL platform, as the most important resource, had special processing logic worth discussion. Processing logic for movement, downtime, repair, and refueling provided the basis for comparative analysis. Repair and refuel logic allowed for flexible macros (future DOE analysis), while downtime was modeled as an exponential distribution with rate parameter of one event per 24 hours. At a minimum, aircraft are expected to have a daily inspection. The expected downtime for this inspection was initially set to 72 minutes but was adjustable by the macro.

Path Networks

Aircraft travel path networks were modeled to reflect feasible paths for 200 NM, 250 NM, 300 NM, 350 NM, and 400 NM aircraft ranges. The 350 NM and 400 NM paths were considered "high altitude," as they traversed terrain in excess of 10,000 feet mean sea level.

Verification and Validation

Decision makers agreed that the model was reasonable for use in the FVL analysis. CASS verified that the model inputs and outputs were reasonable. Certain design characteristics were evaluated to make sure that the model's outputs were appropriate based on the input parameters. The initial casualty stream of 9,293 was replicated in an initial 30 replicates with no statistical difference (sign test). (The first five observed casualty streams were 9295, 9287, 9361, 9186,

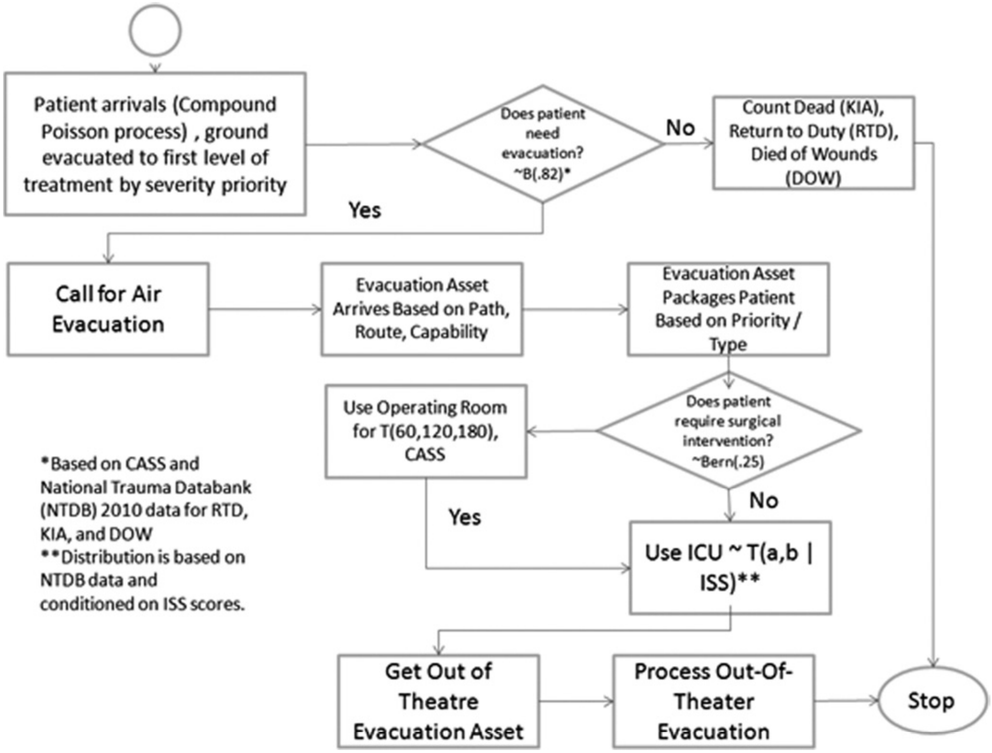


FIGURE 3. The basic flowchart for the DES is shown here. Distributions are indicated by the tilde.

and 9268.) After several runs and modifications, the model appeared to perform as expected.

DES Results and Implications for FVL

Results from all runs suggested that aircraft with speeds greater or equal to 250 knots would reduce the average wait for patients in the queue below 60 minutes, the standard set by the former Secretary of Defense.[5] One should note that expected wait does not ensure all patients would be evaluated within 60 minutes at the nearest medical treatment facility in-theater.

As indicated by Fulton et al, analyzing both workload and geographic factors is important to understanding the requirements for any specific MEDEVAC mission set. What is interesting in this scenario is that geography trumps workload: aircraft with sufficient capability would allow consideration of having fewer medical treatment and evacuation locations in the theater of Afghanistan. For this scenario, highly capable, all-weather MEDEVAC assets would allow the establishment of only two surgical hospitals to support U.S. casualties. In addition, highly capable, all-weather MEDEVAC assets allow the reduction of the number of evacuation locations, which are dictated currently by geographic dispersion rather than by workload requirements. By reducing the number of locations, future issues associated with dispersed maintenance capability like the one identified in Bastian et al might be ameliorated.

TABLE II. ISS Distribution is Shown Along With Associated Probabilities of Surgery (S) and ICU Visit Along With ICU Visit Given No Surgery. Patients Having Surgery Are Assumed to Visit the ICU. Some Patients May Not Have Surgery But Still Visit the ICU (e.g., Heart Attacks)

ISS	Proportion (%)	P (S&I)	P (I|Sc)
0–8	55	0	0.10
9–16	25	0.25	0.25
17–23	15	0.50	1.00
24–75	5	1.00	0.00

Although continued analysis (including DOE using SimRunner) is ongoing, the results suggest that at a minimum, increasing sustained airspeed capability to 250 knots or above would result in successful evacuation of the "average" patient within the 60 minutes authorized, assuming that aircraft were capable of operations at high altitude associated with Afghanistan (13,500 feet). These findings are congruent with the deterministic method used in Bastian et al.[5] The implications for the FVL are clear: speed matters up to the point where coverage is provided. This analysis only applied to stability operations in Afghanistan, however. Ongoing analysis is expanding the analysis to other areas of the world.

RQ2: METHODS, RESULTS, AND DISCUSSION

Analysis of Proposed Engines

The importance of RQ2 is simple: any bridging strategy is associated with this analysis. Addressing this research question required a few simplifying assumptions. First, we used the existing UH-60 fleet and specifically the operator's manual dated September 25, 2009.[14] We compared the GE 701-C engine, the GE 701-D engine, the YT706-700R engine, and the proposed ITEP engine. The first three engines are currently in use for the UH-60.

Facts and Assumptions

Certain facts and assumptions were important to this analysis. First, one should note that fuel burn is a linear function of SHP over most of the relevant range. Second, torque required is linearly related to fuel burn. Third, we had to make the assumption that the ratio of SHPs between engines provides a reasonable but imperfect method for estimating torque requirements. In other words, if an engine with 2000 SHP requires 1,000 SHP for a specific airspeed and altitude, then an engine with 3,000 SHP would require (2/3) × 1000 = 667 SHP. Since the ITEP engine is not yet developed, this assumption was necessary, as no test data exist. We also had to assume that fuel burn rates from GE are accurate.

Engine Descriptive Statistics

Table III provides the fundamental descriptive statistics of the engines. The SHP increase from the 701-C engine to the proposed ITEP is dramatic (>50%), and the proposed fuel burn rate is 25% less. Figure 4 compares the torque required for various flight airspeeds given fixed environmental characteristics and weight.

TABLE III. A Comparison of the Engines Associated With the Current Analysis

Engine	SHP	Fuel lbs/SHP Per Hour at Max Power	Dual Engine lbs Fuel Flow/Hour at Max Power Unconstrained
701-C	1890	0.462	1746
701-D	1994	0.465	1854
YT706-700R	2638	0.462	2437
ITEP	3000	0.347	2079

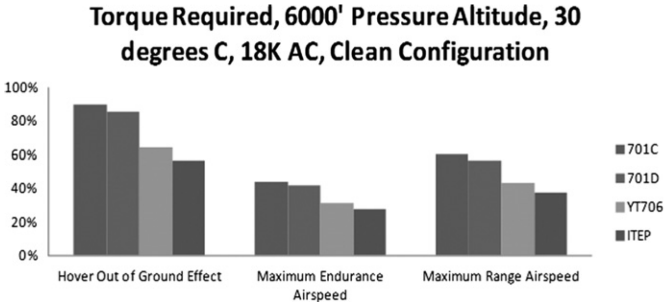


FIGURE 4. A comparison of engine torque percentages at various airspeeds shows the margin of performance that both the YT706 and the ITEP provide over the traditional 701-C and 701-D.

Aeromedical Evacuation Coverage

After comparing the engines descriptively, the study team evaluated the performance using a real-world environment, Afghanistan. At high altitude and hot conditions, the one-hour MEDEVAC coverage circles—circles which depict an "out and back" one-hour travel time—change very little, as the aircraft airspeed is often limited by the main transmission (or engine limits occur near simultaneously with the transmission limit). In other words, sprint speed is limited based on other than just engine considerations, so all engines will be able to meet the one-hour response time window. That said, the ITEP is expected to burn 25% less fuel throughout this relevant range.

In high altitude and hot conditions, the coverage capability in terms of hovering altitude will change. At 30°C surface temperature and calculating a 2°C drop per 1,000 feet, we estimate that an 18,000 pound UH-60 can hover OGE with 701D engines at about 7,000 feet or 2,134 m (interpolated maximum torque available of about 90%). We applied a ratio of SHP to determine the additional altitude that the YT706 and ITEP might provide. We estimate that the YT706 can produce enough power to hover OGE at approximately 11,000 feet or 3,353 m using a proportional power calculation. Specifically, if the maximum power for the 701D is 76%, then the YT706 should be able to produce nearly 76% × 2638 SHP/1994 SHP = 100% power. The ITEP should be expected to allow hover OGE at 14,000 feet or 4,267 m. The estimated maximum power is shown as 73%. Given the ratio of SHP and assuming a proportional engine "bleed" rate, the ITEP is estimated to be able to produce 73% × 3000 SHP/1994 SHP = 110% power, which is less than the UH-60L transmission limit. The limitation in these estimates is such that we assume engine performance curves of the ITEP and YT706 will mimic those of the 701C/D series.

Results of Engine Analysis and Implications for the FVL

The engine comparison for the current fleet was revealing as six major findings emerged: (1) Hour coverage circles are restricted by transmission limits rather than engine considerations at altitudes up to 8,000 and temperatures near 30°C (clean), as the transmission cannot accept additional torque from improved engines. No change in MEDEVAC area coverage occurs for these areas. When engine limits begin in the 701C and 701D, the coverage capability diminishes rapidly; (2) Altitude and torque availability increase with the adoption of either the YT706 or the ITEP; (3) The GE-reported fuel consumption for the YT706 (pounds per SHP per hour) shows only nominal differences between engines except for the planned ITEP, which necessarily must show a 25% decrease in consumption along the relevant range of operation; (4) The YT706 altitude improvement in comparison to both the current 701D and the ITEP is 4,000 feet in terms of hover OGE. Such an increase might be relevant in some situations; however, the cost–benefit may not be sufficient to justify its acquisition as a bridging strategy; (5) Given reasonable planning assumptions for high altitude/hot temperatures and using maximum range airspeeds, the ITEP variant will provide nearly 100 NM additional range for the UH-60; (6) In the end, it may be cheaper to procure new FVL airframes than attempt to retrofit the fleet with new transmissions and other components necessary to handle the capability of the ITEP. This hypothesis needs to be evaluated carefully.

RQ3: METHODS, RESULTS, AND DISCUSSION

Analysis of Fleet Weaponization

As a final research question, the study looked at the effects of weaponizing the MEDEVAC platform. Answering RQ3 is important for both current operations and the FVL configuration. The approach to answering this problem was performance planning.

Comparisons

To see the effects of weaponization, we chose to compare the "clean" UH-60L typically configured for MEDEVAC at various weights versus against a "dirty" UH-60L configured with M-60 machine guns mounted (an increase in flat plate drag of 0.6 and weight with ammunition of 250.6 pounds). For consistency, we used 6,000 feet pressure altitude and 30°C. Calculations were based on travel at maximum range airspeed with a 20-minute reserve at maximum endurance airspeed and a 20-minute run-up, launch, load, and land cycle. We evaluated the percent coverage loss and derived Table IV. The loss in area coverage ranges from 11% at 12,000 pounds to 3% at 18,000 pounds.

Implications for the FVL

Although it is possible to weaponize the MEDEVAC aircraft of the future, the geographic advantage is reduced depending on the weight and drag associated with the weaponization. Specifically, that reduction on the UH-60 might be as much as 14%. Although the exact effect for the FVL is not known, it is known that increasing weight and flat plate drag reduce response time. Given the requirement for two ships per mission that currently limits launch time, leaders will have to assess whether planning for quick launches is a better solution than arming MEDEVAC aircraft.

TABLE IV. The Analysis of Coverage Loss by Weight Class for "Clean" Versus "Dirty" Aircraft

Weight	Max Distance Covered (Clean AC)	Max Distance Covered (Dirty AC)	Difference in Distance Covered	% Loss Area
A, 12K	352.1 NM	331.4 NM	20.8 NM	11
B, 13K	339.9 NM	320.9 NM	18.9 NM	11
C, 14K	331.1 NM	306.5 NM	24.6 NM	14
D, 15K	322.8 NM	304.2 NM	18.6 NM	11
E, 16K	309.1 NM	297.4 NM	11.7 NM	7
F, 17K	291.7 NM	287.4 NM	4.3 NM	3
G, 18K	274.7 NM	271.0 NM	3.7 NM	3

CONCLUDING REMARKS

In this study, we showed the techniques for developing the future MEDEVAC force. These methods are based on both qualitative and quantitative approach, employing mixed methods and soliciting input from the field. We recognize multiple and infinite limitations in attempting to use the current state of knowledge to forecast the future; however, we also recognize that all Bayesian methods require prior distributions and yet form the basis for artificial intelligence. In this case, we believe our analysis is reasonable, and it will be refined over the next decade, as more information becomes available.

The analysis provided here has specific implications for decision makers. First, we confirm previous findings that travel speeds in excess of 250 knots are advisable for the FVL design. Second, capable FVL platforms will reduce the medical footprint in stability operations. (NOTE: this finding is not related to major combat operations, which directly require a workload component.) Third, if the AMEDD must choose between a bridging strategy in the YT706 engine versus waiting for the ITEP, the study team recommends waiting for the ITEP. The YT706 adds some altitude capability, but other aircraft limits will be problematic. Fourth, the weaponization of FVL will have an adverse effect on coverage capability and the potential reduction of force structure possible in stability operations.

Currently, the study team has shifted its attention to the cabin design considerations for the future MEDEVAC variant. We have designed a preliminary survey, which links to three-dimensional, interactive computer-assisted design models. Soldiers in the field will have the opportunity to walk through the proposed cabin designs virtually and provide feedback throughout the development cycle. This work is ongoing and the results are forthcoming.

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