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Quantifying the Impact of Maintenance Manpower on H-60 Helicopter Readiness in the Army National Guard

WG 19 Readiness
89th MORS Symposium

Michael Guggisberg
Nate Latshaw
Christopher Sampah
Julie Lockwood
Joe King
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Executive Summary

Part of a broad effort by the Army National Guard (ARNG) to increase understanding of the relationship between investments in full-time support (FTS) personnel and the ability to perform the ARNG mission, this Institute for Defense Analyses research investigates the relationship between FTS personnel and aviation readiness. Specifically, we estimate how changes in the number of Military Technician (MilTech) aviation mechanics at Army Aviation Support Facilities (AASFs) servicing ARNG helicopters impact the length of time that aircraft are unavailable for flight operations due to having at least one open fault, while holding other factors constant.

AASFs are the most common aviation maintenance facility in the ARNG, with 88 facilities operating in fiscal year 2019. MilTechs are ARNG members who work for the ARNG as civilian FTS personnel in addition to their roles as drilling ARNG members. MilTechs perform the majority of helicopter maintenance at AASFs. For this analysis, the duration of maintenance downtime events—or fault spells—is the outcome of interest, defined as the length of contiguous time a helicopter cannot be flown due a maintenance requirement. This analysis examines H-60 helicopters, including UH-60 Black Hawks and HH-60 Pave Hawks. Comparable analysis of other helicopters (e.g., CH-47 Chinook and AH-64 Apache) was not possible because the required maintenance data was not fully reported for those systems.

Additional AASF MilTech mechanics increase aircraft ready hours

Using a flexible semi-parametric econometric model—estimated with data from September 16, 2010 to September 15, 2019—we find that increasing the number of MilTech mechanics at an AASF reduces the duration of H-60 helicopter maintenance downtime events to a statistically significant degree across facility sizes studied. For the average AASF of a given size, each additional MilTech mechanic decreases fault spell duration by 0.7% to 1.1%, holding constant features such as the number and type of other aircraft assigned to the AASF, upcoming deployments, outstanding parts orders, and facility specific effects. The magnitude of the impact of an additional MilTech mechanic at a specific AASF depends on several factors, among them the facility's baseline MilTech mechanic headcount and the facility's overall volume of work. We find that the marginal impact of an additional MilTech mechanic reduces fault spell duration for AASFs of all staffing levels studied, with smaller marginal increases as baseline MilTech manpower levels rise (decreasing returns to scale in MilTech mechanic manpower). In other words, holding overall work volume and other factors constant, a MilTech mechanic added at a

facility with a lower-than-average MilTech mechanic headcount increases aircraft availability more than one added at a higher-than-average headcount facility.

Applying these findings to the AASFs and workloads for fiscal year 2019, adding an additional MilTech mechanic to each facility with at least one H-60 helicopter year (74 MilTechs total) would result in an additional 18,509 mission capable (MC) hours (or 771 additional MC days) across the ARNG H-60 helicopter fleet on average. A rough estimate shows that of the gain in MC hours, 94% or 17,449 hours are FMC hours, which at average observed usage rates would produce 353 additional flight hours. However, the estimated impact on FMC and flight hours rely on strong assumptions and are subject to selection biases.[1]

Due to the incomplete reporting of non-H-60 helicopter maintenance events, and because MilTech mechanics working on H-60 helicopters are indistinguishable in our data from those working on other helicopter systems at the same AASF, our estimates of the impact of MilTech mechanic staffing on H-60 helicopter readiness should be interpreted as approximating the lower bounds of their actual productivity. However, controls for non-H-60 helicopters were included to mitigate this effect.

Return on Investment (ROI) Comparisons for Various Potential ARNG Aviation Readiness Investments

For a rough ROI comparison, a year's wages for 74 additional WG-12 MilTech mechanics is about $4.8 million. Therefore, were a MilTech mechanic added to each ARNG AASF with at least one H-60 helicopter year, the resulting additional MC hours would cost approximately $262 per MC hour on average in additional annual wages. The ARNG could alternatively obtain an additional MC hour by borrowing a UH-60M Black Hawk at the much more expensive price of $2,920 per hour from a different Department of Defense (DOD) component.[2]

Another option to increase MC hours for ARNG H-60 helicopters would be to purchase new helicopters. A typical H-60 helicopter had 5,723 MC hours in fiscal year 2019. Based on our analyses, hiring an additional MilTech mechanic in each of the 74 ARNG AASFs with at least one H-60 helicopter year is roughly equivalent to gaining 3.2 additional H-60 helicopters. The gross weapon system unit cost of 3.2 new UH-60M Black Hawks is approximately $74 million.[3] Further,

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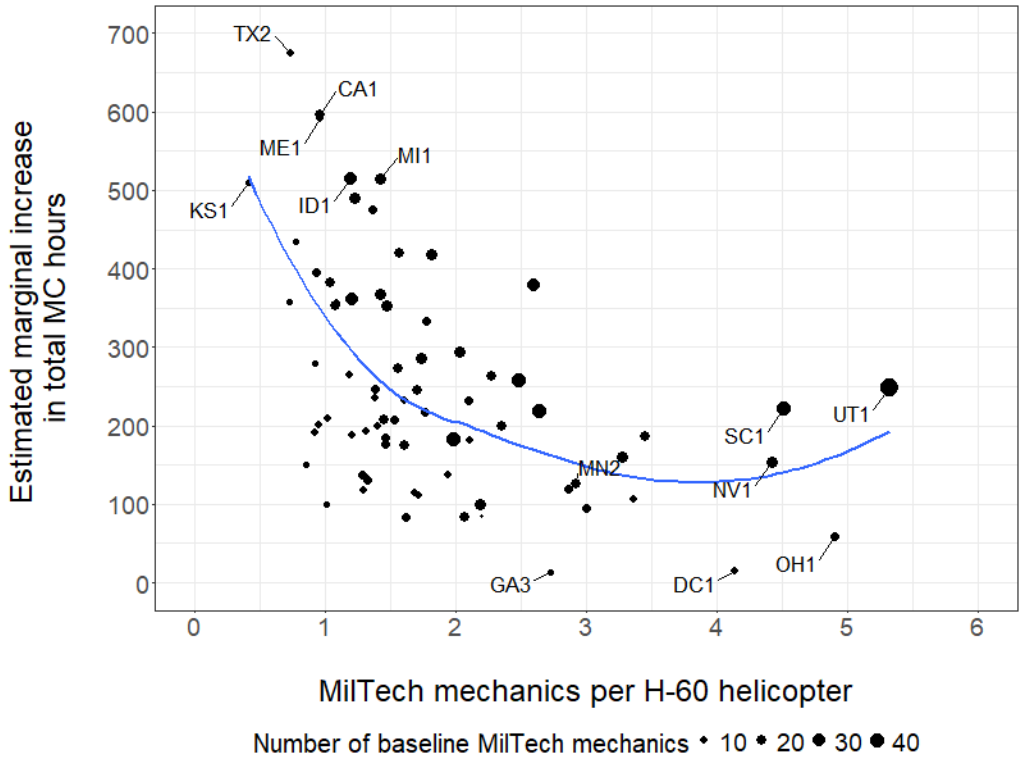
[1] The flight hours are unexpectedly low because a helicopter that is rarely used tends to have low flight hours a large amount of MC time. Our simple models do not account for this bias.

[2] Office of the Under Secretary of Defense, "Fiscal Year (FY) 2020 Department of Defense (DoD) Fixed Wing and Helicopter Reimbursement Rates," Oct. 2019, 1-8. www.comptrollerdefense.gov/ Financial-Management/Reports/rates2020/.

[3] U.S. Department of Defense, Selected Acquisition Report (SAR): UH-60M Black Hawk Helicopter (UH-Black Hawk), RCS: DD-A&T(Q&A)823-341 (Washington, DC: Defense Acquisition Management Information Retrieval (DAMIR), December 2018), https://www.esd.whs.mil/Portals/54/Documents/FOID/ Reading%20Room/ Selected_Acquisition_Reports/FY_2017_SARS/18-F-1016_DOC_40_Army_UH-60M_Black_Hawk_SAR_Dec_2017.pdf.

the annual operating and support costs of 3.2 UH-60M Black Hawks would be $4.5 million per year.[4] We, therefore, conclude that additional MilTechs mechanics are a cost-effective means for expanding MC hours within the ARNG H-60 helicopter fleet.[5]



Note: Dot size is proportional to the number of total baseline MilTech mechanics, which include mechanics for H-60 helicopters, CH-47 Chinooks, and AH-64 Apaches. By contrast, the horizontal axis displays the ratio of total baseline MilTech mechanics per H-60 helicopter.

Marginal Effect of Additional MilTech Mechanics at ARNG AASFs on H-60 MC Hours

The figure illustrates the estimated additional H-60 helicopter MC hours for each AASF that would be realized if every AASF had an additional MilTech mechanic, based on the average MilTech mechanics per H-60 helicopter of AASFs in fiscal year 2019. The IDA team found that the marginal impact of an additional MilTech mechanic to be highest for AASFs with the least number of MilTech mechanics per H-60 helicopter at baseline. The positive returns of an additional MilTech decreases as the baseline number of MilTech mechanics per H-60 helicopter increases.

In this analysis, we investigate the impact of hiring additional MilTech mechanics on a measure of ARNG aviation equipment readiness. In fiscal years 2011 to 2019, we find that an additional MilTech reduces fault spell duration by between 0.7% and 1.1%, or an increase of

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[4] Department of Defense, "Fiscal Year (FY) 2021 Budget Estimates: Program Office Estimate for the UH-60M Black Hawk Helicopter" (Washington, DC: Department of the Army, February 2020).

[5] This is a simplified comparison. MilTechs cost more than their salary due to benefits, training, etc.

23-to-30 MC hours per helicopter-year. If every AASF had an additional MilTech mechanic in fiscal year 2019, ARNG would have gained 3.2 MC helicopter years across its H-60 helicopter fleet. Compared to the cost of other methods considered, hiring additional MilTech mechanics is a cost-effective means of expanding MC hours within the ARNG H-60 helicopter fleet.

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23 June 2021

What impact does maintenance manpower have on Army National Guard (ARNG) H-60 helicopter readiness?

We estimate a partial production function for the return to MilTech mechanics on H-60 helicopter readiness

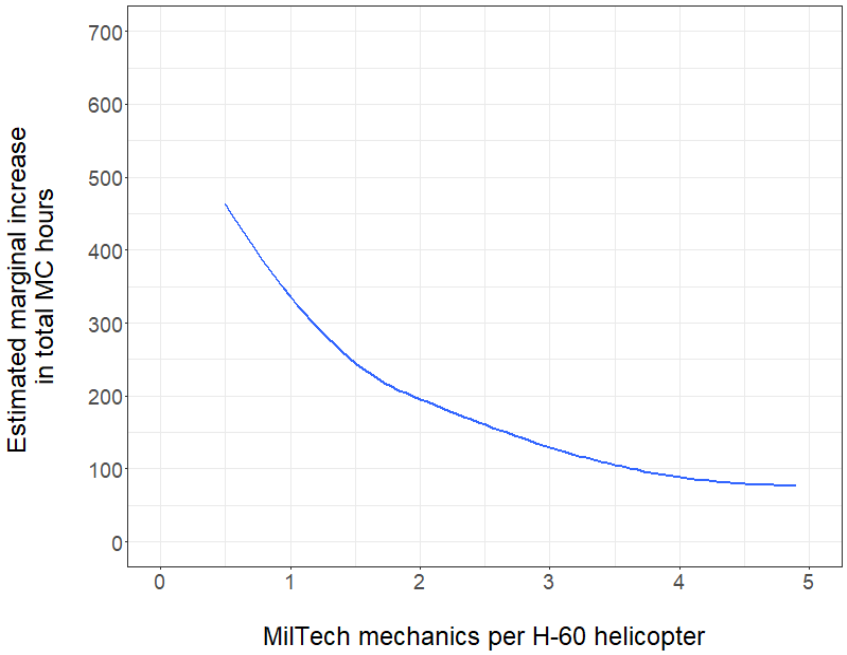
We produced…

Fleet-wide readiness estimates for an increase of one mechanic per facility

Facility-specific estimates

Helicopter-level estimates

A simple cost/benefit analysis



Background: ARNG Aviation Maintenance

The ARNG maintains approximately 1,500 helicopters

Mission Design Series	Number
UH-60 Black Hawk (1979)	899
HH-60 Pave Hawk (1982)	81
UH-72 Lakota (2007)	211
CH-47 Chinook (1962)	191
AH-64 Apache (1986)	73
OH-58 Kiowa (1969-2017)	0

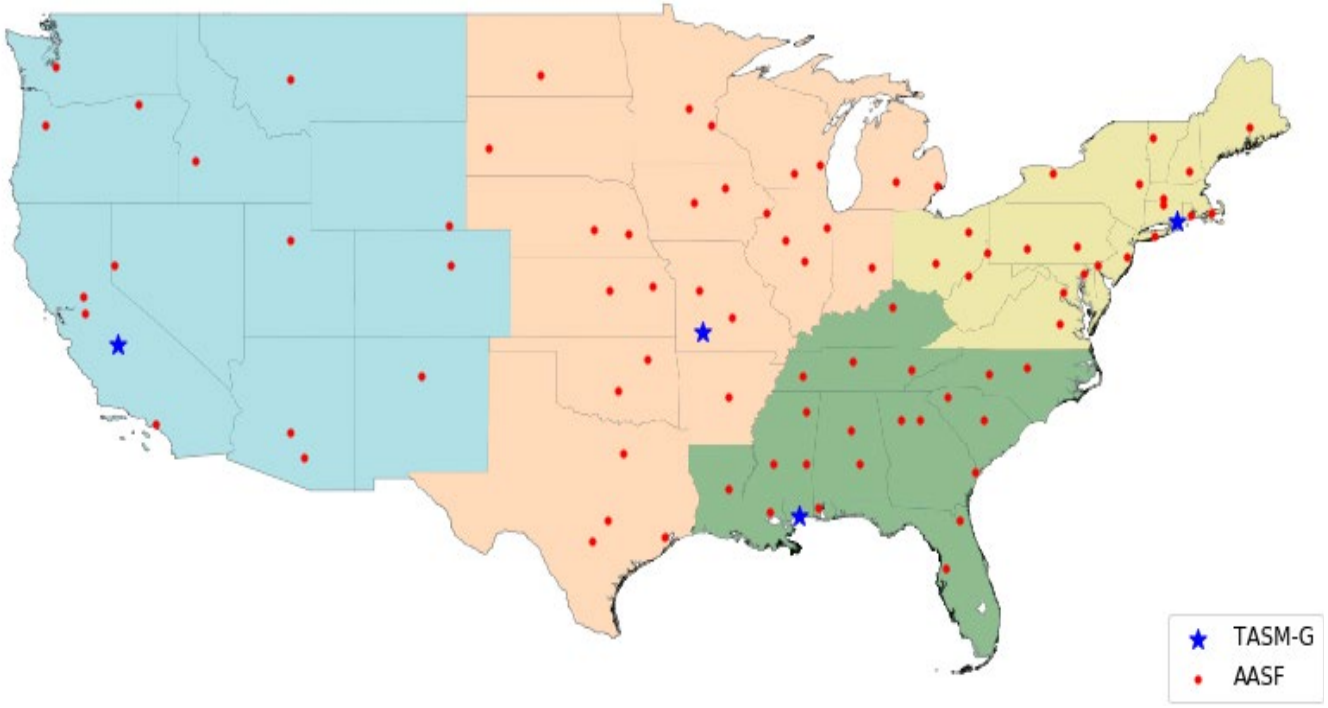
H-60 helicopters include:
UH-60 Black Hawks
HH-60 Pave Hawks

ARNG helicopter maintenance occurs at three levels

We study field maintenance at Army Aviation Support Facilities (AASFs)

*TASMG stands for Theater Aviation Sustainment Maintenance Group

There are 88 ARNG AASF facilities throughout the 54 states, territories, and the District of Columbia



Maintenance at AASFs focuses on making helicopters flyable, and less on repair of components

Unscheduled repairs and replacements

Scheduled inspections and replacements

Direct maintenance and backshop maintenance

Phase maintenance is the most significant scheduled maintenance

Dual-Status MilTechs are the primary source of aviation maintenance manpower

MilTechs are employed full-time by the ARNG and are required to be drilling ARNG members

A typical AASF has 21 MilTech mechanics

Other maintenance labor sources at the AASF are contractors, traveling teams from TASMGs, and Active Duty for Operational Support (ADOS)

Data

Data from eight different sources was obtained, processed, and combined

Data	Source
Readiness	(DA Form 1352) ARNG Aviation
Fault	(DA Form 2408 13-1) – Logistics Support Activity (LOGSA) Redstone contractor
MilTech	Defense Civilian Personnel Data System (DCPDS)
Uniformed Personnel	Reserve Component Manpower System – Guard (DCPDS)
ADOS	ARNG G1-HRM
Traveling Teams and Contractors	Aviation Roundout Maintenance Management System
Parts Orders	ARNG Aviation and Safety Division
Facilities	ARNG

After scoping the data we have 423,580 MilTech man-months and 190,342 fault spells from FY 2011 to 2019

Drop deployed personnel and helicopters

Drop non-AASF facilities

Restrict faults to non-flyable events; collapse into spells*

	Original	Regression set
MilTech man-months	633,170	423,580
MilTech mechanics	175,233	124,724
Number of facilities	104	77
Mean MilTech mechanics per facility	20.8	22.2
Number of faults/spells	6,238,663	190,342
Number of helicopters	1,249	1,199
Median duration (minutes)	4,294	225

* Discussed later

Multiple Imputation by Chained Equations (MICE) was used to impute missing data for 28 covariates

Iteratively impute missing variables with observed and previously imputed values

Requires Missing at Random (MAR)

Alternatives

Case-wise deletion - requires Missing Completely at Random (MCAR), violated

Drop variables with missing cases - causes omitted variable bias

Covariate	Percent complete
Man hours worked by traveling teams at the AASF	36.40%
Indicator for a customer unit mobilization or deployment in 12 months or less	83.40%
Indicator for a customer unit mobilization or deployment in 6 months or less	88.20%
Fraction of AASF's maintainers mobilized or deployed in 12 months	90.10%
Indicator for a customer unit mobilization or deployment in 3 months or less	90.70%

Note: Five multiply imputed datasets with 30 iterations each. van Buuren, S., & Groothuis-Oudshoorn, C. G. M. (2011). mice: "Multivariate Imputation by Chained Equations," *Journal of Statistical Software*, 45(3). http://www.jstatsoft.org/v45/i03

Modeling

We use a constructed measure of Fault Spell Duration to measure the effectiveness of MilTech mechanics

Many faults can be open for a single helicopter at any given time; thus, reducing an individual fault length may not affect helicopter downtime

We collapse overlapping red **X** airframe faults, and those separated by 30 minutes or less, into single Fault Spells

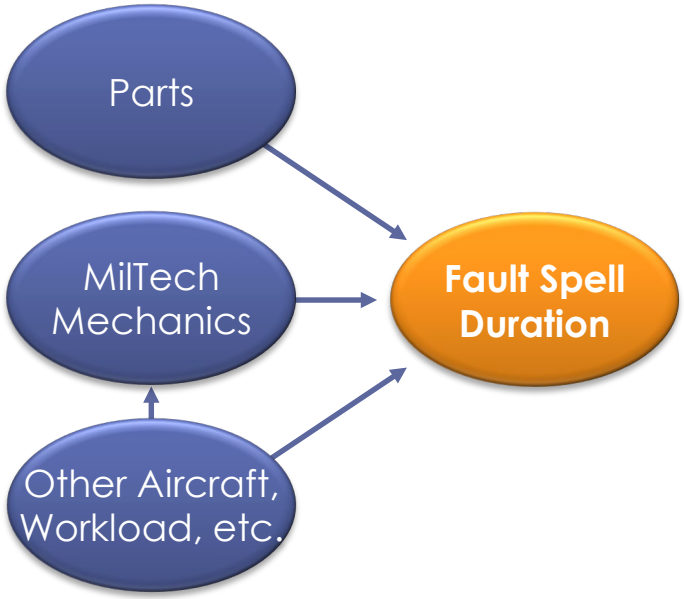
Fault Spell Duration is superior to reported readiness metrics because it correctly treats maintenance events that

1) Span readiness reporting periods as a single event, and
2) Are contained within distinct sets of days but within a reporting period as separate events

A Directed Acyclic Graph (DAG) was used to model the causal relationships and inform the econometric model

Estimating causal relationships with observational data is **difficult**

However, an adjustment criterion applied to a DAG informs how to construct a model in order to identify causal relationships



Note: Simplified DAG shown. Adjustment criterion from Perkovic et. al. 2015. "Article title." *Journal Title*. Volume #: pages referenced. DOI if possible.

Shipster et.al. 2012. "Article Title." *Journal Title*. Volume #: pages referenced. DOI if possible.

The adjustment criteria identified control variables

Which include:

Other types of personnel support

Other aircraft

Facility work load

Facility fixed-effects

Anticipated deployments

Tail number flight hours

Tail number maintenance history

Fault Spell type

Type of helicopter

And more…

```
> library(dagitty)
>
> # Create DAG
> dag <- dagitty("dag {
+   MilTech_Mechanic -> Fault_Spell_Length
 ⋮
+   Facility_Features -> Fault_Spell_Length
+   Facility_Features -> MilTech_Mechanic
+                }")
>
> # Get control variables
> print( adjustmentSets(
> +  dag,
> +  exposure = "MilTech_Mechanic",
> +  outcome = "Fault_Spell_Length",
> +  type = "canonical",
> +  effect = "total" ) )
 { Facility_Features, Aircraft_Type, ...,
Flight_Intensity }
```

The econometric model combines a mathematical formula with data to produce the causal estimates

A Generalized Additive Model (GAM) flexibly estimates the causal relationship with a non-parametric cubic B-spline

$$\log\left(fault\ spell\ duration_{ij}\right) = f\left(Mechanics_{ij}\right) + X'_{ij}\beta + \epsilon_{ij}$$

A first forward difference estimates the percent decrease in Fault Spell Duration for a one MilTech mechanic increase

$$\hat{d}\left(Mechanics_{ij}\right) = \hat{f}\left(Mechanics_{ij} + 1\right) - \hat{f}\left(Mechanics_{ij}\right)$$

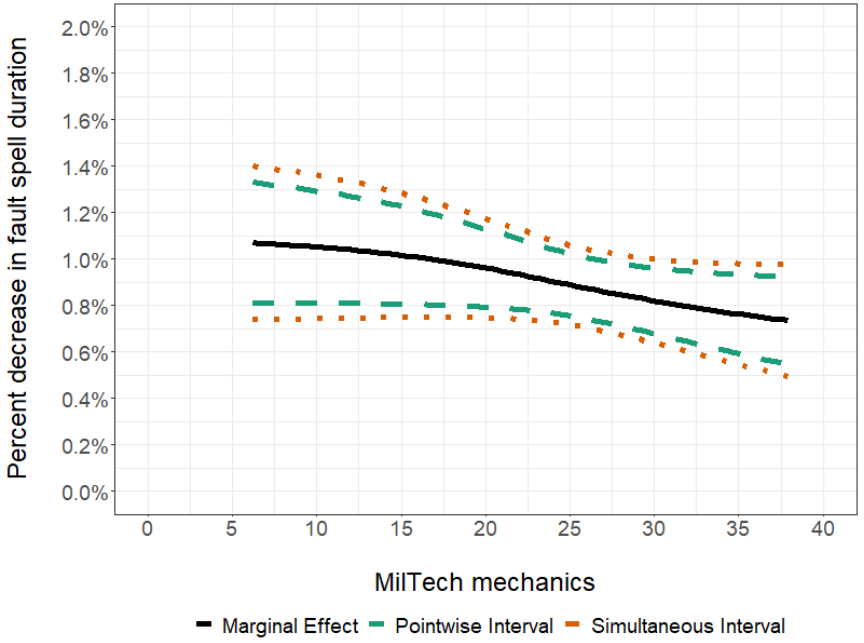
Note: Control variables included in X. Standard errors clustered at tail number level. Wood. 2017. "Article Title." *Journal Title*. Volume #: Pages referenced. DOI if possible.

Results

All AASFs have a statistically significant decrease in Fault Spell Duration with an additional MilTech mechanic

For the average AASF of a given size, an additional MilTech mechanic decreases H-60 helicopter Fault Spell Duration by **0.7% to 1.1%**

Seemingly small reductions accumulate to large improvements over the fleet



Note: 95% confidence

What if each AASF facility in fiscal year 2019 had an additional MilTech mechanic?

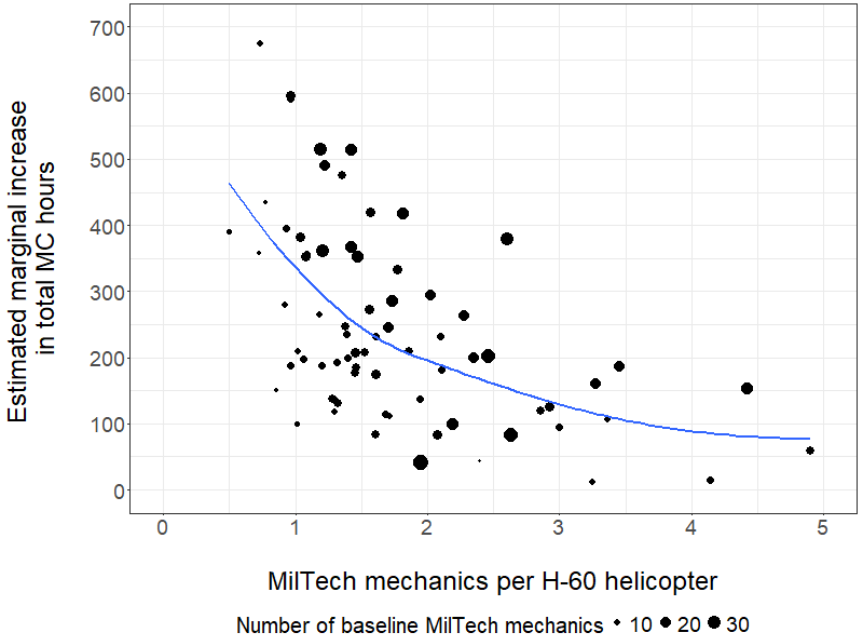
We apply the econometric estimates to the reported Not Mission Capable (NMC) time in fiscal year 2019 to produce this counterfactual

We find the H-60 helicopter fleet would have effectively **gained 3.2 additional H-60 helicopter** ready-years

Positive impact of additional MilTechs weaken as mechanic manpower per H-60 helicopter increases

Some facilities appear significantly understaffed

For example, an AASF would have gained more than **650 additional MC hours** on average in fiscal year 2019 if it had an additional MilTech mechanic



Note: Dot size is proportional to the number of total baseline MilTech mechanics, which include mechanics for H-60 helicopters, CH-47 Chinooks, and AH-64 Apaches. By contrast, the horizontal axis displays the ratio of total baseline MilTech mechanics per H-60 helicopter.

Increasing MilTech mechanic headcounts is a cost-effective way to obtain H-60 helicopter MC hours

The salary for 74 additional MilTech mechanics is roughly **$4.8 million**

The gain of 18,509 additional MC hours would cost approximately **$262 per MC hour** on average in additional annual wages

Borrowing a UH-60M Black Hawk costs **$2,920 per hour**

Procuring 3.2 new UH-60M Black Hawks costs **$74 million**; the annual operating and support costs of 3.2 UH-60M Black Hawks would be **$4.5 million per year**

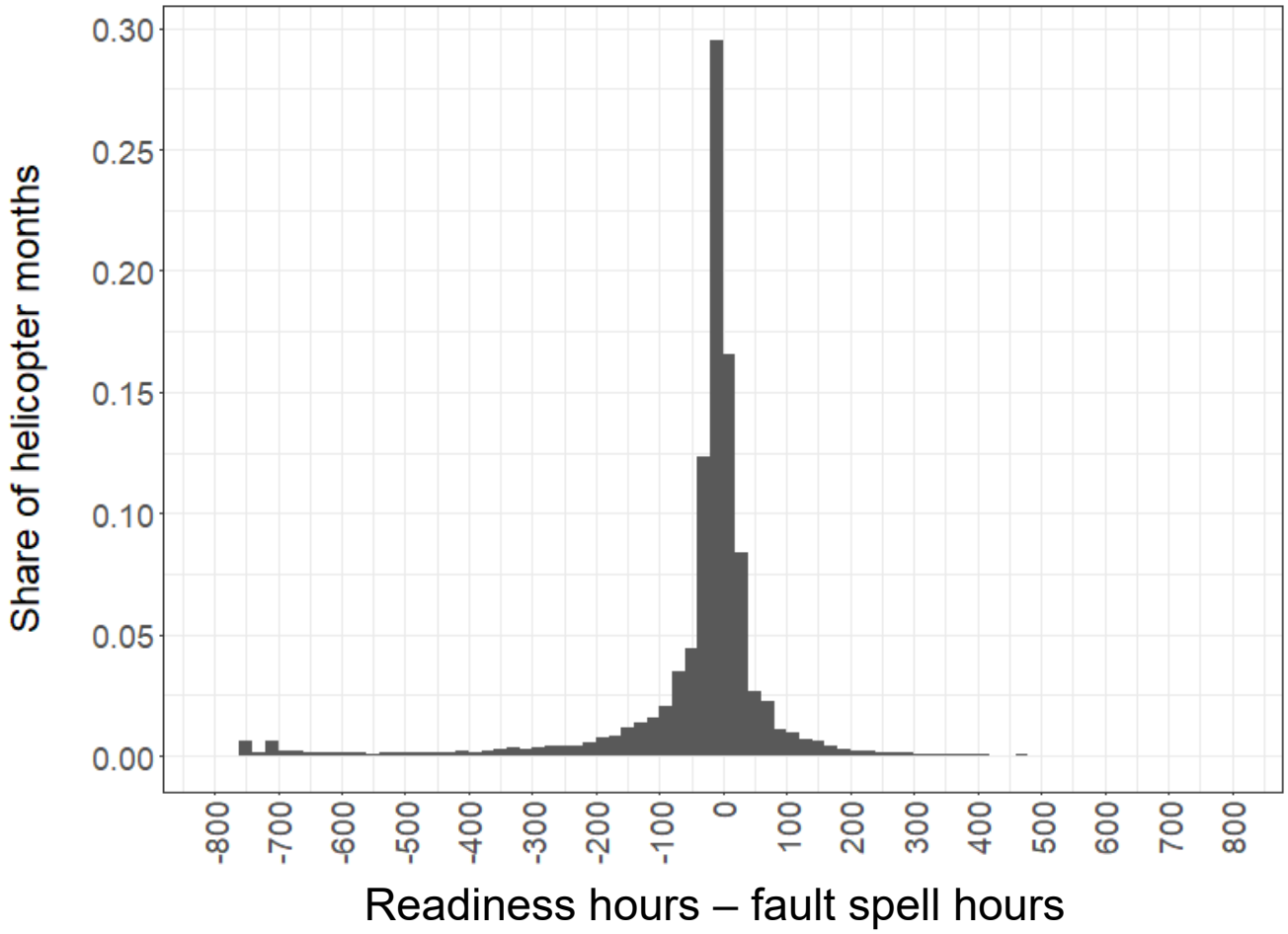
Note: Office of The Under Secretary of Defense, "Fiscal Year (FY) 2020 Department of Defense (DoD) Fixed Wing and Helicopter Reimbursement Rates." Program Office Estimate, UH-60M Black Hawk Helicopter, Selected Acquisition Report. December 2018. Adjusted for inflation.

Conclusion

We find that increasing MilTech mechanic headcounts produces an increase in H-60 helicopter readiness that is both economically meaningful and cost effective

Appendix

Fault Spell Duration is a good approximation to reported readiness rates on average



Latent Dirichlet Allocation (LDA) model was used to extract information from fault free-text fields

Using data from free-text fields reduces statistical uncertainty

LDA generates common topics; each fault is assigned to a topic

Number of topics chosen by AIC

Preprocessing

Remove stop words and symbols

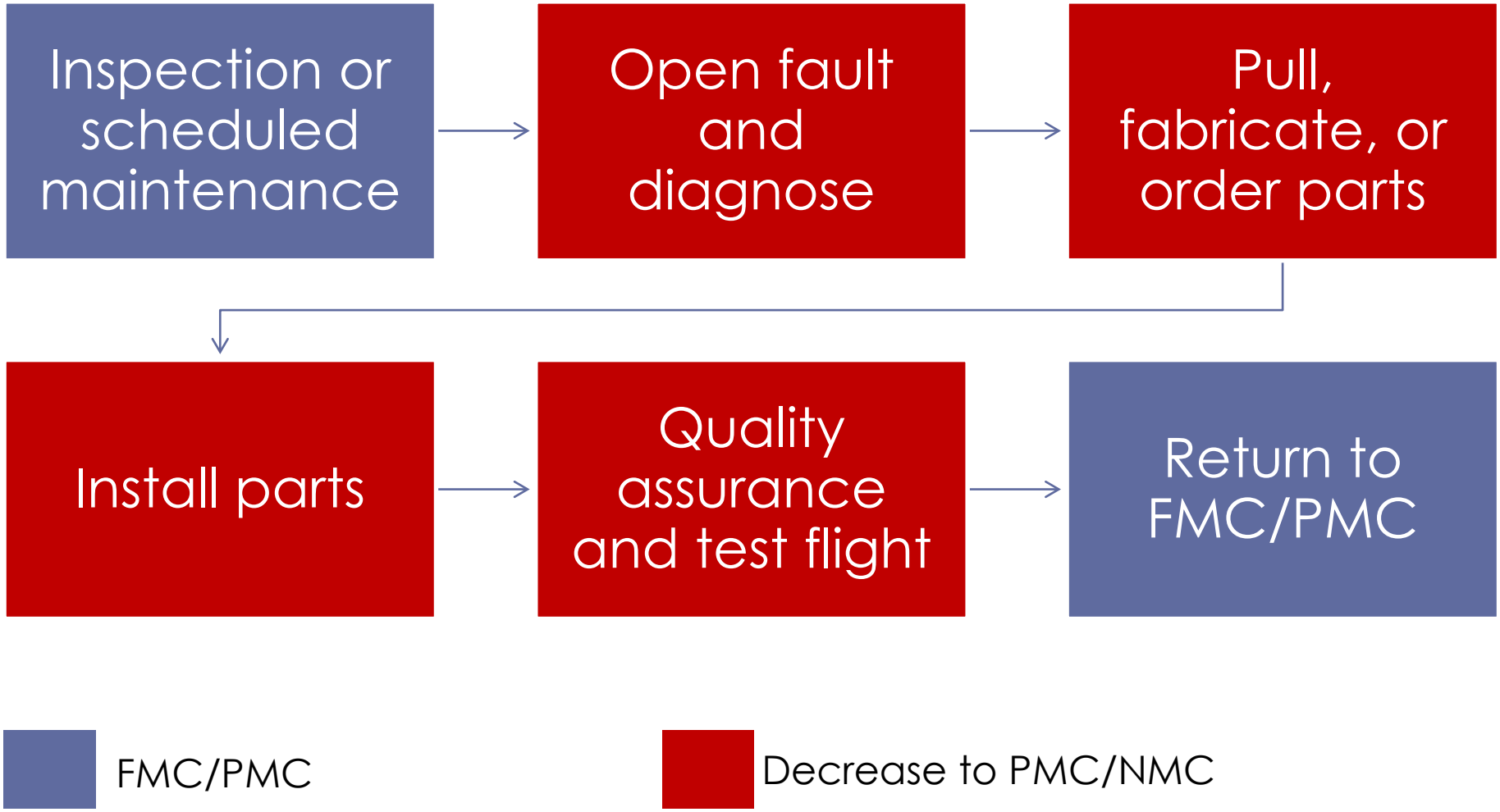
Lemmatization and stemming

Original	Processed	Topic
#1 HYD PUMP RETURN LINE QD NOT TQ, CAN BE SPIN FREELY BY HAND	pump, line, freeli, hyd, return, spin	4
INBOARD SEAL OF RED TAIL ROTOR BLADE BOOT HAD DISBONDED AND IS SEPERATING FROM ZIP TIE	boot, seal, tail, zip, seper, rotor, tie, disbond, blade, inboard	27
BLOT ON TAIL ROTOR SERVO LINK CONNECTED TO PUSH ROD HAS IMPROPERLY INSTALLED COTTER PIN	tail, rod, servo, connect, instal, rotor, cotter, pin, push, link, improp	10

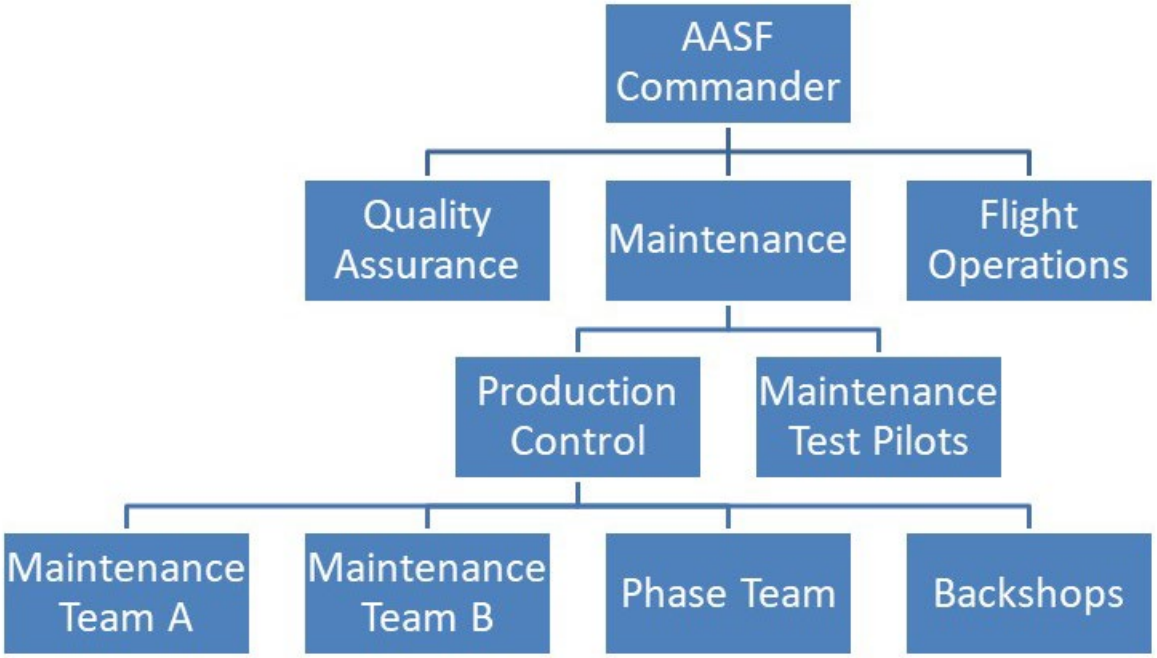
See Blei, D. M., A. Y. Ng, and M. I. Jordan. "Latent Dirichlet Allocation." *Journal of Machine Learning Research 3* (January, 2003): 993–1022. http://jmlr.org/papers/volume3/blei03a/blei03a.pdf.

AIC – Akaike Information Criterion

The maintenance fault process



Organization chart of a typical AASF



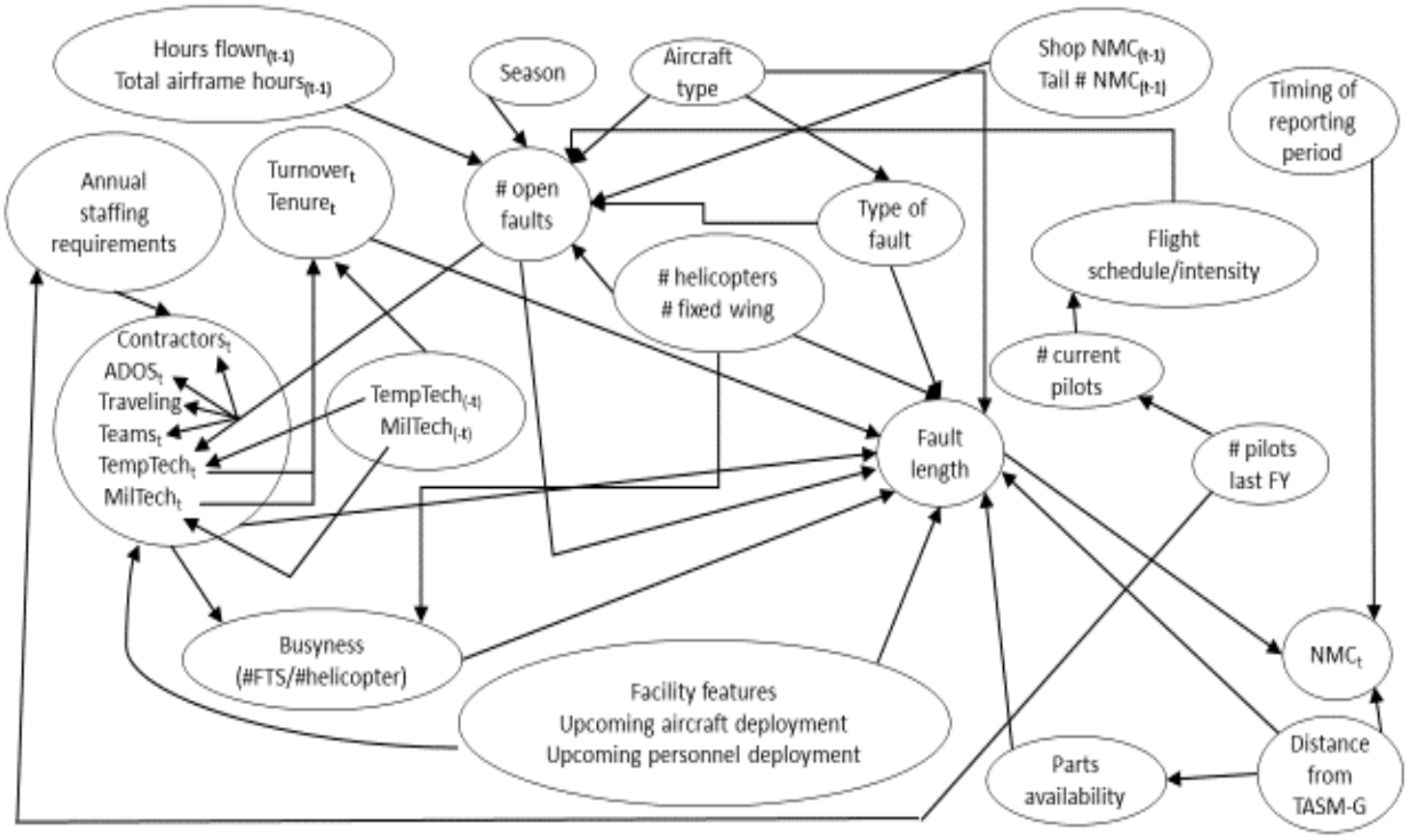
Readiness projections are only for the fiscal year 2019 H-60 helicopter fleet

We attempted to obtain data for other helicopters but the POC could only pull partial historical maintenance records

Many AASFs contain other aircraft (e.g., Chinooks and Apaches) in addition to H-60 helicopters; we controlled for the presence of other aircraft and their workloads at the AASF level, but only study H-60 helicopters directly

We control for backshop MilTech maintainers at each AASF, but do not count them as direct labor MilTech mechanics in our analyses

The expanded DAG captures all the relationships between MilTech mechanics and fault length



If a MilTech mechanic were added to each AASF, the fleet effectively gains 3.2 H-60 helicopter ready-years

There are **74** AASF facilities with **at least one** H-60 helicopter year

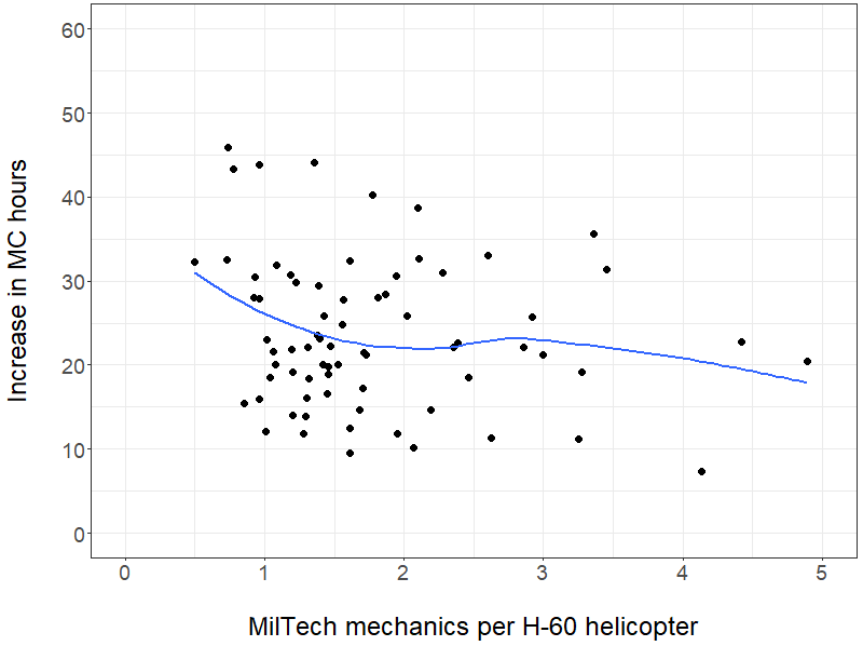
Adding an additional MilTech mechanic to each facility would produce an additional **18,509 mission capable (MC) hours** (or 771 additional MC days) across the H-60 helicopter fleet on average

A typical H-60 helicopter had **5,723 MC hours** in fiscal year 2019

Thus, hiring an additional MilTech mechanic in each of the 74 AASFs in fiscal year 2019 is roughly equivalent to gaining **3.2 additional H-60 helicopters**

We produced helicopter-specific results

An individual H-60 helicopter will gain 18 to 31 additional MC hours on average if its AASF had an additional MilTech mechanic in fiscal year 2019



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14. ABSTRACT

This study quantified the relationship between maintenance manpower investments and H-60 helicopter readiness in the Army National Guard (ARNG). Using causal econometric methods, we found that increasing the number of MilTech mechanics at ARNG Army aviation support facilities (AASFs) of all sizes reduces helicopter maintenance timelines to a statistically significant extent. Grouping faults into contiguous "fault spell" downtime events, we estimate that an additional MilTech mechanic decreases average fault spell duration by 0.7% to 1.1% (depending on baseline MilTech staffing levels). Downtime reductions were greatest for maintenance facilities with lower initial MilTech mechanic headcounts. These downtime reductions accumulate over ARNG H-60 NMC resolution maintenance at the AASF level. We estimated that the addition of a single MilTech mechanic to each ARNG AASF would produce 18 to 31 additional mission capable (MC) hours per H-60 helicopter, or 3.2 additional ready helicopter years across the ARNG's fiscal year 2019 H-60 fleet. These results can provide targeted readiness-enhancing staffing recommendations appropriate for a resource constrained environment by informing placement of additional MilTech mechanics. Per additional ready H-60 helicopter year, we found that additional MilTech manpower is a more cost-effective way to improve readiness than borrowing or buying additional UH-60M Black Hawks.

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Army National Guard, Full Time Support, MilTech, Aviation, H-60, Helicopter, Production function

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