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Building End-to-End Sustainment Models for Weapon Systems

Vincent "Bram" Lillard
Han Yi

June 2021

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4850 Mark Center Drive
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About This Publication

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For more information:

Vincent "Bram" Lillard, Project Leader
vlillard@ida.org • (703) 845-2230

Robert R. Soule, Director, Operational Evaluation Division
rsoule@ida.org • (703) 845-2482

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Building End-to-End Sustainment Models for Weapon Systems

Vincent "Bram" Lillard
Han Yi

Executive Summary

Bottom-up emulations of real sustainment systems that explicitly model spares, personnel, operations, and maintenance are a powerful way to tie funding decisions to their impact on readiness, but they are not widely used. The simulations require extensive data to properly model the complex and variable processes involved in a sustainment system, and the raw data used to populate the simulation are often scattered across multiple organizations.

IDA has worked with military and civilian sponsors to construct such end-to-end simulation models for maritime and aviation weapon systems and to investigate the strategic levers that drive readiness. In this conference presentation, we describe the complexities of properly emulating sustainment concepts and argue for the urgency of increased end-to-end modeling efforts in improving readiness across weapon systems.

First, we discuss the challenges in aggregating and interpreting sustainment data to generate component-level metrics and how we employ statistical best practices to overcome these challenges. Next, we showcase notional examples of excursions into specific investments. Finally, we illustrate how the ability to examine the combined

effects of multiple investments is pivotal in helping senior decision-makers make better investment decisions to improve readiness.



Building end-to-end **sustainment** models for weapon systems

Han G. Yi, PhD
Research Staff Member

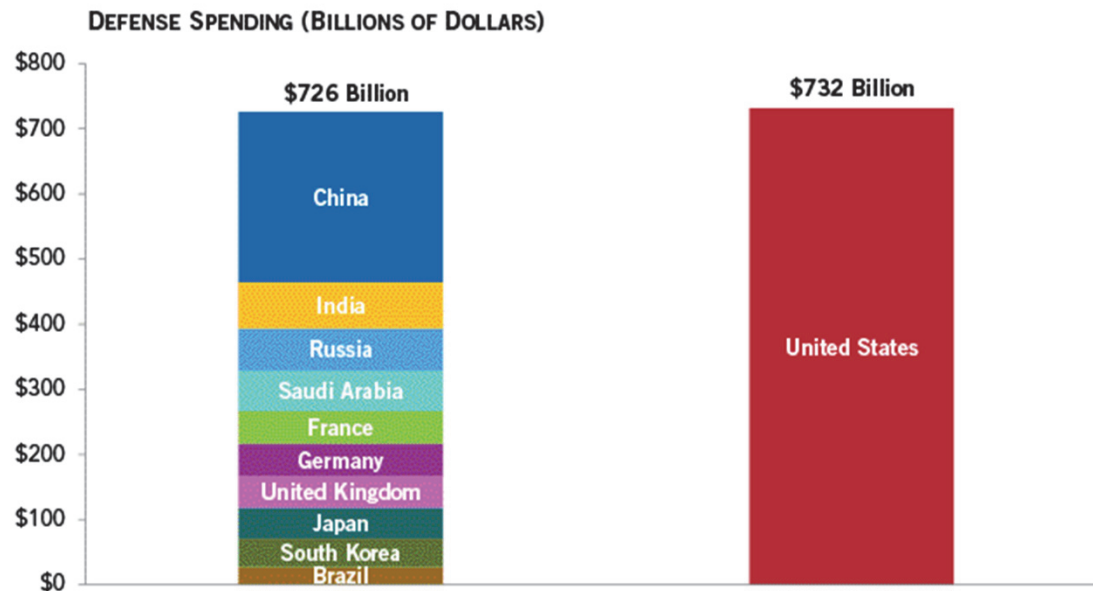
V. Bram Lillard, PhD
Project Lead

June 2021

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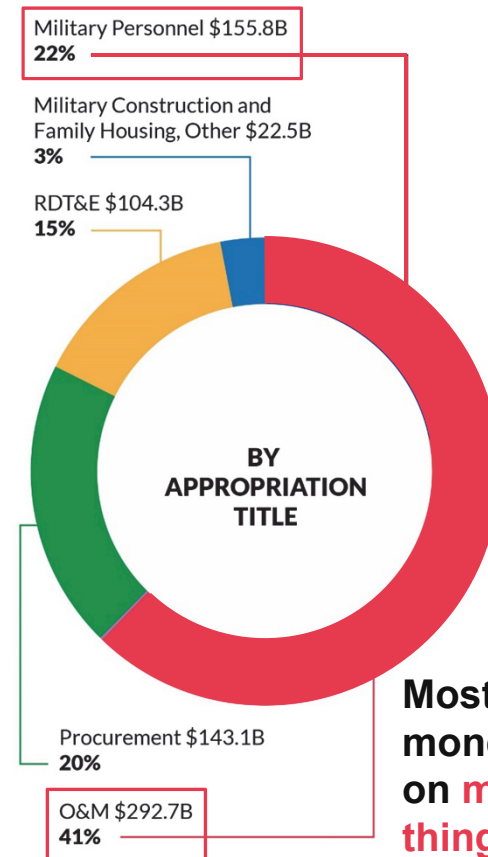
Federal government spends \$400B+ / year on **operating and sustaining** DoD systems

DoD spends \$700B+ each year (~\$2B/day)



SOURCE: Stockholm International Peace Research Institute, SIPRI Military Expenditure Database, April 2020.
NOTES: Figures are in U.S. dollars converted from local currencies using market exchange rates. Data for the United States are for fiscal year 2019, which ran from October 1, 2018 through September 30, 2019. Data for the other countries are for calendar year 2019. The source for this chart uses a definition of defense spending that is more broad than budget function 050 and defense discretionary spending.
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PGPF.ORG



<https://www.defense.gov/Explore/News/Article/Article/1782973/dod-leaders-make-case-to-congress-for-budget-request/>

Most of the money is spent on **making sure things work properly**

The end metric is system **“readiness”** to perform missions

Readiness is a persistent challenge for the DoD weapon systems

Breaking News

Mattis orders fighter jet readiness to jump to 80 percent — in one year

By: Aaron Mehta October 9, 2018



Specific to tactical aircraft, [...] the F-22 Raptor a shocking **49.01 mission capable rate**.

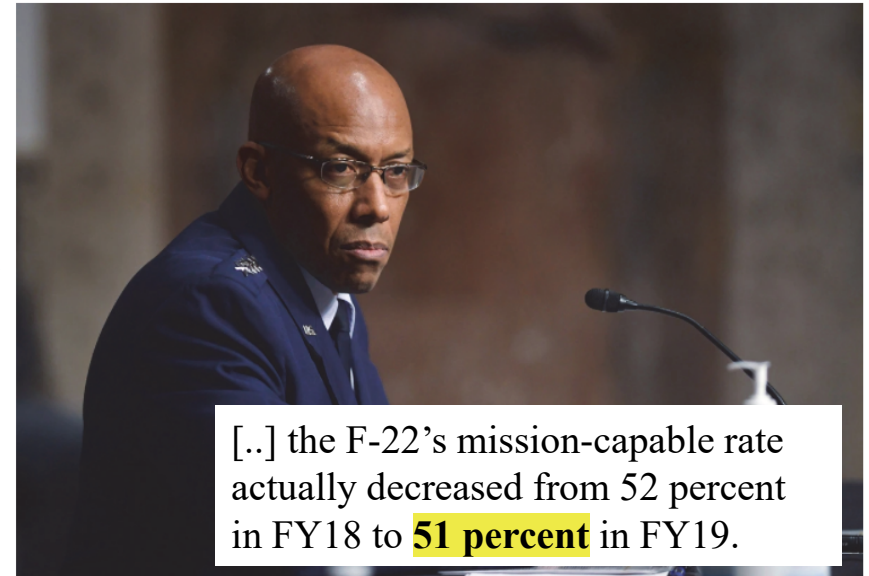
<https://www.defensenews.com/air/2018/10/09/mattis-orders-fighter-jet-readiness-to-jump-to-80-percent-in-one-year/>

18 months later...

Air

US Air Force bails on Mattis-era fighter jet readiness goal

By: Valerie Insinna and Stephen Losey May 7, 2020

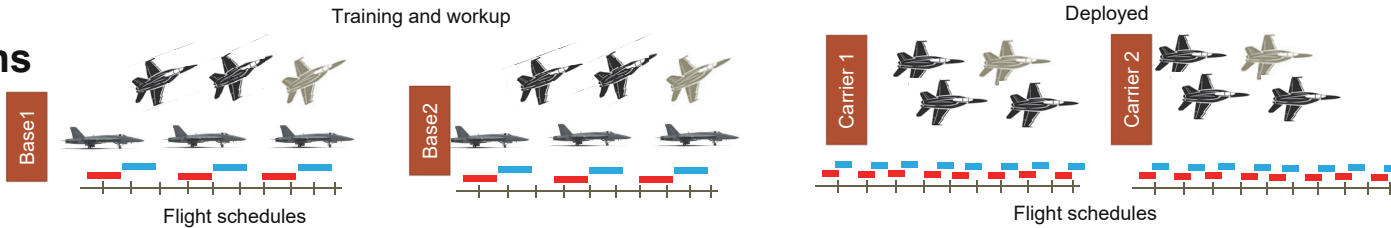


[..] the F-22's mission-capable rate actually decreased from 52 percent in FY18 to **51 percent** in FY19.

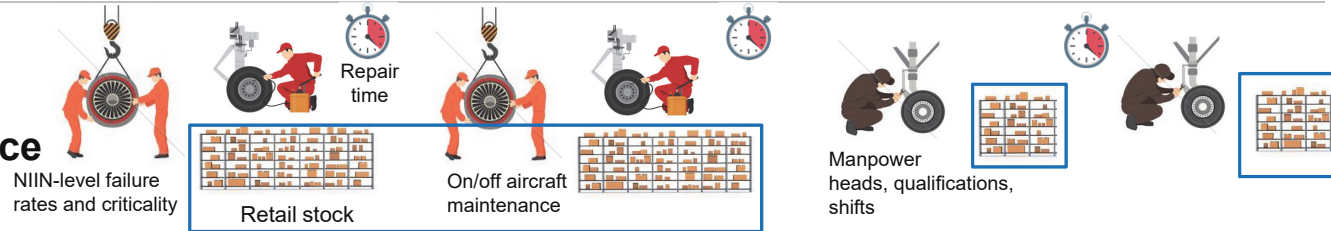
<https://www.defensenews.com/air/2020/05/07/the-air-force-bails-on-mattis-era-fighter-jet-readiness-goal/>

Why is readiness so difficult to maintain?

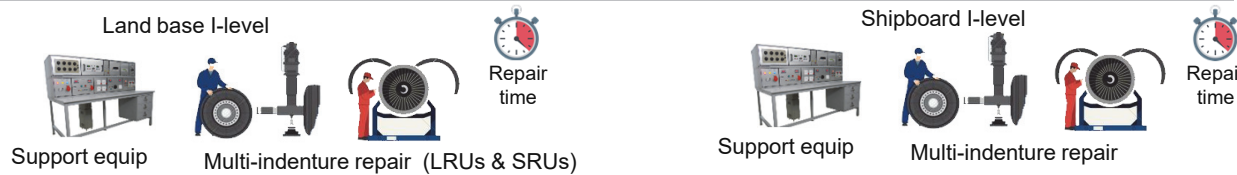
Operations



O-level* Maintenance



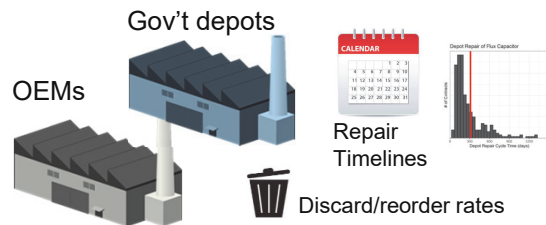
I-level** Repair



Wholesale



D-level*** Component repair



D-level System repair



Sustainment:
What goes into making sure systems are ready?

* Operational-level
** Intermediate-level
*** Depot-level

The Supply Challenge: Can you order and stock groceries for 1,000+ households a year in advance?

A single household has
“demands” with **limited funds**

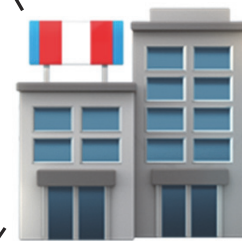


Optimal purchases must foresee **fluctuating demands** over time

Other households will have **different demands**



Local retail stores must have corresponding stock

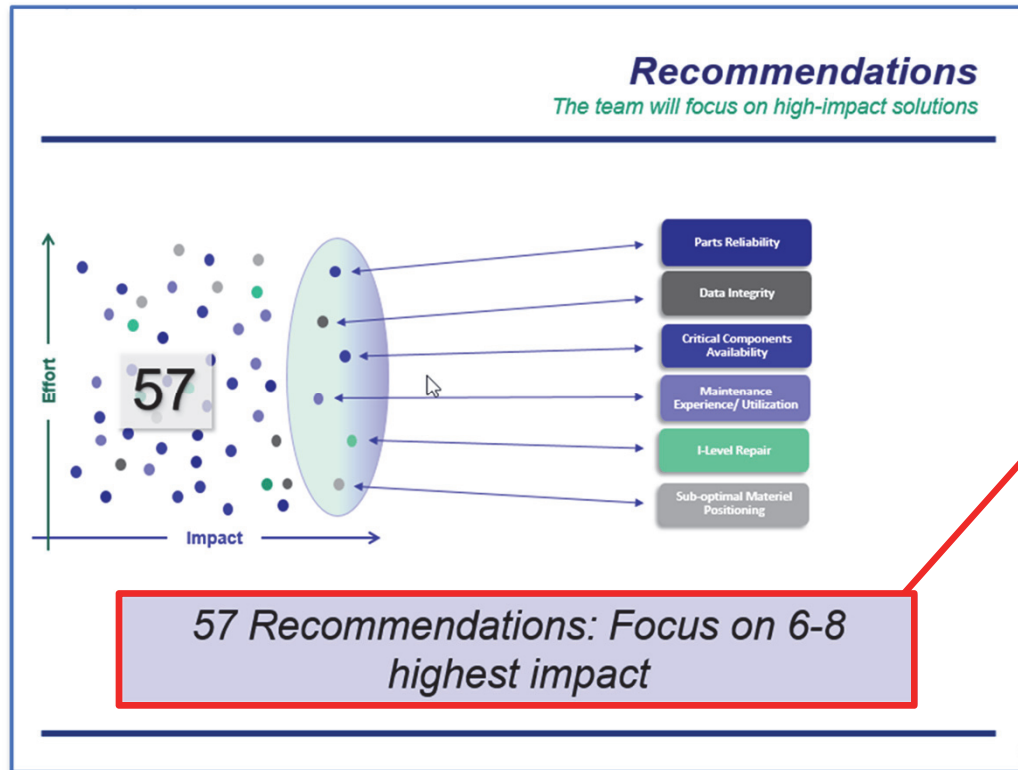


All retail stores are stocked
through **wholesale**



There is no shortage of potential investments DoD could make to improve readiness

Example readiness report from DoD gives
many such recommendations ...



... but how do we know which actions are best?

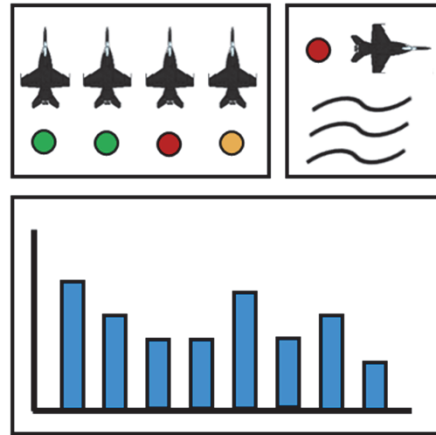
... how much to spend?

... what our returns will be?

IDA model's value added comes from quantification of specific investments

IDA takes a comprehensive **simulation**-driven approach to map out all aspects of sustainment and their effects on readiness outcomes

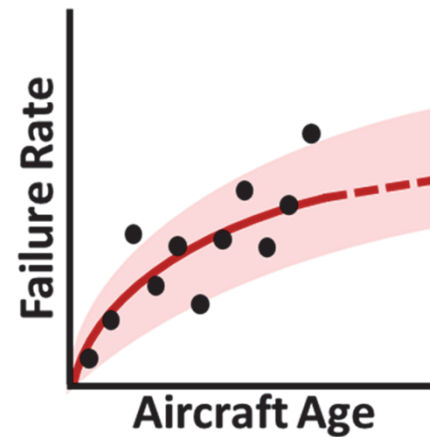
Robust Data-Driven
Decision Making =



Data visualization / dashboards

- Quickly provides ground truth
- Good for diagnosing shortcomings
- Can't make predictions
- Can't tie decisions to outcomes

+



Correlative studies

- Statistical approaches including machine learning
- Historical trends can reveal which factors may drive performance
- Not enough details to support decision-making using "what-if" scenarios

+



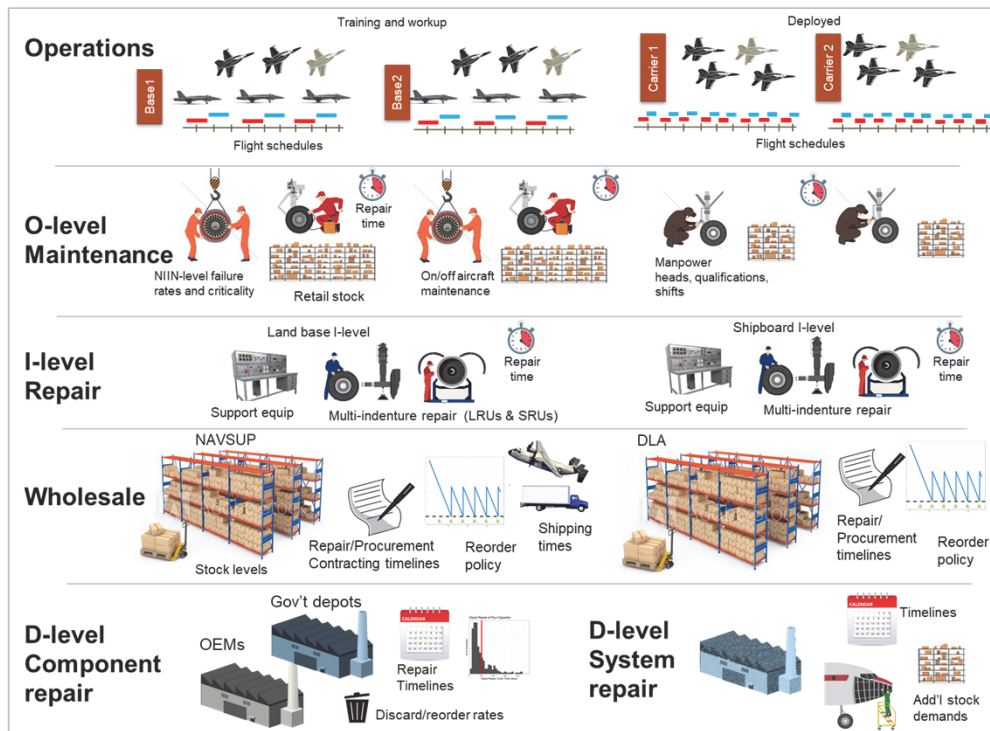
End-to-end simulation

- Explicitly model all aspects of sustainment (spares, manpower, operations, maintenance)
- Make predictions on how specific investments cause changes in readiness
- Model quality is contingent on data quality
- Heavy initial lift to build the model

DoD does little of this approach →

IDA's End-to-End Sustainment Modeling

We use time-varying discrete event simulation on the entire sustainment structure (down to individual parts!) such that we can examine end-to-end effects



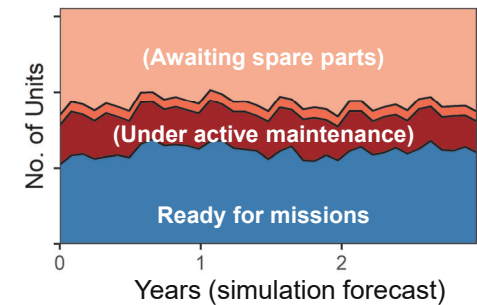
~200,000 lines of input data

What happens ...

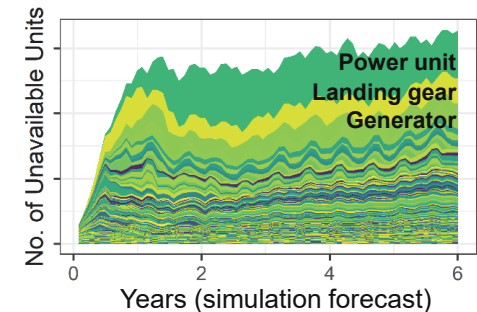
If wholesale stock is increased? If depot repair times are shortened? ...

So how do we construct these models?

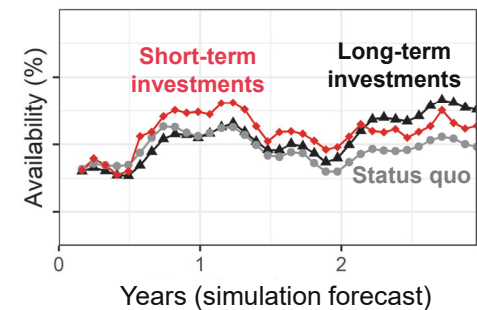
How many units will be “ready”?



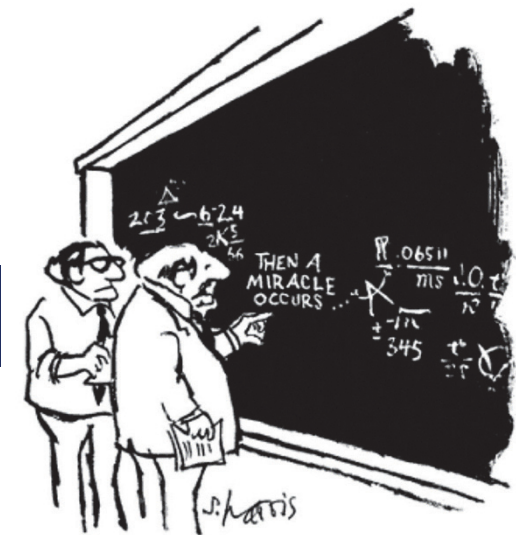
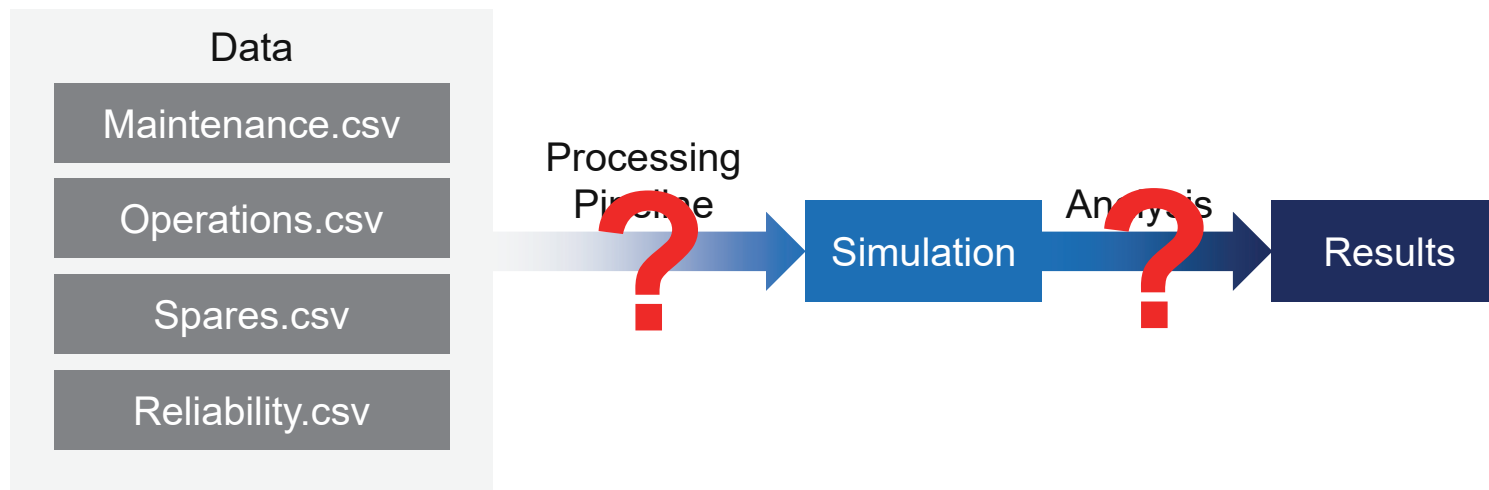
Which items are likely to cause problems?



Which investment path meets DoD's needs?



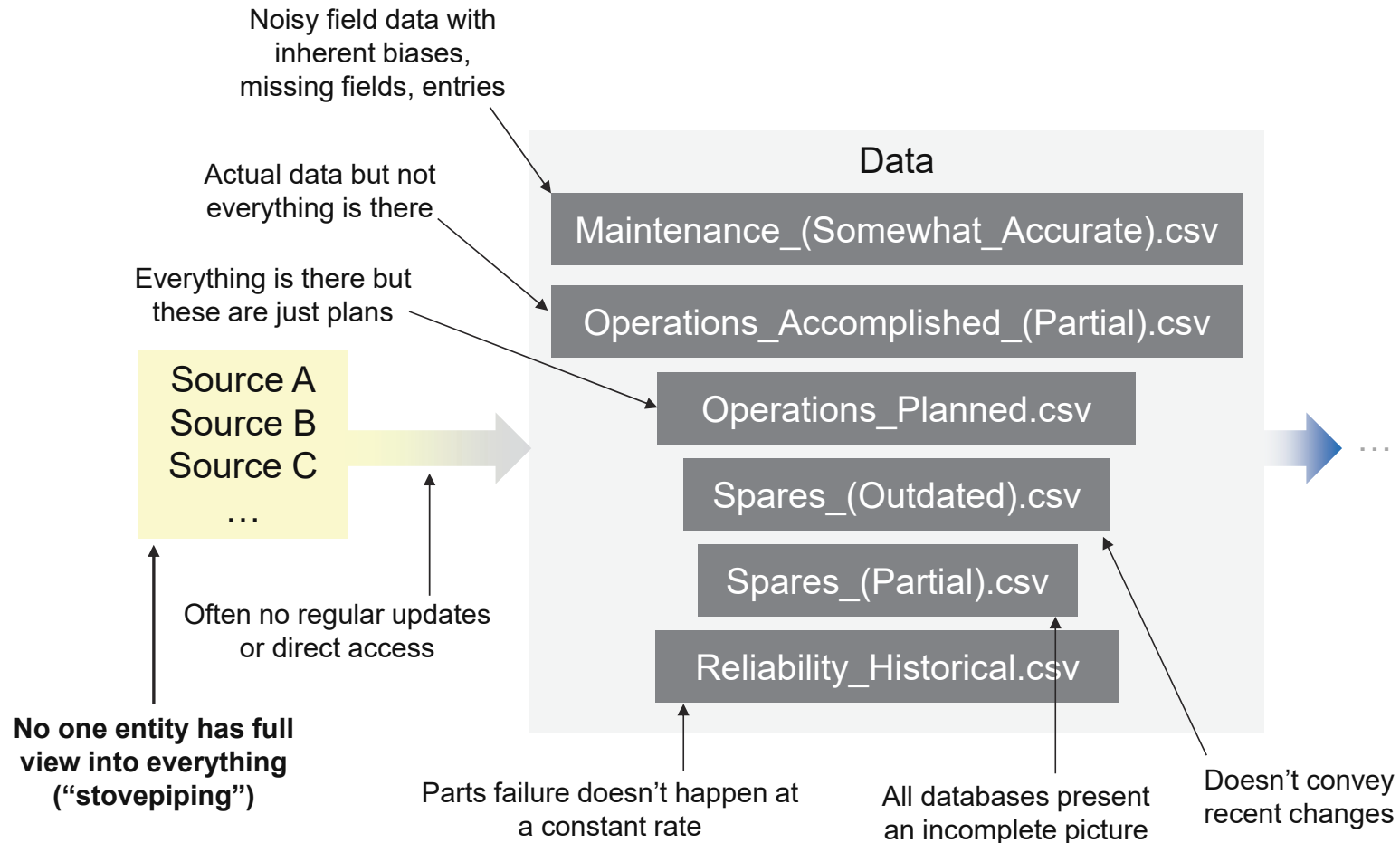
We want to obtain the ground truth on real-world sustainment, process the data, and enter it in the simulation model to get the results



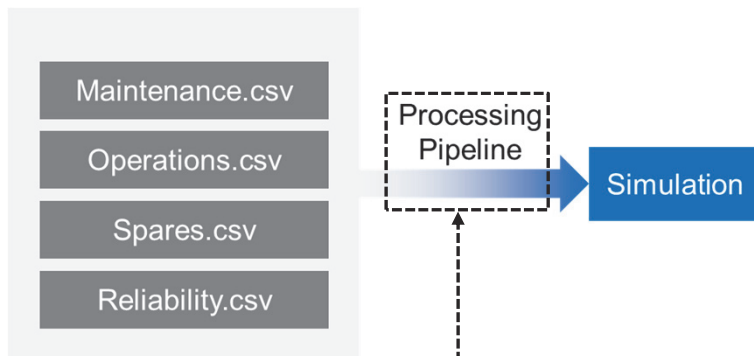
"I think you should be more explicit here in step two."

In practice, this is very difficult to achieve!

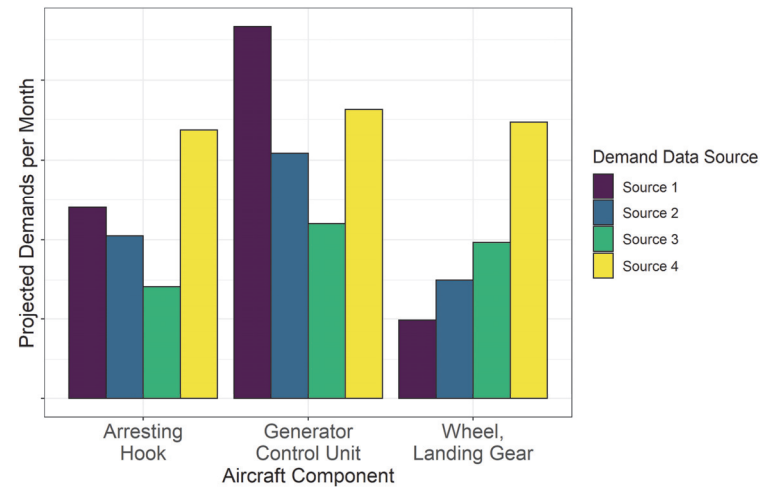
In reality, there is **no “one-stop-shop”** for all databases in the DoD



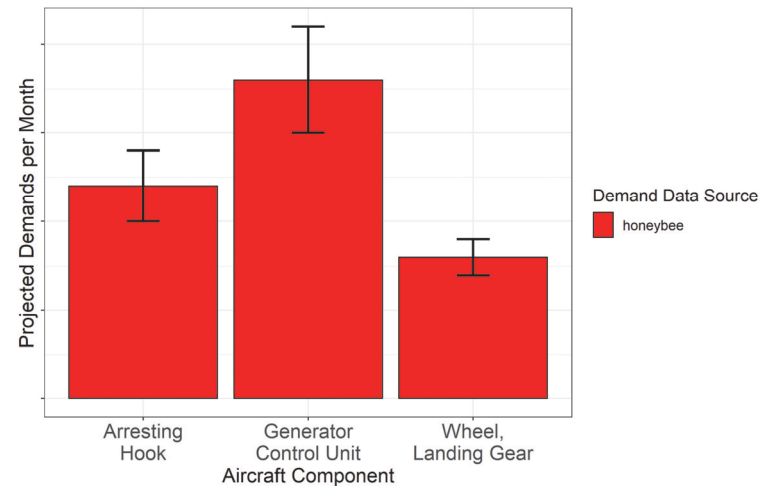
Even after getting the data, there is **no “one value” for key metrics**



Once we have the raw data, estimating and calculating the inputs to the model should be straightforward, **but ...**



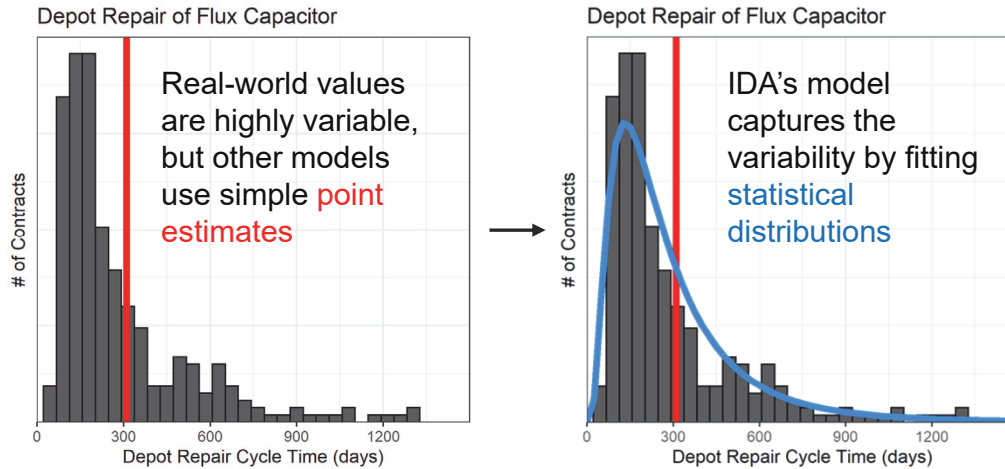
Raw data sources often provide very different calculation methods and estimates for **key metrics** (e.g., how often do these parts fail?)



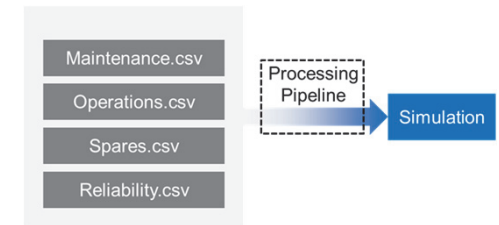
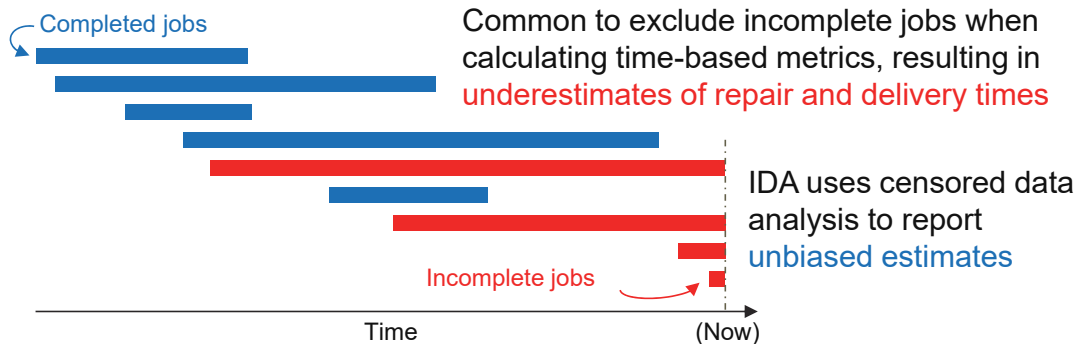
Consulting with subject matter experts enables us come up with **“rules” to translate data into model input**

We use statistical best practices to better estimate the model inputs from raw data

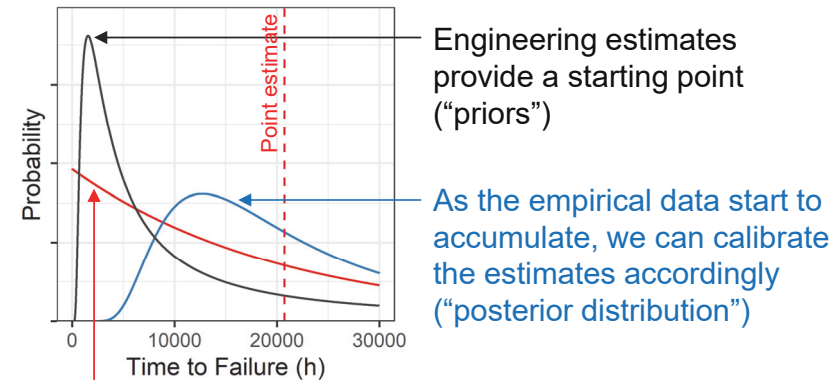
1 | Simple parametric fitting



2 | Censored data analysis (Survival Analysis)

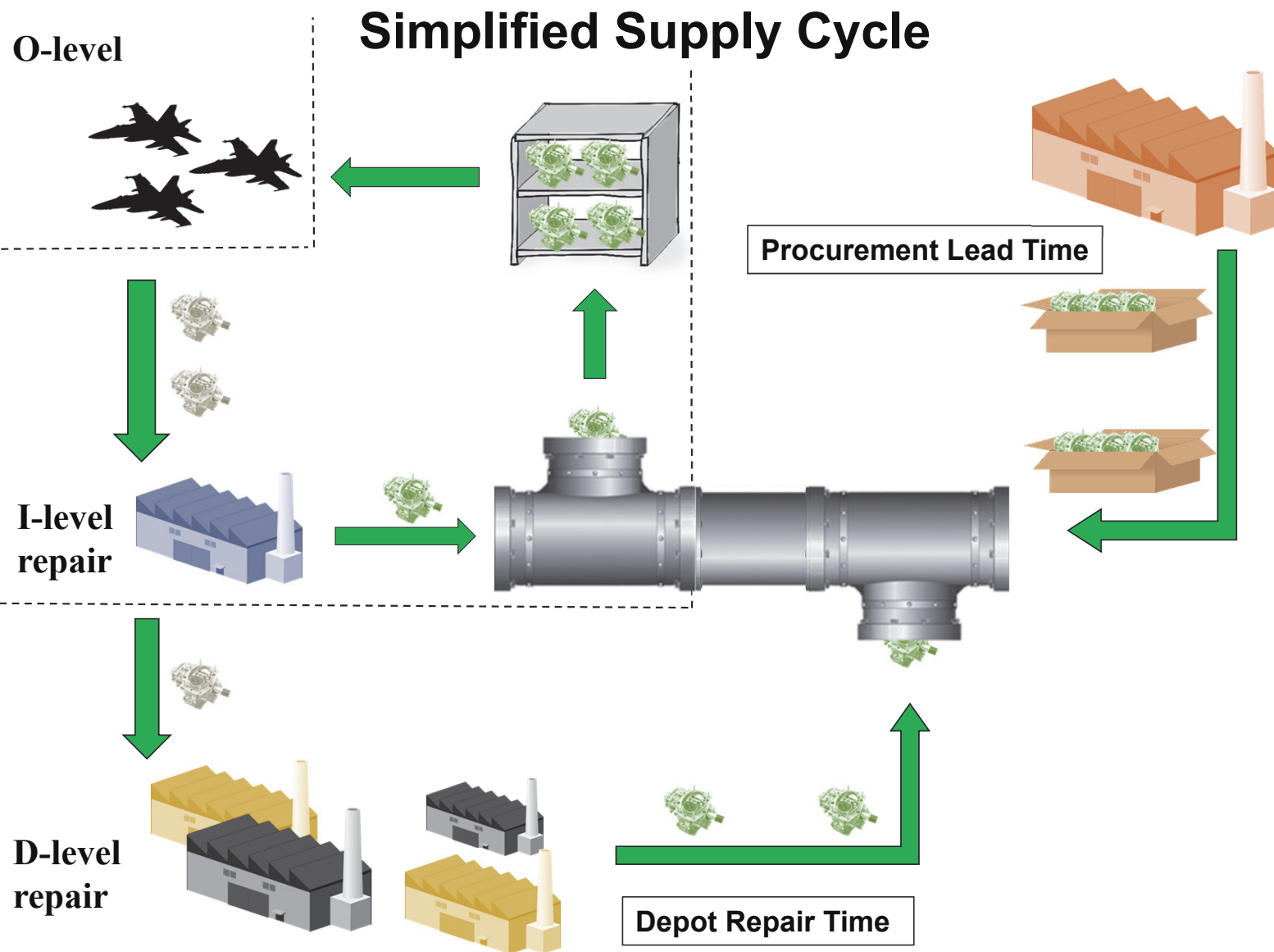


3 | Bayesian analysis



Point estimates are unreliable when the empirical data are scant (e.g., recently introduced component has failed only once or twice)

Using End-to-End Models to Guide Decision-Making



Simplified Supply Cycle

O-level

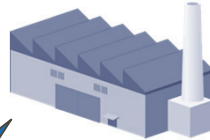
Block Upgrades
... Newer configurations might decrease failure rates or maintenance time?



Improve Reliability
... implement a reliability improvement program? Which parts?

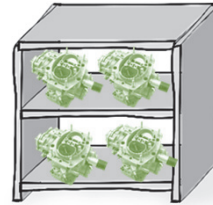
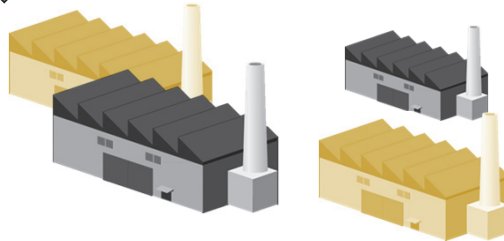


I-level



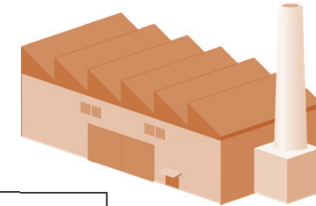
...stand up a new repair capability here?

D-level



Procurement Lead Time

Spares
...just buy more so the long repair times have less impact?



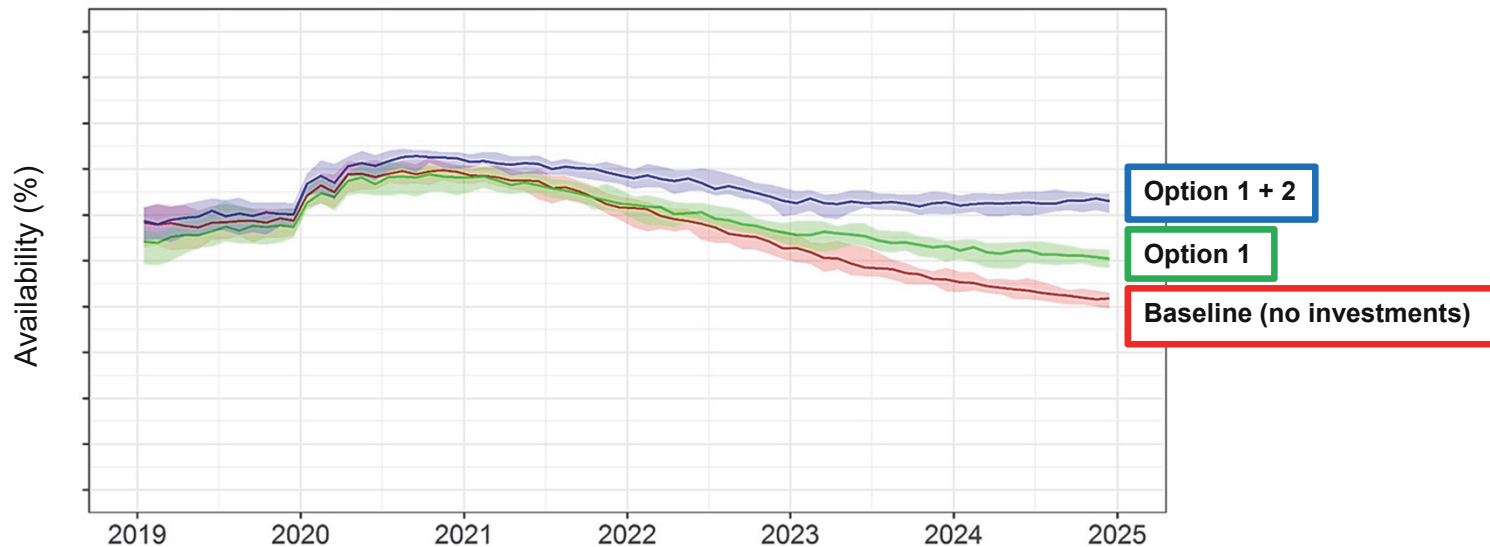
Could negotiate contracts with vendors to speed this up...

Depot Repair
...maybe increase capacity at Depots to speed this up...

Depot Repair Time

Our efforts guide real-world decision-making by **quantifying** benefits of specific “what-if” scenarios

1 | What is the timeline for implementing the proposed improvements?



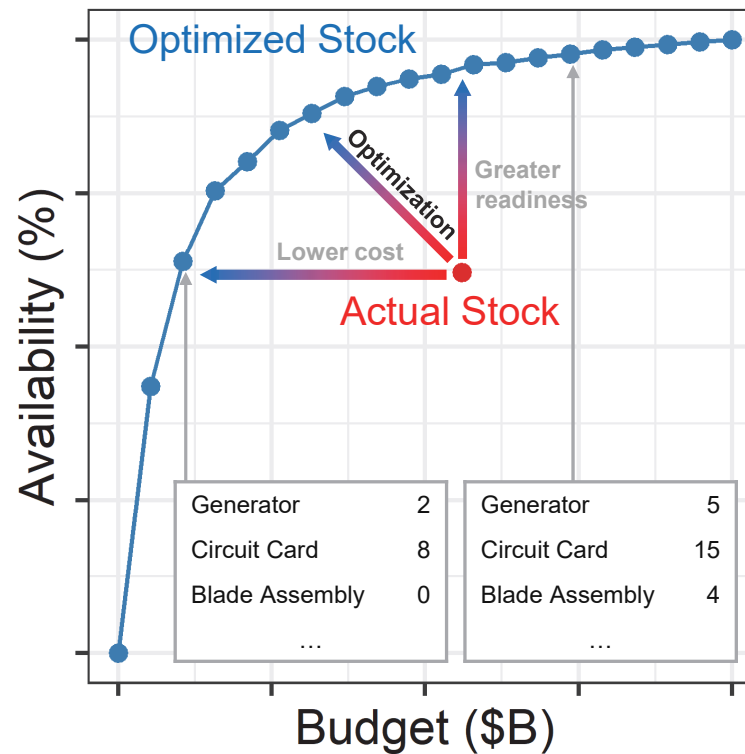
2 | How much will these options cost?

Option	FY20 delta	FY21 delta	FY22 delta	FY23 delta	FY24 delta	Total delta over FYDP	Availability improvement over FYDP
Investment Option #1	\$\$	\$\$	\$\$	\$	\$	\$\$\$\$	X%
Investment Option #2	\$\$	\$\$	\$\$	\$\$	\$\$\$	\$\$\$\$	XX%

Using stock optimization, we can develop detailed stock inventories that will increase readiness and decrease cost

Spares

Readiness-based sparing
finds the optimal combination
of stocks for a given budget



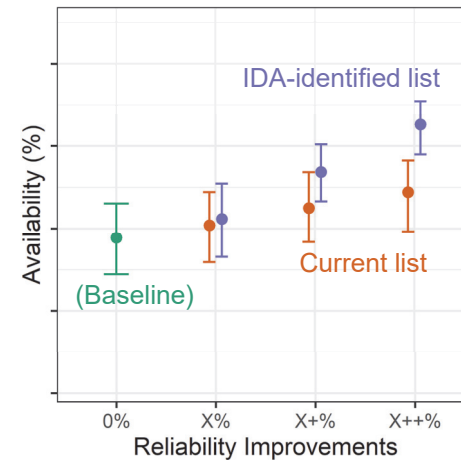
Current stock levels are
not optimized for
readiness

Our efforts guide real-world decision-making by quantifying benefits of specific “what-if” scenarios

What if we identified parts to focus on for reliability improvements?

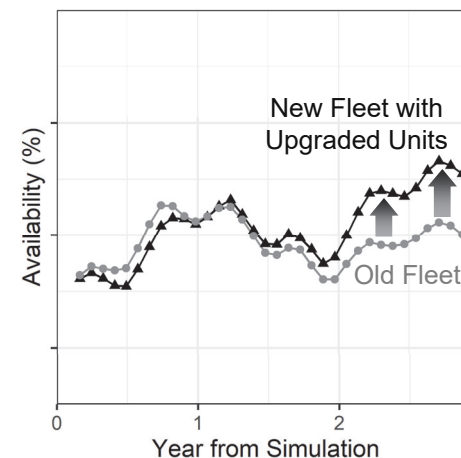
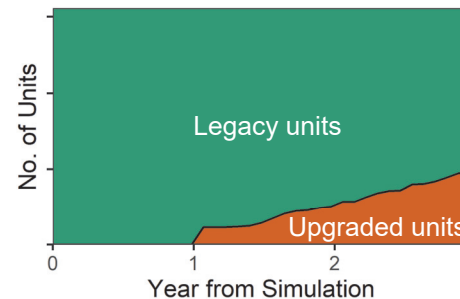
Reliability

Current “Degraded” List	IDA-identified List
ROTOR GEAR BOX	ROTOR GEAR BOX
GENERATOR	LANDING GEAR
POWER UNIT	TRANSMITTER
FLIGHT CONTROL	GENERATOR
BEARING	POWER UNIT
...	...



What if we upgraded some units to a new configuration?

Upgrades



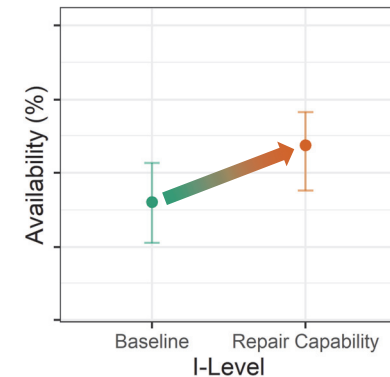
Our efforts guide real-world decision-making by quantifying benefits of specific “what-if” scenarios

Repair capability

What if we expanded on-base (I-level) repair capability?

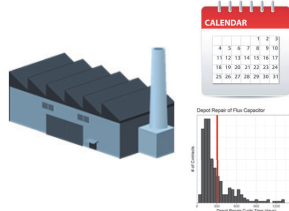


Part	Baseline	What-If
Canopy	30%	50%
Wing	10%	40%
Landing Gear	0%	10%
...		

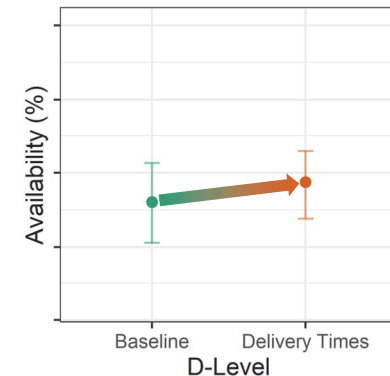


What if we could decrease depot repair time?

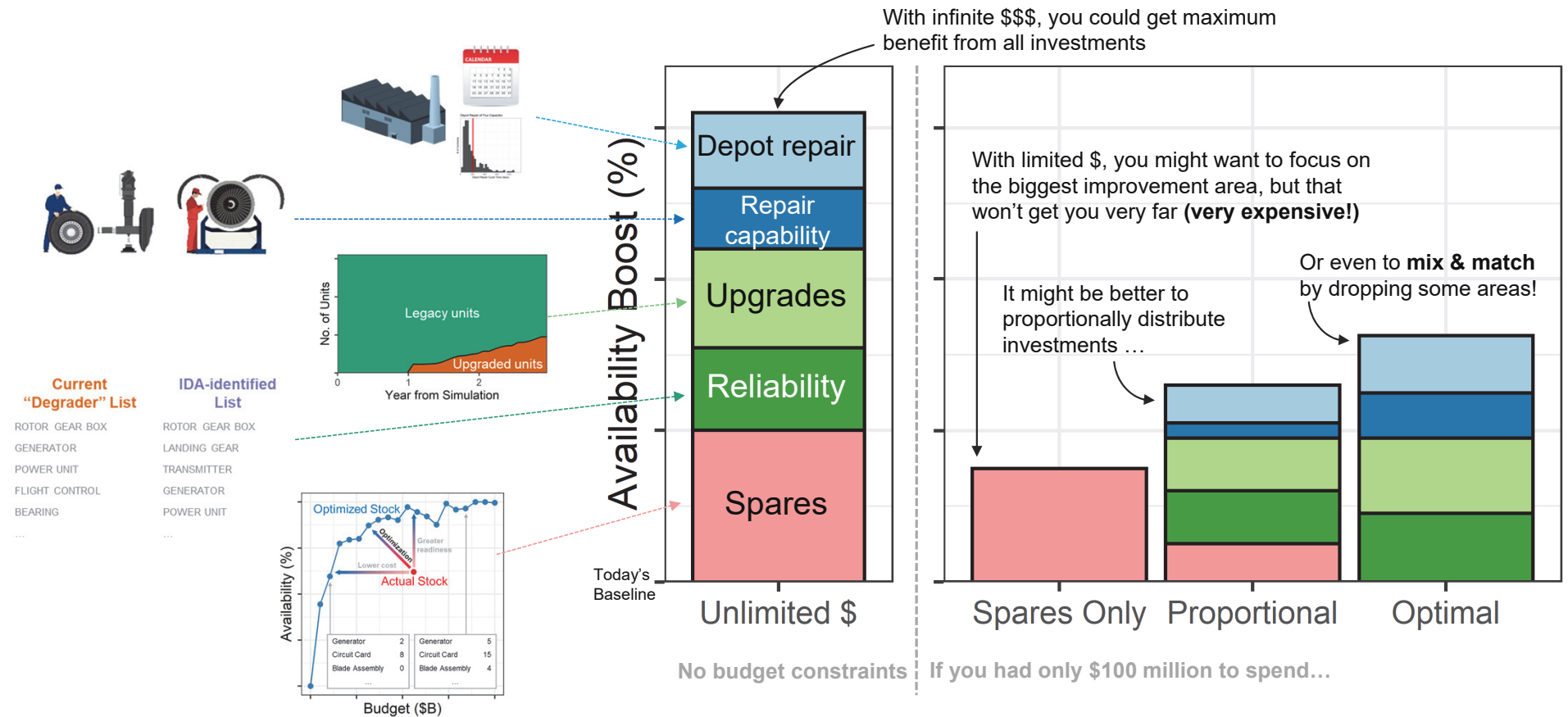
Depot Repair



Part	Baseline	What-If
Canopy	2 months	1 month
Wing	5 months	4 months
Landing Gear	3 months	2 months
...		



Trade-off analysis: Rack & stack multiple investments



End-to-end modeling can account for synergies and bottlenecks

Key conclusions

Many ideas for how to make things better

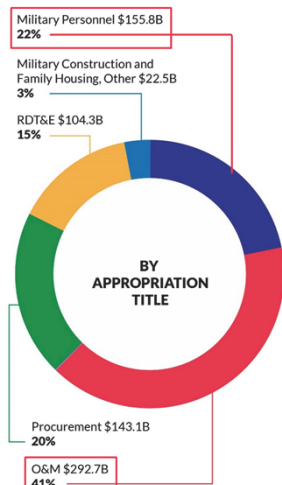
Need an **end-to-end modeling** capability (at the individual part level, not just full-system) to be able, with one toolset, to understand how investments in very different parts of the sustainment system will affect readiness

Decision-makers need to understand the benefit of improvement in one area **relative to** others – stovepiped analyses could be blind to the best combination of improvement efforts in a budget-constrained environment

These approaches require the application of strong data science and statistical best practices, subject matter expertise, and comprehensive data for operations, maintenance, supply, manpower, and logistics

Summary: IDA's end-to-end sustainment models can help improve the readiness of DoD weapon systems

\$400B+/year are spent on readiness, but many systems are NOT ready



<https://www.defense.gov/Explore/News/Article/Article/1782973/dod-leaders-make-case-to-congress-for-budget-request/>

Breaking News

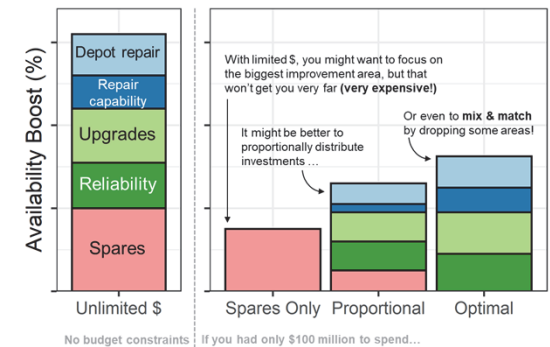
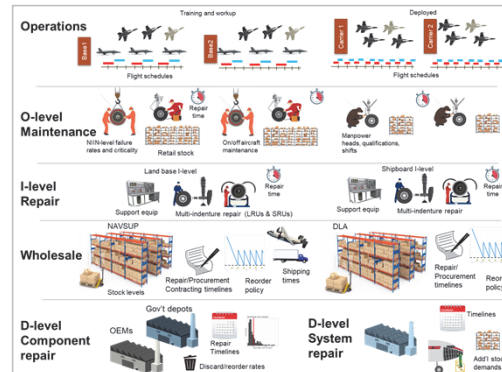
Mattis orders fighter jet readiness to jump to 80 percent — in one year

By: Aaron Mehta | October 9, 2018



<https://www.defensenews.com/air/2018/10/09/mattis-orders-fighter-jet-readiness-to-jump-to-80-percent-in-one-year/>

IDA builds highly detailed sustainment simulation models that can **guide detailed decision-making**



Thank you for listening!

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