RESEARCH SUMMARY

Understanding the Limits of Artificial Intelligence for Warfighters

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ISSUE

The U.S. Air Force (USAF) deploys flying units with readiness spares packages (RSPs) to try to ensure that the units are stocked with enough parts to be self-sufficient for 30 days. Predicting which parts are likely to fail—and, therefore, which parts should be included in the RSPs—is important because overstocking can be expensive and understocking can threaten mission readiness. In this report, we consider whether and when artificial intelligence (AI) methods could be used to improve RSP failure analysis, which currently assumes a probability distribution.

APPROACH

To test how AI might apply, we developed several machine-learning models and tested them on historical data to compare their performance with the optimization and prediction software currently employed. Using A-10C aircraft data as a test case, we addressed the following research questions:

- How does the current RSP failure analysis approach perform in a retrospective analysis against historical data?
- How can AI help inform the failure analysis process, and what are its limitations?
- What other potential improvements can augment the existing approach?

KEY FINDINGS

- AI can improve failure analysis for RSPs on a case-by-case basis. The current probability-based prediction process is a poor predictor of the performance of many parts. AI not only made better predictions but also, as a result, was much more cost effective. Figure S.1 shows one example of the performance of an AI model versus the current process. Updating the current prediction process with data can achieve a performance level that is quite close to that of our AI model.

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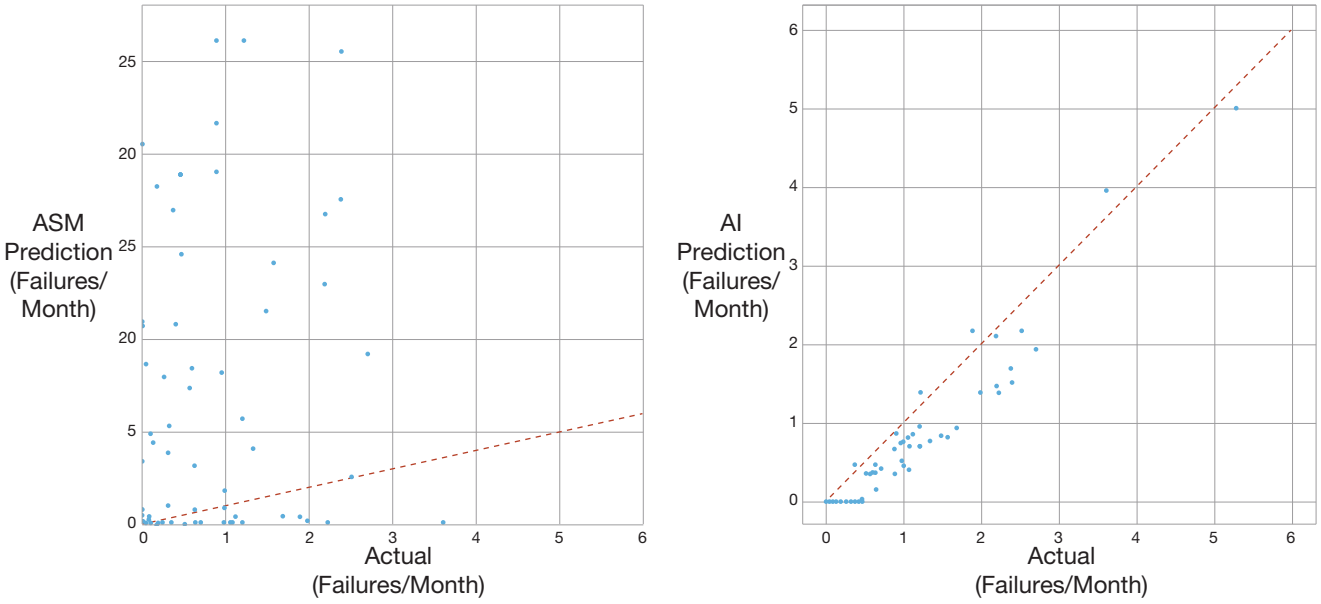
- It is necessary to establish a complex and labor-intensive data operations pipeline to USAF maintenance databases before any large-scale AI implementation can occur. Historical data are essential to train and test AI models, but pulling these data from the relevant systems is a complex, manual process that involves scripting, drop-down lists, and nested menus. Moreover, considerable data cleaning is also needed. Given this situation, leveraging AI is practical only as a proof-of-concept model.
- AI cannot alleviate the scarcity of wartime data. It is unclear whether RSPs developed using peacetime data will be adequate for wartime operations. Moreover, one of the main limitations of AI for this application is its inability to estimate truly rare events, which might be more likely during wartime operations. As a result, different approaches to modeling AI could be required to deal with these changing circumstances. However, regular retraining and updating, which is possible with an AI model, can ensure the adaptability of these models during wartime.

FIGURE S.1. COMPARISON OF ACTUAL PART FAILURE RATES FOR THE A-10C AIRCRAFT FROM 2007–2022 WITH PREDICTIONS BY A CURRENT METHOD AND AN ARTIFICIAL INTELLIGENCE MODEL



NOTE: ASM = Aircraft Sustainability Model. The dotted red line indicates parity in both subplots: If all predictions were accurate, they would all fall on the dotted red lines. The apparent slope of the dotted line is different because the scales of the two charts differ. The AI model (right) better aligns with actual failures per month but tends toward underpredictions. Given the rare nature of failures, high-accuracy predictions are not possible. The AI model predicts within 2 of actual failures per month.

RECOMMENDATIONS FOR AIR FORCE MATERIEL COMMAND

- Work with USAF Logistics (A4) to build a data operations pipeline to conduct retrospective analysis of aircraft maintenance and RSP efficiency. Aircraft maintenance programs and databases function effectively for the purposes for which they were designed, but they were not designed for retrospective analysis or to train AI models. Automation of this data pipeline process could be necessary to make these data pulls before AI can be applied. Without these data, none of the following recommendations can be implemented.

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- Experiment with AI to improve failure analysis for RSPs. Use the data pipeline to extend the proof-of-concept models to all aircraft. We noted subsets of aircraft parts where AI performs poorly. The analysis will likely have to be done on a part-by-part, platform-by-platform basis. Although it is difficult to determine whether AI (versus traditional methods) will perform better during war, AI does give logisticians another prediction tool.
- Limit AI to failure analysis within the RSP process. ASM software tackles the large and complex operations research problem of which parts to send from which depot to which base. Current AI capabilities are data hungry and are better suited to solving narrowly scoped problems.

PROJECT AIR FORCE

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