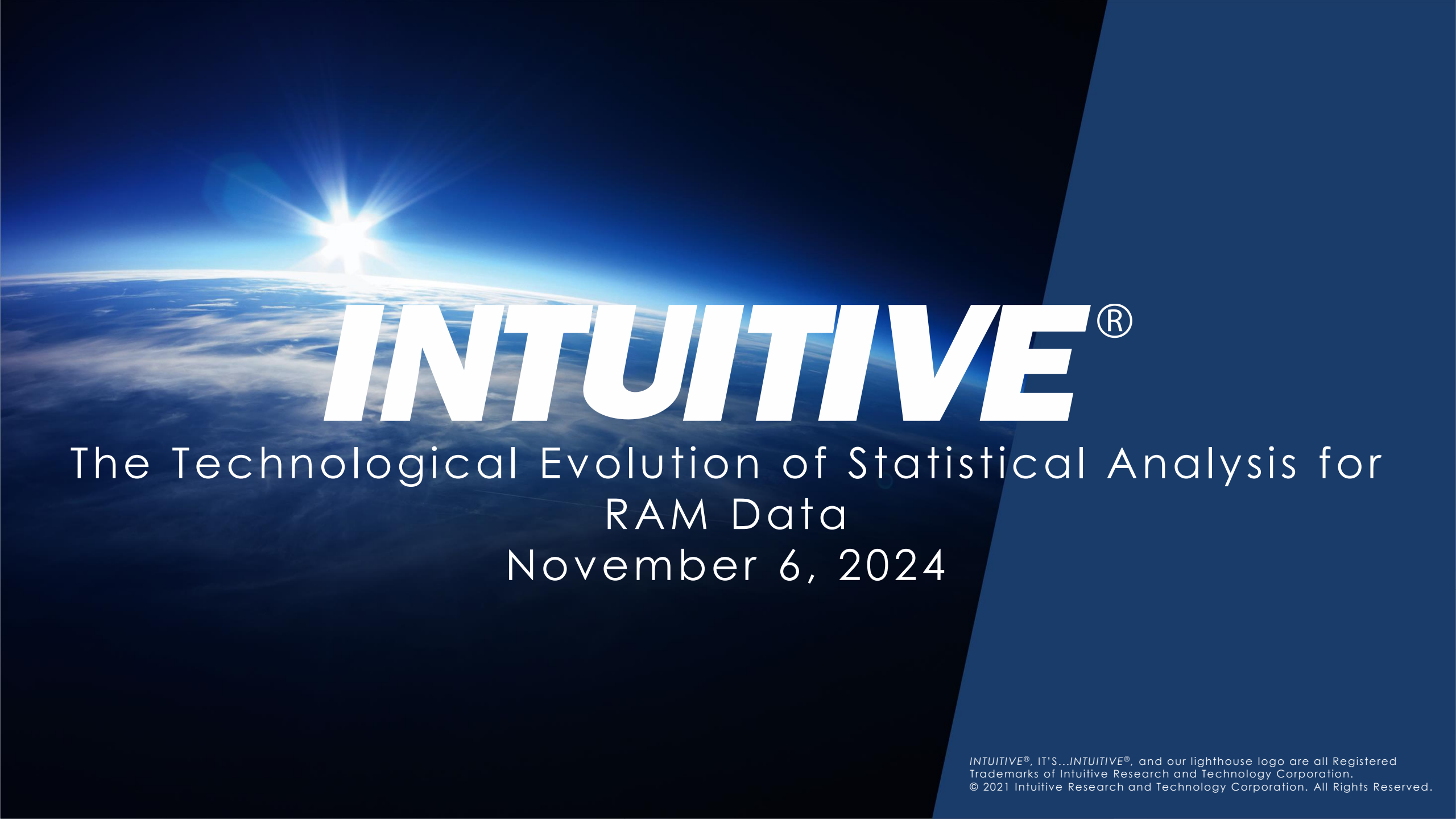

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The Technological Evolution of Statistical Analysis for RAM Data

November 6, 2024

Presenters

- Danielle McDonnell
- Jordan Mills
- Kyle Russell

Outline

- Background
- Introduction
- RAM Data Types
- Weapon System Data Methodology Case Study
  - Problem/Data of Interest
  - Methodology
    - Data Optimization
    - SME Input
    - Data Analysis
    - Automation
- Path Forward

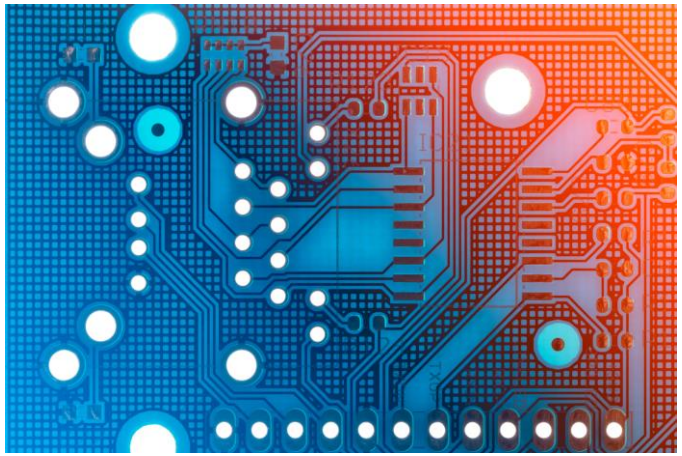
Background

- At RAM Training Summit 2023, we introduced this project in the **"Using Big Data Analytics Approaches to Analyze Aviation and Missile RAM Data."** presentation.
- Key points from 2023 presentation:
  1. **Dimensionality reduction techniques, cluster analysis, application of neural nets and transformers, and NLP can all be used to find patterns and relationships within large data sets.**
  2. For aviation data, looking at relationships and patterns within and between maintenance events and on-board flight sensor data for the UH-60 M aircraft can **provide added value for maintenance and logistics managers.**
  3. For missile system data, looking at relationships and patterns within and between component testing data, flight testing data, field data, and surveillance inspections and testing data to **support the Stockpile Reliability Program (SRP).**
  4. We are working to **mature data science tools and techniques to provide value to RAM stakeholders** through the innovative analysis of aviation and missile big data sets.

INTUITIVE is working an on-going effort with the RAM Engineering and System Assessment Division.

Introduction

- Statistical methods have historically been used to evaluate RAM data, but there are some challenges statisticians face.
- Modern technology (such as AI) provide opportunities to evolve and advance statistical analysis in the RAM field
- The development and implementation of these cutting-edge statistical analysis techniques allows for a more extensive evaluation of RAM data.
- **In relation to RAM data, these techniques can increase system effectiveness by improving operational readiness, aircraft certifications, condition-based maintenance, and lethality.**



RAM Data

RELIABILITY TESTING – SYSTEM LEVEL

The process of verifying and validating the reliability of a system under various scenarios and conditions throughout the lifecycle

- Failures and Time (MTBF, MTBEMA, and MTBMA, etc)
- System Pass/Fail Results

RELIABILITY TESTING – SUBSYSTEM LEVEL

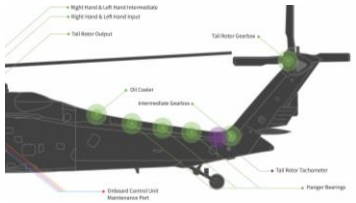
Customizable tests that provide detailed information that may not be available during system level testing throughout the lifecycle

- Lot Acceptance Testing, Aged Assets, Accelerated Life Testing
- Component Pass/Fail Results
- Identification of failure mechanisms

BUILT IN TEST, Health Usage Monitoring System/Structural Usage Monitoring System

On system equipment that allows the system to test itself and detect faults and out of tolerance conditions

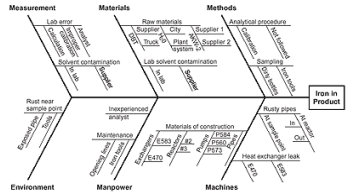
- Go/No Go
- Environmental readings (vibration, shock, temperature, humidity) - discrete signals and parametric data



FIELD DATA: MAINTENANCE, INSPECTION, FAILURE REPORTS

Organizational level maintenance and logistics data that represents the day-to-day burden and impact to maintenance programs and unit readiness

- History logs, System Profiles, Configuration Management, Maintenance Logs
- Failures and Time (MTBF, MTBEMA, and MTBMA, etc)
- Failure Reporting Analysis and Corrective Action (FRACAS)



RELIABILITY ANALYSIS

- Predictions (MTBF, MTBEMA, and MTBMA, etc)
- FMECA – failure severity, mission impact, etc.

RAM Data

RELIABILITY TESTI

The process of verifying an *ditions throughout the lifecycle*

- Failures and Time (MTBF, M
- System Pass/Fail Results

Through our ongoing work with the RAM Engineering and System Assessment Division, we decided to investigate new analysis methods for these types of RAM data

RELIABILITY TESTING – SUBS VEL

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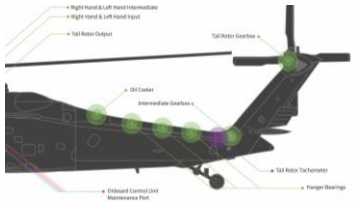

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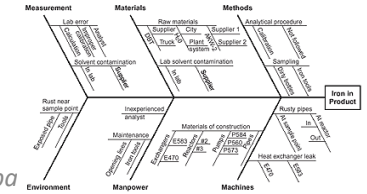

RELIABILITY ANALYSIS

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Problem

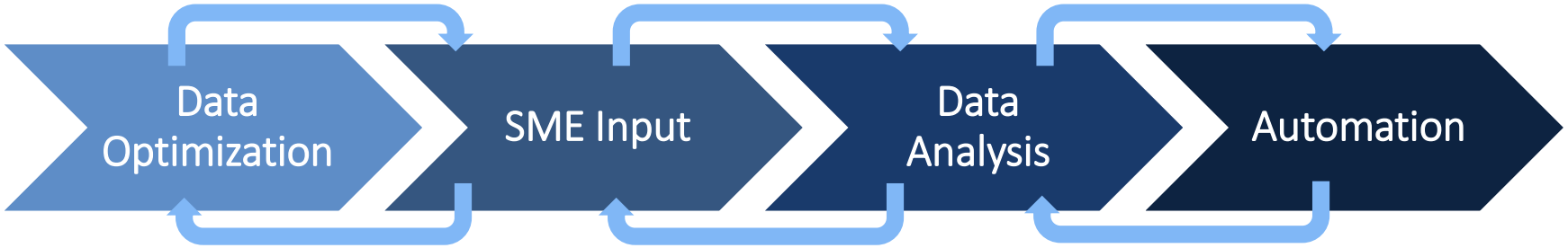
- Are we analyzing the data in the best way possible?
  - Are we making the correct "engineering judgement" calls?
  - Are we looking at the right parts of the data?
  - Or, are we letting time and resource constraints hold us back?

- **Applying advanced statistical analysis techniques and automating these techniques can help to answer some of these questions.**

Combining statistical analysis techniques with modern AI techniques provides RAM with powerful decision-making tools.

Methodology

- How have we tackled this problem for this project?



Use big data analytics tools and methods to convert data into a format that it can be analyzed.

Incorporate both weapon systems and statistics SME experience /knowledge to tackled data analysis.

Identify advanced stati stical analysis approaches that are appropriate for dataset(s)

Use AI/ML and high-performance computing capabilities to allow statistics approaches to be applied on a greater scale and with more precision.

Using a multi-disciplinary team (reliability engineers, data scientists, statistics experts, etc.) has allowed us to identify novel approaches to data analysis challenges.

Data Optimization

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- Often the first step in working with **Big Data**
- Getting the **data** into an intermediate **format** to make it easier to use it in a lot of different ways
- Filling in or deleting entries in an **intelligent** manner

- Benefits of Data Optimization
  - Allows use of a wide array of processes and algorithms
  - Reduces the amount of **rework**
  - Can be version controlled and added to over time

There are many ways to represent the same data

A necessary step to ensure efficient use and storage of the dataset.

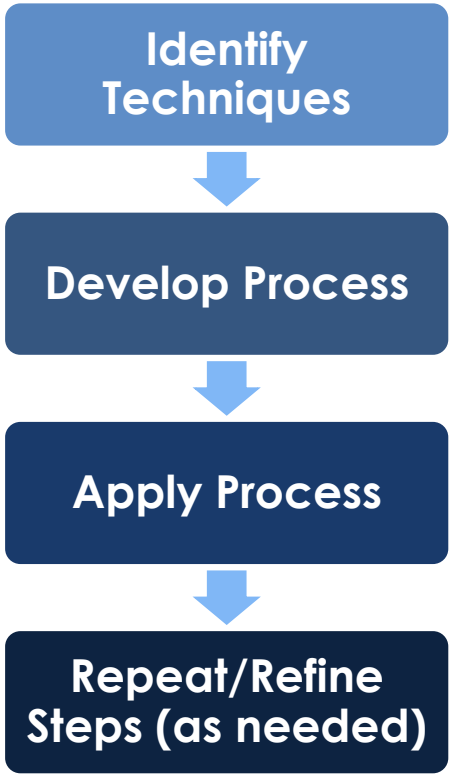
SME Input

- Both operational and statistics subject matter expertise have been invaluable to identifying analysis methods and validating analyses.
- **Operational subject matter expertise includes:**
  - Using engineering judgement to identify potential reliability drivers for weapon system performance
  - Ensuring data analysis results align with engineering knowledge
- **Statistics subject matter expertise includes:**
  - Identifying proven statistical analysis methods to incorporate into process
  - Validate results found using AI

Analysis approaches used mix traditional math/engineering principles with new technologies to evaluate the data in a novel way.

Data Analysis

- Data analysis steps:
  1. Identify data analysis techniques that are backed by sound statistical/mathematical principles.
  2. Develop repeatable and understandable steps that incorporate these robust techniques.
  3. Apply steps on data of interest.
  4. Repeat steps as necessary to refine methodology.



The above steps were used to propose a statistical analysis approach that is repeatable and reliable.

Current Statistical Approach

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1. Conduct **Engineering Design** analysis to determine the initial data set.
2. Conduct **Multiple Regression.**
3. Use **Simple Regression** to identify the most significant input factor.
4. Use **Stepwise Regression** to build the model by incorporating additional significant factors.
5. Consider all two factor interactions for **significant interaction effects**. Incorporate significant interactions into the model using the Stepwise Regression method.
6. Plot Factors and Interaction Effects to **visually examine the effect on the test parameter.**
7. Use the model to determine what values for independent variables may cause us **to go out of specifications.**

Tools Required

The above steps can be used to identify and quantify the significant factors for weapon system performance.

Humans vs. Machines

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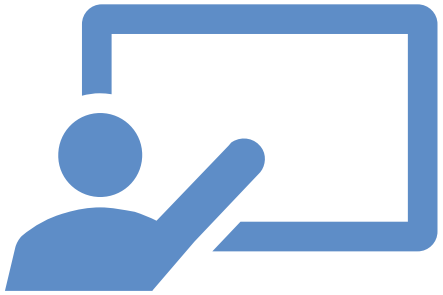
Statistician



Uses engineering judgement to statistically analyze the data.

Cannot perform all combinations of variables and must be selective.

VS.

Machine

Exhaustive method that allows statistical analysis of all combinations in the dataset.

Still requires validation.

Machines can act as a force multiplier and allow analysts to more thoroughly evaluate a dataset and come to a more informed conclusion.

Automation – The Process

Python 3 + MongoDB + SciKit Learn + StatsModels

Source Data	Preparation	Unification/ Staging	Analysis	Reporting
Ingest the data automatically determining format	Makes the data consistent	Combines individual records into a single dataset	Runs statistical algorithms on all combinations of the data	Reports from analyses can be produced as text, CSV, or HTML

We use a highly parallelizable pipeline to go from raw data to reports that analysts can evaluate.

Benefits of Automation

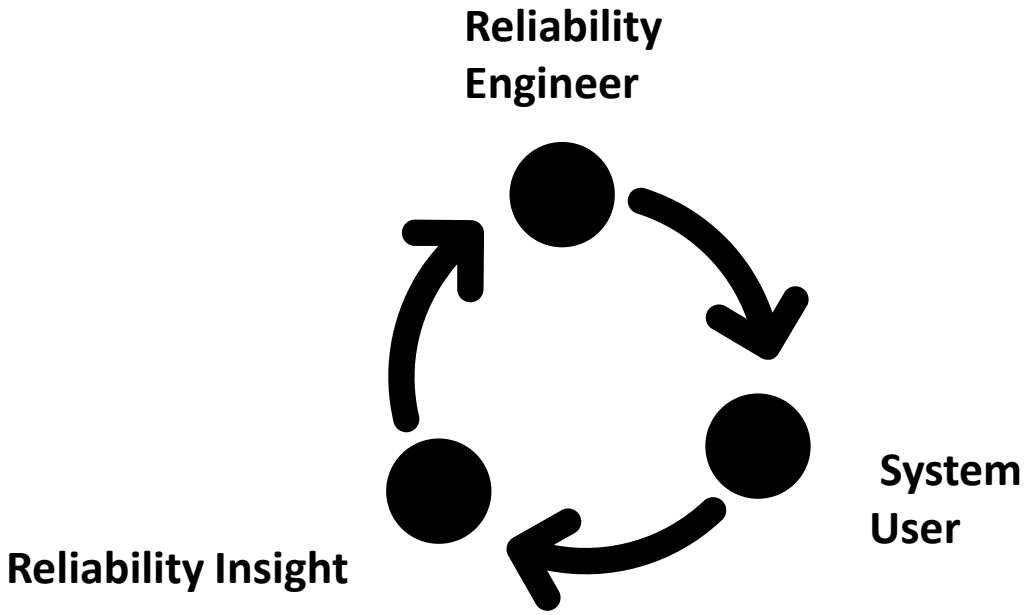
1. Results are obtained **faster** than manually running traditional statistical tools
2. Results provide a more **complete view** of the data
3. Requires **less man-hours** to evaluate the automated reports than performing the traditional statistical analysis
4. Reduces the amount of grunt work – you don't have to manually crunch numbers
5. Can be used for **current** data and **future** data

Validation: The same results were found using the automated statistical approach as the manual traditional statistical approach with less manual labor.

Impact

- Robustness of new analysis approach and the automation of that approach provides a thorough and fast approach to analyzing RAM data.
  - This allows critical reliability information to be provided to the missile community faster.
  - This also allows engineers to focus their efforts on data analysis/interpretations rather than data organization/visualization, etc.

Optimization of engineer time resources



Conclusions and Future Work

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Summary

- Automating proven statistical methods allows us to combine traditional engineering techniques and modern technologies to provide novel solutions for RAM data analysis programs.

Future Work

- Continue to finalize automation of new methodologies.
- Continue to work to integrate methodology into reliability program procedures.
- Refine into a tool that can be run by reliability engineers.
- Integrate new tools into reliability program to look for new findings
- Review new findings and conduct SME Validation