Sustainment Analysis Methodology for Cost Models and Business Cases

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May 17, 2022

2022 ICEAA Workshop

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Introductions

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George Bayer

- Senior Director at Cobec Consulting
- Currently leads investment analysis consultant teams developing costs, benefits, and business cases for FAA acquisitions
- B.S. in Business Administration (Finance & English majors) from the University of Florida
- MBA in Corporate Finance from The University of Texas at Austin
- Project Management Institute (PMI) Project Management Professional (PMP)
- Over 20 years of Finance experience in capital investment valuation, forecasting & budgeting, cost estimation, benefits quantification, and business case development
- Developed discounted cash flow models in Investment Appraisal for major Power Generation capital investments at ConocoPhillips
- Evaluated major capital investments/acquisitions in the Business Case Group of Investment Planning & Analysis at the FAA

Introductions

Austin Lutterbach

- Analyst at Cobec Consulting
- B.S. in Mathematics and Statistics at Purdue University
- M.Eng in Operations Research at Cornell University
- 3 years of experience in machine learning and statistical modeling

Government Capital Investments & Legacy Infrastructure

Sustainability Analysis

- Federal agencies try to sustain large infrastructure systems much longer than their intended lifecycle and must choose between investments to fund and ways to sustain existing systems
- Cost estimators and data analysts (1) analyze supply chains, (2) conduct failure analyses, and (3) estimate the sustainability of legacy systems to better inform agency decision-makers
- For Sustainment Analysis, the **critical components** are:
  - Parts Failure/Demand Analyses
  - Inventory and Procurement Data Collection
  - Sustainment Modeling
- This presentation **focuses** on **Sustainment Analysis Methodology** and empowering federal agencies to make data-driven decisions using 3 models:
- This is achieved by delegating different models for different tasks:

1. **Large-scale sustainment model** to identify high-risk parts that drive system End-of-Life
2. **Deep dive sustainment model** to validate risk and analyze sustainment options
3. **Sustainment procurement model** to create risk-mitigation solutions

Government Capital Investments

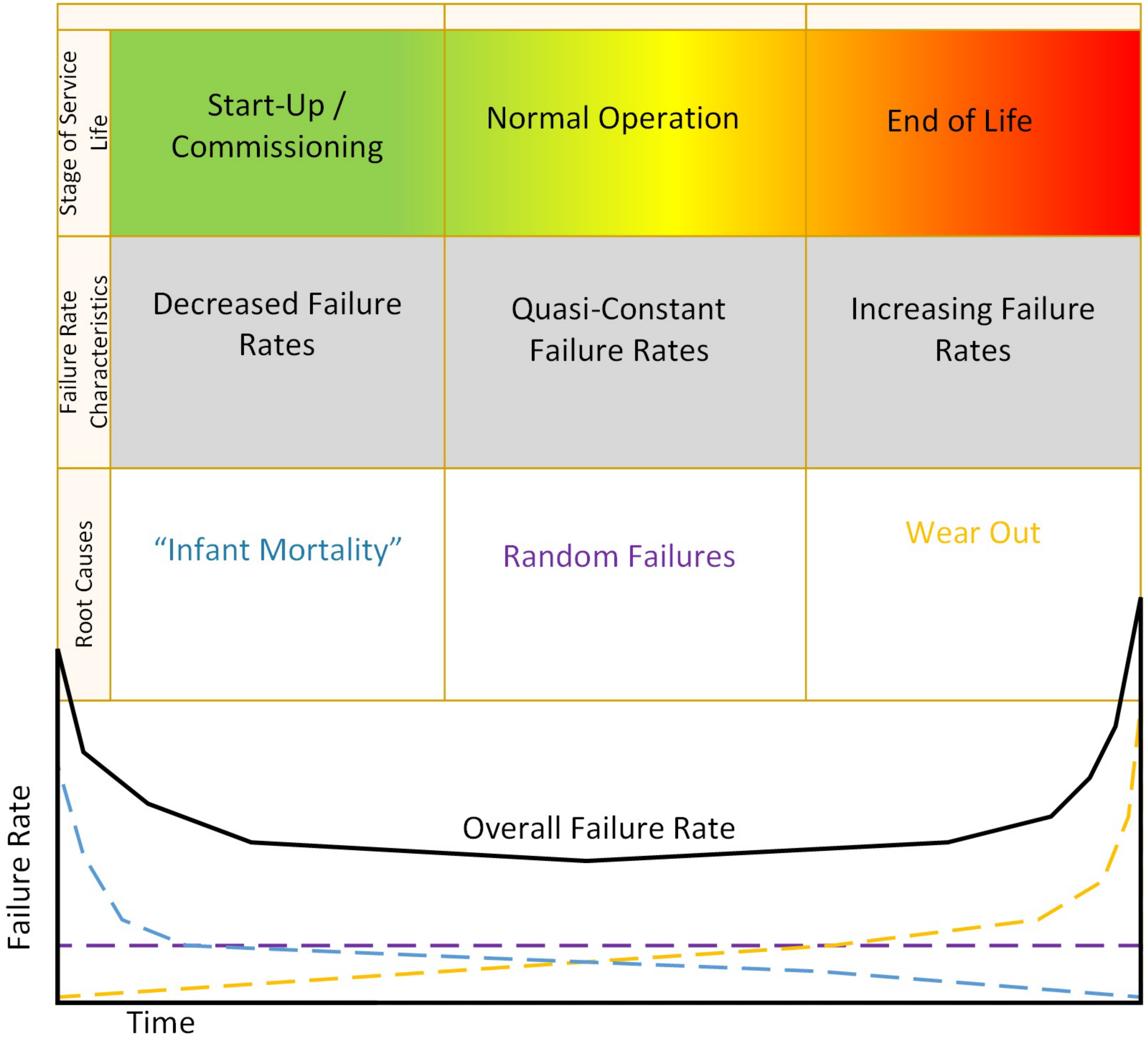
- Federal Aviation Administration (FAA) and other civil agencies develop business cases to justify investment funding.
  - Focus on Cost-Benefit Analysis to justify investments
  - Brings private industry investment rigor to the agency for investment decisions
    - Identify the agency need
    - Why do we need to invest in this project?
    - What problem (shortfall) are we solving?
    - Who benefits and by how much? Benefits = FAA, airlines, public
    - Two types of investments – (1) new investment, (2) infrastructure sustainment
    - Quantify both costs and benefits for multiple alternative solutions
    - Develop legacy reference case (compare to alternative cost models, basis of cost avoidance)
    - Evaluate with Finance metrics – NPV, IRR, Payback, B/C Ration

Failure Analysis

- Government Agencies – Large Infrastructure
  - Aging infrastructure programs need operational sustainment
  - When should we replace aging infrastructure programs?
  - Establish criteria by which to justify infrastructure replacement.
    - Historical and projected parts failures
    - Difficulty to procure replacement parts
    - System obsolescence
    - Risk of loss of service
  - Failure Analysis Answers:
    - What is vulnerable? Higher cost to sustain? Loss of Service?
    - Safety risk?
    - Sustainability – At what date can agency no longer sustain legacy system?
    - What parts are failing?
    - What is remaining inventory of parts, and how long will it last?
    - Are some old parts no longer manufactured and are difficult to procure? Consider lifetime buy.
    - How many parts must program procure to continue operation over lifecycle?
    - What is the total cost to sustain legacy system over lifecycle?

Failure Analysis

- **Parts Failures Over Lifecycle**
  - How long can a system be maintained?
  - What does a system failure curve of critical parts look like?
- **Bathtub Curve**
  - Systems kept beyond intended useful life experience full lifecycle of parts failures
  - **Early Phase –** Infant Mortality
  - **Primary Phase** – Consistent Failure Rate (as intended)
  - **End-of-Life** – Parts Wear Out, Exponential Failures



Infrastructure Investments

- **Infrastructure Investment Decisions**
  - Two Major Types of Government Investments – **(1) infrastructure, (2) new capabilities**
  - Approximately half of FAA business cases devoted to maintaining, improving, or replacing existing infrastructure.
  - To assess needs, timing of needs, & best spending of limited capital budgets, agency needs to:
    - Evaluate the condition of **existing operations** and their components,
    - Determine the logistics and spare parts **sourcing requirements** and availability,
    - Conduct an **inventory analysis of spare parts**,
    - **Evaluate the supply chain** of the infrastructure sustainment operations,
    - **Mutually Exclusive** – Compare **infrastructure investments** to determine **which is more urgent**,
    - **Justify Investment** – Evaluate each investment and portfolio against a **constrained capital budget** and determine best time to invest in each project

Infrastructure Investments

- **Five Cost Estimation Considerations:**
  - **Cost to Sustain –** What is the cost of sustaining operations with existing operational expenses versus replacing aging infrastructure in the National Airspace (NAS)?
  - **Ability to Sustain** – At what point will continuing existing operations risk loss of service, or at what point will sustainment without significant investment no longer be feasible?
  - **Sustainment Methods to Extend Useful Life** – Replacing parts, failure analyses, lifetime buys
  - **Cost/Benefit Analysis** – Justify capital investment – When do the costs of continued sustainment with increased parts failure or loss of service risk outweigh cost of replacement?

Sustainability Analysis & Business Cases

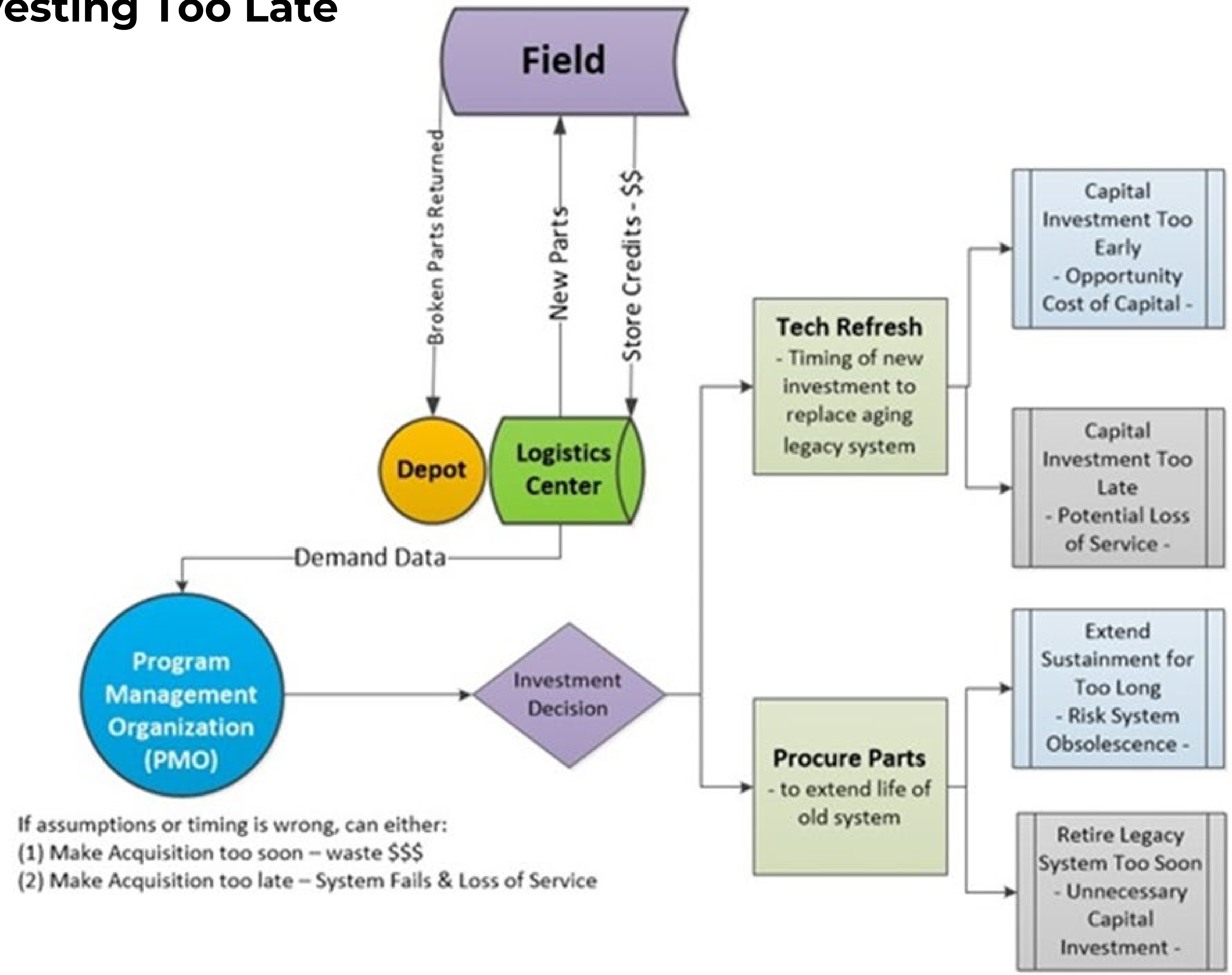
- **Sustainment Analysis Objectives for Government Business Cases**

1) **Estimating End-of-Life**
   - How long can system be sustained without running out of parts?
   - Determine impact of EOL. Loss of Service? Impact to stakeholders?
2) **When to Invest**
   - Optimize timing of new investments that replace aging legacy systems
3) **Investment Trade-offs and Justification**
   - Some agencies require cost-benefit analysis to justify investment is “worth” investment capital
   - Estimating obsolescence of parts in sustainment analysis can justify investment and urgency
4) **Means of Evaluation – Sustainability Analysis as Repeatable Process for Stakeholders**
   - Repeatable objective process of analyzing system sustainability and capital expenditure commitments

Timing of Replacement

Investing Too Early

Investing Too Late



Investing Too Early – Based on sustainment analysis, agency might decide to procure replacement system before the end-of-life of the legacy system

Limited annual capital budgets

Mutually exclusive investments

Premature investment at expense of other more deserving investments

May delay new services that improve the lives of the public

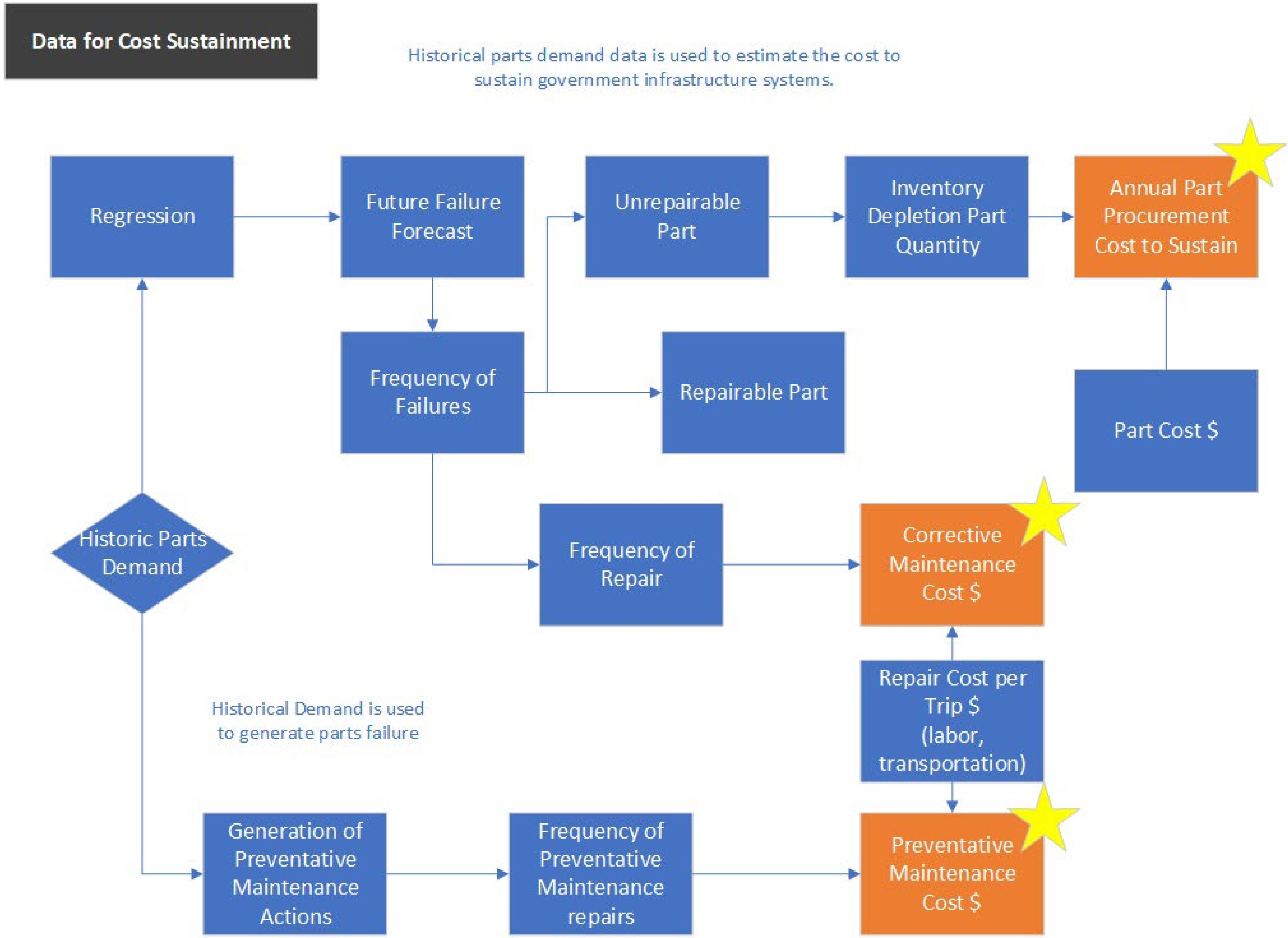
Timing matters

Investing Too Late – If agency delays procurement of a replacement system and waits too late,
Could risk loss of service
High-risk consequences

Sustainability – Estimating End-of-Life

- **End-of-Life**
  - Government infrastructure systems have intended system lifecycle with sustainability metrics (preventative maintenance, corrective maintenance, spare parts for lifecycle)
  - Many systems are retained well beyond intended useful life, presenting sustainment issues
- **End-of-Life Sustainment Forecasting Factors**
  1) **Failure Rates** – How often part fails and system fails as result and requires repair
  2) **Failure Growth Rates** – How much more frequently parts are failing than prior
  3) **Scrap Rate/ Beyond Economic Repair (BER)**
     - For parts which are repaired (Exchange & Repair Parts), scrap is percentage of parts which cannot be repaired and must be discarded
     - For E&R parts, scrap defines the inventory depletion
  4) **Inventory** – Beginning inventory and ongoing inventory that defines how long can sustain
  5) **Procurement** – Availability of parts to purchase on market. As system ages, less availability
  6) **Substitution** – Ability to substitute obsolete parts with like-for-like new ones. Defines obsolescence

Sustainment Costs

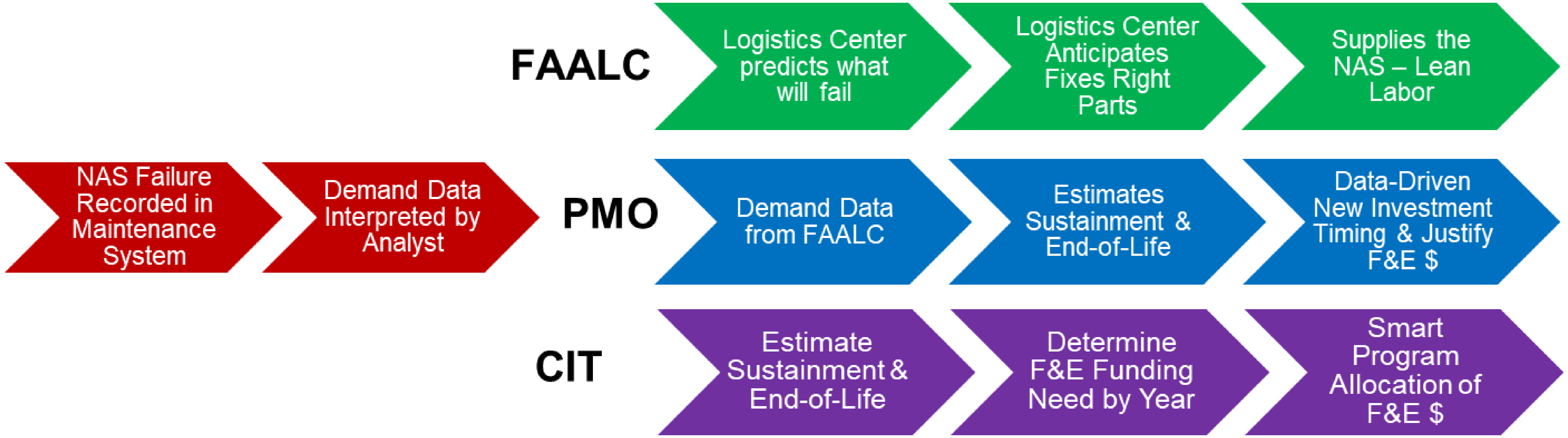


- **Sustainment Analysis**
  - **Historic Parts Demand –** drives cost frequency and volume
- **Cost of Procuring Parts**
  - **Failure Rates**
  - **Failure Growth** – Regression
  - **Scrap**
  - **Inventory Depletion**
  - **Part Cost $**
- **Corrective Maintenance Costs**
  - **Failure Rates**
  - **Failure Growth** – Regression
  - **Frequency of Repairs**
  - **Cost per Repair**
- **Preventative Maintenance Costs**
  - **Preventative Assessment**
  - **Frequency**
  - **Cost per Repair**

Repeatable Sustainability Process for Stakeholders

- **Means of Evaluation – Develop Repeatable Sustainability Analysis Process for Stakeholders**
  - FAA has specific stakeholders who rely on sustainability forecasts to make critical investment decisions

1) **FAA Logistics Center**
   - Inv Readiness – Forecasts how many parts by type to repair to meet annual demand
2) **Program Management Organization (PMO)**
   - Uses sustainability analysis to decide when to replace systems and how to sustain them
3) **Capital Investment Team (CIT)**
   - Uses sustainability analysis to decide how to allocate fixed F&E budgets across investments



Legacy System Sustainment Cost Drivers

- **Legacy System Cost Driven by Parts/ System Failures**
  - Agency tries to estimate cost of legacy system sustainment and timing of replacing legacy infrastructure.
  - Legacy infrastructure system costs driven by estimates of failures over lifecycle.
- **Major Legacy System Sustainment Considerations:**
  - **Cost Per Maintenance Action**
    - Logistics and maintenance costs for each outage
  - **Labor**
    - Repairs in the field, preparation of field spares, tracking outages
  - **Analysis**
    - Investment Planning & Analysis (IP&A) oversight group use legacy system sustainability as a driver for investment decision timing
    - Historical failure analysis helps demonstrate new investment urgency and helps agencies decide in which business cases to invest based on need and timing

Legacy System Sustainment Cost Drivers

- **Major Legacy System Sustainment Considerations** (continued)**:**
  - **Parts Procurement, Storage, and Distribution**
    - **Procurement** – Critical Demand data drives procurement volume and operations costs to source replacement parts
    - **Storage** – Failures and parts demand drive inventory storage levels and cost
    - **Distribution** – Demand data used for "inventory readiness" and to repair right parts for distribution
  - **Time to Repair**
    - Calculate Mean Time Between Failure (MTBF) to measure parts demand and inventory depletion
  - **Ability to Source Parts & Manage Risk**
    - Some parts are customized; others no longer manufactured; some drive system end-of-life.
    - Agency manages parts sustainability risk by tracking parts procurement availability, cannibalizing parts, and making lifetime buys.
  - **Condition of Data for Analysis/ Assessments**
    - Is historical data accurate? What is the basis?
    - Analyze source data and assumptions for fidelity.

Cost Estimating & Failure Analysis Methodology

Failure Analysis Methodology

Failure Analysis & System Sustainment Methodology

- The cost team developed a standard methodology for estimating legacy system sustainment, including in-depth failure analyses by part and part type. This included examining procurement practices for each part at Logistics Center.

Failure Analysis Methodology –

- Comprehensive list of steps in sustainment analysis for government decision-making

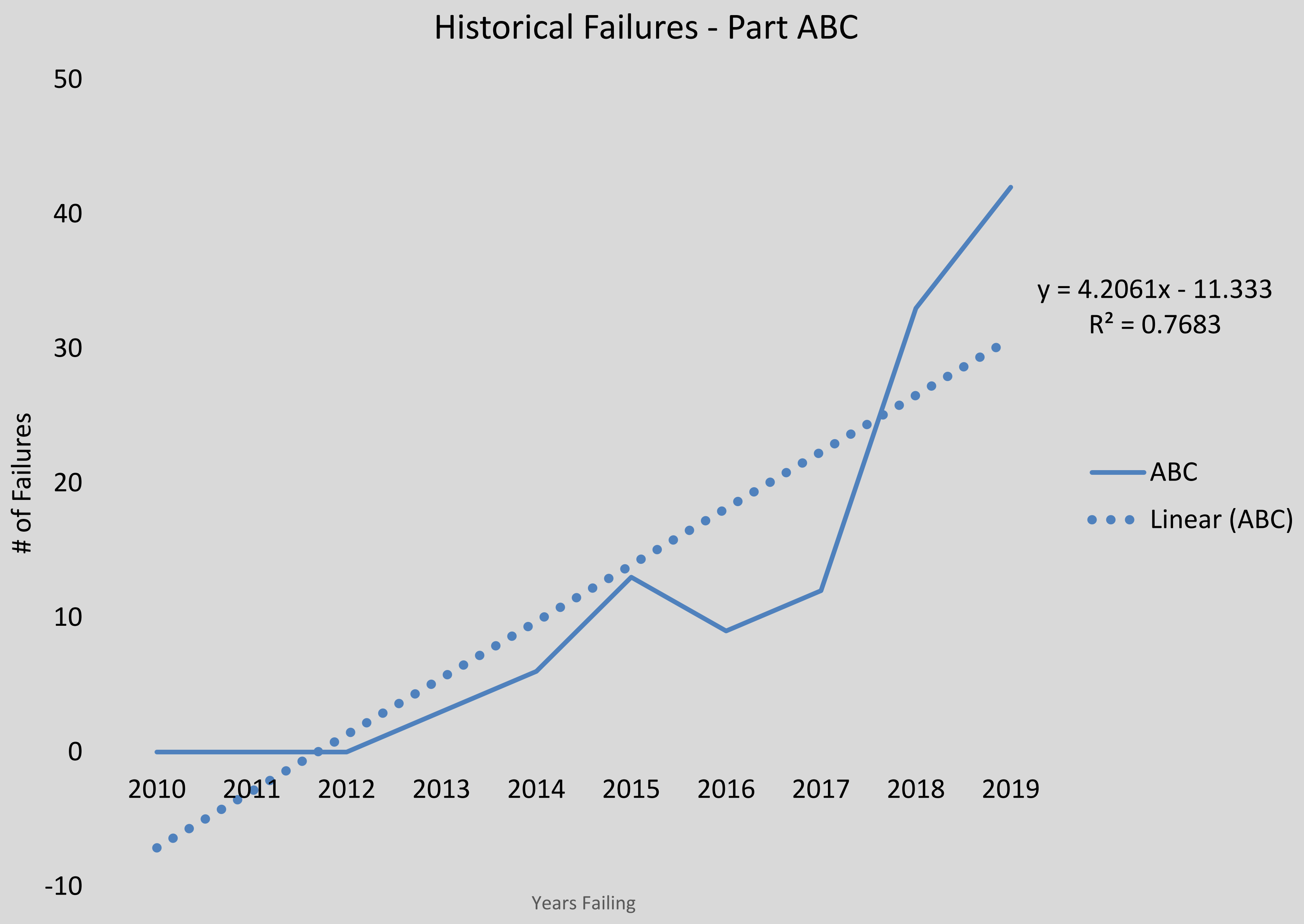
Inventory Assessment

1. **Comprehensive Inventory of Systems and Parts**
   - Conduct audit of full list of system parts and the associated Lowest Replaceable Units (LRU) numbers.
   - Get initial inventory of parts in storage
2. **Parts Categorization**
   - Break parts supply into functional categories of parts (COTS, easy to procure, hard to procure, aging, custom for the FAA)
   - **Low Risk** – No procurement risk
   - **Medium Risk** – Supplier risk
   - **High Risk** – No supplier available

Failure Analysis Methodology

Demand Analysis

1. **Historical Demand** – Use Logistics demand data from parts returns to the Logistics Center to estimate historical demand.
2. **Trend Analysis** – Analyze historical demand data by part number and check for failure trends.
3. **Failure Growth Rate** – Estimate failure growth rate for each part based on trend analyses
   - **Growth Rate Regression** – Using historical observable trend analyses, develop growth curves that represent the historical data set and which still represent a growth rate which is both (1) realistic and (2) sustainable over many years. By training regression models in python on historical annual failure data, we can adjust forecasts with scenarios and context.
   - **Inventory Turnover** – Forecast growth rates for entire lifecycle with caps on annual failure rate to a maximum of full inventory turnover every three years for high failure rate parts.



Failure Analysis Methodology

Sustainability Analysis

4. **Scrap Rate** – Estimate scrap rate for each NSN based on cumulative scrap numbers
   - Percentage of parts Depot cannot repair
   - Estimates inventory depletion
5. Collect **centralized inventory** counts from the Logistics Center for Exchange & Repair (E&R) parts and a starting point for expendable parts
6. **Time Horizon** – Analyze by NSN the ability to sustain procurement of each E&R and Expendable part over the system lifecycle of 10 years.
7. **Forecast Procurement** – Forecast the annual inventory procurement of parts/ NSNs for each year using the demand forecast and appropriate failure growth rates. This becomes part of annual spares budgeting forecasts.

Failure Analysis Methodology

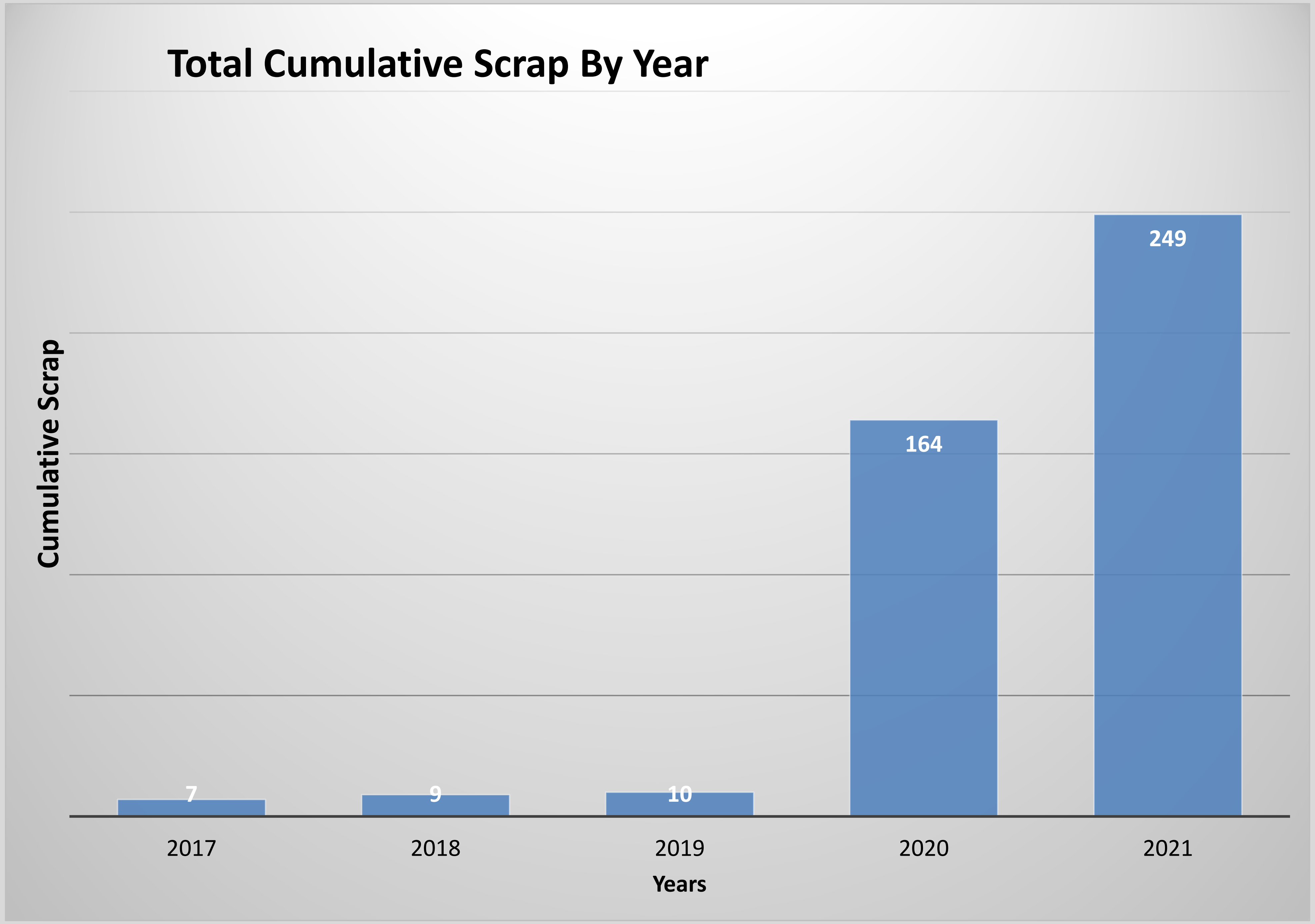
Sustainability Analysis

1. **Lifecycle Analysis** – Finalize inventory procurement and sustainability forecast for entire business case lifecycle.
    - Assess current inventory levels deployed and at the Logistics Center
    - Compare this inventory versus standard demand levels
    - Compare these levels to full inventory needed to get to system end of life or next Tech Refresh
2. **Cost Estimation** –
    - **Procurement/Sustainment Cost –** Multiply annual inventory procurement volume by the unit cost of each spare part

      Cost = Price X Volume
    - **Annual Budget Forecast** – Forecast annual cost requirements to procure spares in legacy cost estimate.
    - **Corrective Maintenance** – Measure frequency of maintenance events by quantity of parts repaired by year and multiply by labor cost

Scrap Rate & Data Challenges

- **Scrap Rate** – Point estimate of proportion of parts that will be thrown away when attempting to repair failure
  - **E&R Parts** – Exchange and repaired. Parts that can no longer be repaired are scrapped = Beyond Economic Repair (BER)
  - **Estimate for Inventory Depletion** – In E&R parts, scrap rate is percentage of failures that depletes existing inventory of spare parts
  - **Data Challenge** –
    - FAA data for scrap rate is not collected in a standardized way. Dependent on SMEs, free text field notes on scrap, or cumulative scrap that is not provided by year and convoluted by inconsistent testing
    - Causes large increases in scrap rate percentages in data, impacting sustainability forecasts



Large-Scale Sustainment Model

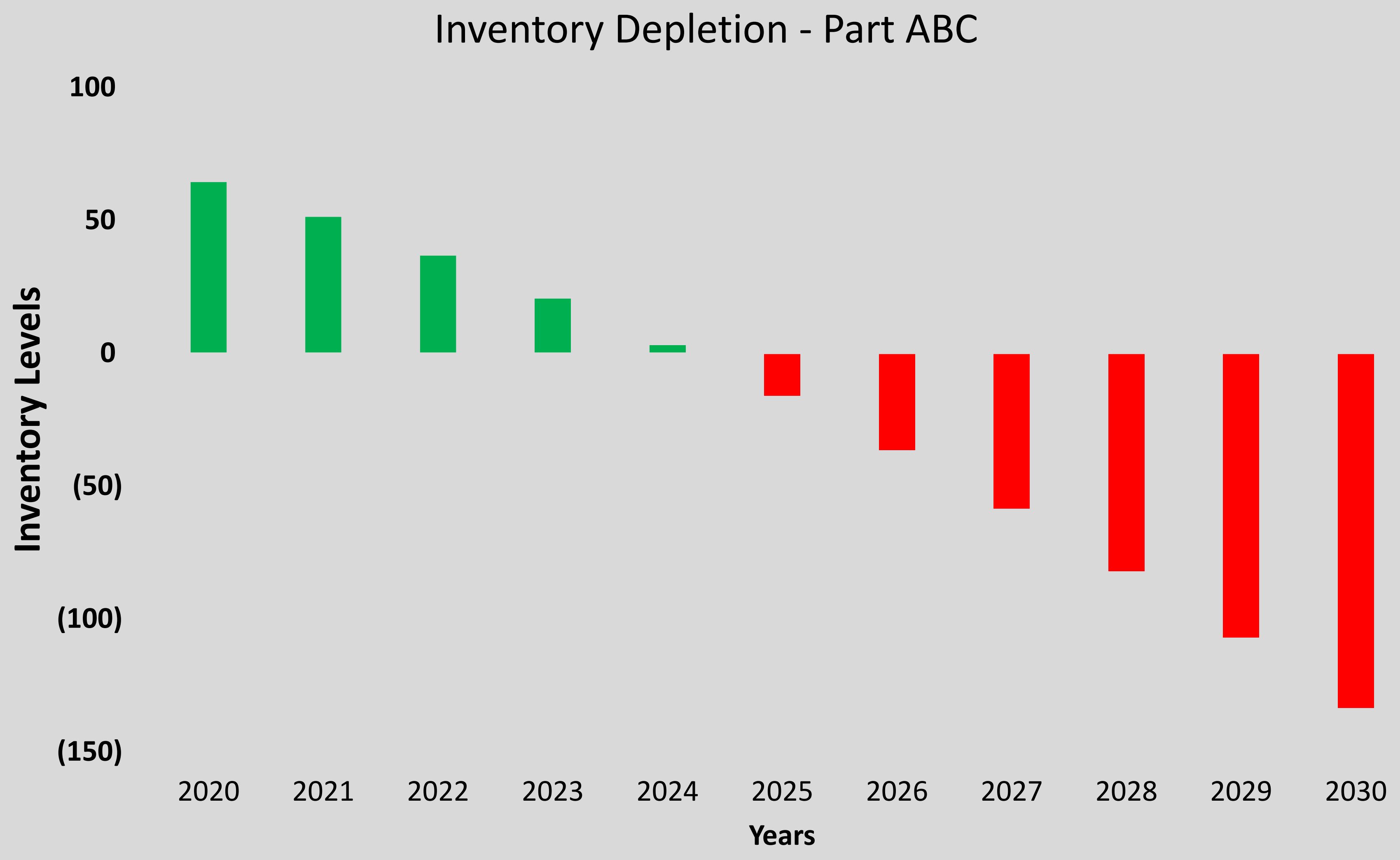
Utilization of Python for Scalable Analyses and Identification of High-risk parts

1. **Data Engineering** – Construct historical annual failures, in-service, current inventory levels, and estimated scrap rate from the FAA depot data
   - Part serial number and timestamp of failure arrival to depot used to count number of failures per year
   - Inventory levels include parts ready off the shelf as well as parts currently in repair at the depot or vendor
2. **Regression Analysis** – Conduct regression analysis (estimating failure growth from fitted trend line and forecasting failures) on failures time series data selected by selection algorithm
   - Selection algorithm uses statistical tools for outlier detection to select accurate time series data to base regression analyses on
   - Slope from trend line of regression analysis performed with Python is used to estimate the failure growth rate
3. **Inventory Simulation** – Utilize estimated scrap rate and forecasted annual failures to simulate impacts on current inventory levels and to estimate date of full inventory depletion
   - Full depletion of inventory → part can no longer be sustained and requires additional procurement, cannibalization, or like-for-like replacement

Deep Dive Sustainment Model

Deep Dive Validation of Large-Scale Sustainment Model

- Large-scale sustainment model generates list of potentially high-risk parts → **deep dive model** validates output
  - Deep dive model incorporates latent factors that may affect demand volume or rate of inventory depletion
  - Requires additional manual work – consulting engineers, identifying other drivers of demand, sourcing and procurement capabilities of parts
- Deep Dive model utilizes identical demand analyses used in large-scale sustainment model in addition to other researched factors that impact sustainment



Sustainment Procurement Models

Mitigation of high-risk parts

- Utilizes results from large-scale and deep dive sustainment model to identify quantity needed to procure in order to meet sustainment goals
  - Developed for each high-risk part validated by deep dive model
- Performs sensitivity analysis on important metrics such as scrap rate and failure growth rate to observe impacts on inventory levels and to quantify risks
  - All metrics used in sustainment procurement models are derived from the large-scale and deep dive models
  - Sensitivity analysis increases or decreases these metrics and observes to what degree inventory depletion changes with respect to changes in scrap rate, failure growth rate, etc.
- Can be used to estimate costs of sustainment and can incorporate other latent costs such as the cost of losing functionality of a system

Sustainment Analysis Pipeline

Union of all three sustainment models

- The core demand analysis principles form the backbone of the three primary sustainment models.
- Each sustainment model works in conjunction with the other to perform the most accurate sustainment analysis in the most efficient manner.
- This is achieved by delegating different models for different tasks:
  1. The **large-scale sustainment model** for **high-risk part identification**,
  2. The **deep dive sustainment model** for **high-risk validation** and **analysis**,
  3. The **sustainment procurement model** for **high-risk mitigation**.

Sustainment Analysis Impacts

Application of Sustainment Models for FAA Legacy System Sustainment & Inv Decision

- Applied "Deep Dive Sustainment Model" to Shortfall Analysis and Large Scale to Lifetime Buys:
  1. **Large-Scale Sustainment** –
     - Separated hundreds of parts into high-medium-low risk categories and successfully identified high-risk parts that could drive legacy system "end of service"
     - Greatly increased efficiency of **high-risk part identification** – rather than manually check each part, the model **automatically detects** each part that is causing sustainment issues, and this is accomplished in minutes compared to days or months
  2. **Deep Dive Sustainment** –
     - Analyzed high-risk parts for legacy system as part of investment Shortfall Analysis. Justified to Investment Planning & Analysis (IP&A) in model forecast of critical part EOL and EOS where inventory depletion would put at risk legacy system sustainability.
     - Model and analysis used to **justify new investment**.
  3. **Sustainment Procurement Model** –
     - Performed sensitivity analysis on key metrics to capture different paths for achieving sustainment goals
     - Provided **lifetime buy recommendations** for multiple high-risk parts, **mitigating sustainment risks**.

Backup

Infrastructure Investments

- **Five Cost Estimation Considerations (continued):**
  - **Timing of Replacement** – When is the best time to invest new capital to replace existing infrastructure? Consequences of not getting it right:
    - **Investing Too Early**
    - **Investing Too Late**