Data-Driven Life Cycle Analysis to Optimize Cost, Risk, and Sustainability

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Agenda

- **Introductions**
- **Sustainment of Aging Legacy Government Systems & Operations**
- **System Trade-Offs**
  - Analyzing Backup Systems to Optimize Cost, Minimize Risk, and Retain Sustainability
- **Life Cycle Estimation**
  - How Do We Use Incomplete Data to Estimate System Life Cycles?
- **Use Case Conclusions**

Introductions

Introductions

George Bayer

- Senior Director at Cobec Consulting
- Currently leads investment analysis consultant teams developing costs, benefits, sustainability analyses, 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, shortfall and 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

Brian Carroll

- Consultant at Cobec Consulting
- B.A. in Mathematics at Kean University
- Leads cost/benefit and shortfall analyses for major FAA capital investments
- 4 years of Value Stream Mapping and benefits quantification experience for government agencies
- Major contributor to the agency's supply chain integration projects and data-driven decision-making strategic objectives

Sustainment of Aging Legacy Government & Operations

Retaining Systems >Useful Life

- After implementation, Federal agencies try to sustain large infrastructure systems for as long as their intended useful life, planned in Investment Analysis
- In reality, **agencies retain systems much longer than their life cycle estimate**
  - Challenging to keep systems running
  - Service contracts with 3rd Parties Expire
  - Agency continues to sustain well beyond expected useful life
- Federal agencies trying to sustain infrastructure systems longer than intended life cycles must estimate and evaluate:
  1. **End-of-Service Date** – How long they can sustain a system without it failing
  2. **Sustainment Cost** – How much it will cost to continue to sustain (as failures increase)
  3. **Replacement Cost & Timing** – How much it will cost to replace with a new acquisition or the impact of replacement timing on cost (delays increase cost)
  4. **Replacement Timing** – The optimum time and risk trade-off to replace the existing system

Standard Life Cycles

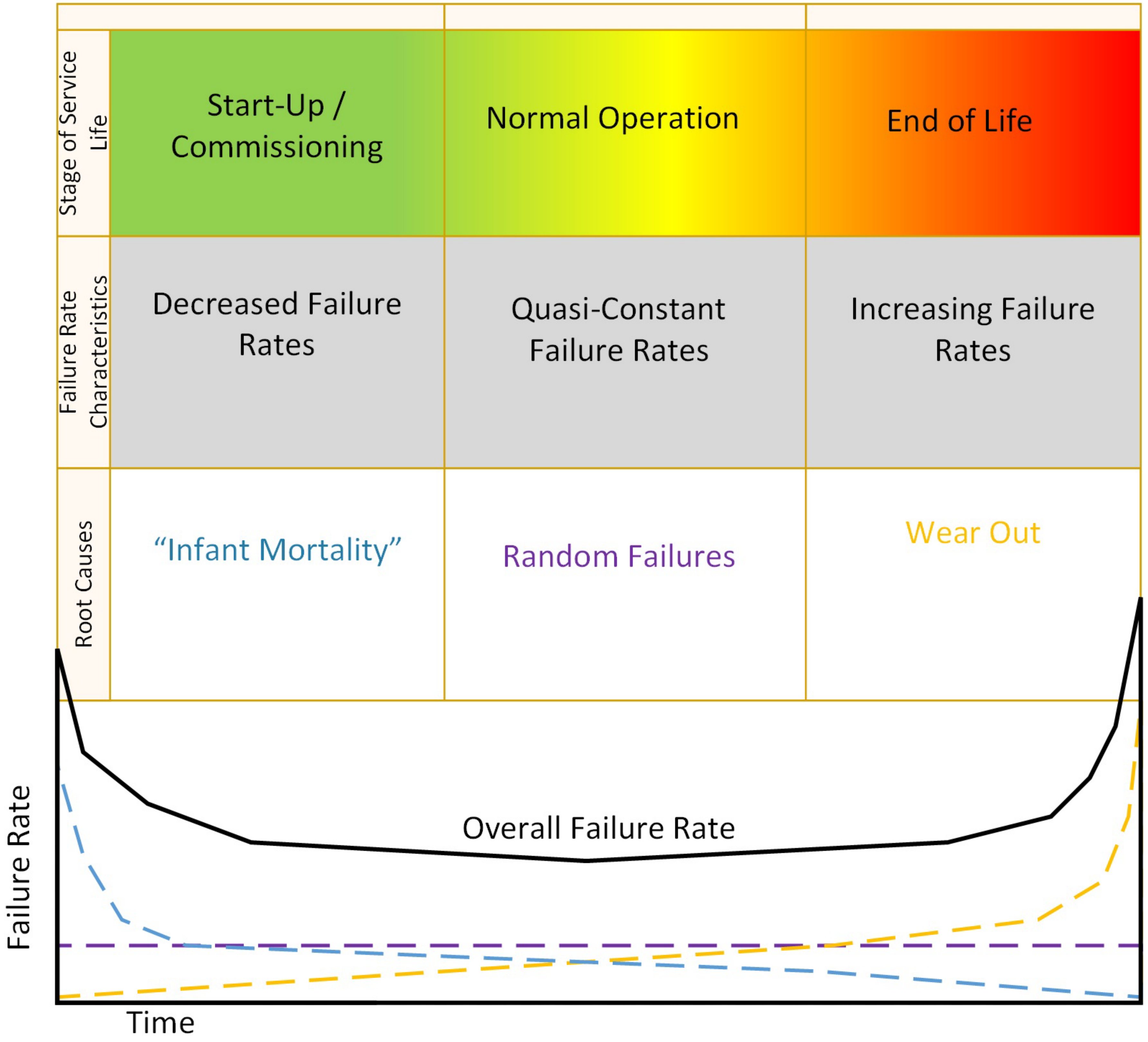
- What is a **standard life cycle?**
  - Standard period-of-time a program is implemented and maintained before replacement
- **What is considered in a standard life cycle?**
  - Government supports projects until End-of-Life (EOL).
  - **End-of-Life =** Point at which systems can no longer be maintained, where parts are no longer manufactured, and 3rd party maintenance contracts are no longer available.
  - **End-of-Service =** Point at which system failure is imminent (due to prolonged EOL issue). Can cause system to no longer function.
  - **Estimate project useful life by:**
    1) manufacture estimates,
    2) historical estimation,
    3) generic standards for hardware or software programs.
  - Return on Investment (ROI) – Retained long enough for benefits to agency and stakeholders to exceed acquisition cost and for investment to "pay off"

Standard Life Cycles

- **Advantages**
  - Standard basis to **compare mutually exclusive projects**
    - Can evaluate projects equally – Net Present Value (NPV), Internal Rate of Return (IRR), Payback
  - **Contract standards** – regular timeline by which to set maintenance contracts
  - **Maintenance planning** – Maintenance teams can plan sustainability and sparing around standard timeline
- **Disadvantages**
  - Standard life cycle timeline not the same for all Hardware (HW) or Software (SW) systems
    - **Sustainability** – Some systems cannot be maintained for 20-year HW life cycle
    - **Obsolescence** – Some systems and technology become obsolete. Cannot procure parts.
    - **Systems Age at Different Rates** – Historical life cycle estimates and manufacturer standards may not be good indicator of useful life of a specific project
    - **Risk Tolerance** – Agency systems which have no tolerance for failure (risk averse) have shorter life cycles to avoid failures

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



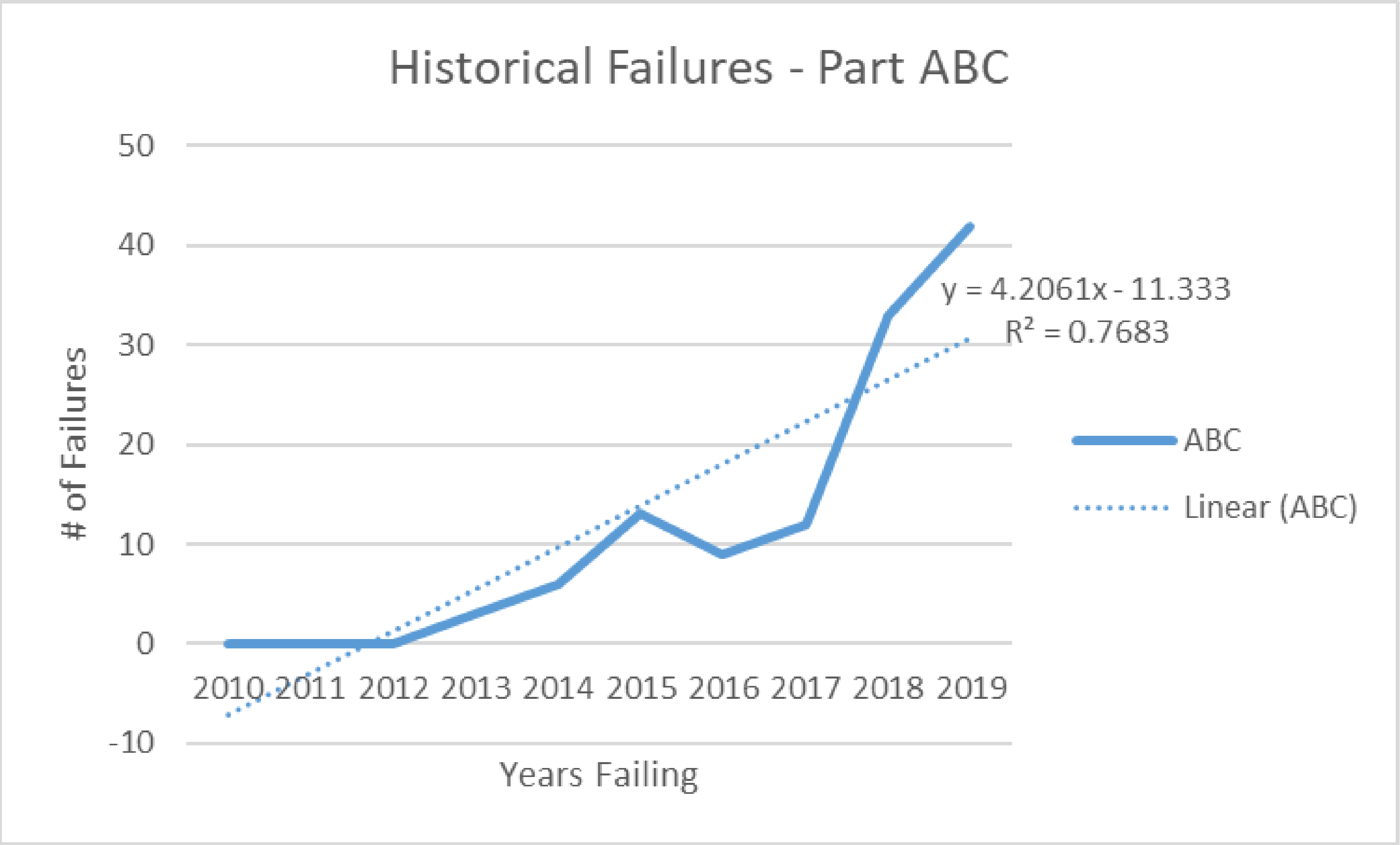
Sustainability Analysis

- To help agencies optimize legacy system sustainment, 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
- Evaluate System Sustainability, End-of-Life, and Optimum Time for System Replacement.

- **5 Factors of Infrastructure Life Cycle Decision-Making:**
  1. **Cost to Sustain –** What is the cost of sustaining operations with existing operational expenses versus replacing aging infrastructure in the National Airspace (NAS)?
  2. **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?
  3. **Timing of Replacement** – Optimum time to replace, limiting risk of operational interruption
  4. **Sustainment Methods to Extend Useful Life** – Replacing parts, failure analyses, lifetime buys
  5. **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?

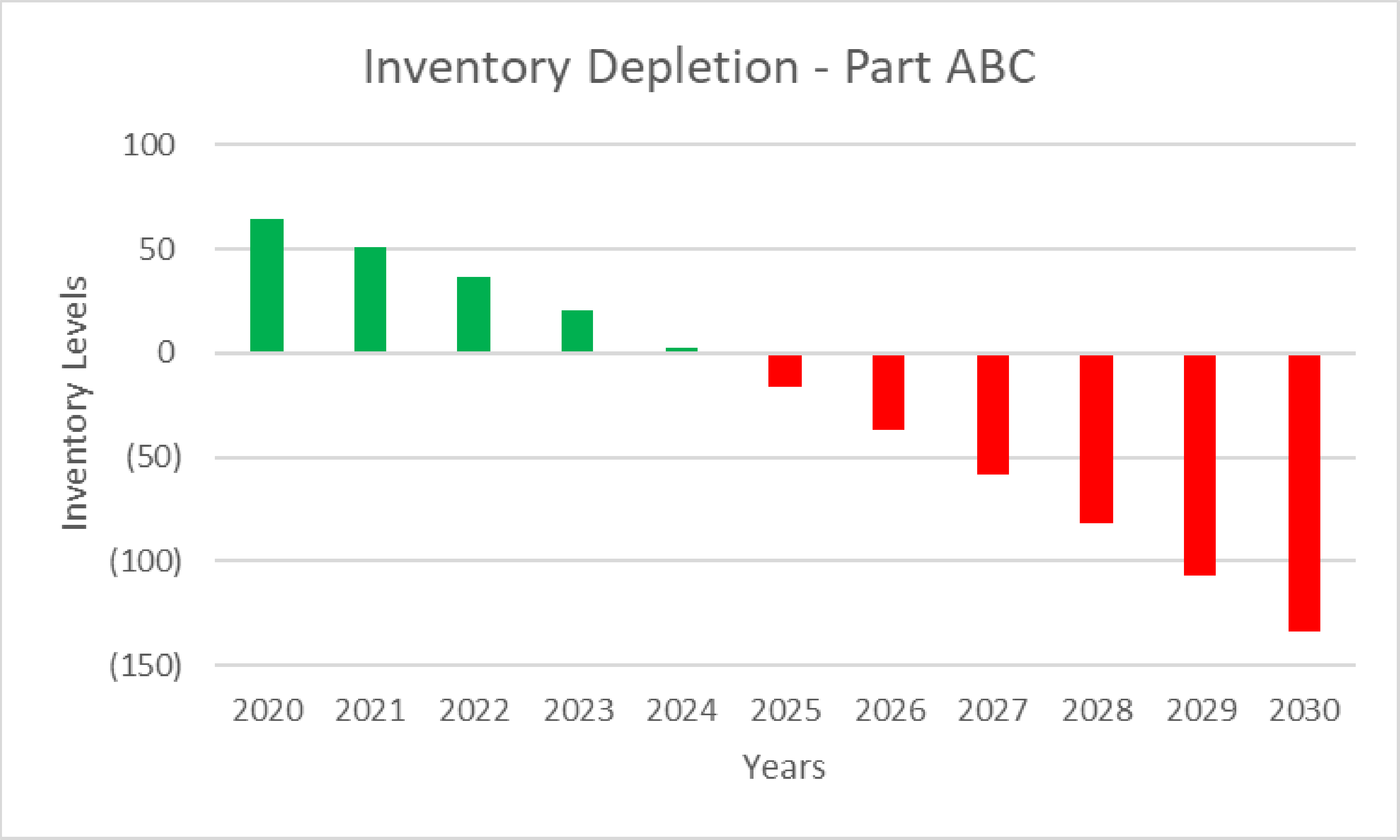
Sustainability – Estimating End-of-Life

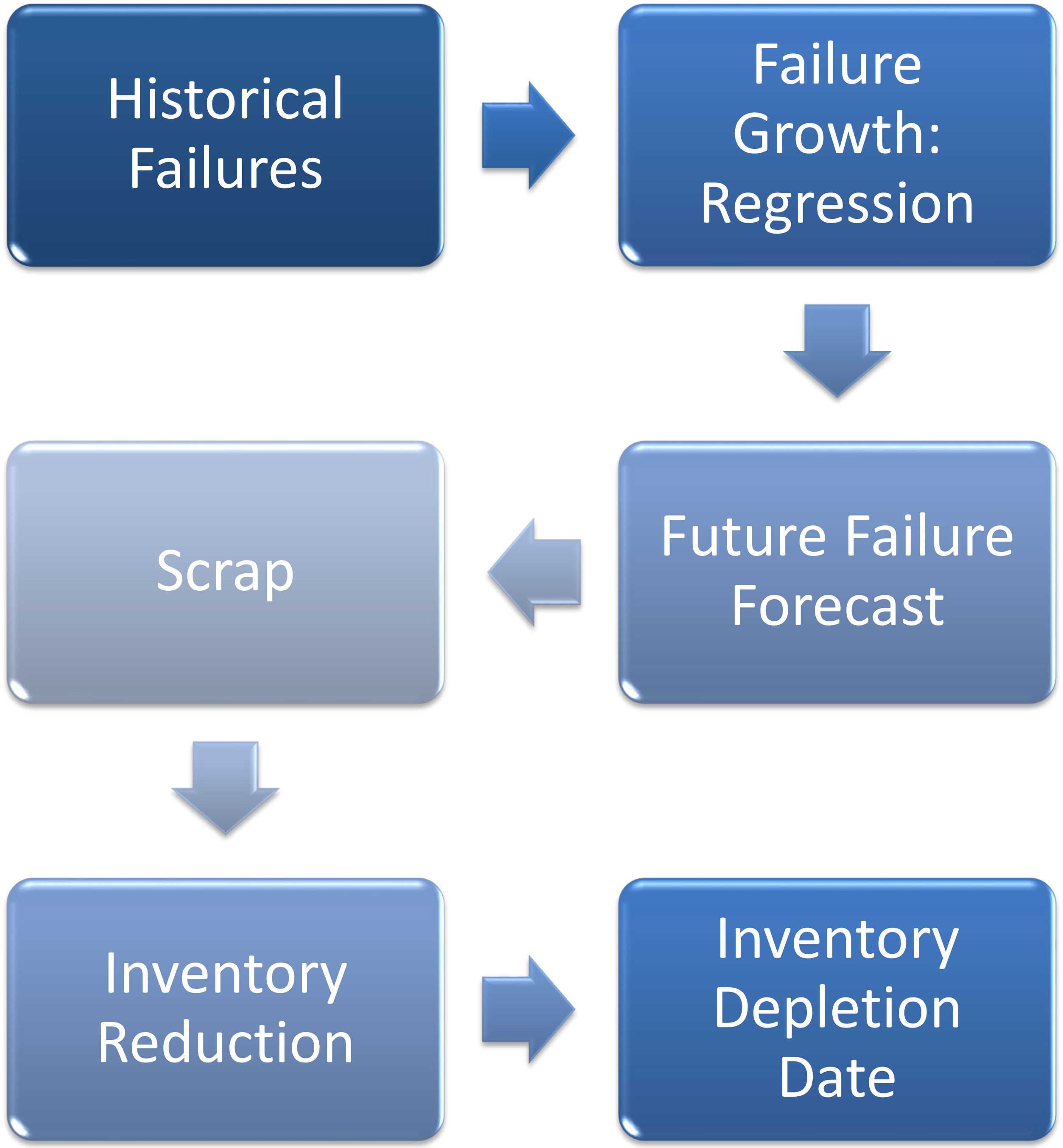
- Many systems are retained well beyond intended useful life, presenting sustainment issues
- **End-of-Life Sustainment Forecasting Factors**
  1) **Failure Rates** – How often part fails and system fails as result and requires repair
  2) **Failure Growth Rates** – How much more frequently parts are failing than prior
  3) **Scrap Rate/ Beyond Economic Repair (BER)**
     - For parts which are repaired, scrap is percentage of parts which cannot be repaired and must be discarded
  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



Sustainability – Inventory Depletion

- Sustainment Analysis helps Program Offices (Pos) forecast how long they can maintain legacy infrastructure systems
- Parts sustainment is one means by which we can estimate End-of-Life and Life Cycle
- Beg Inv. – (Failures X Growth X Scrap) = End. Inv.





Failure Analysis & EOL Forecasting

Failure Rate

- Use historical failure data by year to estimate an annual failure rate
- Draw trends about parts demand growth
- Estimate current failure rate and failure quantity by year

Failure Growth Rate

- How are failure rates trending over time? Are failure rates increasing?
- Use linear regression to estiamte failure growth rates
- Apply failure growth rates to forecast 10+ years of annual failure quantities

Scrap Rate

- Estimate scrap rate from historical logistics and repair data. What percentage of parts returne to the Depot for service can be reparied?
- BER (Beyond Economic Repair) - When parts are too expensive to repair, they are often scrapped, and parts inventory become expendable.

Inventory Depletion & EOS

- Collect current inventory
- Determine if Logistics can continue to procure inventory. If system is EOL, parts may no longer be manufactured, and procurement might not be an option.
- Agency may not have adequate funding to procure additional parts to supplement inventory, contractually or budgetary.

Sustainment Predicting Life Cycles

- By applying probabilistic forecasting, impact analysis, and risk evaluation, **predictive analysis** helps to "optimize life cycle sustainment and replacement timing."
  - **Data-Driven Probabilistic Analyses**
    - Using historical data – failure analyses, root cause, statistical regression, data trends – to forecast operational interruption
  - **Risk Management & Trade-Offs**
    - Probability of Risk vs. Risk Tolerance/ Thresholds
  - **Level of Criticality** – Impact if risk is realized. If low impact, can assume risk of longer life cycle.
  - **Level of Redundancy & Operational Resilience** – system redundancy mitigates risk of failure
  - **Risk Tolerance** – how much risk agency is willing to assume in event of failure
    - ***Risk Tolerance = Probability of Failure X Frequency of Failure X Impact***
  - **Cost-Benefit Analysis to Evaluate Risk**
    1. **Estimating End-of-Life (EOL)** – to estimate how long system can be sustained. Cost to replace
    2. **Sustainment** – cost for continued sustainment over project life cycle and beyond
    3. **Cost Avoidance** – cost of sustainment vs cost of replacement; different timing scenarios

System Trade-Offs – Analyzing Backup Systems to Optimize Cost, Minimize Risk, and Retain Sustainability

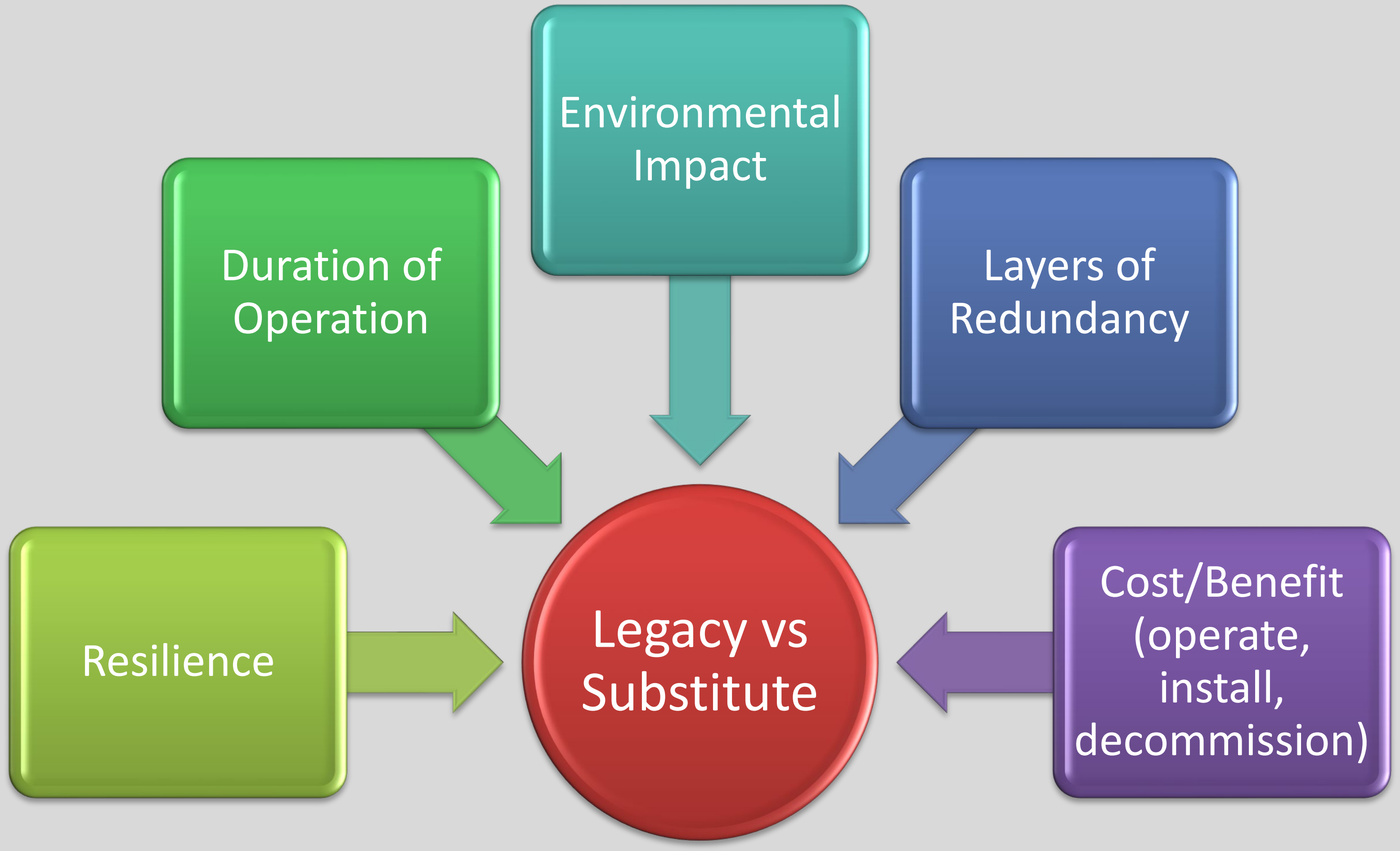
System Trade-offs vs Life Cycles

System Trade-offs

- System Trade-offs – Instead of replacing system with exact same at end-of-life, other option is replacement with different type of system
- **Legacy vs. Substitute –** How do we evaluate if **substitutes** are a **greater value** to the agency than current system?
  - Compare systems technical and cost/benefit

Case Study – Secondary Power

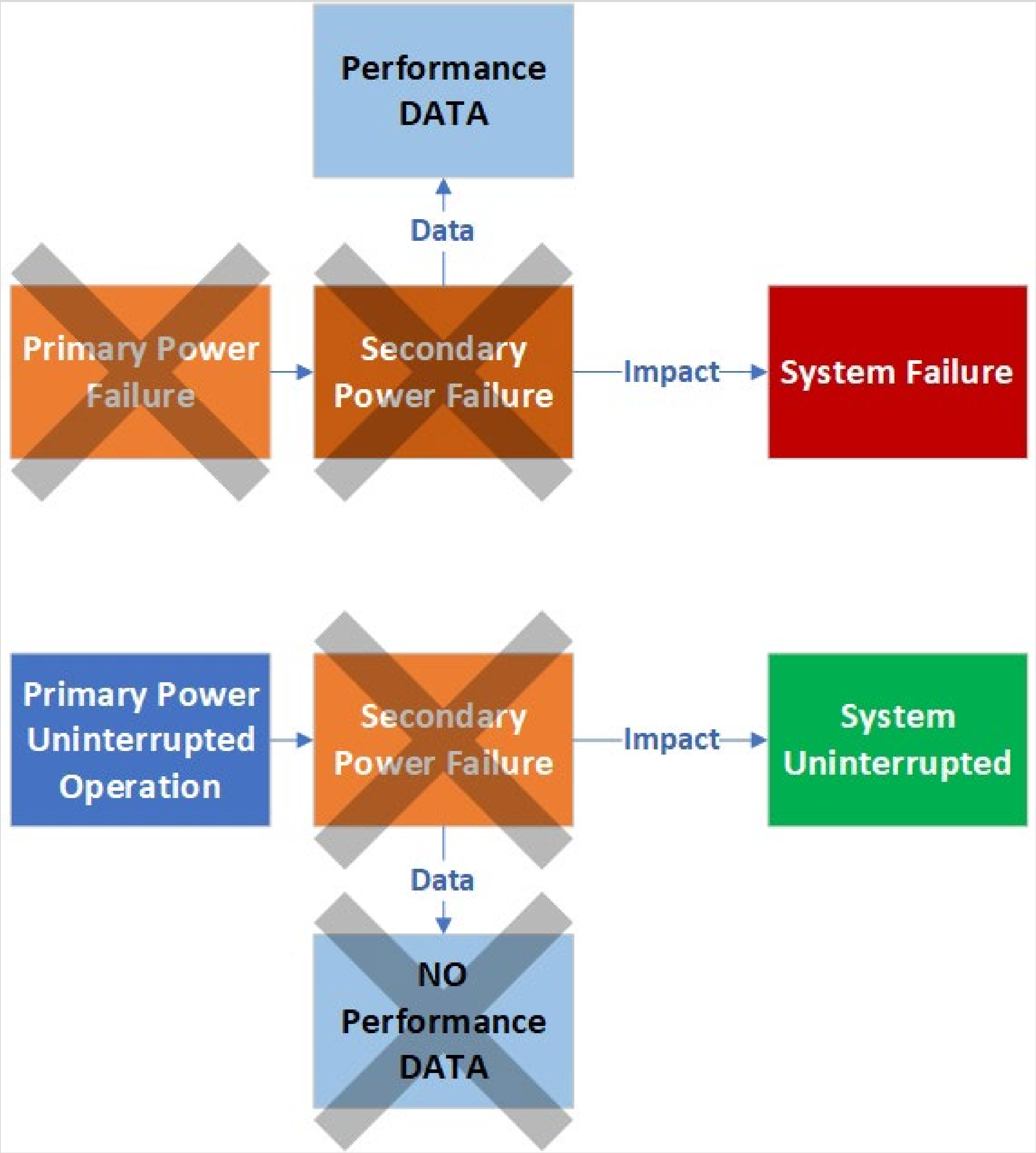
- Compare different power systems, configurations, technical details, functions for best fit by site, instead of one-size-fits-all.



System Trade-offs vs Life Cycles

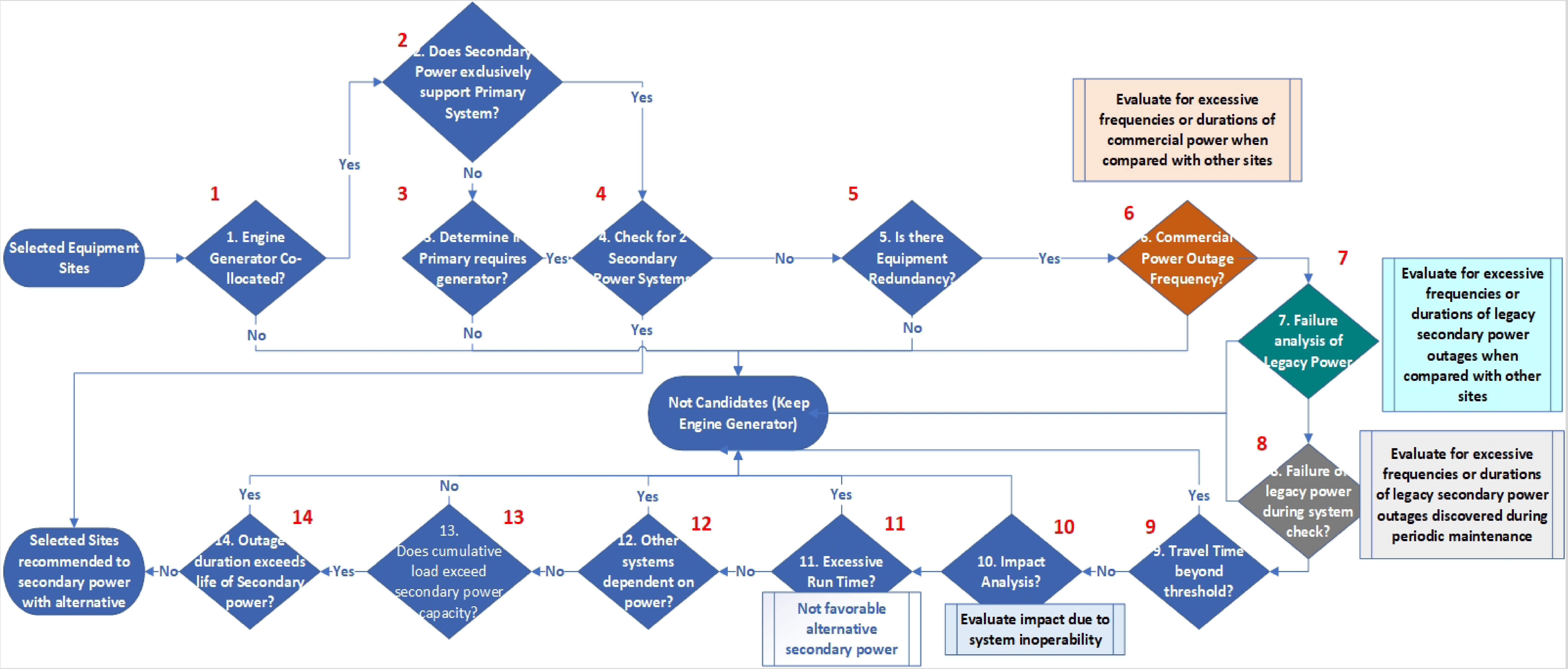
Challenges – Secondary Power

1. **Data Scarcity & Data Collection Frequency**
    - Data included in different databases. No single source of failure, demand, location, configuration, and system dependencies.
    - Cause of outages not comprehensively defined, categorized
    - Multiple classifications can lead to misinterpretation of data
2. **Secondary System Operation Not Transparent**
    - Unlike primary systems, secondary systems not constantly running
    - **Operations Data** – To capture operational failure of secondary system, primary system must fail first
    - **No Operations Data** – If primary power continues uninterrupted, and secondary power fails, data of secondary power failure may not be captured
3. **Other Operational Data Sources**
    - **Periodic (regularly scheduled) Maintenance** – adds operational datapoints for secondary power operation via testing
    - **Data Not as Robust** – Data not as frequent or comprehensive as if monitored and always on. For systems which are only turned on as needed, it is more difficult to monitor failure frequency



Trade-off Analysis Decision Tree

Risk Analysis, Sustainability, Life Cycle Measured as Combination or Risk Factors & Trade-off Capabilities



How to Measure Trade-offs

Trade-Off Factors

1. Examine Pros and Cons

- Data included in different databases. No single source of failure, demand, location, configuration, and system dependencies.

2. Redundancy

- What is level of system redundancy? Is there a backup system?
- Is this level of redundancy intended, or could it be changed?
- How many layers or redundancy? At what point are operations impacted?
- How many levels have to fail before operations are impacted?

3. Failure Analysis

- **Primary Power Failure Frequency** – measure of resiliency and probability of secondary power need; impacts trade-off analysis
- **Primary Power Failure Duration Analysis** – measures duration of required secondary power operation; impacts trade-offs
- **Secondary Power Failure Frequency** – measures Mean Time Between Failure (MTBF) of secondary power; reliability; *data can be convoluted*
- **Secondary Power Failure Duration Analysis** – estimates required capabilities of secondary power; trade-off configuration

4. Other Factors

- **Travel Time/ Response Time to Repair** – measures duration of required secondary power before repair is possible/ power restored
- **Impact Analysis** – shortfall analysis that estimates degree to which operations impacted if all power is lost – **RISK TOLERANCE**
- **Runtime** – measures wear on power systems and **directly impacts ability for life cycle extension**

Life Cycle Estimation – How Do We Use Incomplete Data to Estimate System Life Cycles?

Standard Life Cycle Durations

Standard Life Cycle Durations as Means of Investment Comparison

- **Business Case/ Finance Metrics**
  - Gov't evaluates business cases across a **standard life cycle**, often 20-year life cycle for HW or HW/SW systems
  - Standard life cycle makes for an easier comparison using finance metrics like **NPV, IRR, Payback, B/C Ratio**
  - Can compare business cases equally with cost and benefits monetized over the same number of years
- **Standard Life Cycle vs Risk of Loss of Service**
  - If company or gov't uses std life cycle, not data-driven life cycle
  - **Operations Data** – To capture operational failure of secondary system, primary system must fail first
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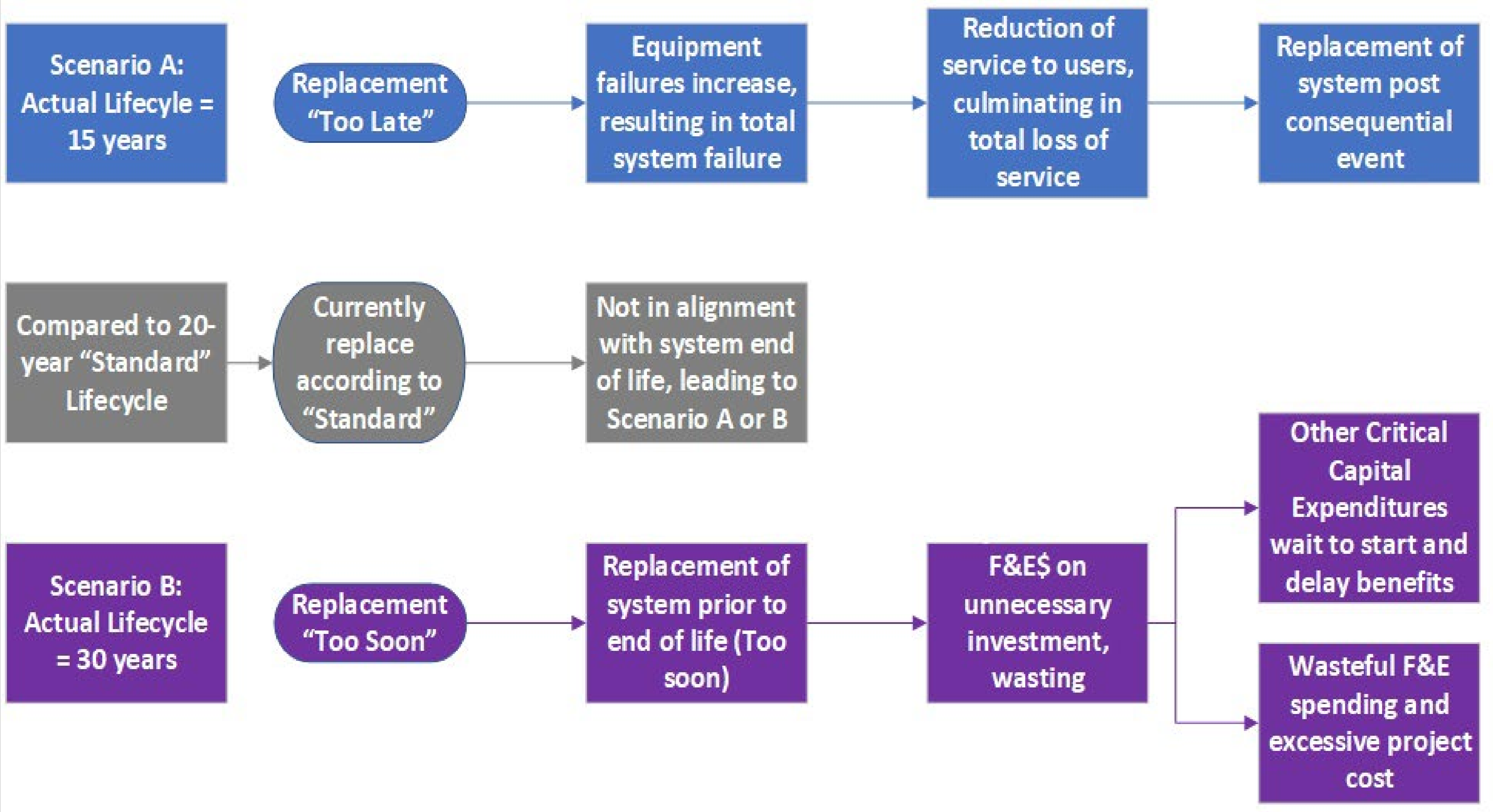
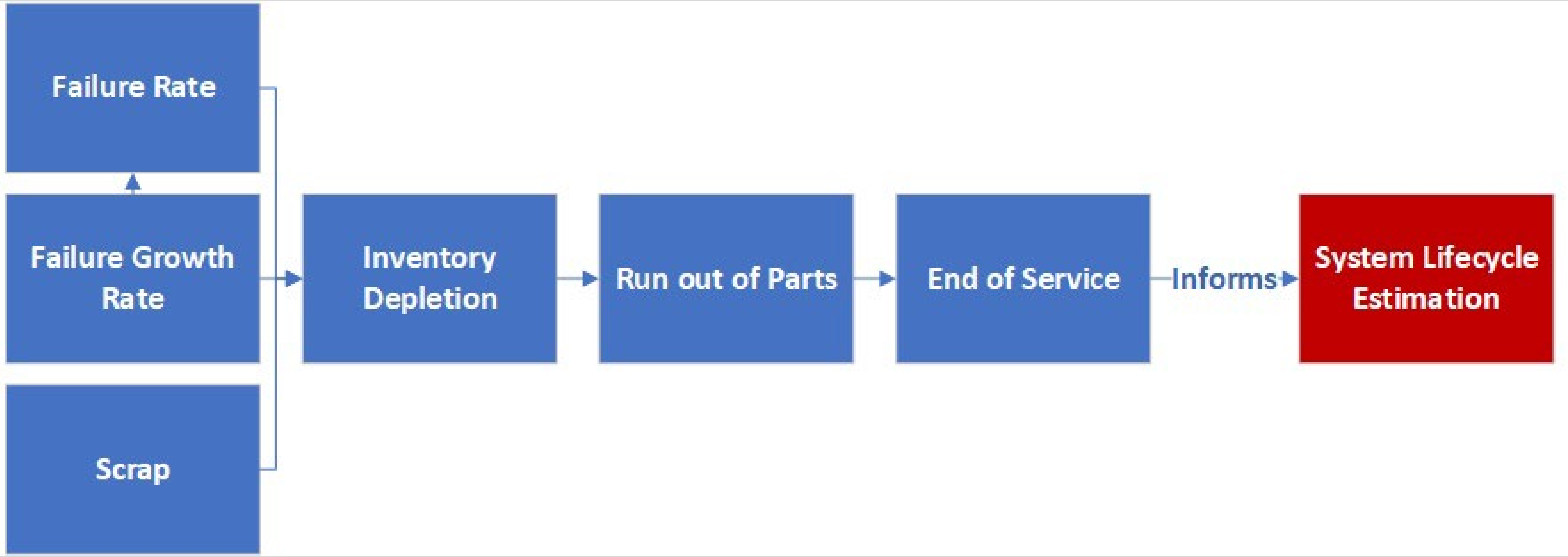


- **Standard Life Cycle vs Premature System Replacement and Waste of Agency F&E Dollars**
  - **Replace System Too Soon Compared to Useful Life** –
    1) **Wasted F&E Dollars and Not Cost Effective**
    2) **Invest Early at Expense of Another Acquisition**

Life Cycle Estimation Factors

Failure Analysis with Scarce or Incomplete Data Is Challenge to Life Cycle Estimation

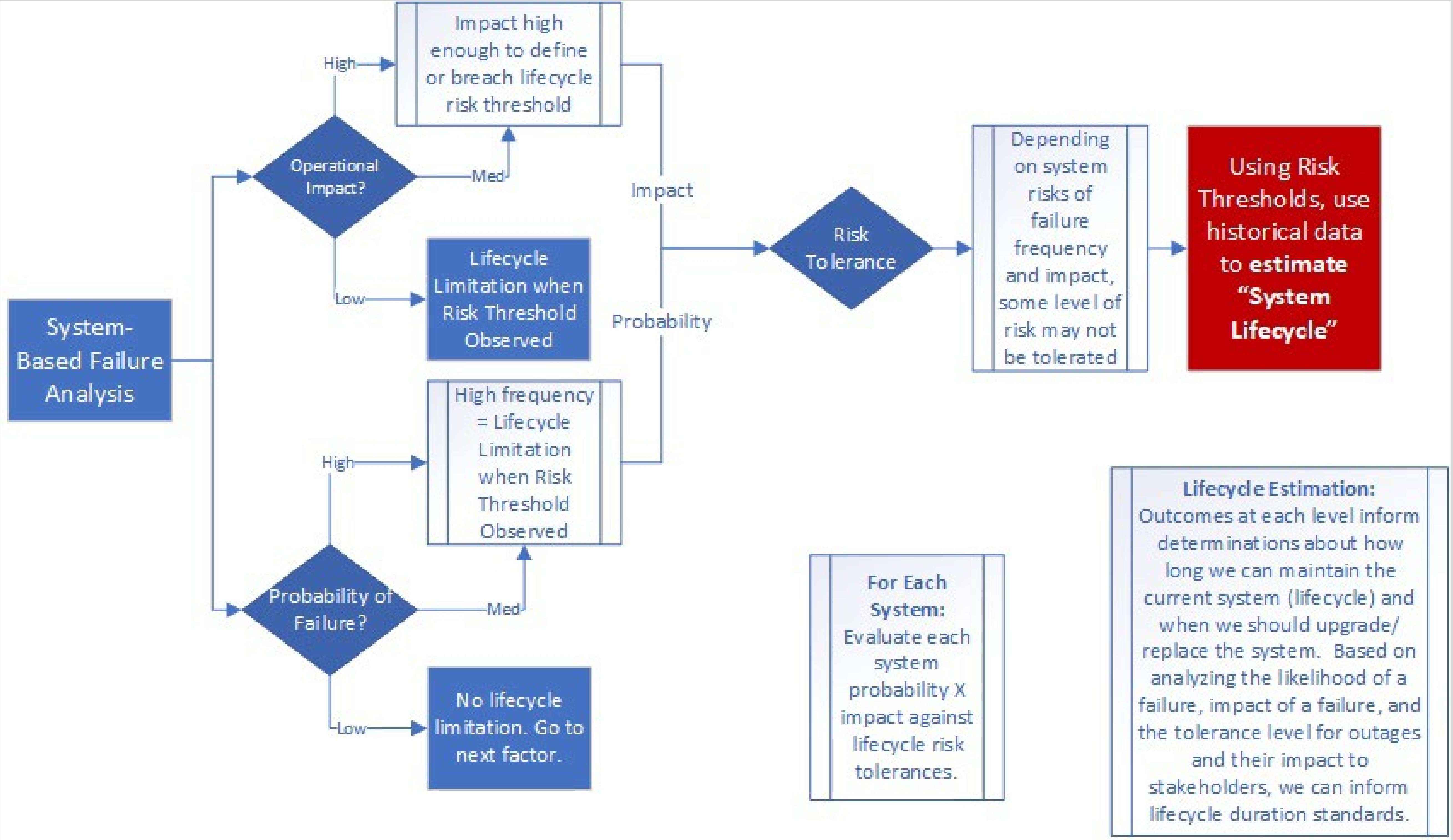
1. **Use Failure Analysis of System Components and on Full System Performance to Estimate How Long Agency Can Sustain the System**
   - Critical to measure system life cycle as nearing End-of-Life (EOL)
   - Using historical parts failures to estimate when fully deplete existing inventory of EOL systems = estimates duration of system life cycle
   - Failure Rates
   - Growth Rates
   - Scrap Rates
   - Inventory
   - Procurement
   - Inventory Depletion
   - End-of-Service (EOS)



2. **Secondary System Failure Analysis**
   - Difficult to gather complete data on system failures of secondary systems when secondary systems only operate when required (when primary systems fail first)

Life Cycle Estimation Factors

Estimate Overall System Failure Frequency Using Regression Analysis and Compare to Risk Tolerance



Life Cycle Extension Factors

Other Major Measures of Life Cycle Estimation and Extension

1. **Analyze Run Times or Other Measures of Operation**
   - Compare actual operational run times versus standard estimate useful life standards from manufacturer.
   - Estimates wear of system and how much life is remaining – can consider **life cycle extension**
2. **Age of System as Life Cycle Indicator**
   - Analyze older systems first where decision-making is more critical for future investments
   - Using historical failures as compared to age standards, estimate future failure frequency and impacts. Extend life cycle?
3. **Age of System Determines if Qualify for Analysis**
   - Repair Prioritization
   - Timing of Investment and System Replacement

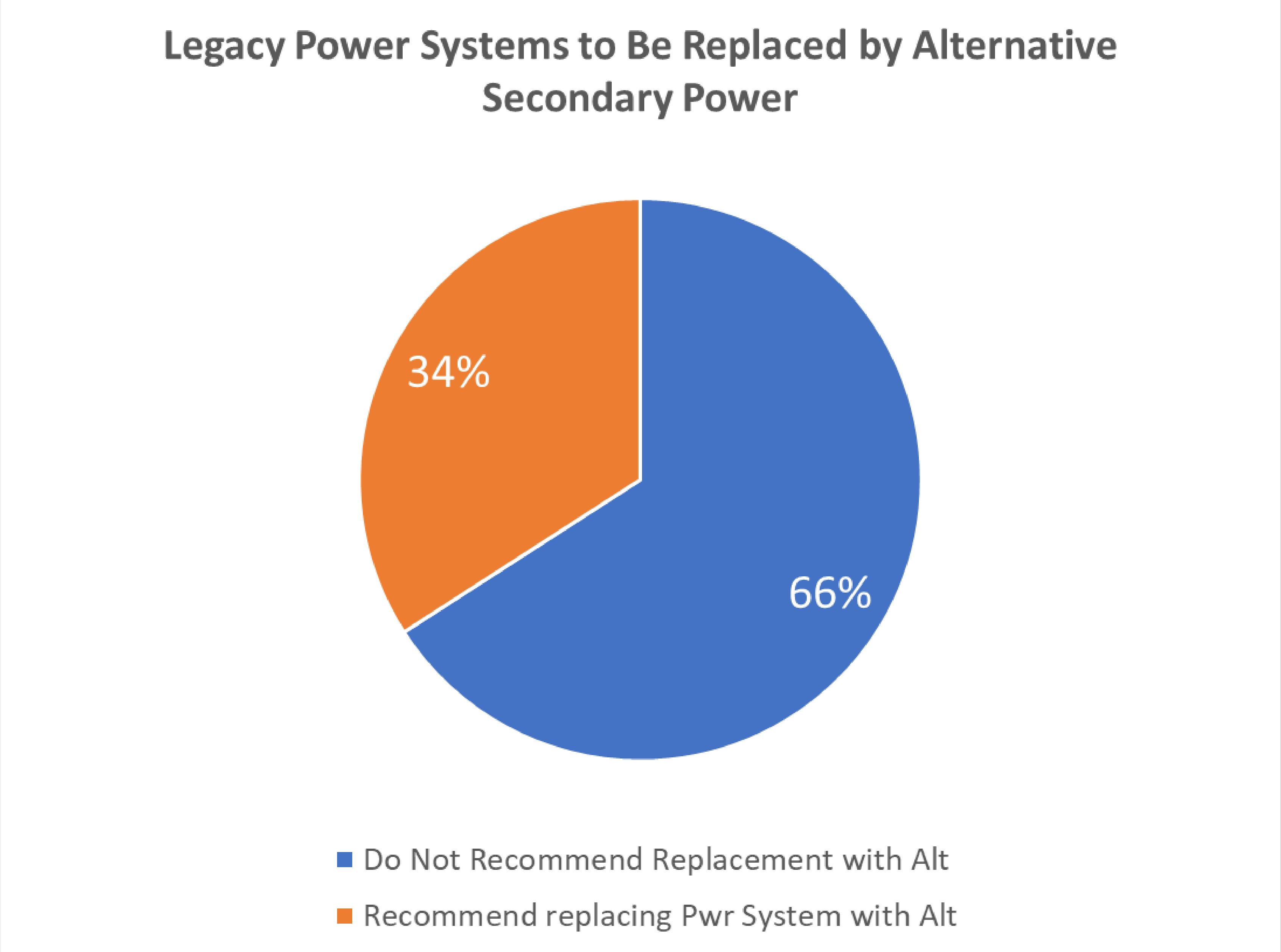
Risk Analysis Factors that Adjust Risk Tolerance Levels

1. Redundancy – Backup Systems
2. Multiple Layers of Redundancy Adds Operational Complexity

Use Case Conclusions

Secondary Power Trade-Off Analysis

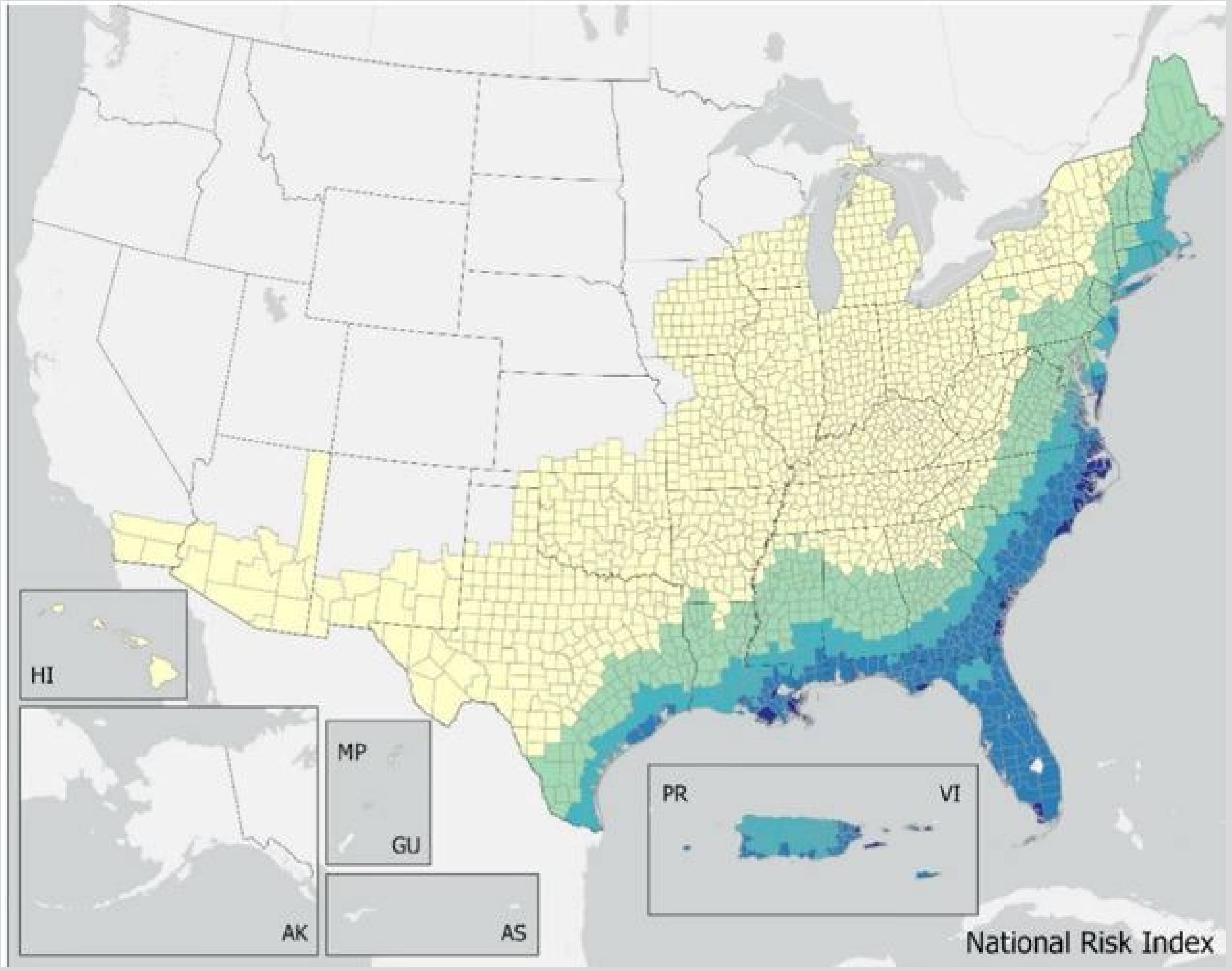
- **Conducted Trade-Off Analysis of Secondary Power Systems – Assess Application More Efficient Replacement System**
    - Analyzed Pros and Cons of each system capabilities
    - Cost/benefit analysis
    - Design constraints and system requirements
- **Results** – 34% of systems qualified for more efficient replacement secondary power
- Right-sized candidate systems to equipment
- Full assessment of risk tolerance
- Model accounted for potential changes to risk tolerance and exceptions with unique risk parameters



Use Case Conclusions

Secondary Power Life Cycle Extension

- **Considered factors and analyses to identify for which sites could extend life cycle 5 or 10 years**
  - Failure Analysis of commercial power and of system outages
  - Regression analysis to measure increased numbers of outages correlated with age of system
  - Compared with standard life cycles used for investment analysis and sustainment
  - Recommended ~60% of systems for life cycle extension on site-by-site qualifying basis



Natural Disaster Risk Analysis

- **Conducted Risk Analysis in Case of Natural Disasters – Additional Assessment of Configurations & Life Cycle**
  - Analyzed potential risks of natural disasters on resiliency profiles of systems
  - How does this impact life cycle extension or replacement of systems?
  - Right-sizing includes risk profiles and risk tolerance levels