Forecasting & Advance Analytics for Engine Maintenance Cost Control

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Delta Air Lines
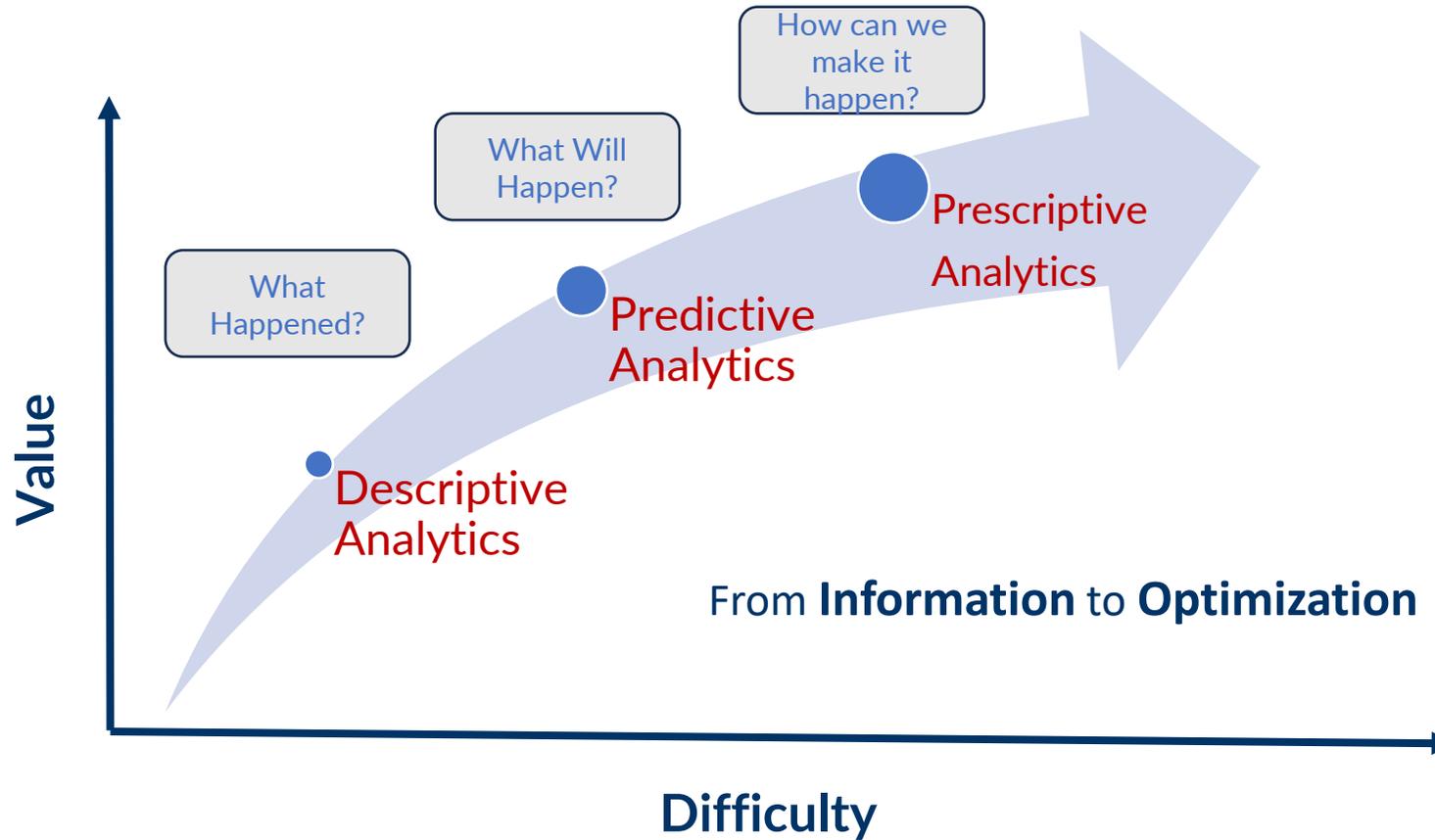
Engine Maintenance Costs

⟩ **Volumes**

How many assets (engines, modules or components) will require maintenance? How many sub-components (piece parts) will require repair or replacement (scrap)?

⟩ **Inventory**

How much buffer inventory is needed to support the operation? What Service Level is needed for my business?

⟩ **Rates**

What will it cost to repair or replace the parts forecasted as total demand?

Material Supply & Demand Profile Development

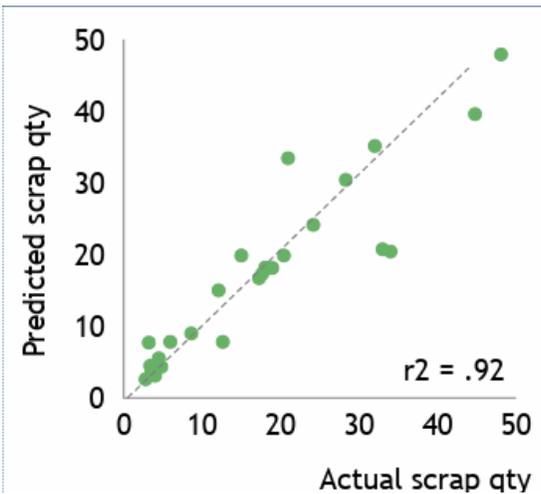## Analytics can be used to Forecast Volumes, Inventory and Rates

Breaking down demand to the piece part level will allow for optimization of supply

Demand Profile

**Forecasting demand, both at the engine (or asset) level all the way down to the piece parts**

- Engine Removal Forecasting
- Engine Workscope Type Forecasting
- Piece Part Scrap Demand
- Scrap Variability

Buffer & Replenishment

**Calculating Buffer and Replenishment needs based on Little's Law and Theory of Constraints**

- Engine TAT Requirements
- Historical Piece Part TAT
- Forecasted TAT Variability
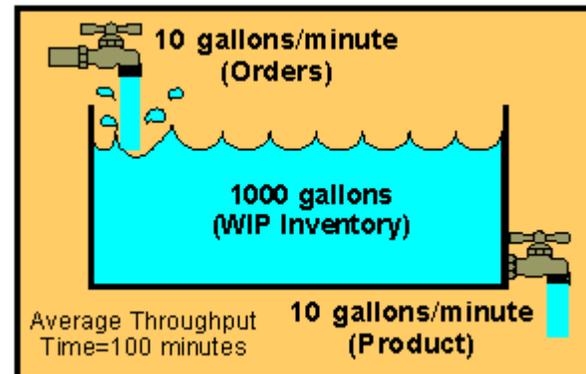
Supply Profile

Advanced demand and buffer forecasting allows for optimization of supply profile

- Current Inventory
- Material On Order
- Used Material Availability
- Part-Out Material Availability
- Unserviceable Material Availability
- Repair Development Opportunities
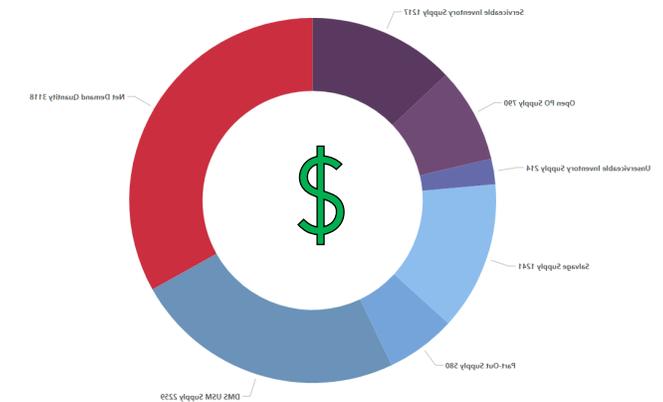
Demand Forecasting

- Forecasting removals (planned + UER) at the ESN or removal attribute level allows for probabilistic modeling at the piece part level
- Expanding piece part forecasting from Empirical Forecasting to include probabilistic models can greatly improve accuracy
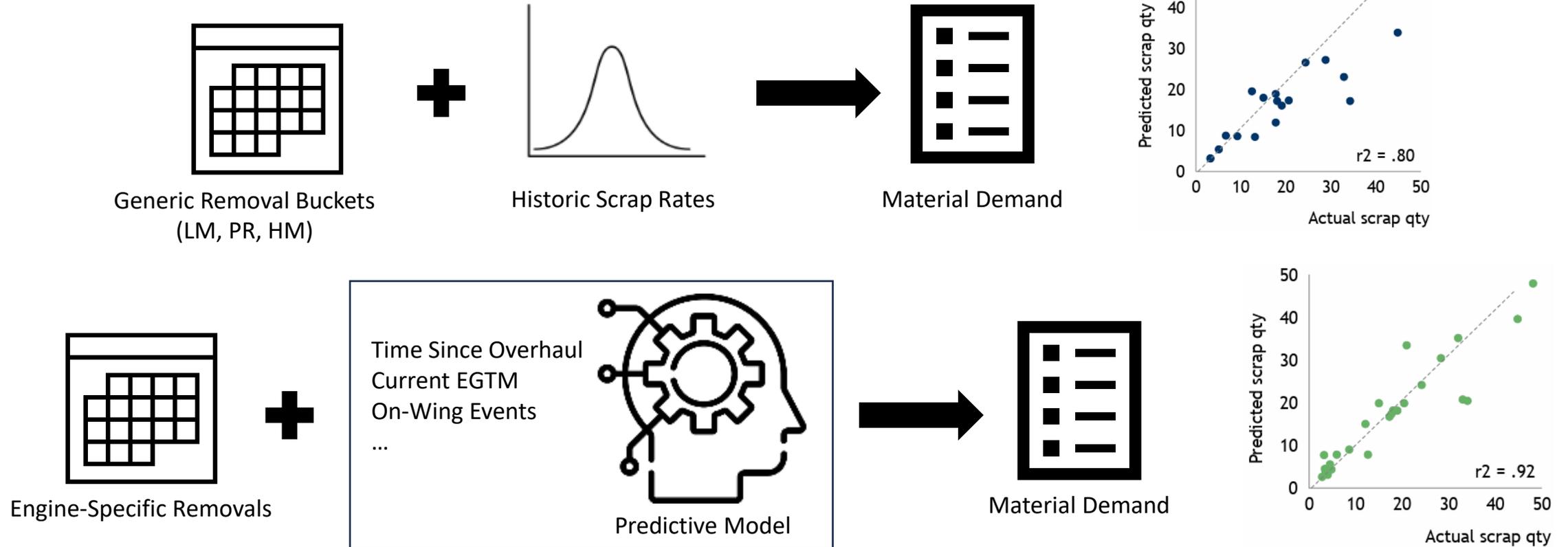
Feature Forecasting

- Feature based scrap forecasting allows for ESN specific modeling based on engine, module and piece part characteristics (actual or projected) at time of removal
- Model features can be forecast months and even years in advance to enable extended production and material demand forecasts

Expected Removal Date	04/2026
EGTM	16
Engine TSO	20k
HPT TSO	12k
HPC TSO	7.6k
…	…

Part #1 Feature Forecast
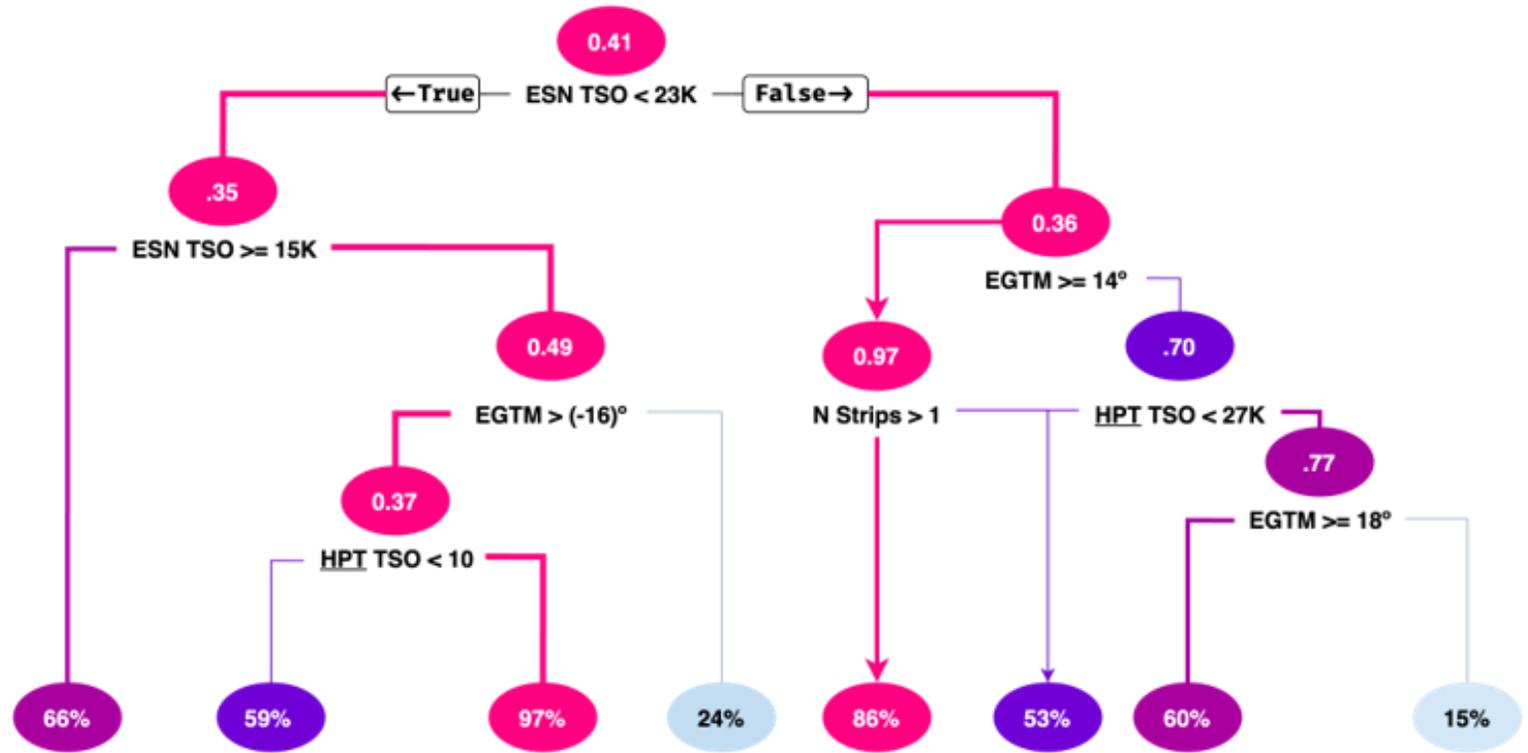
Buffer and Replenishment

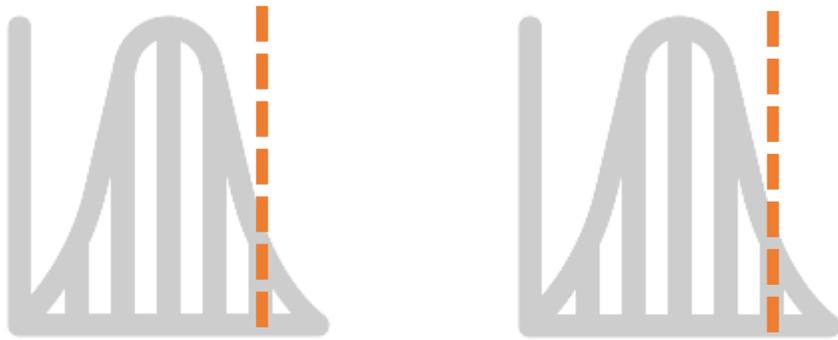- User-desired service levels provide buffer inventory requirements to hedge against forecast error and lead time variability
- Order Up To Levels (OUTLs) reconcile predicted demand with actual demand to smooth inventory position and keep service levels consistent

Forecast Error   **Historic Lead Time**

Desired Cycle Service Level	Z-Factor
85%	1.04
90%	1.28
95%	1.65
99%	2.33
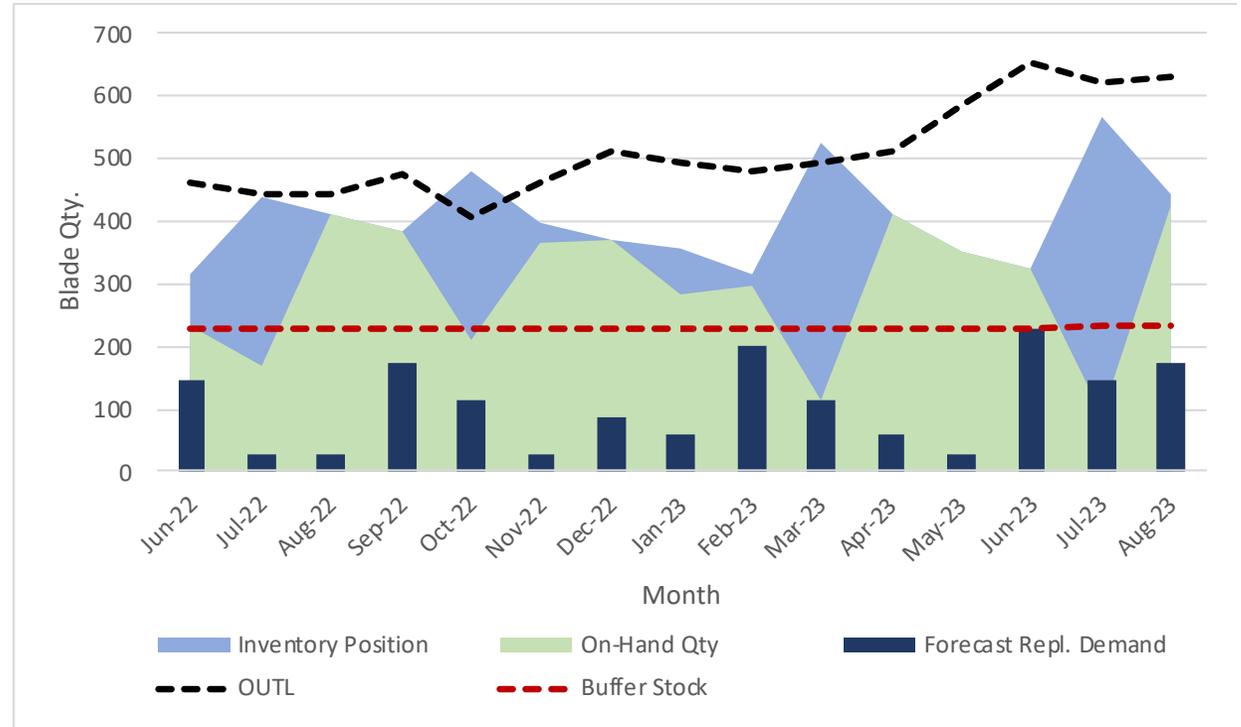
$$Total\ Buffer\ Stock = Z * \sqrt{\left(\frac{PC}{T_1} * \sigma_D{}^2\right) + \left(\sigma_{LT} + D_{avg}\right)^2}$$

Total Replenishment

- Desired service levels are part-specific. Setting service levels to maximize engine A0 under budget constraints is an optimization exercise
- Accurate inventory levels and up-to-date lead/TAT distributions are critical to accurate forecasting

Forecast Scrap $+$ Forecast Error $+$ Lead Time/TAT Distribution $\Rightarrow$ Total Replenishment
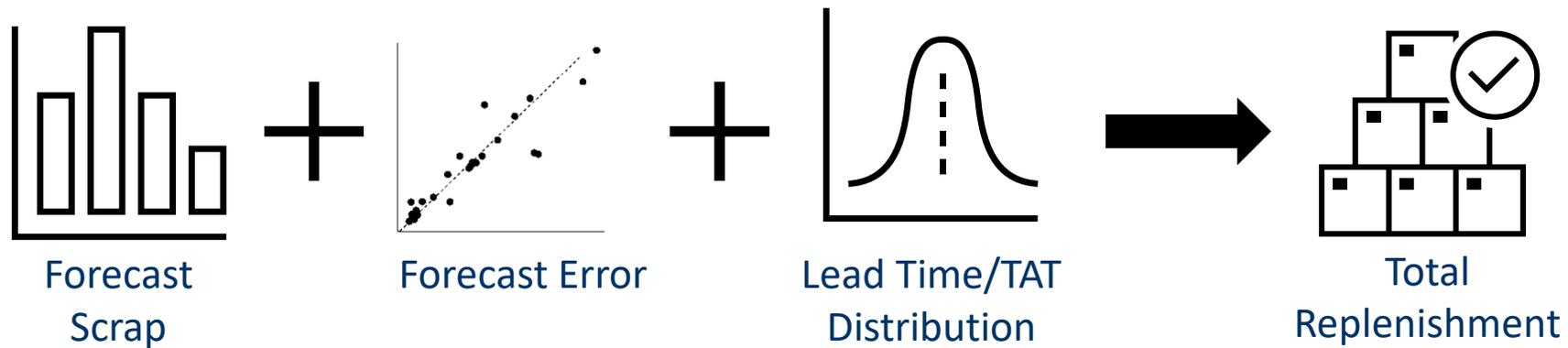
Acceptable levels of risk remain strategic business decisions and risk is managed through the desired service levels.

Supply Profile

- Accurate demand forecasting and timing allows for strategic sourcing of supply
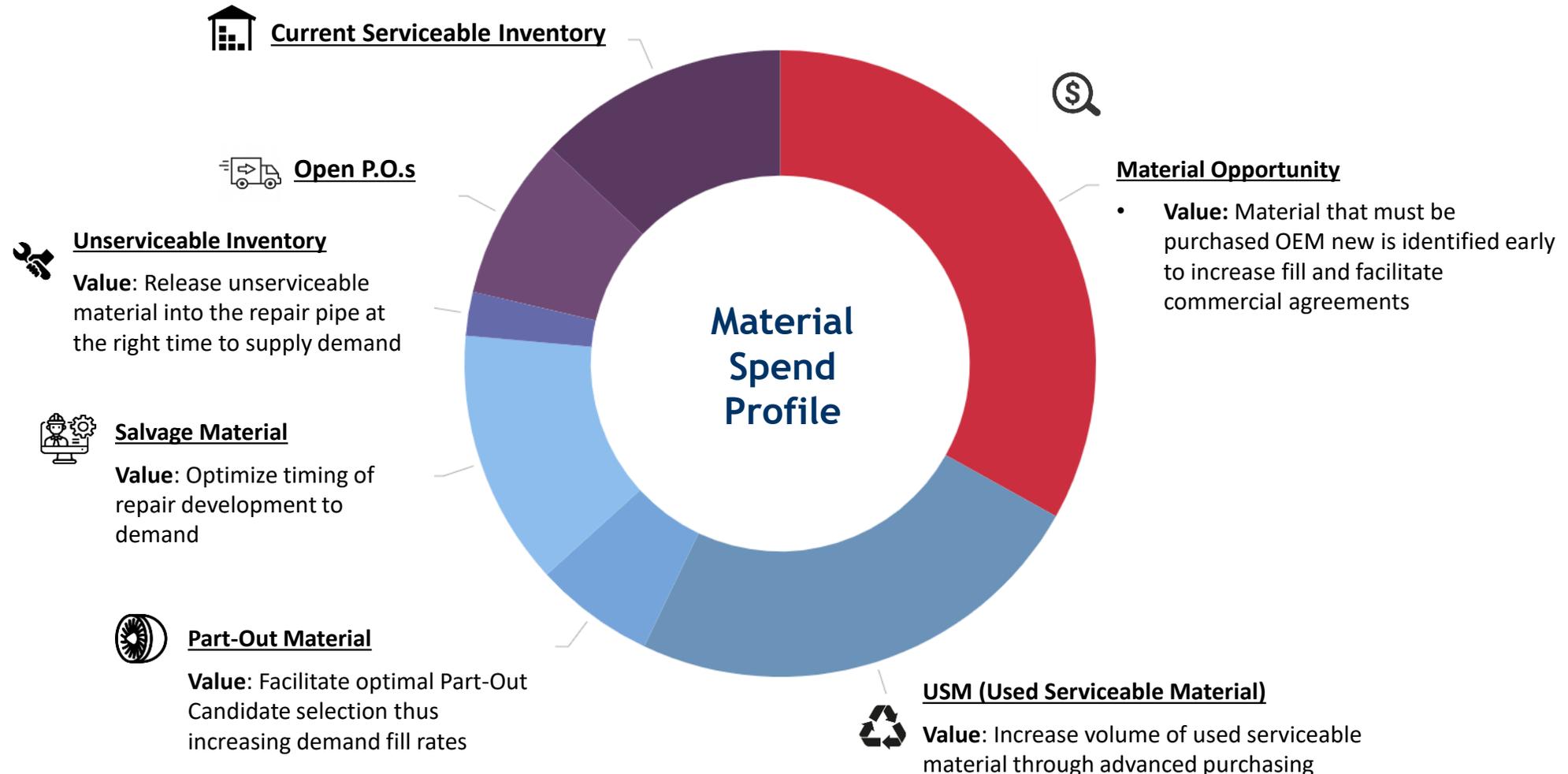- Replacement cost for scrap parts can be dramatically reduced through advanced purchasing and efficient use of existing materials

Current Serviceable Inventory

Open P.O.s

Unserviceable Inventory

Value: Release unserviceable material into the repair pipe at the right time to supply demand

Salvage Material

Value: Optimize timing of repair development to demand

Part-Out Material

Value: Facilitate optimal Part-Out Candidate selection thus increasing demand fill rates

Material Spend Profile

Material Opportunity

- **Value**: Material that must be purchased OEM new is identified early to increase fill and facilitate commercial agreements

USM (Used Serviceable Material)

Value: Increase volume of used serviceable material through advanced purchasing

Reducing Piece Part Volumes

- Historically, "cost buckets" are developed to derive Fleet Management Plans (FMPs) and shop Minimum Build Standards
- Optimization modeling can be used to move from these single event maintenance optimization technique to full engine life cycle optimization
- Enhance modeling using ESN unique characteristics, performance entitlement and reliability

Single Event Maintenance Optimization

Multi-Event (lifecycle) Maintenance Optimization
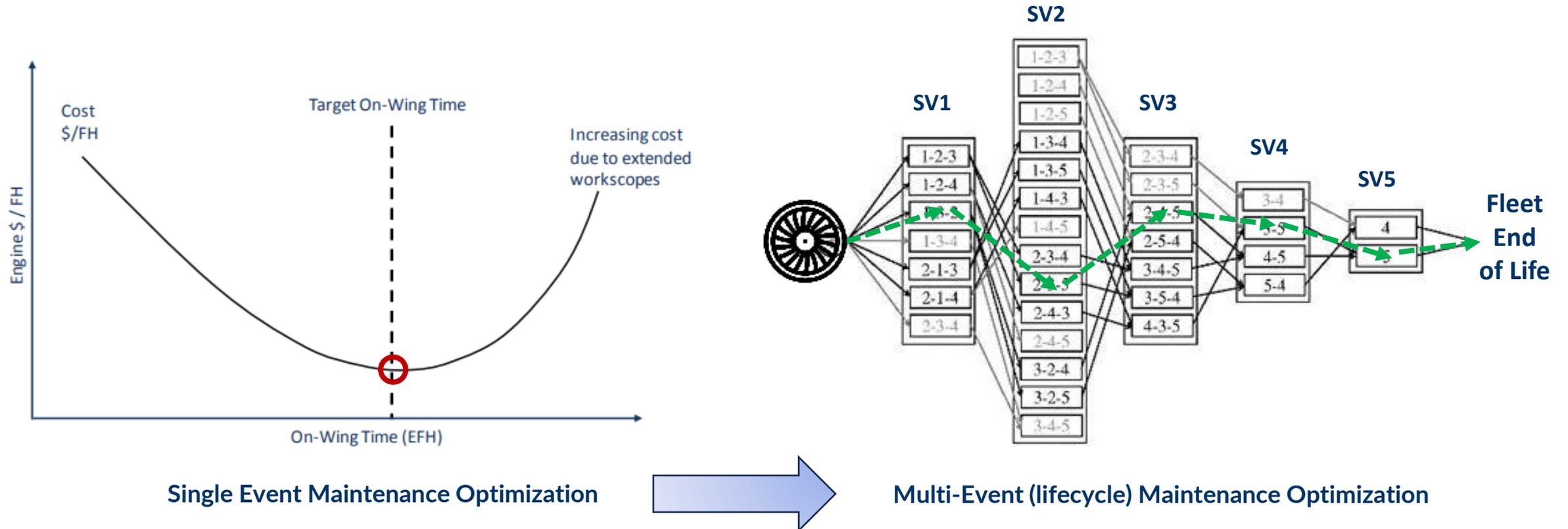
Analytic Capabilities

Selecting the RIGHT Analytics to invest in is as important as the model development itself

Understand Your Data

Data quality and availability is often the greatest barrier of entry for advanced analytics. Know the current state of your data and what investment must be made.

Know your Value Objectives

Understanding your primary objectives and target use cases will streamline your journey to value creation.

Understand Ongoing Investments

Most advanced models require some level of sustainment. What will that be and how can you support it?
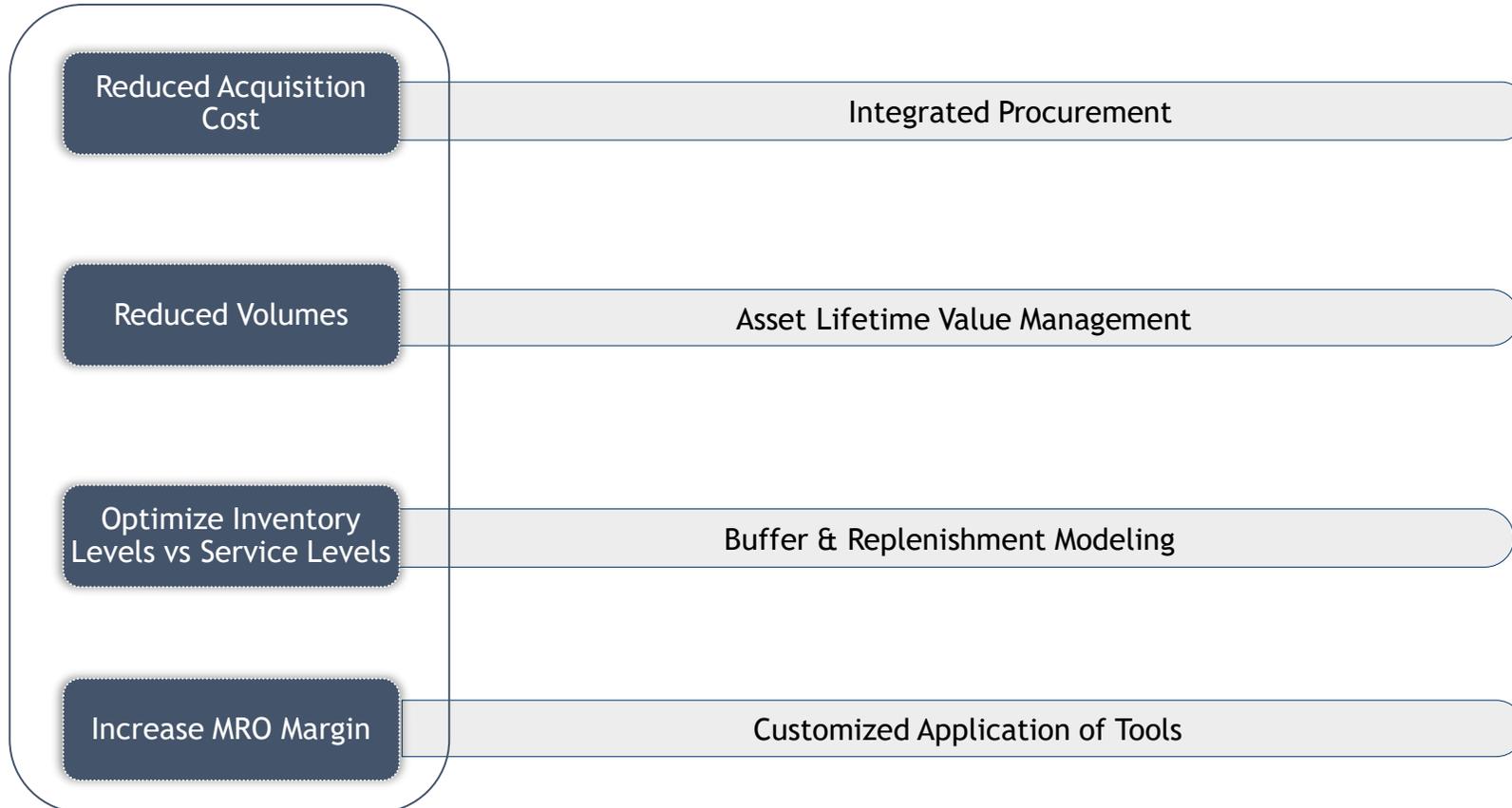
Analytic Capabilities

Building suite of analytic tools to support CASM Reduction

Value Generation

Reduced Acquisition Cost — Integrated Procurement

Reduced Volumes — Asset Lifetime Value Management

Optimize Inventory Levels vs Service Levels — Buffer & Replenishment Modeling

Increase MRO Margin — Customized Application of Tools
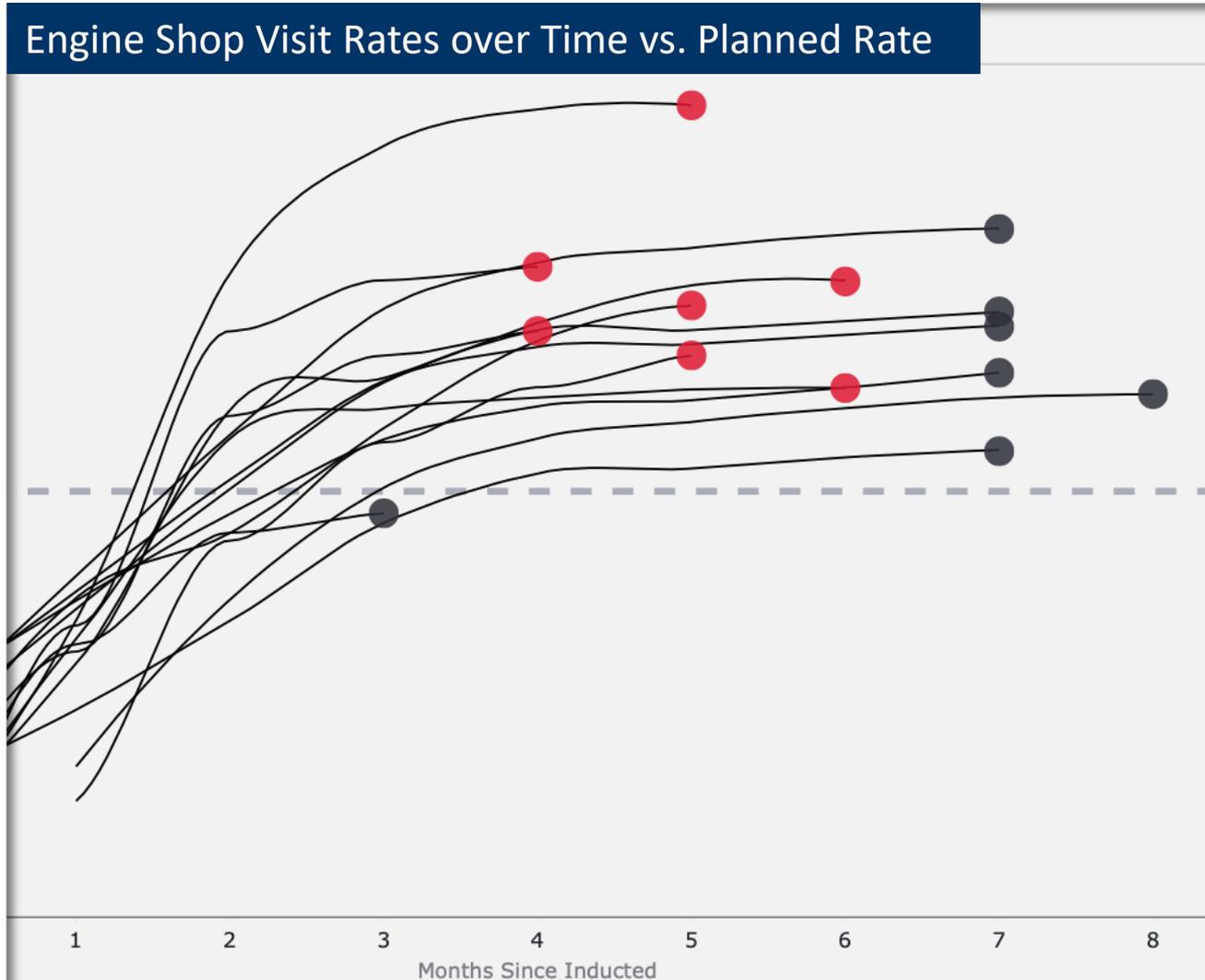
Foundational Efforts

Predictive Analytics
Scrap Rate Modeling

Data Layer
Robust data curation

Machine learning models require re-training and monitoring

Human intervention will be constantly required to update, expand and re-train models. Changes to your fleet, operation or reliability requirements will drive perpetual updates.

Engine Shop Visit Rates over Time vs. Planned Rate

Months Since Inducted

Questions?