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Creating a Fleet Management Decision Tool Using Mixed Integer Linear Programming

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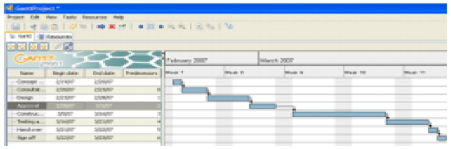
Background

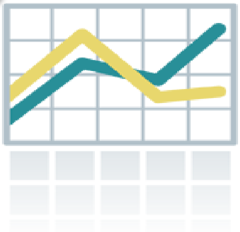
New Alternative Replacements

Platform Upgrades

Balancing Performance, Cost, Requirements

Over Time





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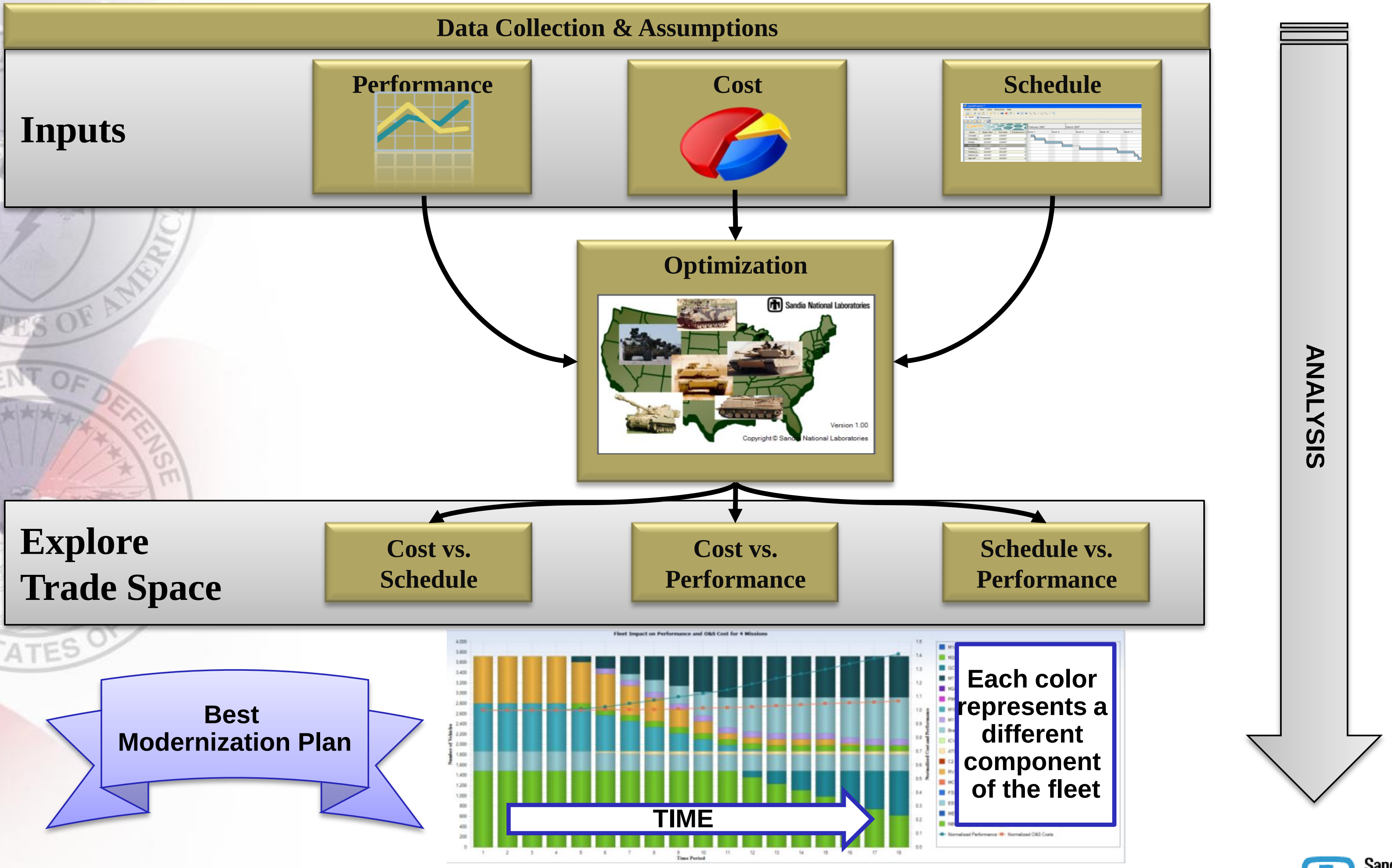
Fleet Management Challenge

- Program executives face the perpetual fleet management challenge: The need to create optimal investment plans for fleet obsolescence mitigation and modernization. These investment plans must be comprehensive, ensuring an optimal balance between capability, schedule and cost.
- Critical questions:
  - What fleet composition will maximize overall performance?
  - Can we minimize cost while maintaining a performance threshold?
  - What fleet compositions meet schedule and cost constraints?
  - What is the required funding profile over the planning horizon given schedule and performance requirements
- Fleet Management problems are highly complex due to the large number of decision variables, constraints, and dependencies

Fleet Management Optimization Process



Model Inputs

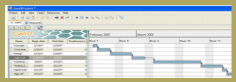
Data Collection & Assumptions

Inputs

Performance

Cost

Schedule



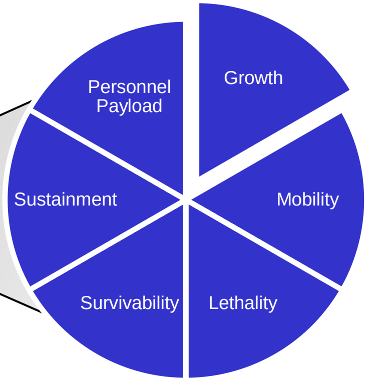
- PM Community
- TCM Community
- MCOE
- FCOE

Qualitative

- SME Opinions
- Mission role weighting
- Metric importance

Quantitative

- Vehicle performance
- Schedule
- Cost



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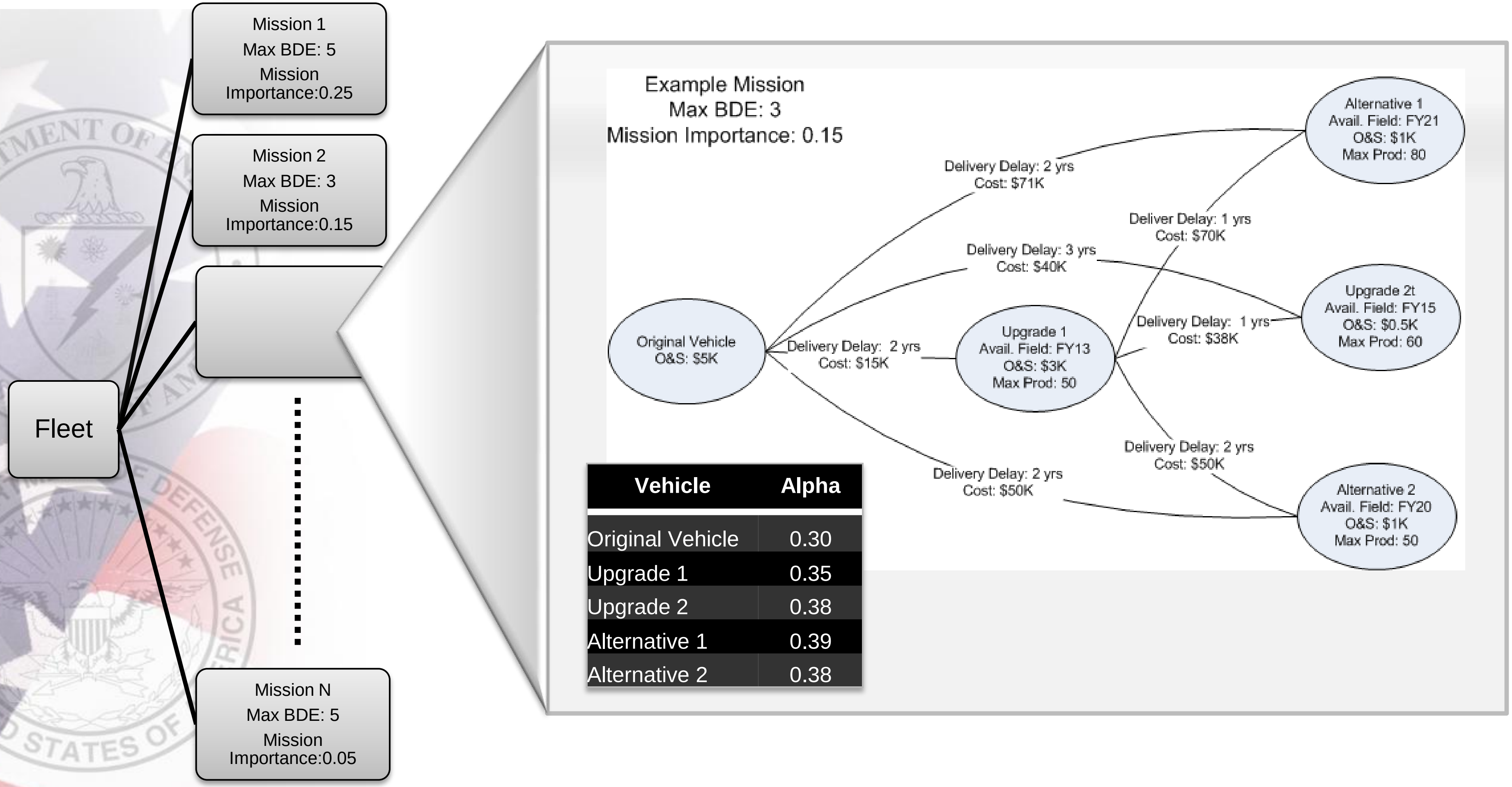
Transitions Model



Vehicle	Alpha
Original Vehicle	0.30
Upgrade 1	0.35
Upgrade 2	0.38
Alternative 1	0.39
Alternative 2	0.38

Transitions models defines available upgrades and vehicle alternatives for each mission

Mixed Integer Linear Program - Objective

Objective

– **Maximize fleet performance**

Vehicle *i* mission *m* combination

Starting Inventory

Transition into Vehicle *i*

$$\text{Max} \sum_{t} \sum_{i,m} \alpha_{i,m} \left(\text{Initial}_{i,m} + \sum_{ii,t' \le t} \text{Transition}_{m,ii,i,t'} - \sum_{ii,t' \le t} \text{Transition}_{m,i,ii,t'} \right)$$

time *t*

Performance

Transition out from vehicle *i*

Maximizes the overall cumulative performances of the entire fleet by summing over each time interval. Note that this encourages early improvements

Mixed Integer Linear Program – Constraints (1)

Subject to:

– **Maintain fleet size consistencies**

Global conservation - Total number of vehicle *i*'s for mission *m* must equal to the required number vehicle need for mission *m*.

Mission *m*
Time *t*

$$\forall_{m,t} \quad \sum_{i}\left(\text{Initial}_{i,m} - \sum_{ii,t'\le t}\text{Transition}_{m,i,ii,t'} + \sum_{ii,t'\le t}\text{Transition}_{m,ii,i,t'}\right) = \text{MissionVehReq}_{m}$$

$$\forall_{i,m,t} \quad \sum_{ii,t'\le t}\text{Transistion}_{m,i,ii,t'} \le \text{Initial}_{i,m} + \sum_{iii,t'\le t}\text{Transition}_{m,iii,i,t'}$$

Note: Transitions are s.t. a Transition Map defining the transition models

Vehicle, *i*
Mission, m
Time, t

Local conservation – at any vehicle *i* transition leaving *i* cannot be greater then the sum of initial inventory and transition into *i.*

These constrains ensures that the accounting for upgrades and purchases are valid with the mission requirements

Mixed Integer Linear Program – Constraints (2)

Subject to:

– **Percent modernization**

Mission *m*
Vehicle *i*
Time *t*

Transition leaving vehicle *i*

The percent of vehicle I for mission m by time t that should be modernized

$$\forall m,i,t \quad \sum_{ii,t'\le t} \text{Transition}_{m,i,ii,t'} \ge \text{PercentModernized}_{i,m,t} \times \text{Initial}_{i,m}$$

Note: only valid for those with initial inventory

Transition leaving vehicle *i* (upgrades or new acquisitions) must be greater than percent modernized by time period *t*

In addition to implicit desire for modernization by the objective function, this constraint forces modernization over schedule requirements

Mixed Integer Linear Program – Constraints (3)

Subject to:

– **Upgrades and acquisitions production limits**

Vehicle *i*
Time *t*

Transition into vehicle *i*

Maximum allowable transition into vehicle *i* per time period *t* (upgrades or acquisitions)

$$\forall_{i,t} \quad \sum_{ii,m} \mathrm{Transition}_{m,ii,i,t'} \leq \mathrm{MaxTransitIn}_{i,t}$$

$$\forall_{i} \quad \sum_{ii,m} \mathrm{Transition}_{m,ii,i,t'} \leq \mathrm{MaxTotalTransitIn}_{i,t}$$

Total maximum allowable transition into vehicle *i* over the entire planning horizon

Limit the availability of upgrades or acquisitions. This constraint can be used to reflect production limits or brigade availability for modernization

Mixed Integer Linear Program – Constraints (4)

Subject to:

– **Integral brigade limits**

Vehicle *i, ii*
Mission *m*
Time *t*

Any transitions into vehicle *i* must be in multiples of full brigades

y is a integer variable

Number of vehicle in a brigade for mission *m*

$$\forall_{i,ii,m,t} \quad \underbrace{\mathrm{Transition}_{m,ii,i,t'} = y_{m,ii,i,t} \times \mathrm{OrderQuantity}_m}$$

$$\forall_{m,t} \quad \sum_{ii,i} y_{m,ii,i,t} \le \mathrm{MaxBDE}_m$$

Maximum number of brigade for mission *m* that can be modernized at any time period

Limit the number of brigade by mission that can be modernized at each time period

Mixed Integer Linear Program – Constraints (5)

Subject to:

– Cost constraints (Purchases and O&S)

Time *t*

Cost of transitioning into vehicle *i* times number of transitions into *i*

Budget for upgrades and purchases at time *t*

$$\forall_t \sum_{i,ii,m} \mathrm{TransitCost}_{m,i,ii} \times \mathrm{Transition}_{m,ii,i,t} \le \mathrm{AquisitionBudget}_t$$

$$\forall_t \sum_{i,m} OSCost_{i,m} \times \left(\mathrm{Initial}_{i,m} + \sum_{ii,t'\le t} \mathrm{Transition}_{m,ii,i,t'} - \sum_{iii,t'\le t} \mathrm{Transition}_{m,i,iii,t'} \right) \le \mathrm{OSBudget}_t$$

Operating cost of vehicle *i* performing mission *m*

Number of vehicle *i* in service at time *t*

Operation budget at time *t*

Modernization is constrained by availability of acquisitions and operations funds. Note: The optimization model do consider delivery delay (e.g., time when funds are allocated vs. when the vehicle is actually fielded), not shown for simplicity

Mixed Integer Linear Program – Constraints (6)

Subject to:

– **Cost constraints (RDT&E)**

RDT&E Group g

Sets binary indicator for RDTE group (vehicle that requires RDT&E cost

$$\forall g \quad \sum_{i \in \mathrm{Group}_g, ii, m, t} \mathrm{Transition}_{m,ii,i,t} \le \mathrm{RDTEGroupIndicator}_g \times \mathrm{MAX}$$

$$\forall g \quad \sum_{i \in \mathrm{Group}_g, ii, m, t} \mathrm{Transition}_{m,ii,i,t} \ge \mathrm{RDTEGroupIndicator}_g$$

$$\forall t \quad \sum_{g} \mathrm{RDTEGroupIndicator}_g \times \mathrm{RDTECost}_{g,t} \le \mathrm{RDTEBudget}_t$$

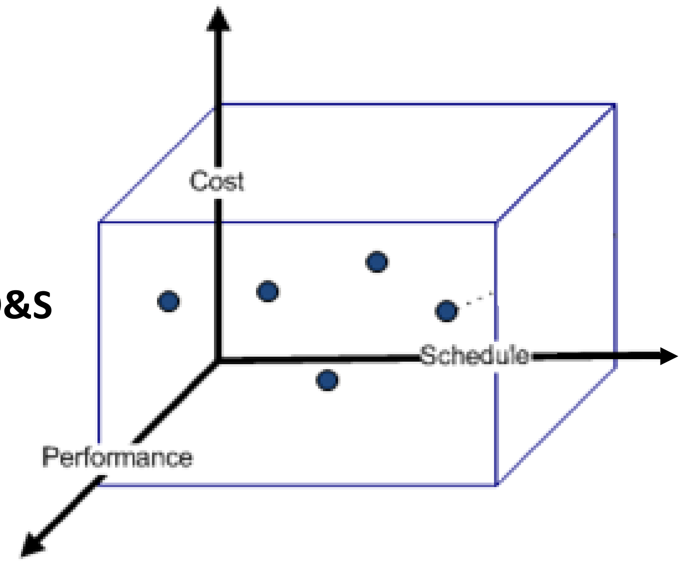
RDT&E Group g that at least one fielded vehicle is in service times the RDT&E cost at time t

RDT&E budget at time t

RDT&E cost represents investment cost associated with certain upgrades and acquisitions. RDT&E groups indicate group of vehicles that will incur the same RDT&E cost if anyone of them where chosen

Mixed Integer Linear Program- Summary

- **The optimization model provides the ability to explore the *Cost*, *Schedule*, and *Performance* trade space and develop an optimized fleet modernization plan**
- ***Objective:***
  - **Maximize fleet performance**
  - **(Alternatively) Minimize cost over time**
- ***Subject to*:**
  - **Ability of vehicle variants to perform mission roles**
  - **Available budget over time: R&D, Procurement, and O&S**
  - **Schedule**
    - **Vehicle replacement rate**
    - **Availability of alternative vehicles**
  - **Mission capabilities defined for each platform**
  - **Sets of upgrades and alternative vehicles available over time**



- ***Results*:**
  - **Number of vehicles to modernize, upgrade, repurpose, or purchase over time**
  - **Selection of best alternative vehicle variants based on performance and cost**
  - **Performance vs. cost vs. schedule tradeoffs**

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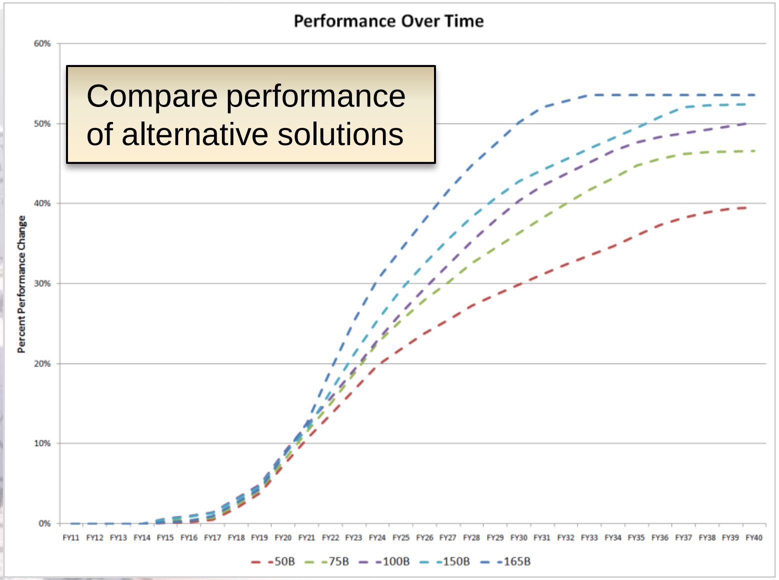
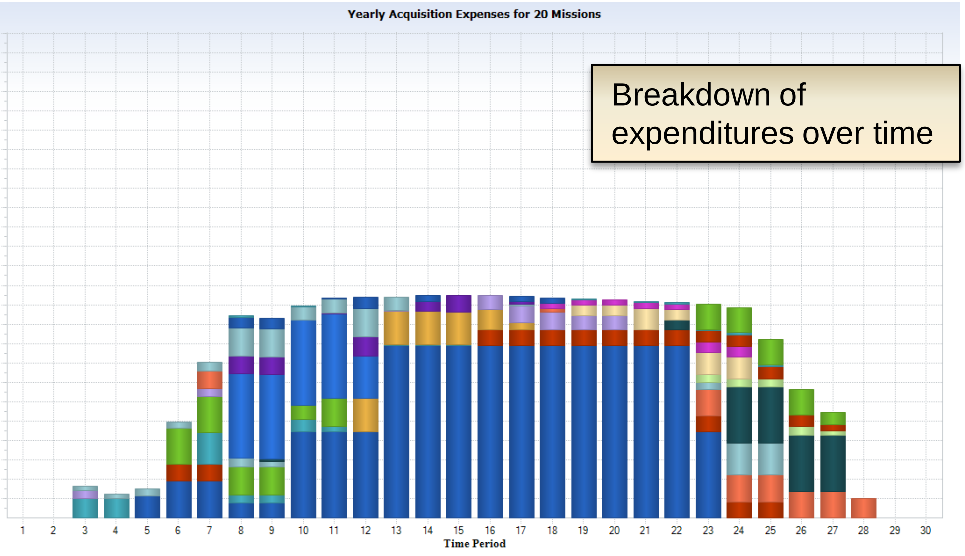
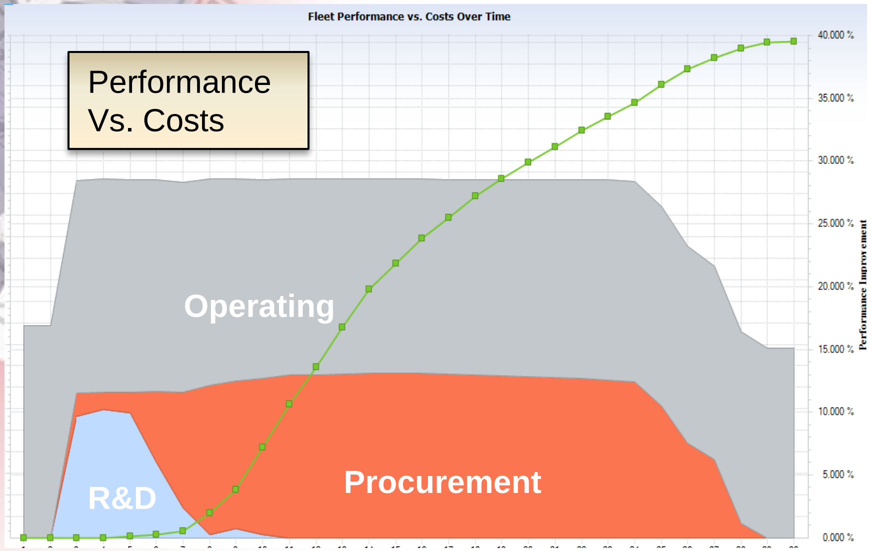
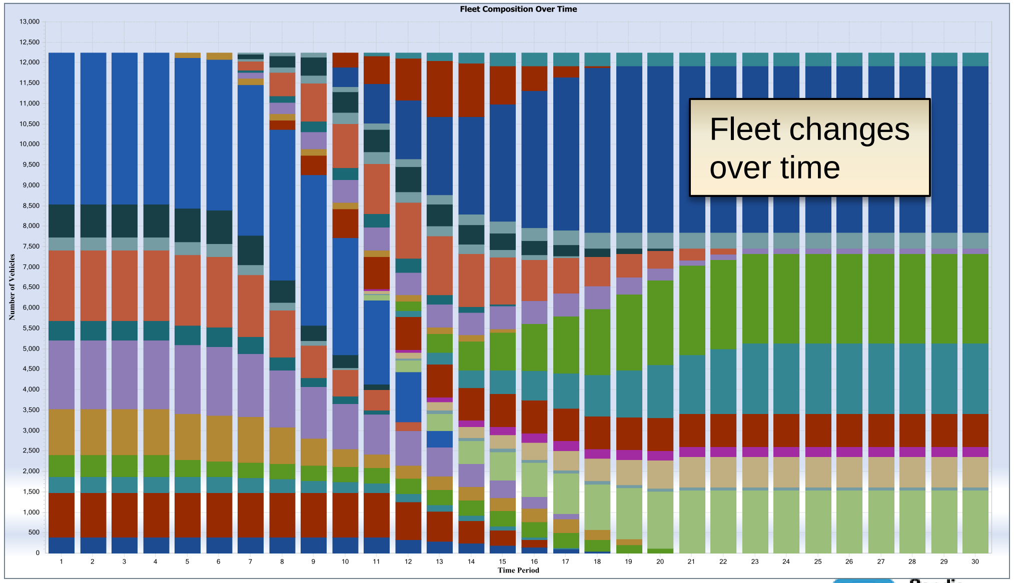
Sample Results









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