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Modeling Improvements and Refinements to the Fleet Modernization Capability Portfolio Analysis Tool (CPAT)

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Introduction

- Work Sponsor: Mary Nesbitt
  - Program Executive Office Ground Combat Systems (PEO GCS)
  - Program Executive Office Combat Support & Combat Service Support (PEO CS&CSS)
- Team:
  - Sandia National Laboratories
  - Booz Allen Hamilton
- Program executives face the fleet management challenge:
  - The need to create optimal investment plans for fleet obsolescence, mitigation, and modernization
  - Investment plans must be comprehensive, ensuring an optimal balance between performance, schedule, and cost
- Questions they want answered include:
  - What fleet composition provides the highest performance?
  - What fleet composition meets schedule and budget constraints?
  - Is it possible to minimize cost while maintaining fleet performance?
  - How does fleet and vehicle age change through time?

Current CPAT Models

- Ground Combat Systems (GCS) Fleet (for PEO GCS)
  - ~ 20,000 vehicles
    - ~100 vehicle types
  - ~20 missions
  - ~23,000 variables
  - ~ 120,000 constraints

- Tactical Wheeled Vehicle (TWV) Fleet (for PEO CS&CSS)
  - ~ 200,000 vehicles
    - ~200 vehicle types
  - ~200 missions
  - ~ 200,000 variables
  - ~ 450,000 constraints

  - Requires strategic modelling fidelity to even attempt to solve the problem
    - Not tractable to allow the optimization to make choices at the individual vehicle level rather decisions are made at the brigade (group of vehicles) level

CPAT Model

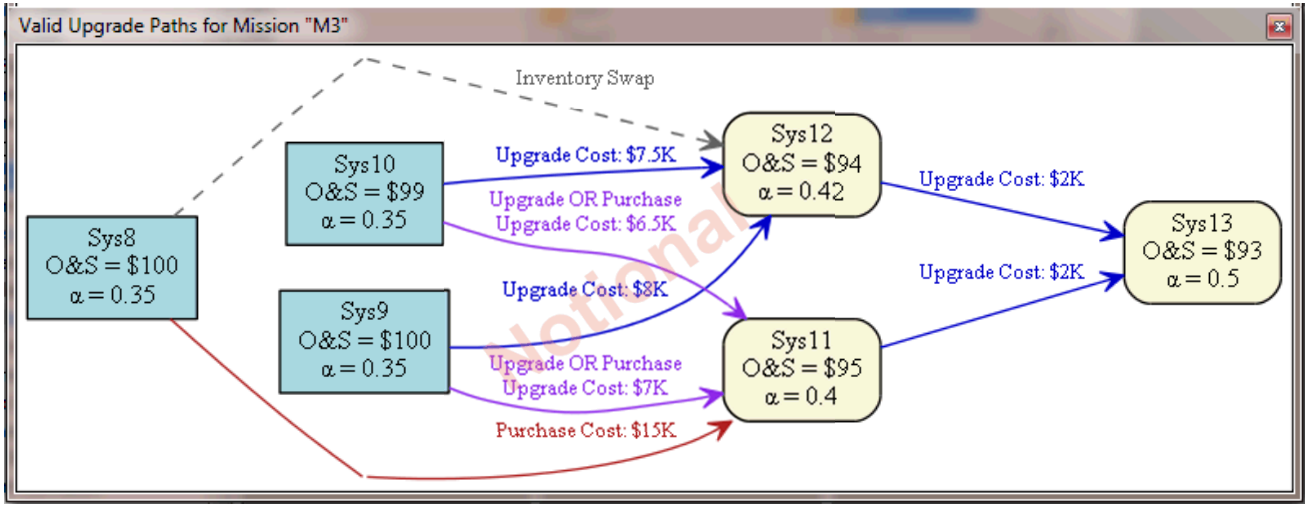
- CPAT models explore different areas of schedule, cost, and performance to develop and optimal fleet modernization plan
- Objectives
  - Minimize schedule violations
  - Minimize age violations
  - Minimize budget violations
  - Maximize overall fleet performance
  - Minimize yearly and horizon cost inefficiencies
- Constraints
  - Schedule constraints on vehicle retirement and replacement requirements
  - Budget restrictions on procurement, O&S, and RDT&E
  - Vehicle availability to particular missions via upgrades or purchases
- Results
  - Displays the optimal fleet performance over time broken out by vehicle, mission, family, or program
  - Displays optimal fleet modernization schedule indicating which vehicles to upgrade or purchase over all time periods
  - Gives costs of the modernization plan broken out by procurement, O&S, RDT&E, mission, family, program, etc.

CPAT Fleet Structure

- Structure of the GCS and TWV Fleets
  - CPAT optimizes the mixture of vehicles within each Mission of the fleet through time to meet future mission needs

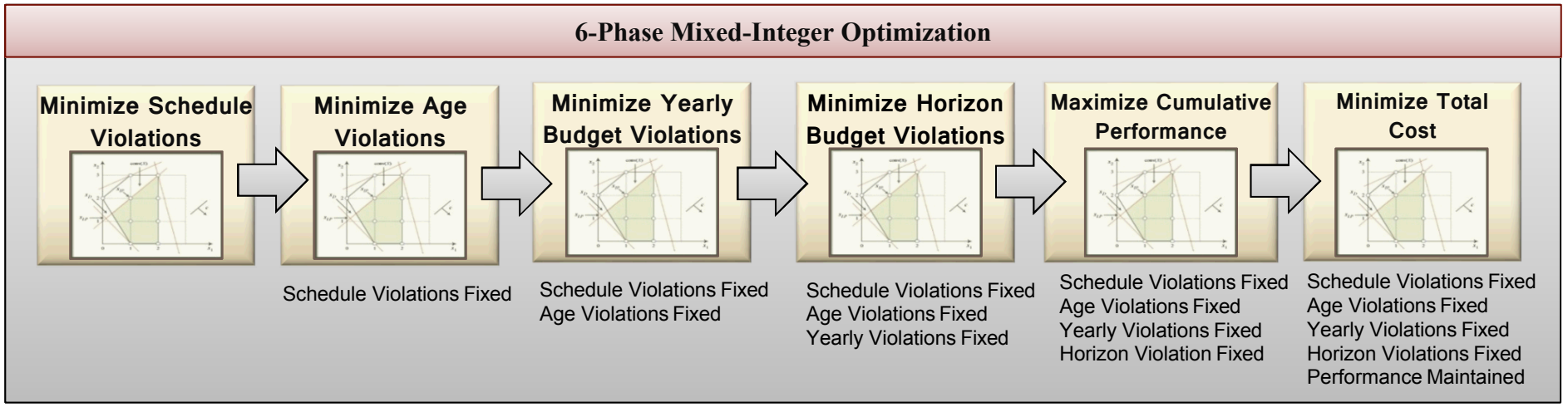
Current fleet Future fleet

  - This is done via transitions for all missions



CPAT Phases

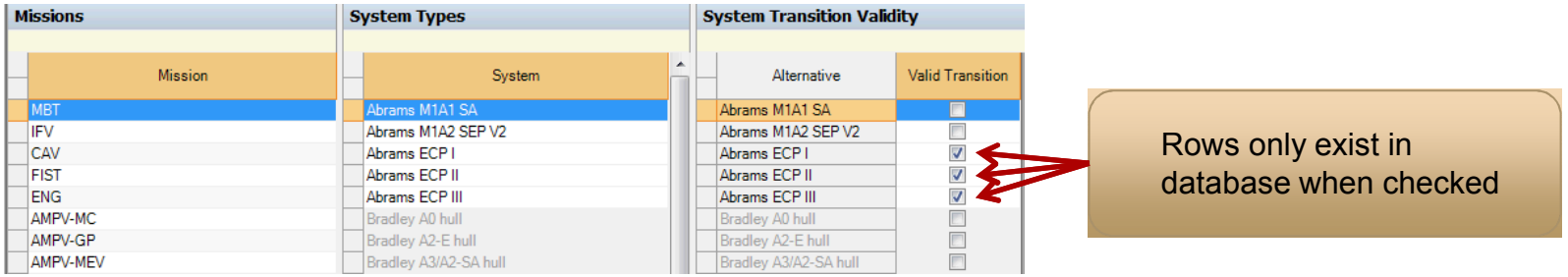
- CPAT TWV is a 6-phase MILP solved using Gurobi or CPLEX
  - Schedule, Age, Yearly Budget, Horizon Budget, Cumulative Performance, Cost
    - Information from previous phase is fed forward to subsequent phases and not allowed to do any worse



- Phase ordering is arbitrary
  - We could choose to minimize Age Violations before Schedule Violations

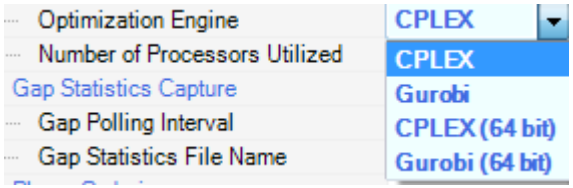
General Improvements

- TWV Model is large (200,000 variables and 450,000 constraints) which the GCS Model is smaller (23,00 variables and 120,000 constraints)
  - TWV database files were in the hundreds of megabytes
  - GCS models are in the tens of megabytes range
- Took steps to reduce the size of the database
  - For the largest tables we no longer store empty database rows
    - They are created as needed and deleted when no longer needed
  - Added database integrity checks to ensure input tables are written and stored properly



General Improvements

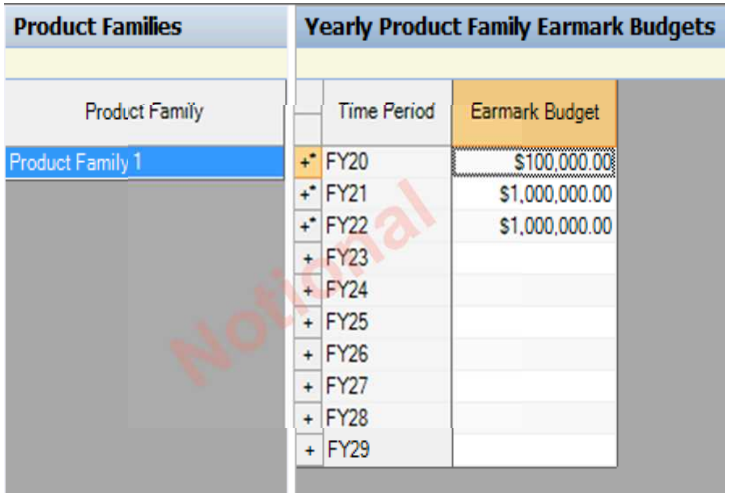
- TWV Model is large (200,000 variables and 450,000 constraints) which the GCS Model is smaller (23,00 variables and 120,000 constraints)
  - TWV models required 3-14 gigabytes of RAM to run
  - Most GCS models only need 2-3 gigabytes of RAM
  - CPAT is a 32 bit application but can call 32 or 64 bit Gurobi or CPLEX
    - This allows the model to utilize more than 4 gigabytes of RAM



  - Post-processing time was also taking much longer for TWV models
    - TWV models took about 30 minutes to write the results to the database
    - GCS model took a few minutes to write the results to the database
  - Results are stored in an Access database and are written using SQL queries
    - Improvements to queries and only writing non-zero rows to the database decreased the writing time in the TWV model from 30 minutes to just a couple of minutes

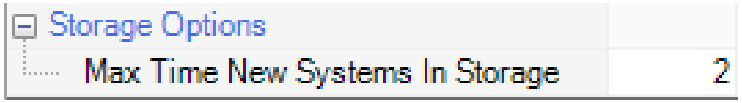
Capability Improvements

- Product Family Earmarks
  - A Product Family is a set of vehicles that have something in common such as a design or share a production facility
  - Some Product Families may be given additional funding as a Congressional Earmark which is money that is only allowed to be spent for upgrades and purchases of the vehicles in that product family
  - If the Earmark is not spent on the vehicles in the product family then it cannot be spent elsewhere in the fleet implying a "use it or lose" concept



Capability Improvements

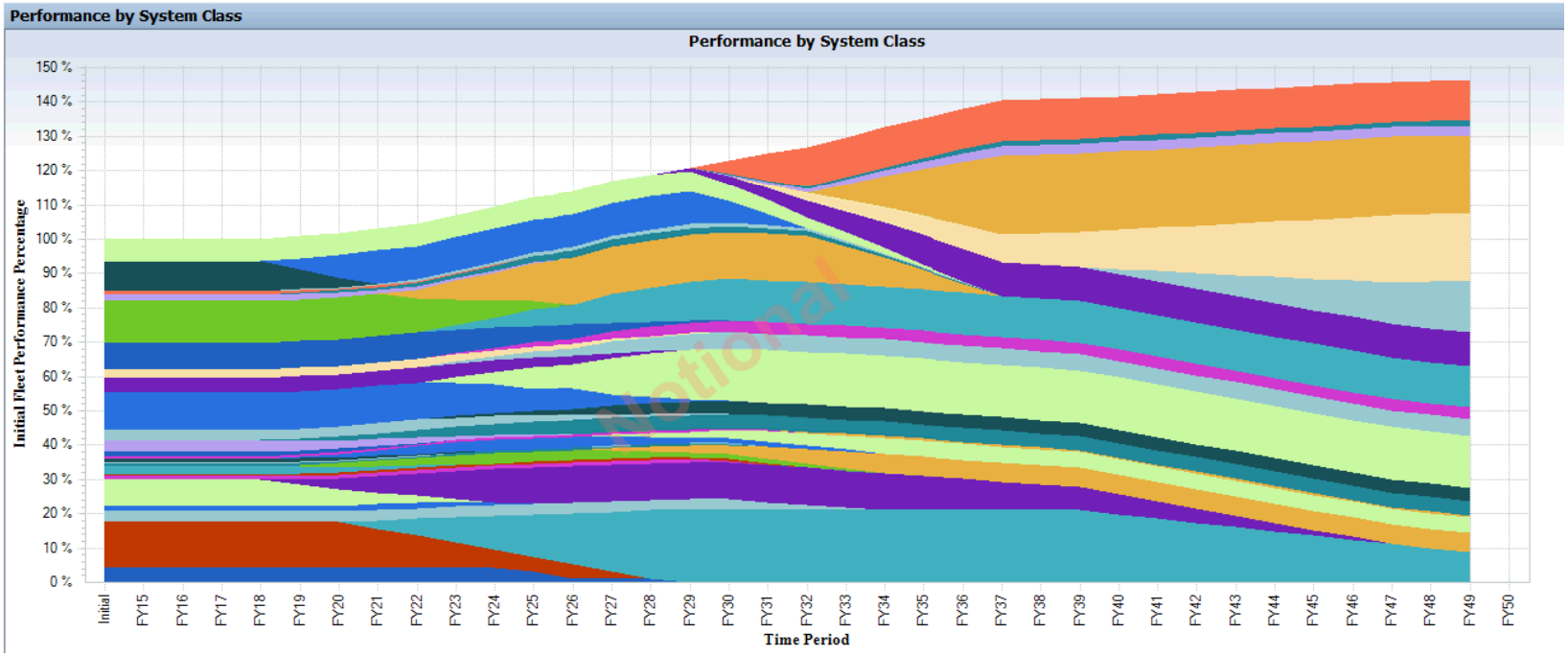
- Field within a certain number of years of production
  - CPAT allows for the decoupling of production and fielding
    - Vehicles may be produced but not required to transition to a mission in the same year that production is completed
    - Such vehicles are considered to be “in storage”
  - Vehicles spending a long time in storage is not desired
    - For example, systems produced in FY15 but not fielded to a mission until FY25 would not really be considered “new” anymore
  - A new parameter specifies how long a newly produced vehicle can be in storage before it must be fielded to a mission



  - A vehicle will not be allowed to be produced if it cannot field to a to a mission within the number of timeframes specified by this parameter

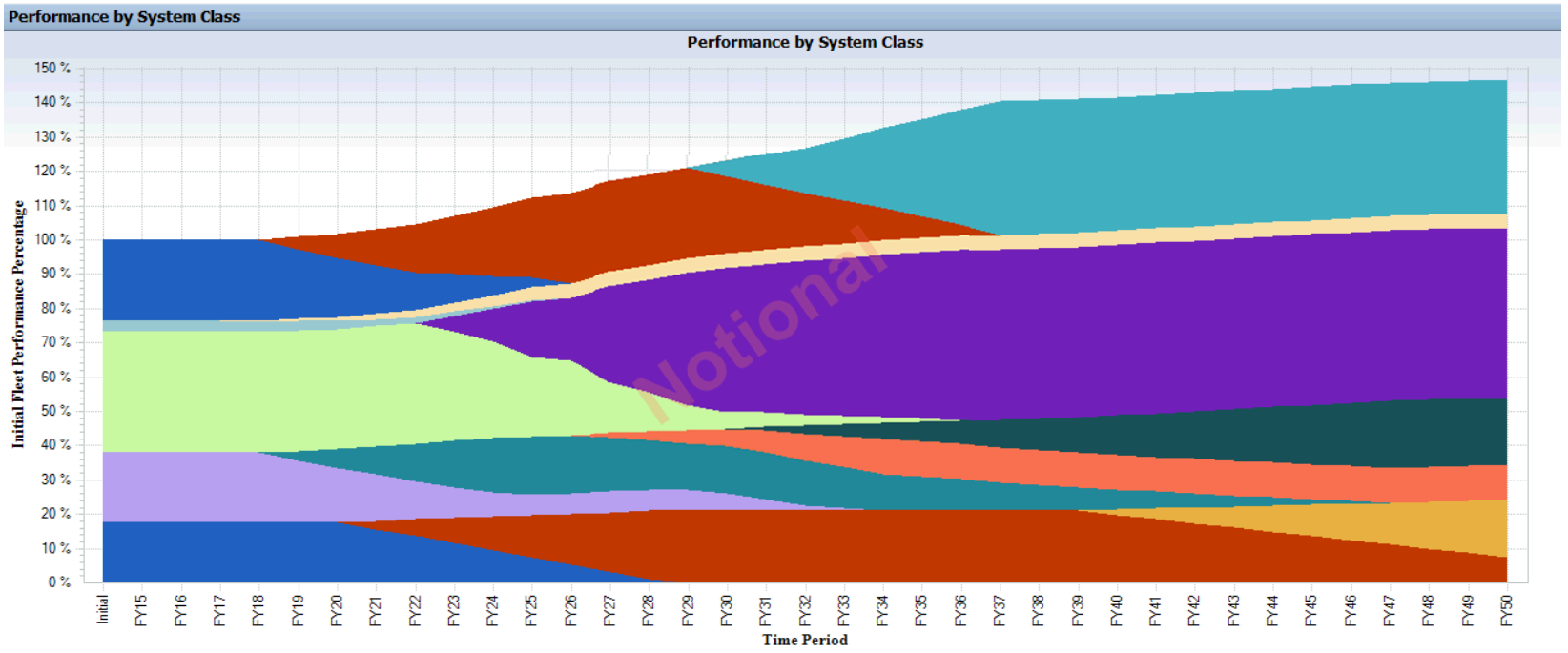
Improvements to Result Views

- The GCS Fleet has around 100 vehicle types while the TWV fleet has around 200 vehicle types which can make viewing results difficult.
- Example: Performance by System (47 systems)



System and Mission Classes

- We can group similar system types together to make results more readable
  - Example: Abrams M1A1 SA and Abrams M1A2 SEP V2 are groups into the System Class Abrams SQ
- Example: Performance by System (14 System Classes)



- Similar Missions can also be grouped together into Mission Classes

Analysis Work

- TWV analysis within the last year
  - Initial briefing provided to PEO CS&CSS October 2015
    - Understood what modernization plans provided the best performing fleet under budget and age considerations
    - Compared performance and modernization of the fleet with and without age considerations
    - Analyzed second and third order effects of budget, scheduling, and age requirements
    - Reviewed performance vs. cost trade-offs
    - Understood which vehicles provided the best performance for their cost
  - Follow-on briefing February 2016
    - Compared different Mission weighting sets to understand the sensitivity of the model
- No GCS analysis work in the last year

Path Forward

- Refine the TWV model with new data to provide follow-on analysis
  - New data will include new alternative vehicles, updated purchase costs, updated performance values, and updated budgets
- Updating GCS model (over two years old) with current data and vehicles for analysis beginning in November 2016
  - First analysis work for the GCS fleet since 2014
  - New data includes changes to the fleet structure (fleet structure has changed a lot), updated vehicle concepts, updated costs, updated performance, and updated budgets

Thank you!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