RDECOM

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

The Use of Physics of Failure Tools for Reliability Improvement and Addressing Modularity Issues in Evaluation and Physical Testing

Approved for public release;
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Introduction

- Benefits of Modularity in Army Systems
  - Simpler Logistics
    - Fewer distinct parts mean more spares available
    - Smaller footprint
  - Less Specialized Training Required
    - Operators
    - Maintainers
  - Reduced Cost

Infantry Carrier Vehicle (ICV)

Commander's Vehicle (CV)

Fire Support Vehicle (FSV)

Mobile Gun System (MGS)

Nuclear Biological Chemical Recon Vehicle (NBC RV)

Fire Support Vehicle (FSV)

Medical Evacuation Vehicle

Anti Tank Guided Missile (ATGM)

Engineer Squad Vehicle (ESV)

120mm Mounted Mortar Carrier (MC)

Introduction

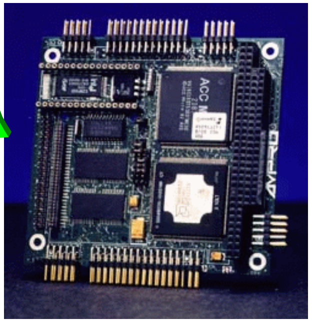
- Question: How do we address the complexity associated with testing and evaluating a modular system?
  - Is it necessary to test all possible configurations?
  - Exacerbated by system upgrades, armor kits, re-power efforts etc.

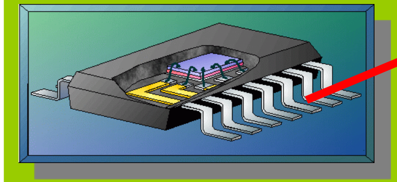
- Answer: Use of Modeling and Simulation
  - Physics of Failure analysis
  - Development and validation of dynamic models

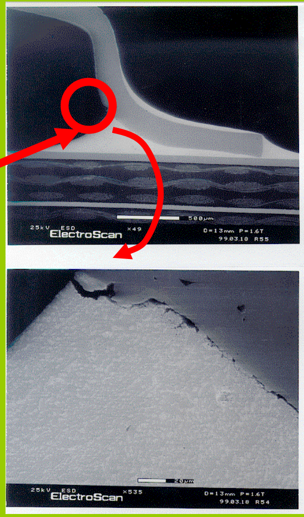
PoF – A Comprehensive Engineering Based Reliability Approach

- A.K.A. Physics of Failure, Predictive Technology, Predictive Engineering, Physics of Reliability
  - Model the root causes of failure (e.g., fatigue, fracture, corrosion & wear)
- Failure models & CAD tools developed
  - By industry/academia/government
  - To address specific materials, sites, & architectures

Stress (e.g., vibration) is propagated from system level to failure site







Failure root-cause is cracking of solder joint

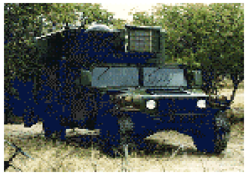
Benefits
- Design-in reliability
- Eliminate failures prior to test
- Better chance of passing test
- Increased fielded reliability
- Improved prognostics
- Decreased O&S costs

Physics of Failure Success Stories

Surveillance System

- Analysis showed commercial CCA OK

$1.2M Saved



Tri-Service Radio

- Identified weak link in design & verified

$27M Cost Avoidance

Army Vehicle

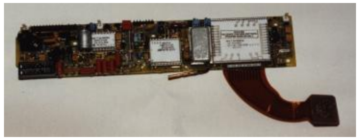
- Fix confirmed through low-level test and M&S instead of full-up testing

$1M Cost Avoidance

Improved Monitor

- Corrected vibration problem

Design Changes Implemented



Power Supply

- Significant failures reduced w/ minimal cost fix

Reliability Improved

Mobile Bridge

- Reduced testing

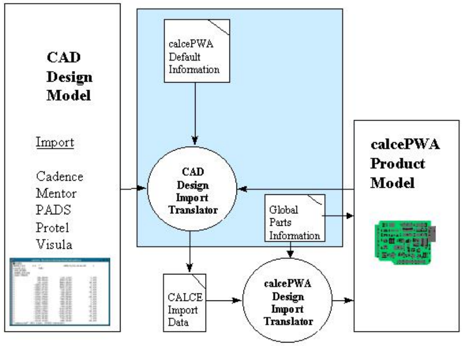
$1.5M Savings

New Missile System

- PoF analysis on Plastic Ball Grid Array

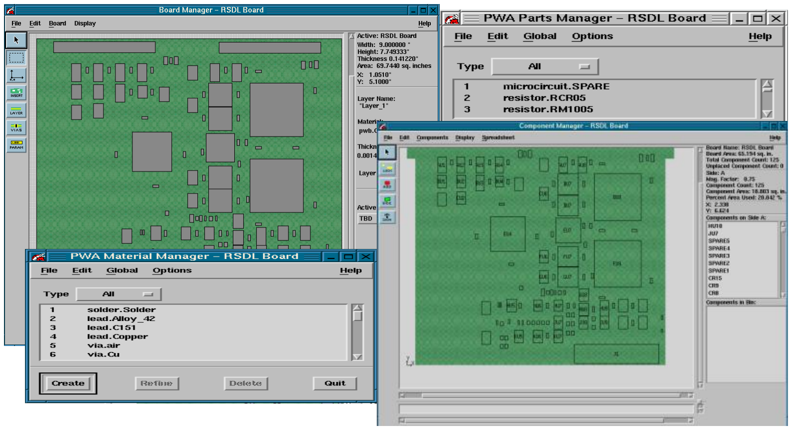
Evaluate New Technologies

Physics of Failure Process for Electronics

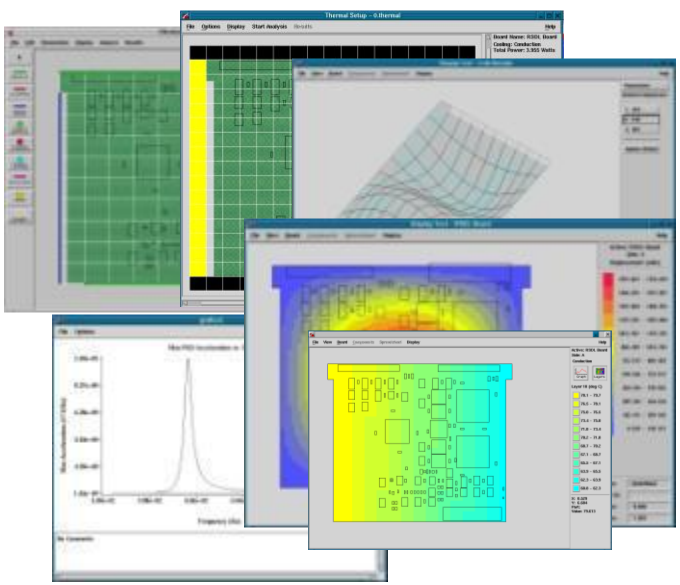


Support for importing CAD design files

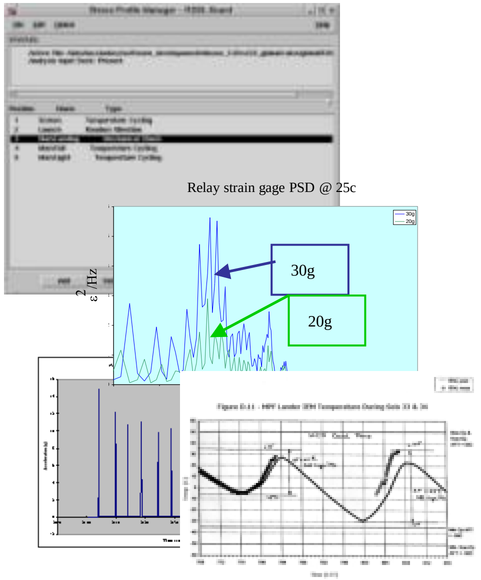
Toolbox



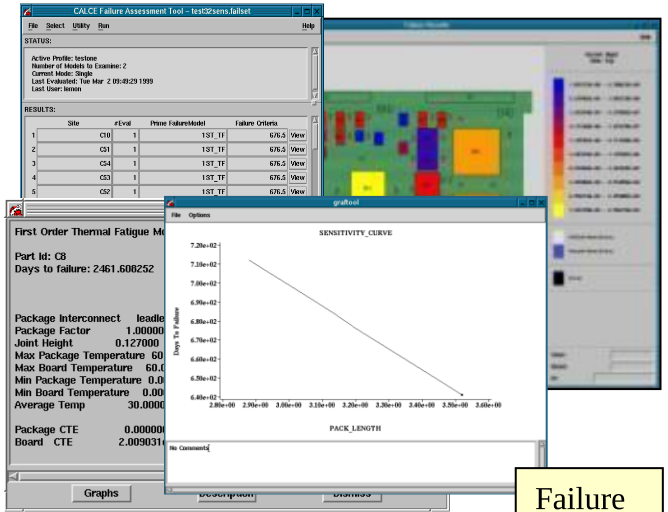
Product Modeling and Databases



Load Transformation



Environment Characterization



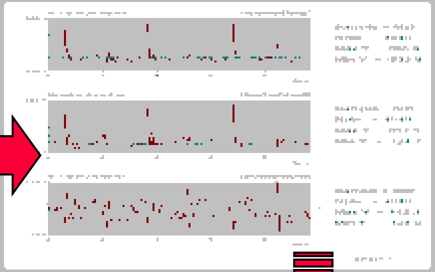
Failure Risk Assessment & Sensitivity Analysis

Failure Model Plug-ins

Mechanical PoF Process

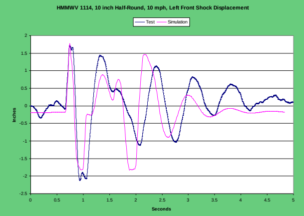
System-level Dynamics Model

Live Data from Instrumented Tests

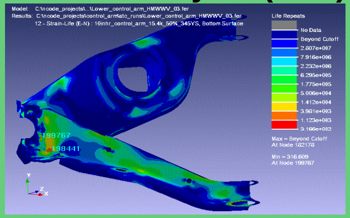


Strains, Accelerations, Displacements

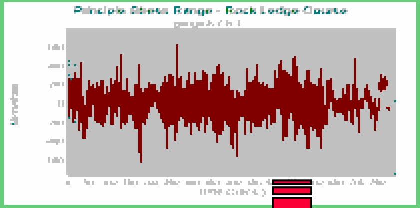
Loads, Accelerations



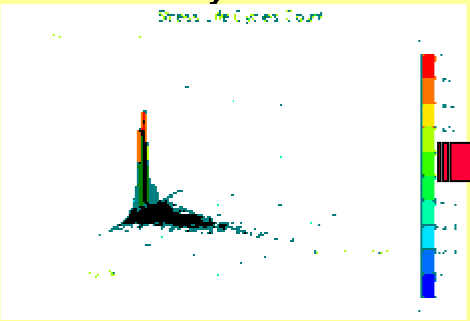
Finite Element Analysis (FEA)



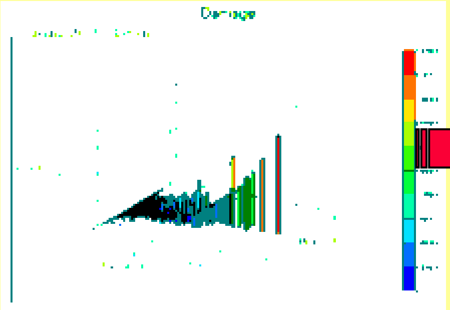
Strain Time History



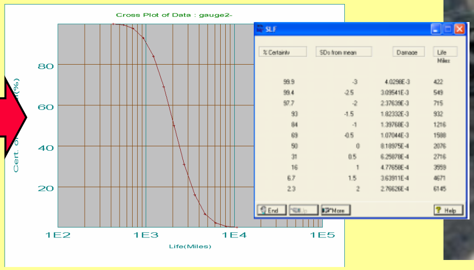
Rainflow Cycles Count



Damage Cycles Count

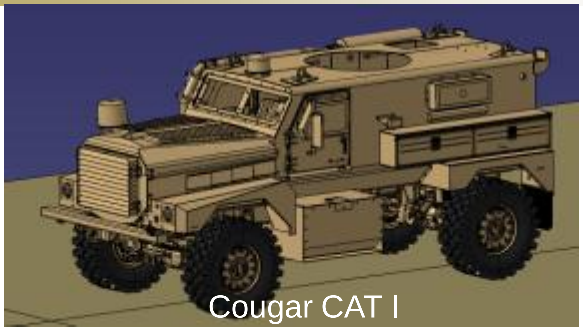


Component Life Prediction



PoF reveals underlying physics – Helps to identify the root-causes of failures!

Dynamics Models to Support T&E


Cougar CAT I


Cougar CAT II


BUFFALO


HMMWV M1114


HMMWV w/ outriggers

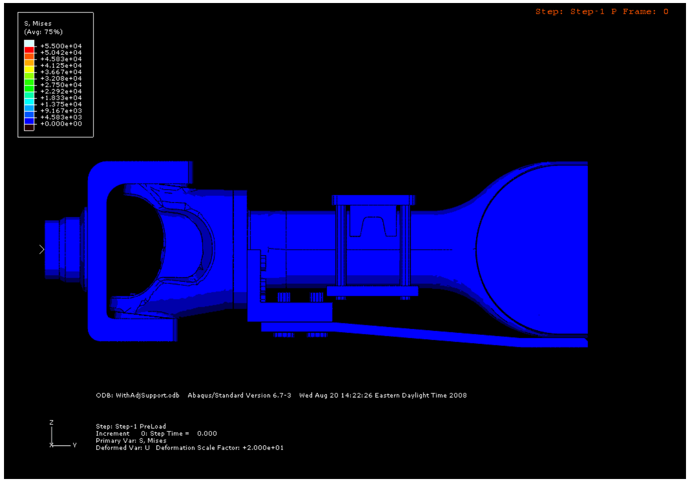

HMMWV 1097 A2

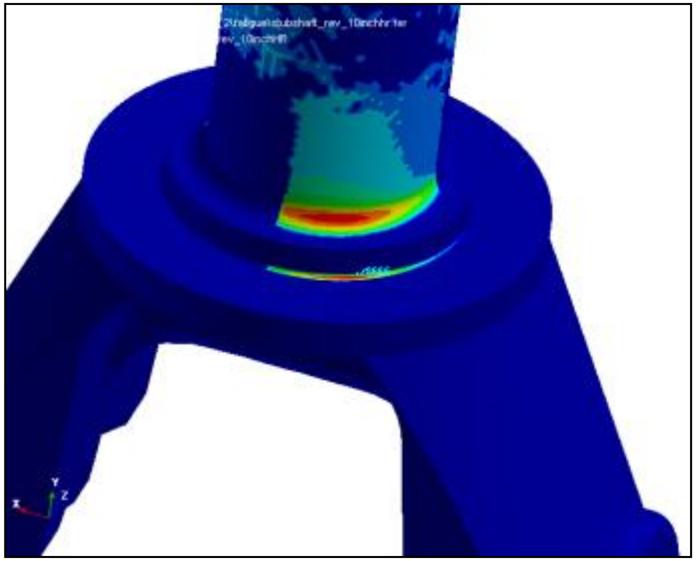
- Quick and inexpensive to perform
- Very repeatable compared with physical testing
- Easy to make changes between variants/kits
  - Mass
  - Inertia
  - Center of Gravity
- Parameterization critical for efficient development
- Used to identify critical configurations and reduce risk of untested poor performer

Finite Element and Fatigue Analysis to Support T&E

- Finite Element Analysis
  - Type available based on failure mode:
    - Structural – Static, Dynamic, Shock and Vibration
    - Thermal
    - Computational Fluid Dynamics (CFD)
  - Identifies critical configurations or events

- Fatigue Analysis
  - Determine miles or cycles to failure
  - Scope test by providing critical events and making time and cost estimates to experience failure

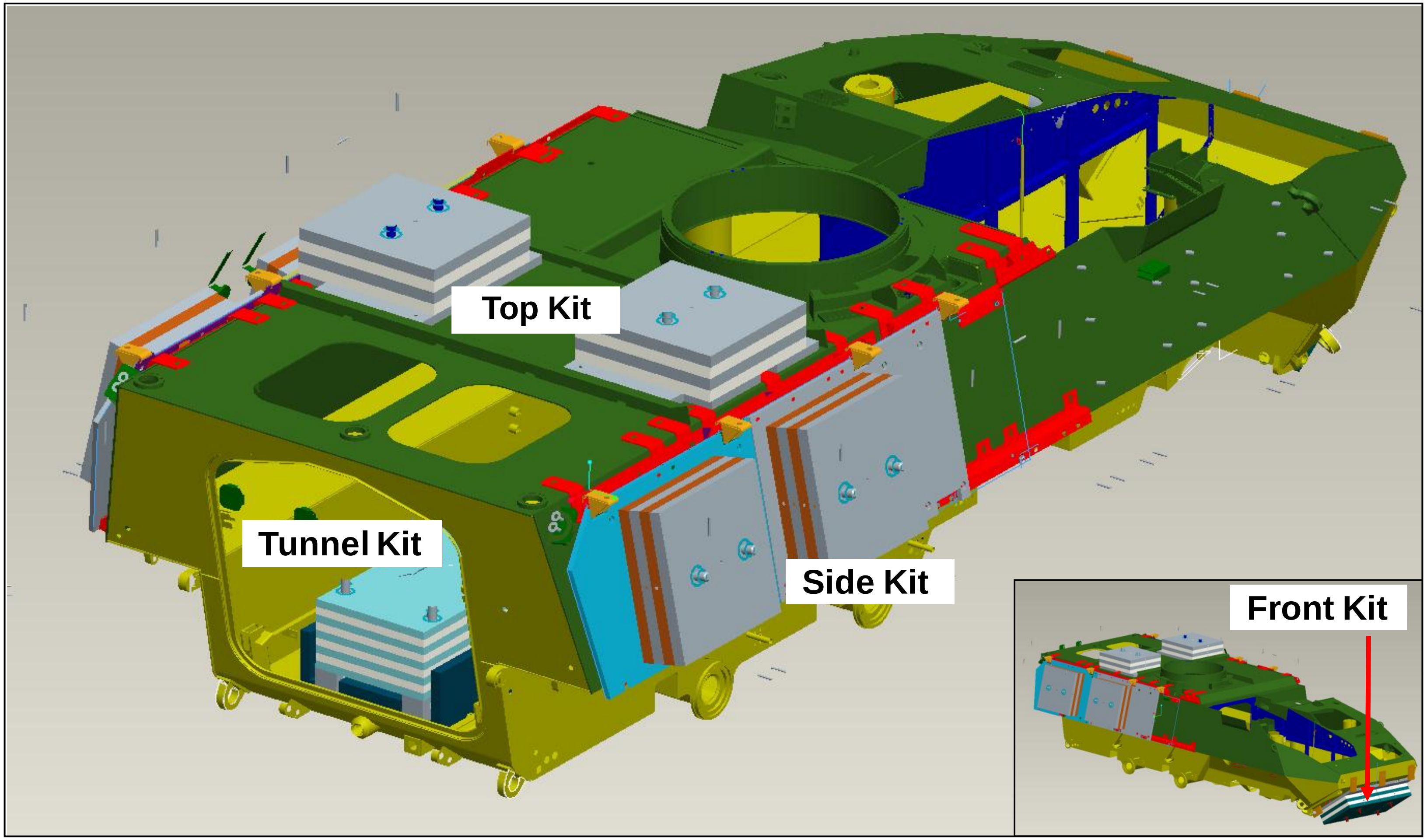




Test Asset Availability

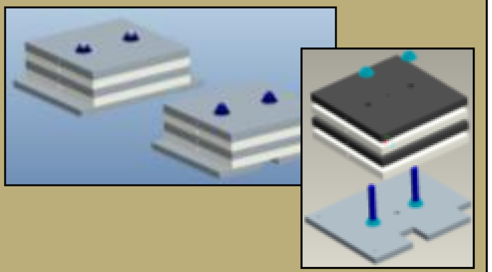
- Testers requested help to improve their ability to ballast a vehicle, their goals:
  - Modular, inexpensive kit
  - Reduce test cost
  - Reduce time and labor for ballast process
- Why were they seeking this capability?
  - Ballasting process was time consuming, customized, iterative
  - Many vehicle variants
  - Several add-on armor kits, some variant specific and not commonly available

Ballast Kit Locations



Ballast Kit Elements

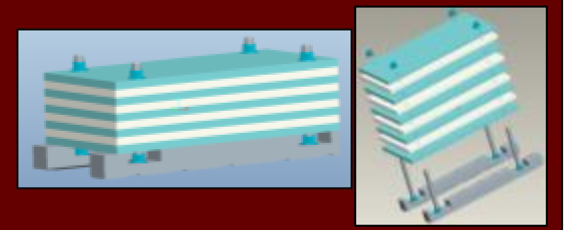
Top Kit



- Base Plates on Left and Right
- 4 Ballast Plates per Location
- 26 Configuration Options

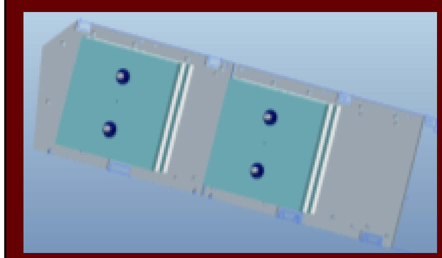
- Modular Ballast Kit
  - Ballast plates mounted at 4 locations
  - Roughly 4 million different total configurations

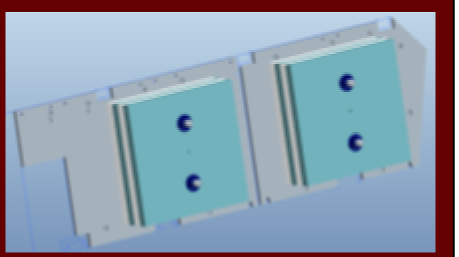
Tunnel Kit



- 2 Mounting Beams
- 9 Ballast Plates
- 10 Configuration Options

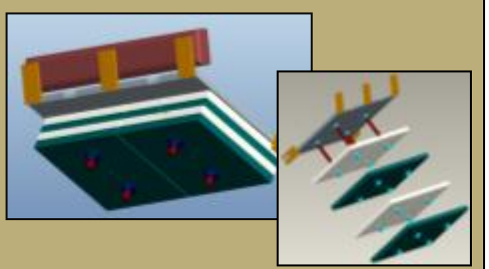
Side Kit





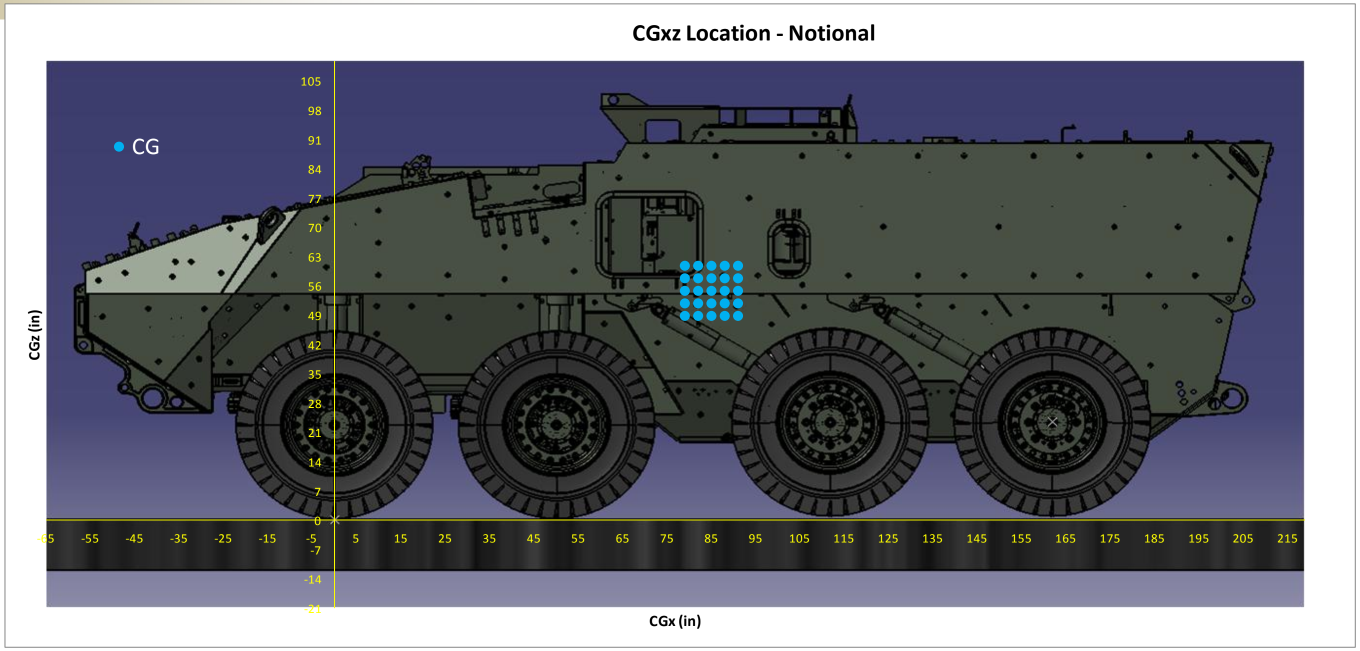
- 4 Base Plates
- 4 Ballast Plates per Location
- 625 Configuration Options

Front Kit



- Base Plate With Left and Right Side Mounting Points
- 4 Ballast Plates per Location
- 25 Configuration Options

Initial Calculations



Ballast Location			
Front	Roof	Tunnel	Side
X			
	X		
		X	
			X
X	X		
X		X	
X			X
	X	X	
	X		X
		X	X
X	X	X	
X	X		X
X		X	X
	X	X	X
X	X	X	X

- Dynamics model initially used to estimate the extreme CG locations as well as the baseline properties for each variant
- Due to the complexity of the dynamics model and resulting simulation times, all configurations were not analyzed

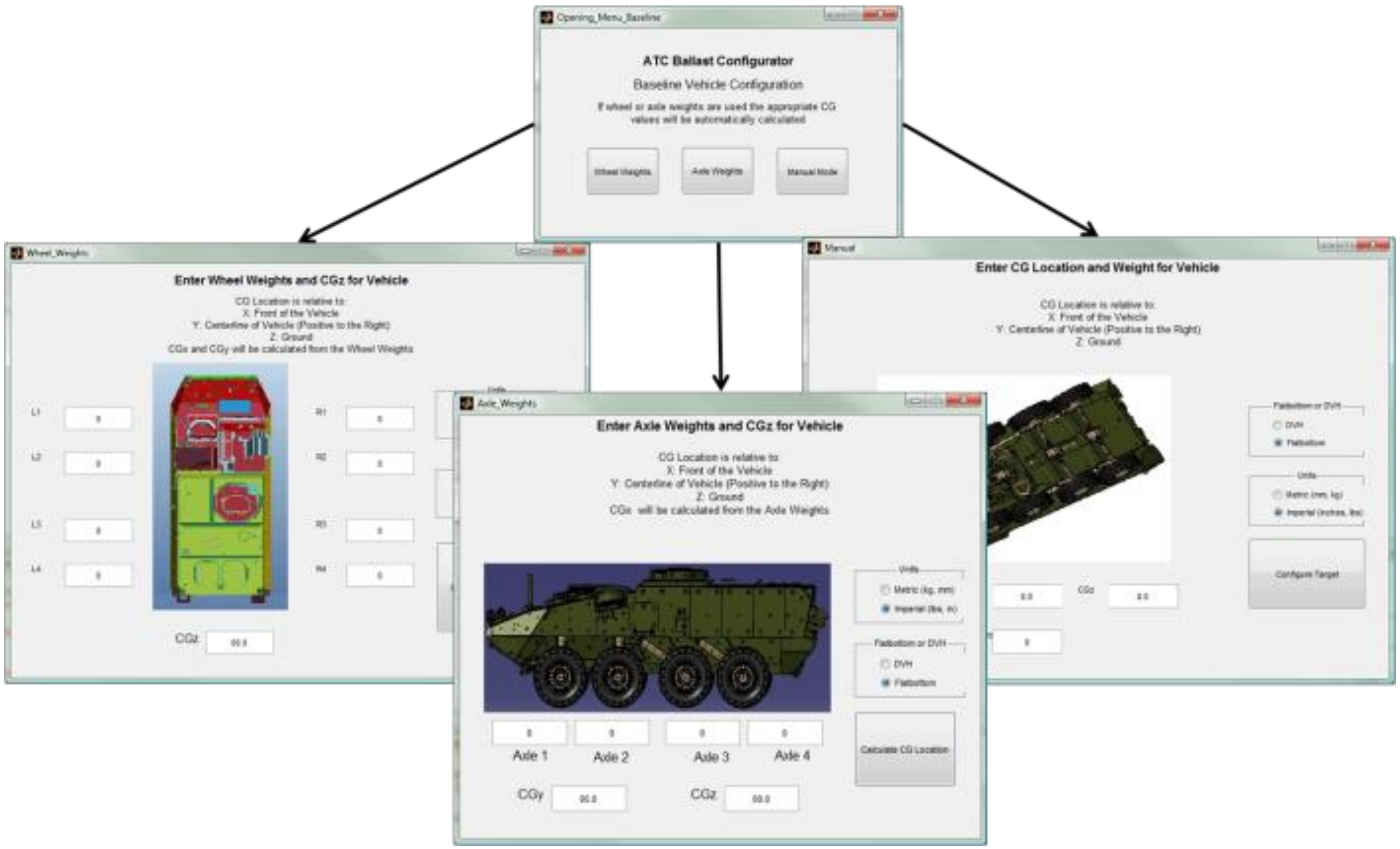
Configurations

- Code developed to calculate the best arrangement of ballast weights
  - Least squares method to find the closest CG location

$$\sqrt{\left(CG_{x_{target}} - CG_{x_{ballasted}}\right)^2 + \left(CG_{y_{target}} - CG_{y_{ballasted}}\right)^2 + \left(CG_{z_{target}} - CG_{z_{ballasted}}\right)^2}$$

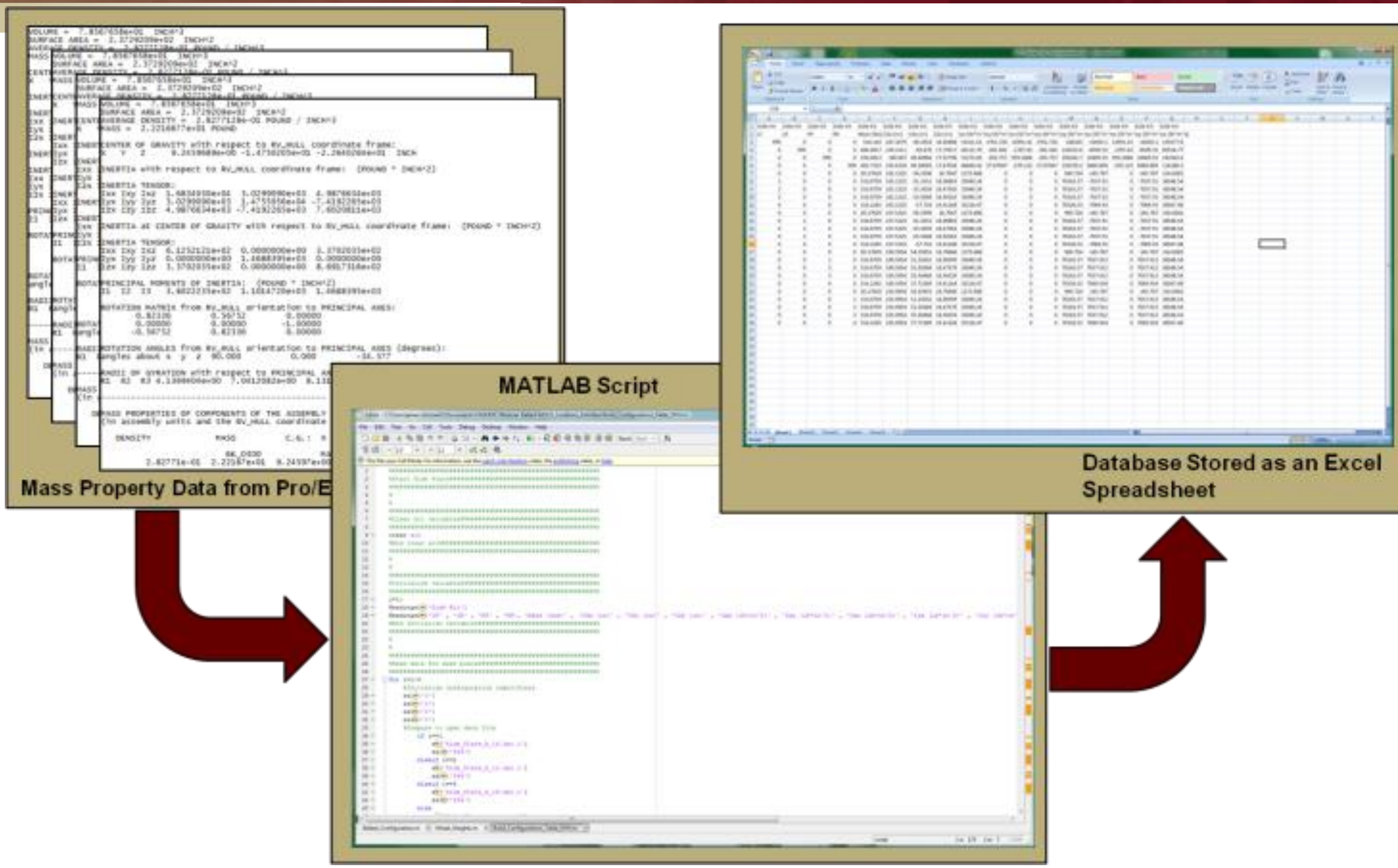
  - Determines 20 nearest CG locations within a weight range
- Inertial properties checked versus simulation results or measured test data
- Verification of results performed based on test vehicle.

Interface



- Configuration tool can accept wheel weights, axle weights or CG location to calculate ballast configuration
- CGz data frequently has to be approximated from dynamics models or previously measured vehicles

Back End



- Mass Property data for each ballast plate and base plate obtained from CAD software
- Code (separate from the configuration tool) reads the CAD data
- Stores mass, CG and inertial properties in spreadsheet

Results

- Results are written onto a new tab in the spreadsheet
  - 20 closest matches are stored to provide options for best inertial fit
  - Number of plates required at each location provided for each configuration

- Ballast Kit manufactured and in use at multiple test facilities
- Software and support provided for:
  - Re-ballasting test vehicles to match a different variant
  - Ballasting in place of armor kits or other equipment
  - Matching test assets to vehicles used at other facilities

Summary

- Modular Army systems simplify logistics, reduce specialized training, and overall cost, but also provide challenges to the test and evaluation community
- PoF tools provide a method to address these challenges and mitigate the risk associated with the inability to test all combinations and configurations of modern Army systems
- A modular ballast kit was designed and methodology developed using these principles to assist with the testing of not readily available vehicle variants and configurations
  - PoF analysis performed to ensure robust design and verify robustness of solution
  - Wheel weight and CG matching software developed to ensure rapid response
  - Ballast kit and associated tools utilized for multiple tests, at multiple test sites resulting in reduced test time and cost

Questions?