U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – GROUND VEHICLE SYSTEMS CENTER

Next-Generation NATO Reference Mobility Model (NG-NRMM), The New NATO Mobility Standard

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Off-Road Mobility Challenges

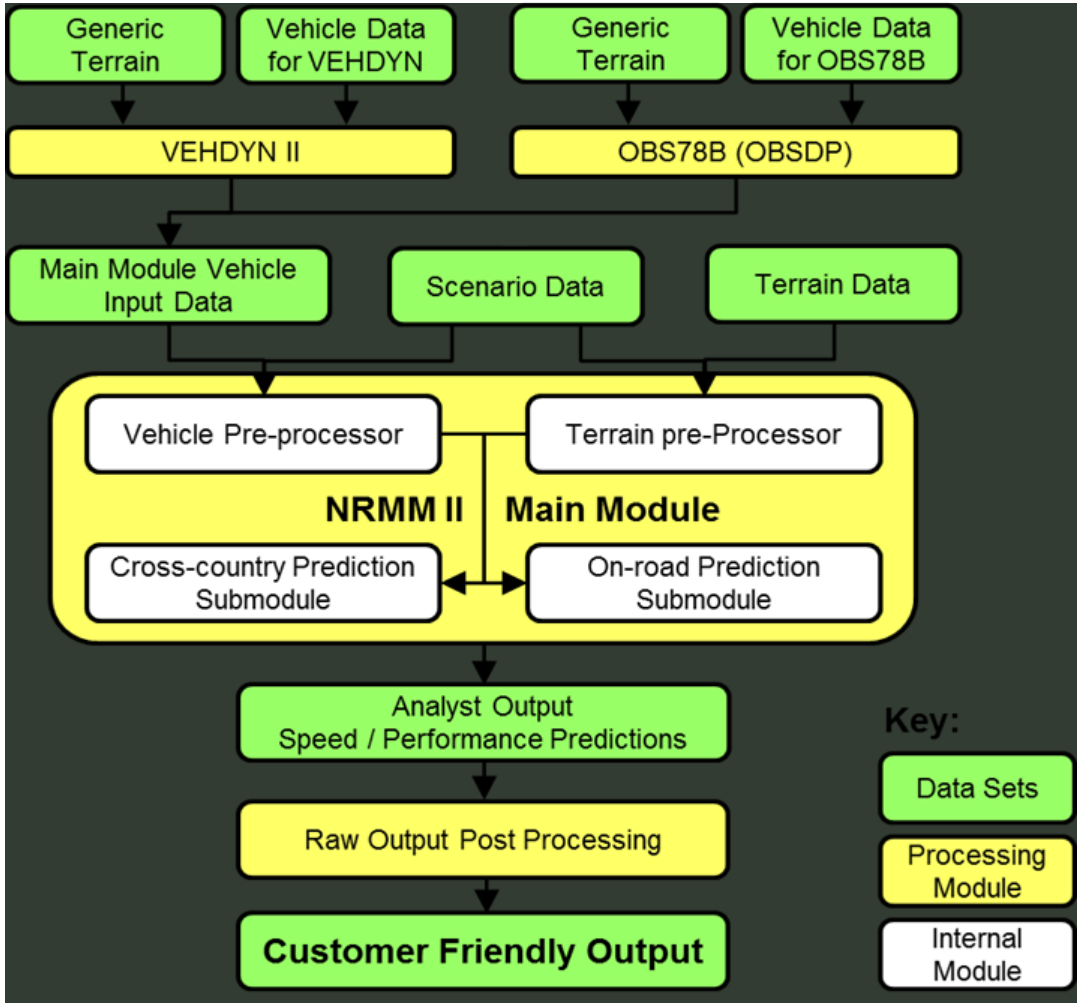
Military Challenges are Unique

PRESENTATION OUTLINE

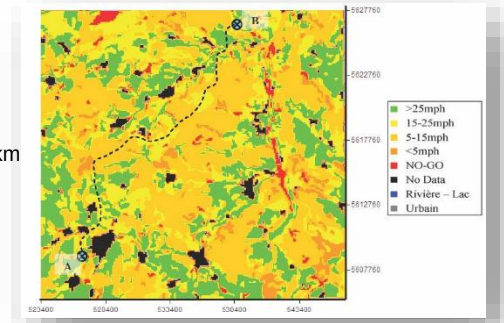
- What is NRMM
- Why NRMM is outdated
- What is NG-NRMM
- Why use NG-NRMM
- NG-NRMM, New NATO Standard
- Next Steps

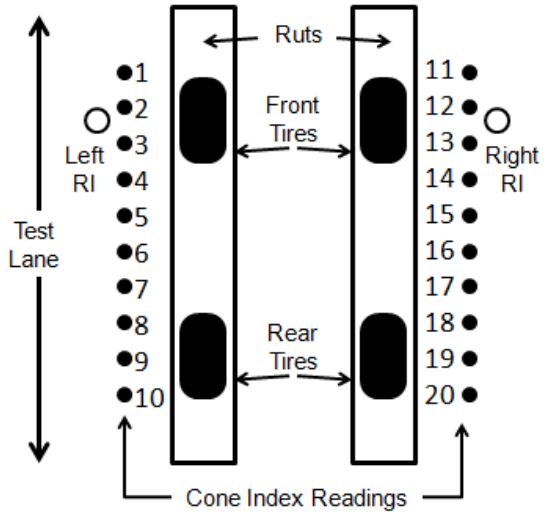
NRMM OVERVIEW

- FORTRAN code
- **2D pitch plane vehicle dynamic models for ride quality and obstacle performance**
- Terrain data are maps of soil, slopes, vegetation, roads, obstacles for specific world regions
- Scenario data overlays weather effects
- Main operational module considers seven major speed limiting factors
- **Empirical soft soil trafficability models based on rating and vehicle cone index** (RCI / VCI)
- **Widely used for**
  - **operational analysis**
  - **acquisition**
  - **design**



NRMM, AN EMPIRICAL APPROACH





NATO Reference Mobility Model (NRMM)

- Dr. M. G. Bekker of TARDEC is the "Father of Terrain-Vehicle Systems"
- NRMM was developed in 1960-70 by TARDEC and ERDC
- Worked towards NATO standardization in 1977-78
- Methodology relied on empirical relationships and **not** physics-based
- Does **not** extrapolate to contemporary vehicle designs and technologies
- Does **not** benefit from advances in simulation and computational capabilities

WHAT NRMM CAN'T DO

- Methodology not physics-based – relies on empirical, in-situ soil measurements

- Does not support 3D models
- Does not consider steering performance and lateral vehicle dynamics

- Does not extrapolate to contemporary vehicle designs and technologies
- Does not predict mobility for systems dissimilar to past systems (weight, power, suspension system, controls, etc.)

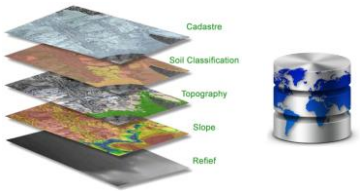
- Does not benefit from advances in simulation and computational capabilities
- Does not cover uncertainty, intelligent vehicles, or data sets for urban areas

NG-NRMM, A PHYSICS-BASED APPROACH

Data Environment

TA1

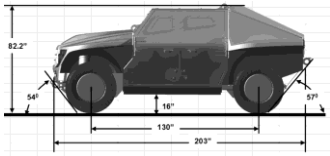
GIS Data



GIS Data Layers

Geo DB

Vehicle Data



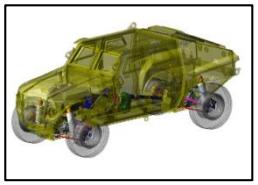
Scenario Data

RMS Course

Sand Grade

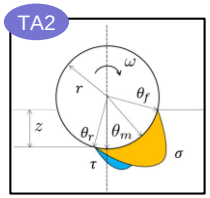
M & S Environment

Vehicle Models



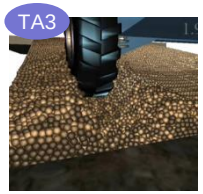
Terrain Models

TA2



Simple Terramechanics

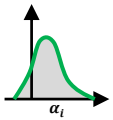
TA3



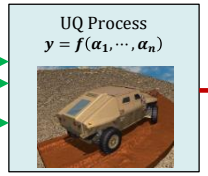
Complex Terramechanics

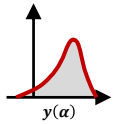
TA5

Uncertainty Quantification



Soil Variability



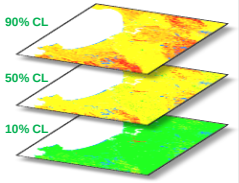


Speed Variability

Mobility Metrics

Operational Planning

Geo DB



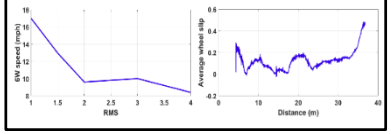
Stochastic Mobility Maps

TA6

Vehicle Design and Acquisition

Ride Quality

Grade Performance

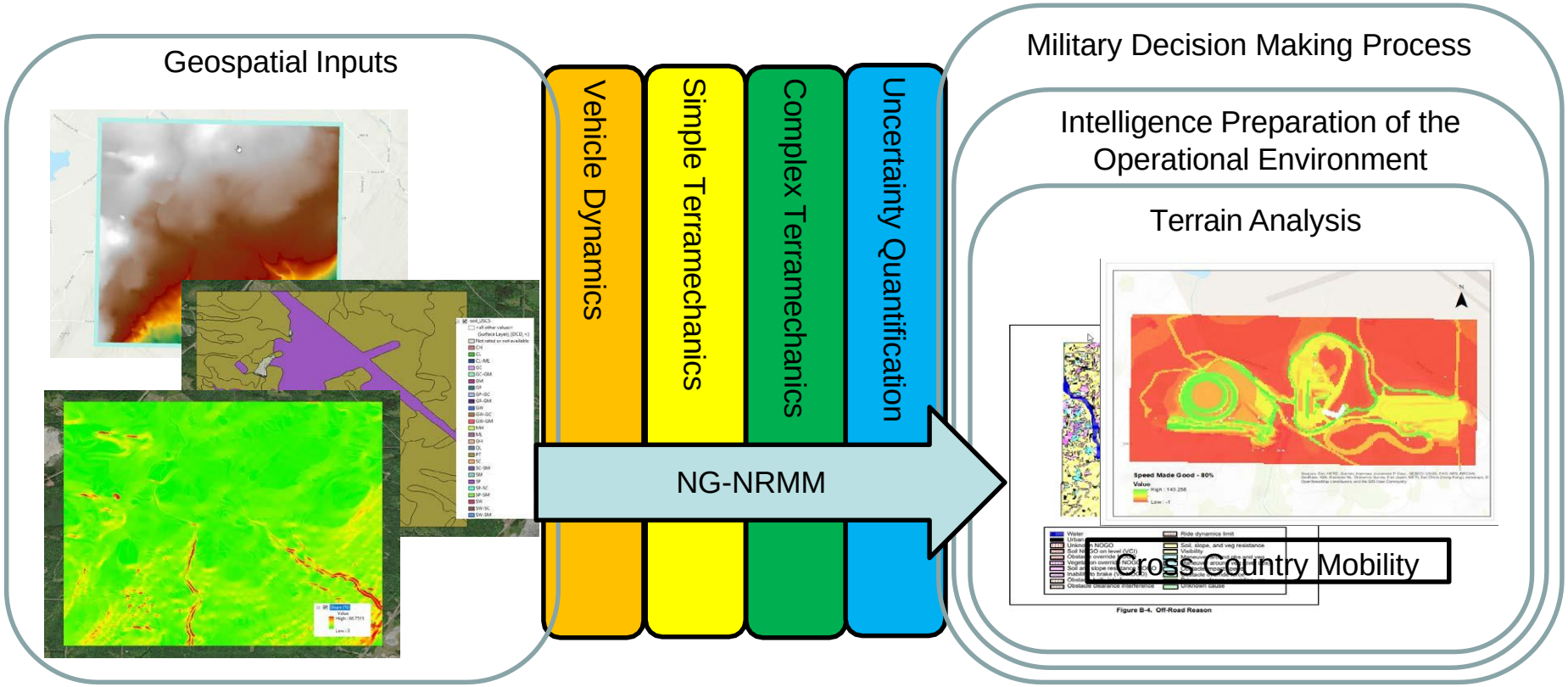


Qualitative — 1970

NRMM

NG-NRMM — 2020

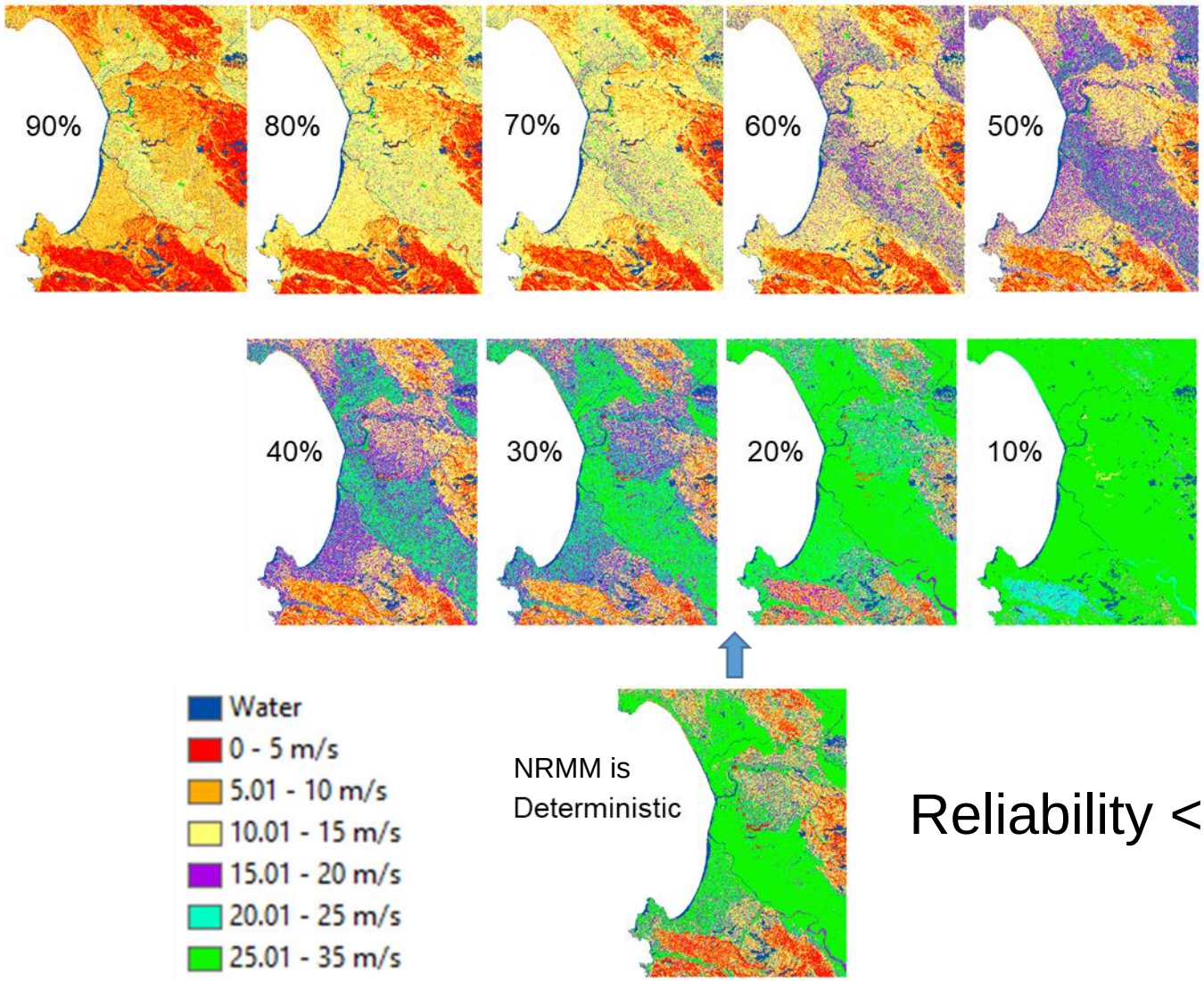
NG-NRMM, AN ANALYTICAL COMPONENT TO PLANNING



AUTOMOTIVE EVENT SIMULATION CAPABILITY

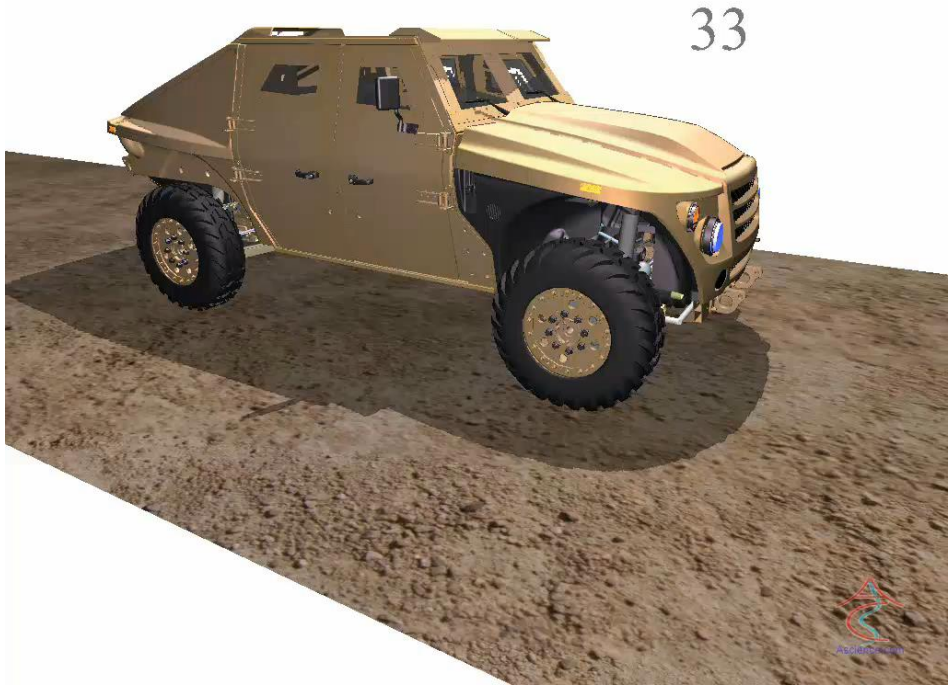
Test	NRMM	NG-NRMM	Comments
Wall To Wall	✘	✓	No 3D Steering Mechanism in NRMM
Steady State Cornering	✘	✓	No Steering, Load Transfer Capability in NRMM
Straight Line Acceleration	✘	✓	NRMM over-predicts acceleration performance
V-Ditch	✓	✓	
Step Incline (12”,18”,24”)	✓	✓	
Double Lane Change (Paved and Gravel)	✘	✓	No Steering, Roll and Lateral Dynamics in NRMM
Side Slope Obstacle Avoidance	✘	✓	No Steering and Lateral Load Transfer in NRMM
60 % Grade Paved	✓	✓	
Half Round (4”, 8”, 10”, 12”)	✓	✓	
Symmetric RMS (1”,1.5”,2”,3”,4”)	✓	✓	
Asymmetric RMS (1”-1.5”, 1.5”-2”)	✘	✓	No Roll Dynamics in NRMM

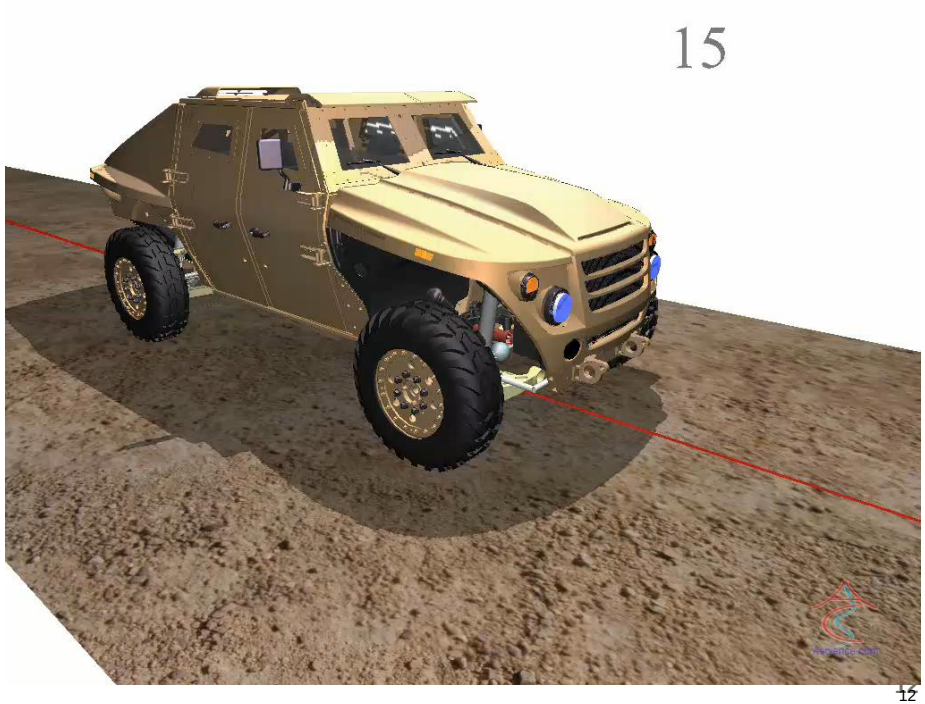
RELIABILITY OF SPEED-MADE-GOOD MAP



Reliability < 30%

RIDE QUALITY DEMONSTRATION

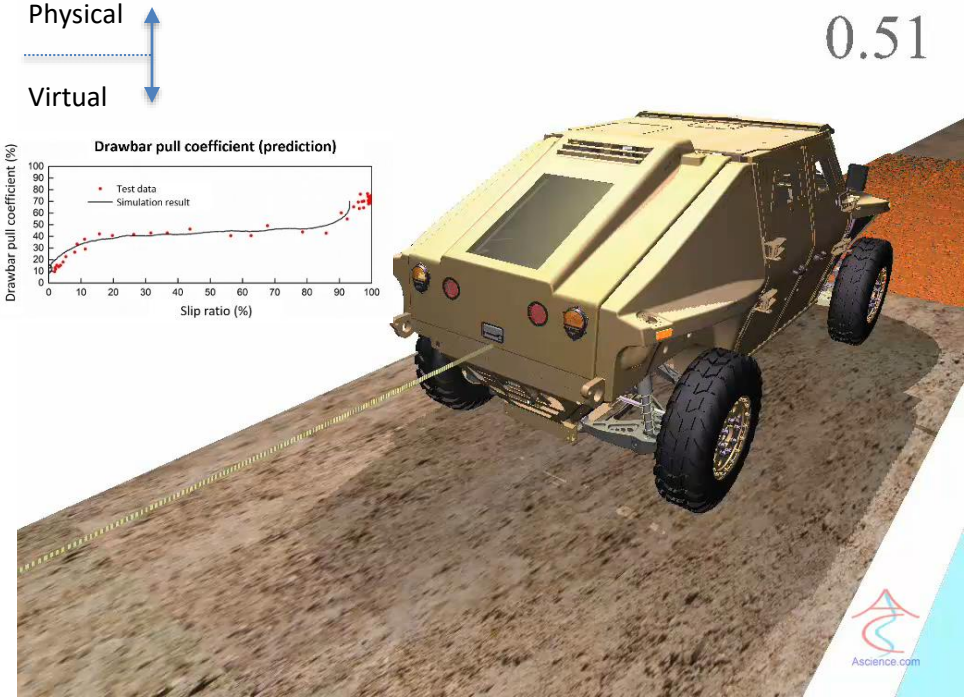




Soft Soil Mobility Demonstration

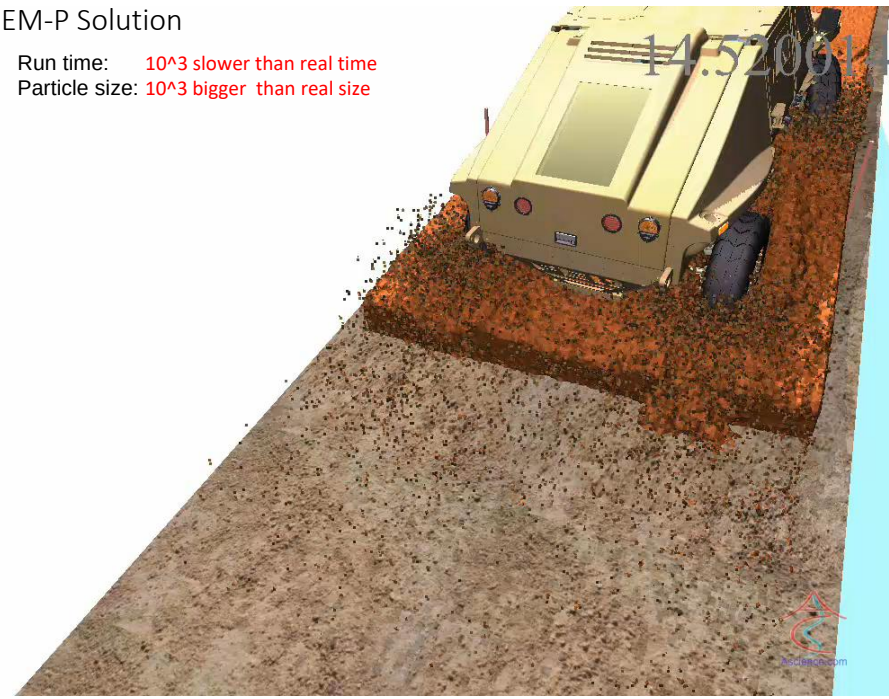
Physical

Virtual



DEM-P Solution

- Run time: 10^3 slower than real time
- Particle size: 10^3 bigger than real size



Mobility Traverse Speed Comparison: NRMM *vs.* NG-NRMM

Traverse Loop Summary			
	Method		
AVG. Speed	NG-NRMM	TEST	NRMM
(m/s)	7.4	7	11.5
(km/hr)	26.6	25.3	41.4
(miles/hr)	16.5	15.7	25.7

- NG-NRMM over predicts S-M-G by 10% while NRMM over predicts by 60%

Section	Description	Speed Variance (%)	
		NRMM	NG-NRMM
B1	RMS 1.0 with Exit onto Gravel Pad	14.0	23.4
B2	Up Slope on Gravel Pad with Down Slope through 2NS Sand Grade	31.3	1.9
B3	Construction Site Road to Gravel Access Road & Loop 2, Rink Field Traverse with setup for OEF	18.6	-1.4
B5	Gravel Road to Stability Side Trail, Sinusoidal Side Slope with Setup for Moisture Dependent Area	54.4	49.0
Y1	Stability Field Traverse with Sinusoidal Side Slope, Loop 2 with Panic Stop	26.9	-5.4
Y2	Loop 2 with Rink Field Traverse & Setup for Wadi	38.8	5.0
Y3	Wadi	264.9	-20.2
Y4	Rink Field Traverse with Setup For Coarse Grain Pit	85.9	32.8
Y5	Sinusoidal Coarse Grain Pit	97.2	4.7
Y6	Rink Field Traverse with Loop 2 & Access Road to VDA 2 Field Traverse & Setup for Fine Grain Soil Pit	38.5	-8.8
Y7	Fine Grain Soil Pit - Up slope into pit then 90 degree turn in pit with accelerated exit	142.2	3.8
Y8	Construction Site Road to Side Slope, Obstacle avoidance on Side Slope, then RMS 2.0	88.0	-10.1

NRMM

- Consistently over predicts SMG for ALL segments
- Over predictions range from 14% to 265%
- Average over prediction error is 75%

NG-NRMM

- Both over and under predicts S-M-G
- Over predictions range from 2% to 49%
- Under predictions range from -1% to -20%
- Average value 6%

PERFORMANCE METRICS CONFORMANCE WITH NG-NRMM

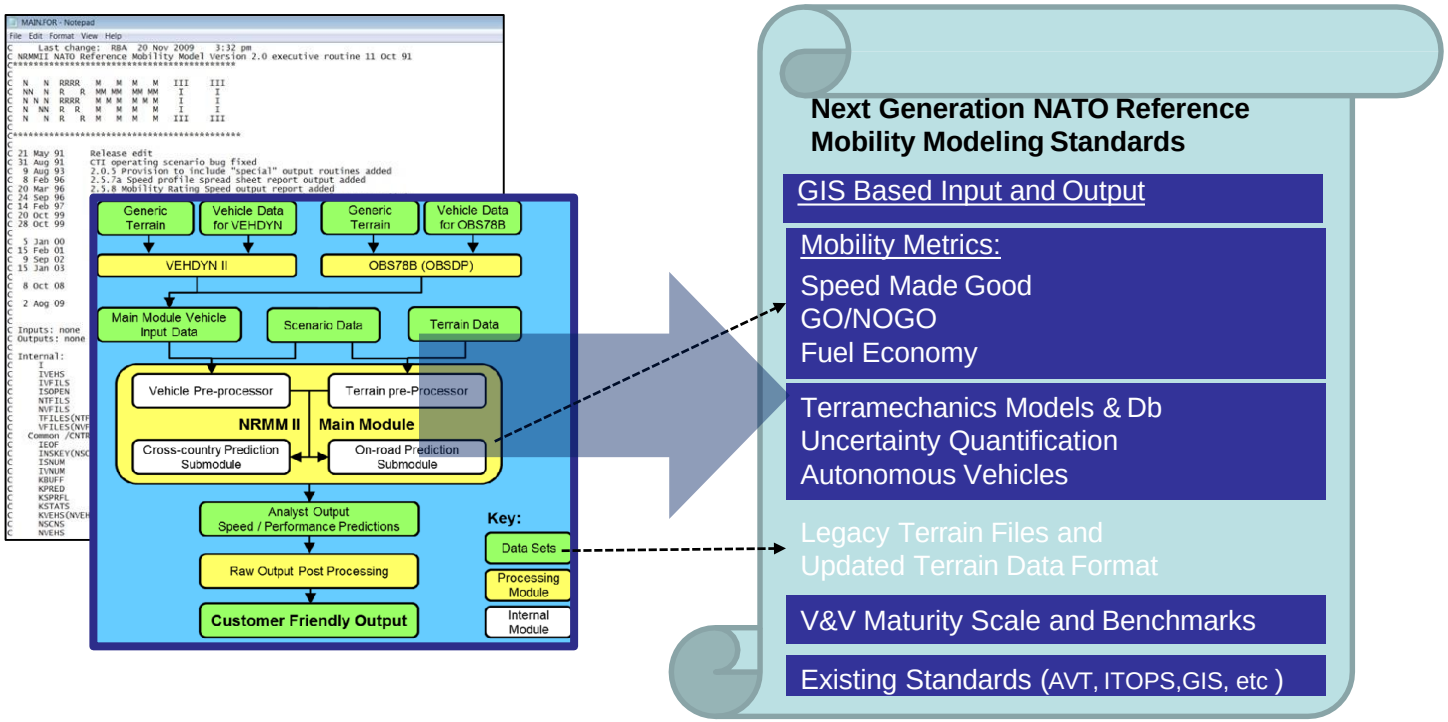
Test Event	Performance Metric
Straight Line Acceleration	Speed *vs.* time
Wall-to-Wall Turn Circle	Minimum turn circle radius
Steady State Cornering	Understeer gradient, Max speed
Double Lane Change, Paved & Gravel	Max speed
Side Slope Stability with Sine Steer	Max side slope
Longitudinal Grade Climbing, Paved	Max grade
Obstacle Crossing, Step and V-Ditch	Go/NoGo
Ride Quality	6W speed *vs.* Road rms, sym & asym
Shock Quality	2.5g speed *vs.* Half-round height
Off-Road Trafficability	Drawbar pull *vs.* Slip
Longitudinal Grade Climbing, Sand	Max sand grade
Mobility Map Generation	Speed-Made-Good % Go % Reliability

NEW / REVISED

WHY USE NG-NRMM

- NG-NRMM captures decades of advancements since the development of NRMM.
- Modern methods available in NG-NRMM can significantly improve our ability to make mobility predictions and assessments. These hold the promise of improving prediction errors by an order of magnitude.
- There are simplified NG-NRMM solutions, running in real time or better, that can replace NRMM for use in operational planning, training, and field deployment.
- There are high fidelity solutions which are suitable for research and development work at the technology and procurement levels.
- Accounting for uncertainties, especially in terrain properties, improves confidence in mobility maps.

NG-NRMM, NEW NATO STANDARD



- An enduring artifact and development path for NATO nations' mobility modeling methods, benchmarks, and source databases that should be applied to physics based simulations of all operational land and amphibious mobility among the alliance.
- NG-NRMM is a Standard, not a specific computer code.
- NG-NRMM compliant tools can be Govt. or COTS software.

NEXT STEPS

- Issuance of a new Army Policy that recommends NG-NRMM Standards be the basis of mobility M&S for design, acquisition, and operational planning.
- U.S. Army to transition from NRMM to NG-NRMM Standards.
- U.S. Army DEVCOM GVSC to lead the implementation activities.
- Adapt key mobility performance metrics, used in acquisition contracts, to NG-NRMM Standards.
- Contractors are to perform verification and validation of models per NG-NRMM Standards.

WHY MOBILITY IS IMPORTANT