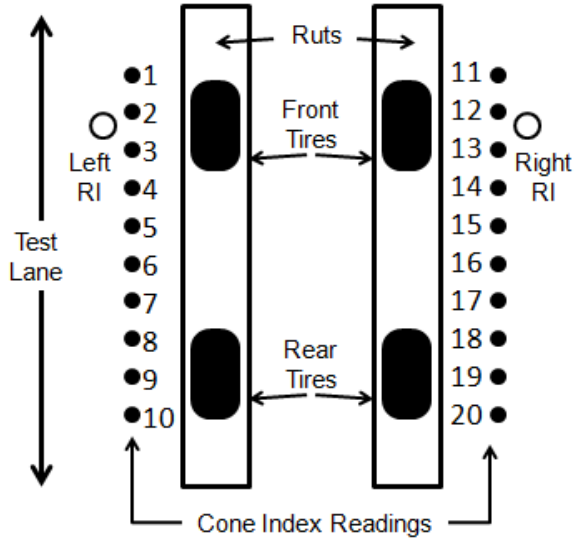
Annex B – HISTORY, MOTIVATION, AND GOALS FOR NG-NRMM

Note: This Annex appears in its original format.

History, Motivation, Goals for NG-NRMM

Dr. David Gorsich
TARDEC Chief Scientist
USA

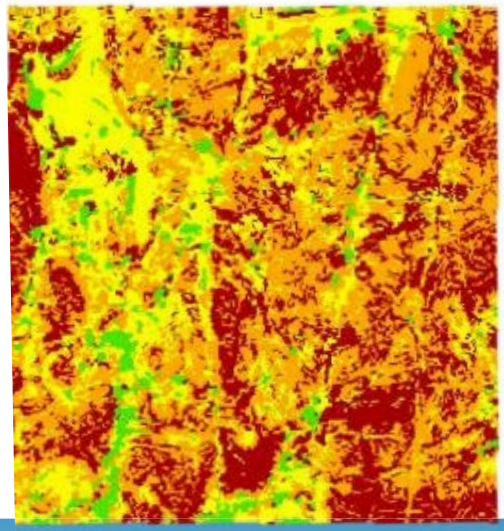
NATO Reference Mobility Model (NRMM)



- 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
- Has extensive, global validated soil properties
- Used extensively to evaluate vehicle designs in acquisition.

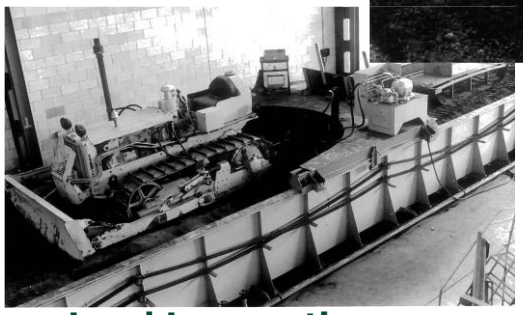
Current Bradley Go/NoGo Map

NoGo: 22%
V50: 10 mph

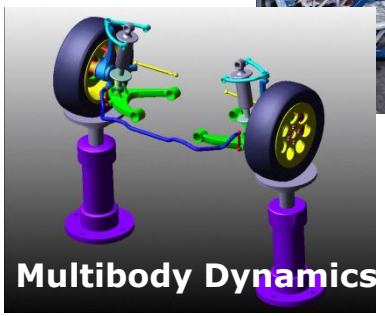


NATO Reference Mobility Model (NRMM)

Marsh Buggy



Land Locomotion



Autonomous Systems

1954 – Land Locomotion Lab established; led by Dr. Bekker

1971: AMC-71 Mobility Model

1974: AMC-74 Mobility Model

1978: NATO Reference Mobility Model

1992: NRMM II

2014: ET148, NG-NRMM

2016: RTG248 NG-NRMM

2019: NG-NRMM STANAG

1950 1960 1970 1980 1990 2000 2010 2020

What NRMM Can't Do

- Methodology **not** physics-based – relies on empirical, in-situ soil measurements
- Does **not** consider turning performance and lateral vehicle dynamics
- Does **not** support 3D models
- Does **not** extrapolate to contemporary vehicle designs and technologies
- Does **not** benefit from advances in simulation and computational capabilities
- Does **not** cover uncertainty, intelligent vehicles or data sets for urban areas
- Does **not** predict mobility for systems dissimilar to past systems (weight, power, suspension system, etc.)

Development of A Next Generation NRMM

NATO S&T Organization Applied Vehicle Technology Panel

- Project proposed at Copenhagen PBM April 2014
- Exploratory Team (ET-148) lasted from April 2014 - Dec. 2015
- Research Task Group (AVT-248) running from Jan. 2016 - Dec. 2018
- 70 members & participants from 15 nations

Goals

- Develop and demonstrate NG-NRMM process & technologies
- Incorporate NG-NRMM as a NATO Standard
- Conduct Verification and Validation benchmarking studies
- Demonstrate technology through a CDT

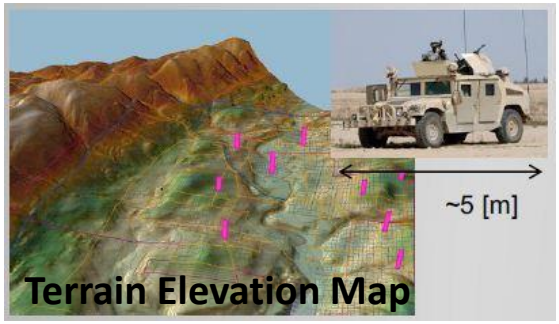
Co-Leads

- Dr. P. Jayakumar (TARDEC)
- Dr. M. Hoenlinger (KMW GmbH, Germany)

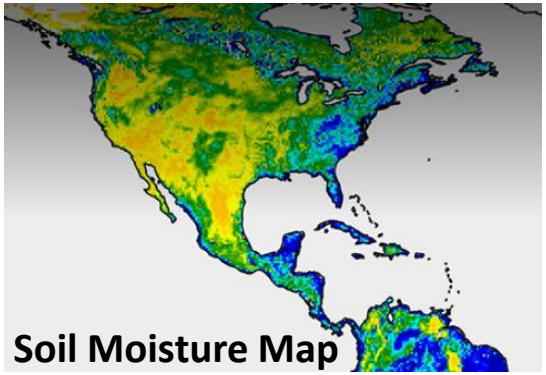
- Panel Member Sponsor: Dr. D. Gorsich

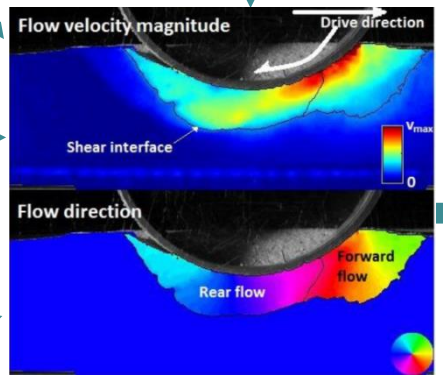
AVT-248 on Estonia Field Trip

Next Gen NATO Reference Mobility Model (NG-NRMM)



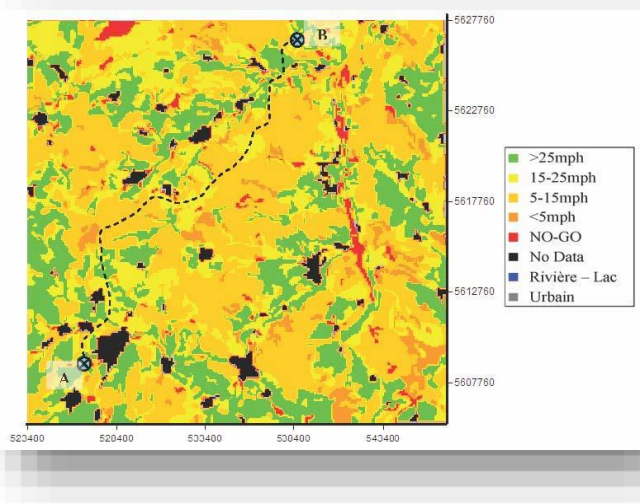
Vehicle Parameters

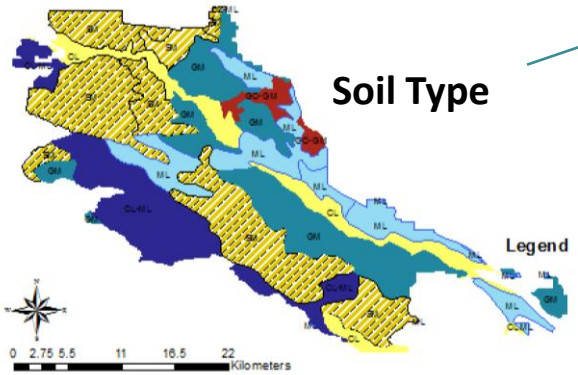




Physics-Based M&S

Mobility Go/NoGo Map





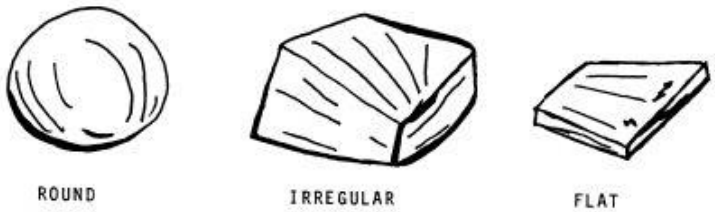
Qualitative — NRMM — NG-NRMM

1970 — 2020

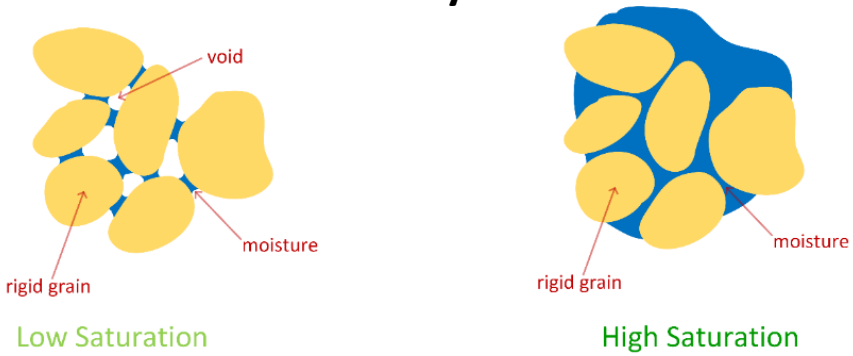
Multidisciplinary University Research Initiative (MURI)

TARDEC awarded a FY19 DOD MURI for $6.25 M
Prediction and Control in Particulate Systems

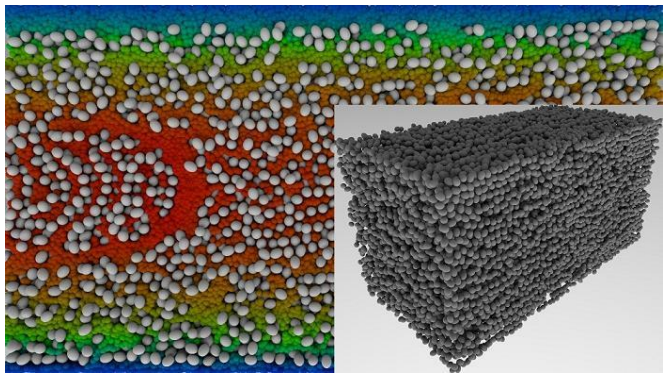
Heterogeneity



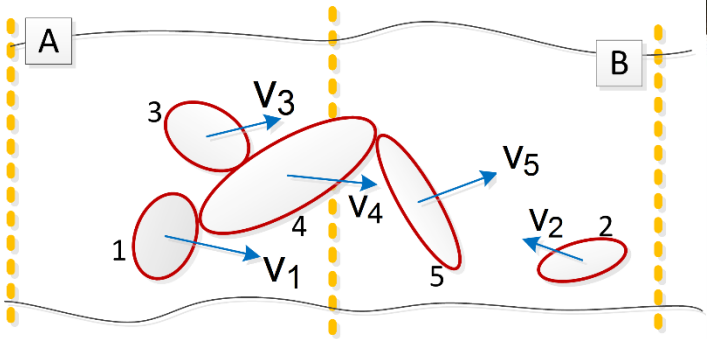
Multi-Physics



Scalability

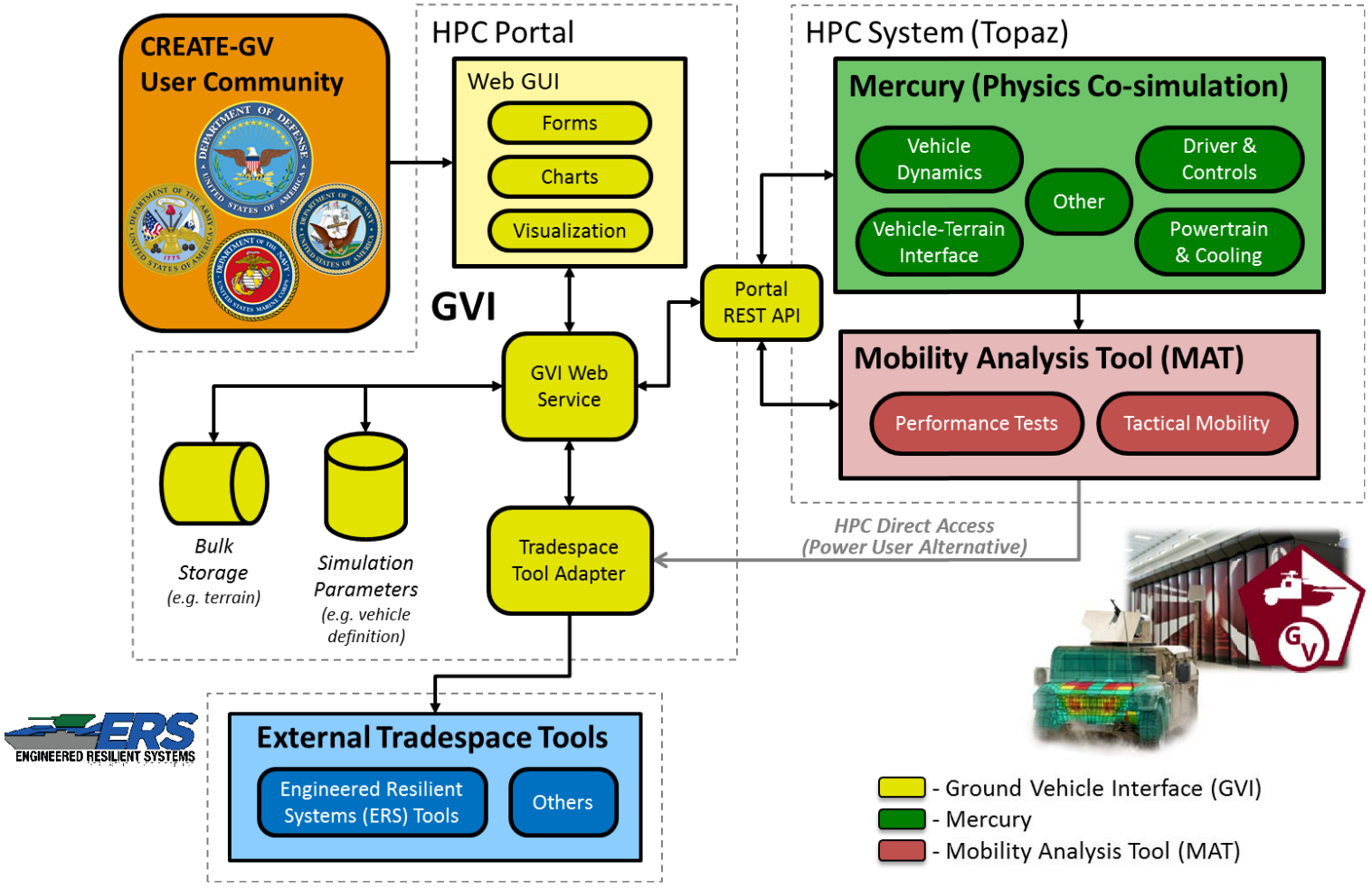


Dynamics



Multi-Scale

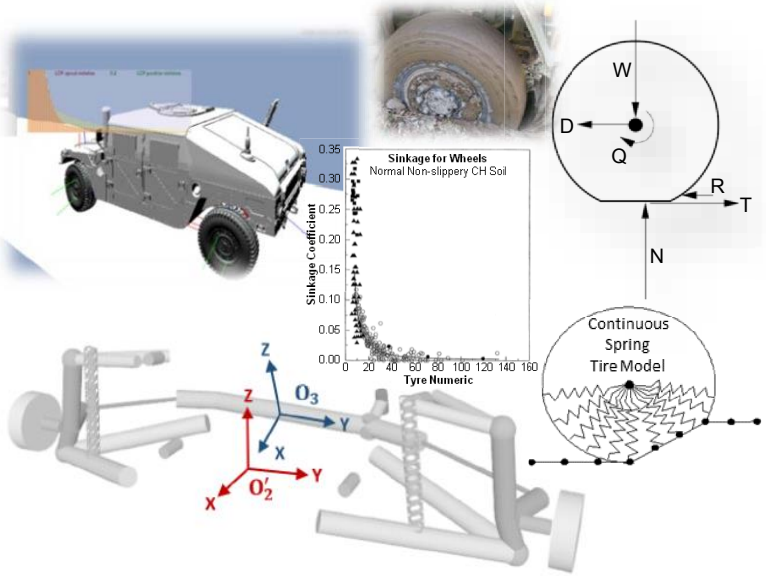
CREATE-GV: Current Architecture



HPC Computational Tools

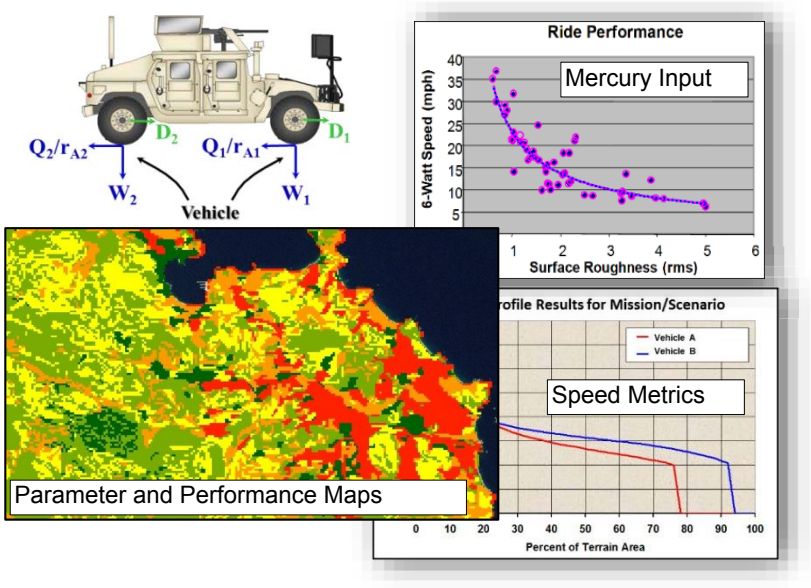
Mercury

- Simulates engineering performance tests of wheeled and tracked ground vehicles for proving-ground type developmental testing.
- Co-simulation framework for integrating physics domains.
  - Powertrain
  - Vehicle Dynamics (wheels and tracks)
  - Tire-soil & track-soil interaction



Mobility Analysis Tool (MAT)

- Converts vehicle performance metrics and terrain information into mission-based analysis of performance over large areas of terrain.
- Predicts multiple metrics currently used in acquisition processes.
  - % NOGO
  - Mission rating speeds



Mercury Status

- **Running gear types modeled**
  - Wheeled
  - Tracked (available in V2.0)

- **Metrics produced**

Max Speed Test

  - Tilt-Table Test
  - NATO Double Lane Change Test
  - J-Turn Test
  - Sand Slope Test
  - Soft-Soil (VCI_1) Test
  - Drop Test
  - Ride Quality Test
  - Shock Test
  - Drawbar Pull Test (Hard-Surface Tractive Effort)
  - Rollover Stability Test
  - Steady-State Circular Turn Test

More Mobility Metrics to Pursue

Requirement Type	Metric
Soft Soil Mobility	VCI
	Dry sand slope
Ride Quality	6 Watt RMS Ride Quality
	Half Round Vertical Shock
	ISO2631 Ride Quality
	Out of Phase and WNS Ride Quality
Speed & Acceleration	Speed on Grade @ GVW
	Acceleration
	Dash Test
	Top Speed
Maneuverability	Turning Radius
	Lane Width @ 90 deg intersection
	Turning Test
	Defilade Firing Maneuver
	Differential Steer
	Pivot Steer
Obstacle Crossing	Vertical step
	Trench Crossing (V-ditch or gap)
	Approach Angle
	Departure Angle
	Breakover Angle
	Curb Climb
	Pothole Traverse
	Stair Climb
	Rubble Climb
	Fording Depth
	Ground clearance
	Suspension Travel

Requirement Type	Metric
Stability	Double Lane Change
	Static Side Slope
	Dynamic Side Slope
	Steady State Circular Steer Test
	ESC Yaw Control
	Understeer gradient
	Gravel Lane Change
	Road Edge Recovery
	Steering Torque Gradient
	Steering Wheel Angle Deadband
	Roll gradient
Gradeability	Longitudinal Grade
	Stop/Start on Grade
	Tractive Effort
	Tow Like Vehicle
Braking	Brake effectiveness and system safety
	Maximum Stopping Distance
	Grade holding ability
	Mountain Braking & Off Road Braking Evaluation
	Brake System Structural Integrity Test
	ABS
Other	Fuel Economy/Range
	Cooling
	HP/ton
	Run Flat

Highlighted Cell- Current Mercury Tests

New NATO Exploratory Project

Assessment Methods and Tools for Autonomous Military Ground Systems

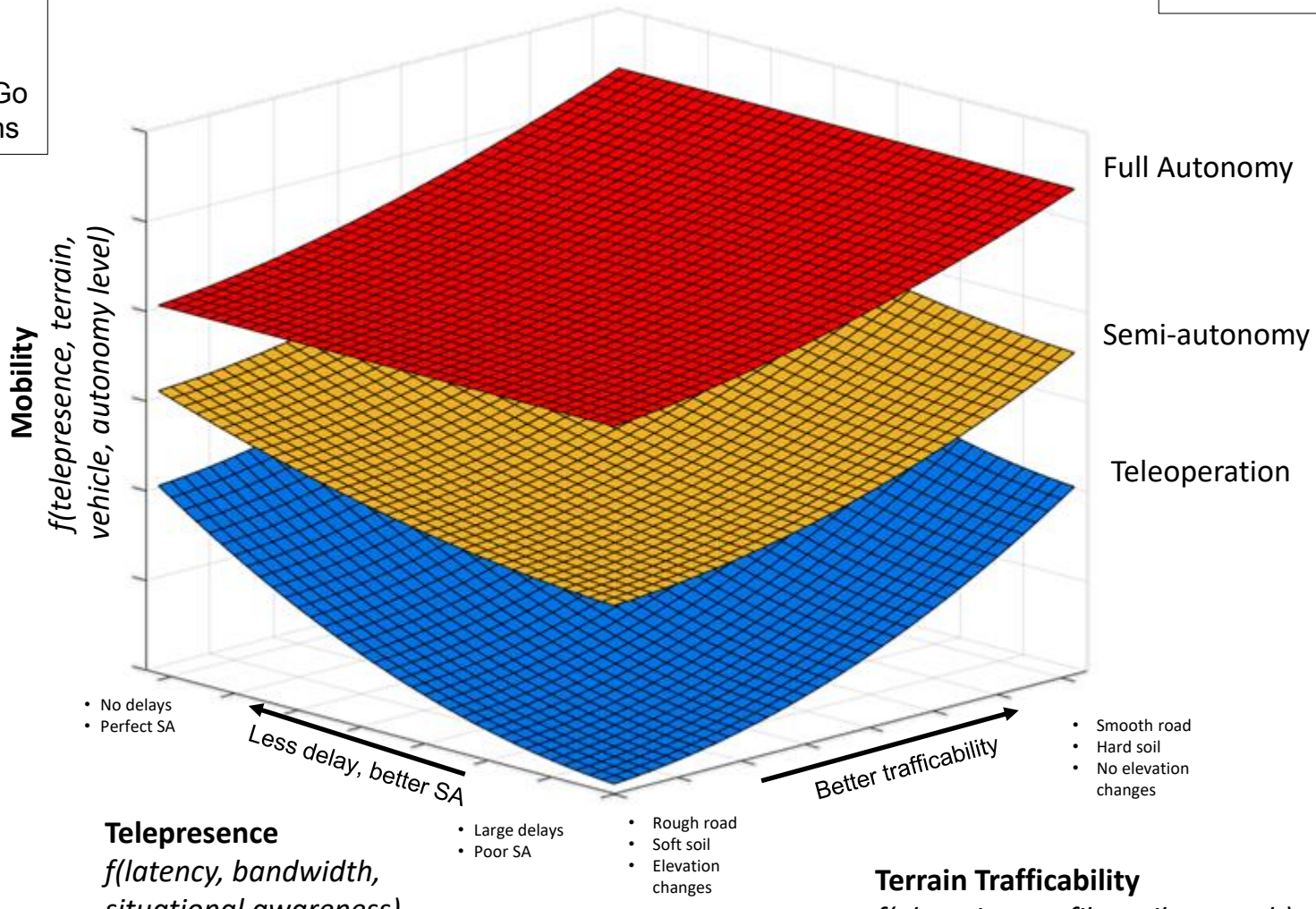
- To be proposed at PBM in Athens, December 2018
- Proposed dates: January to December 2019

- Goals
  - Identify the challenges and special requirements associated with modelling and simulation of autonomous military systems
  - Identify the current state-of-the-art software for assessing the performance (mobility) of autonomous military systems.

Notional Relationship: Autonomy Levels

Mobility
- Speed
- Error
- Go/No-Go
- Collisions

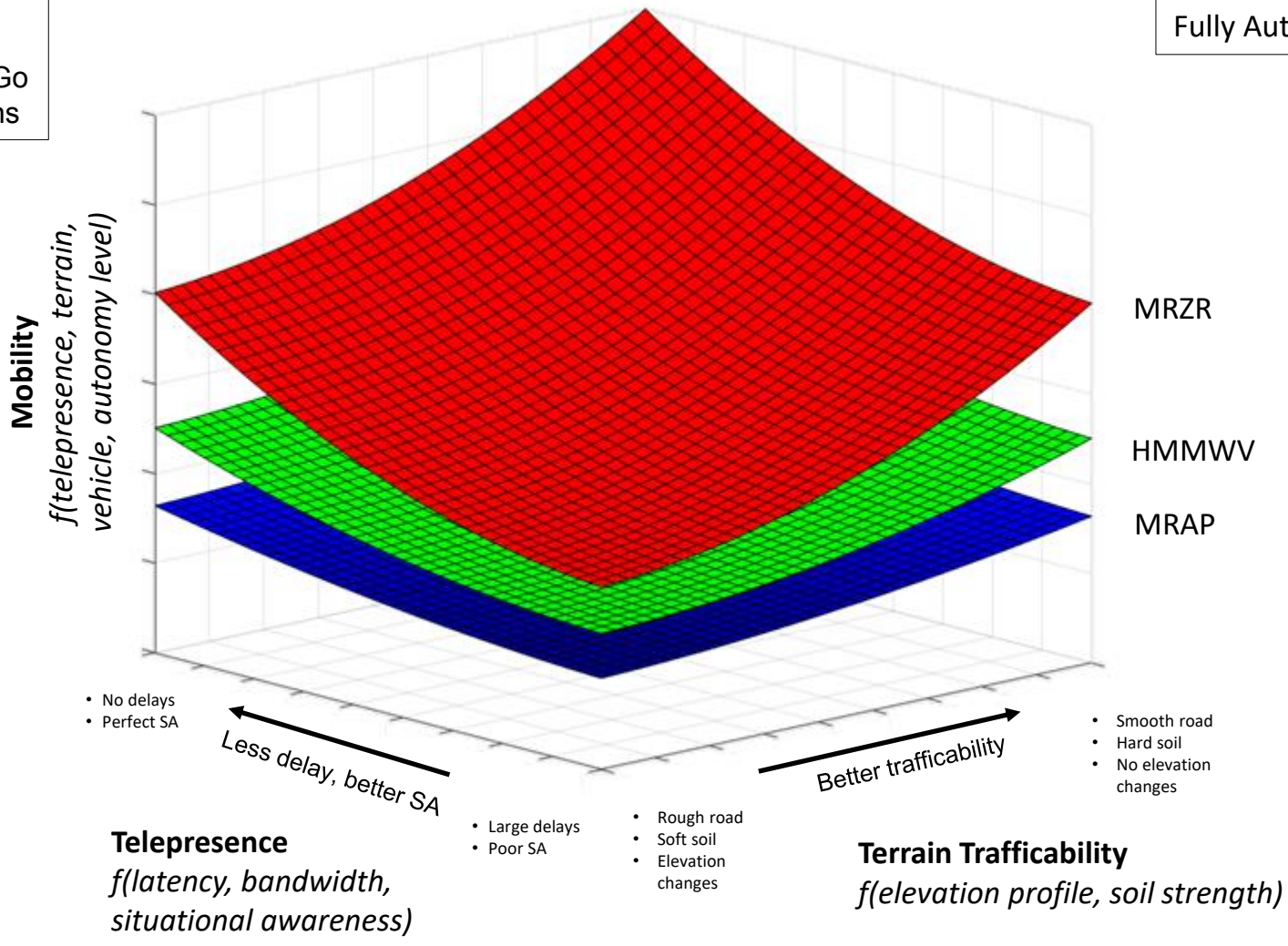
Vehicle: HMMWV



Notional Relationship: Ground Vehicle Comparison

Mobility
- Speed
- Error
- Go/No-Go
- Collisions

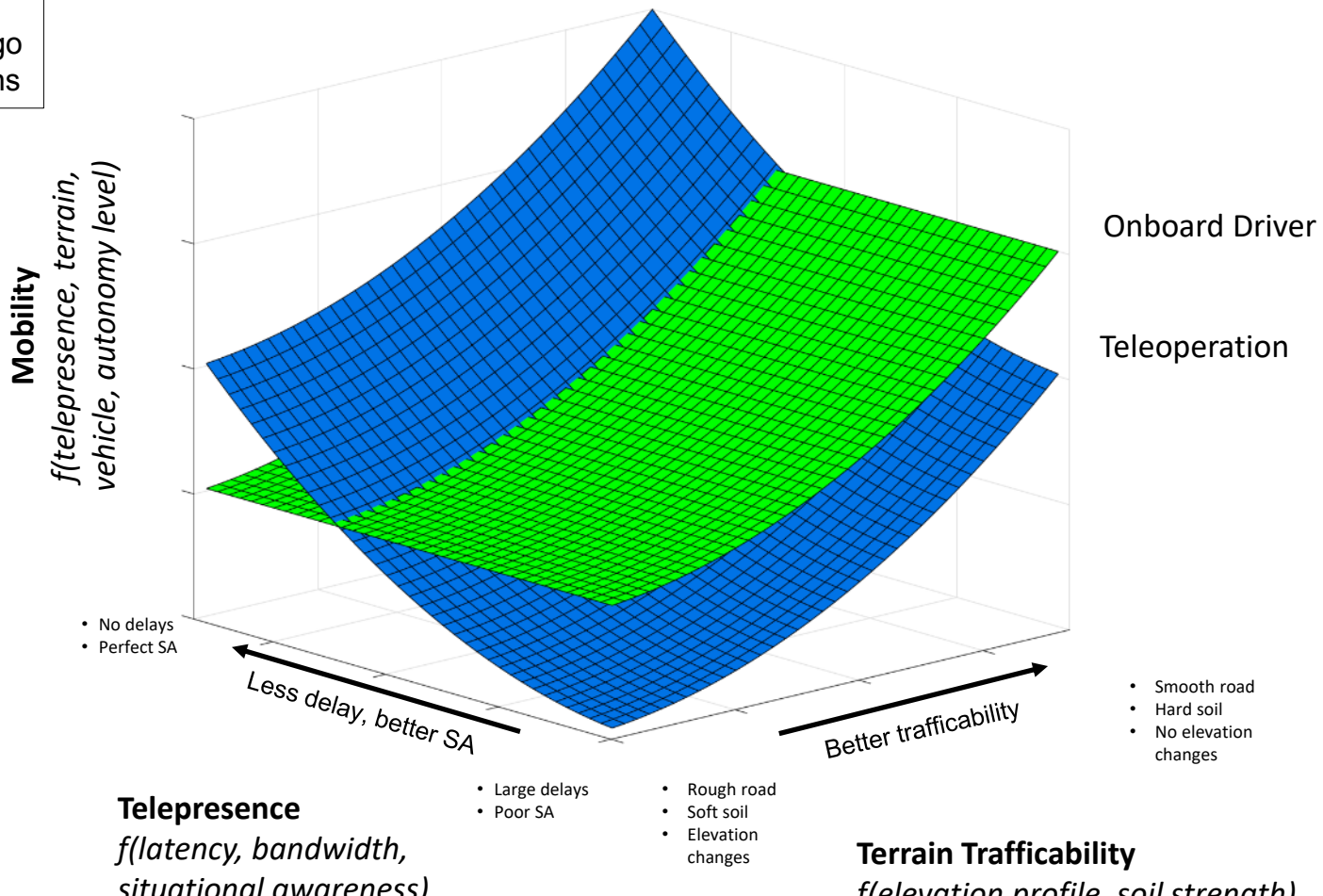
Autonomy Level:
Fully Autonomous



Notional Relationship: Teleop vs. Onboard Human Driver

Vehicle: HMMWV

Mobility
- Speed
- Error
- Go/No-go
- Collisions



It's All About the Warfighter

DISTRIBUTION A. Approved for public release; distribution unlimited. OPSEC #: 1444)