Annex C – NATO TASK GROUP AND CDT REVIEW

Note: This Annex appears in its original format.

NATO Task Group and CDT Objective

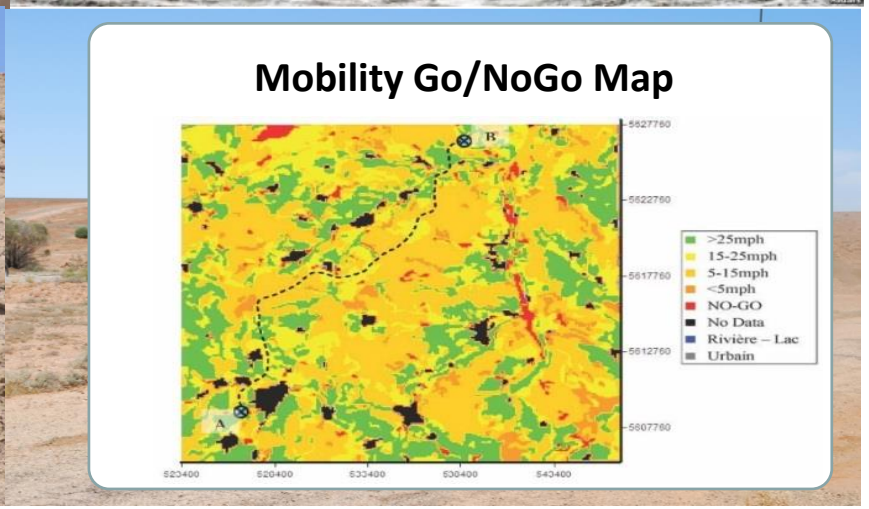
CDT Meeting
KRC, Houghton MI

Dr. Michael Hönlinger

Krauss-Maffei Wegmann GmbH&Co.KG

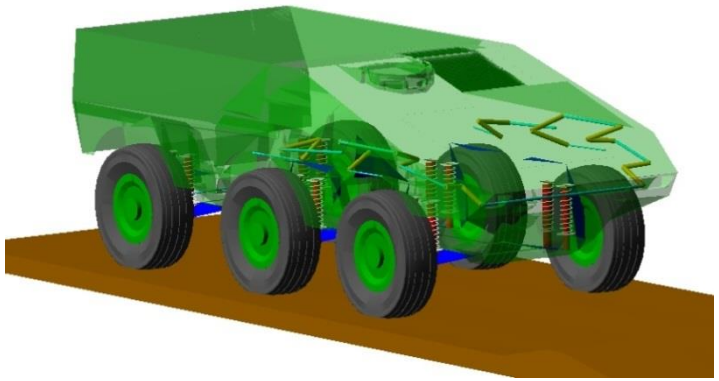
September 25th 2018

Mobility Challenges of NATO Vehicles



Design of Highly Mobile NATO Vehicles

- ❑ Mobility
- ❑ Environment
- ❑ Safety
- ❑ Comfort



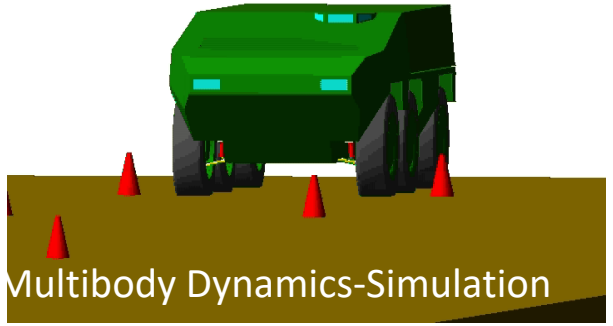
Multibody Dynamics (MBD) - Simulation

Mobility Evaluation of NATO Vehicles

- **Performance Features**
  - Velocity & traction force
  - Driving behaviour
  - Crossing soft soil and uneven ground
  - Traction on soft soil
- **Verification Tests (AVTP, SAE)**
  - Fast lane change and cornering
  - Fast obstacle clearance (sine wave, half round, ramp)
  - Slow obstacle clearance; (step, ditch,ridge)
  - Pull test on soft soil

- **Evaluation Criteria (AVTP, SAE)**
  - Velocity and traction force
  - Loads on crew (impact & vibration)
  - Stability against roll-over
  - Steering behaviour (under steering)
  - Ground pressure and wheel fluctuation


Vehicle Terrain-Interaction


Multibody Dynamics-Simulation

Intelligent Vehicle Mobility

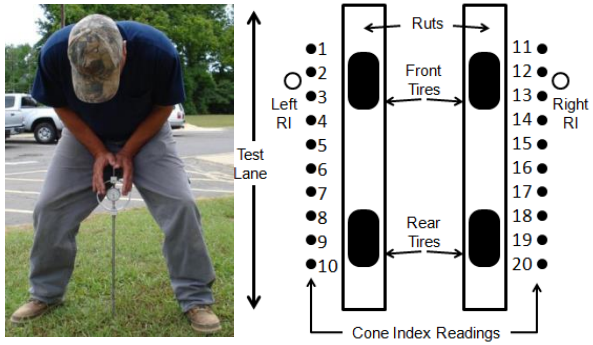
Intelligent Vehicle (Levels)

- Intelligent Actuators and Sensors
- Direct interaction V2V, V2I
- Autonomous vehicle

Intelligent Actuators and Sensors

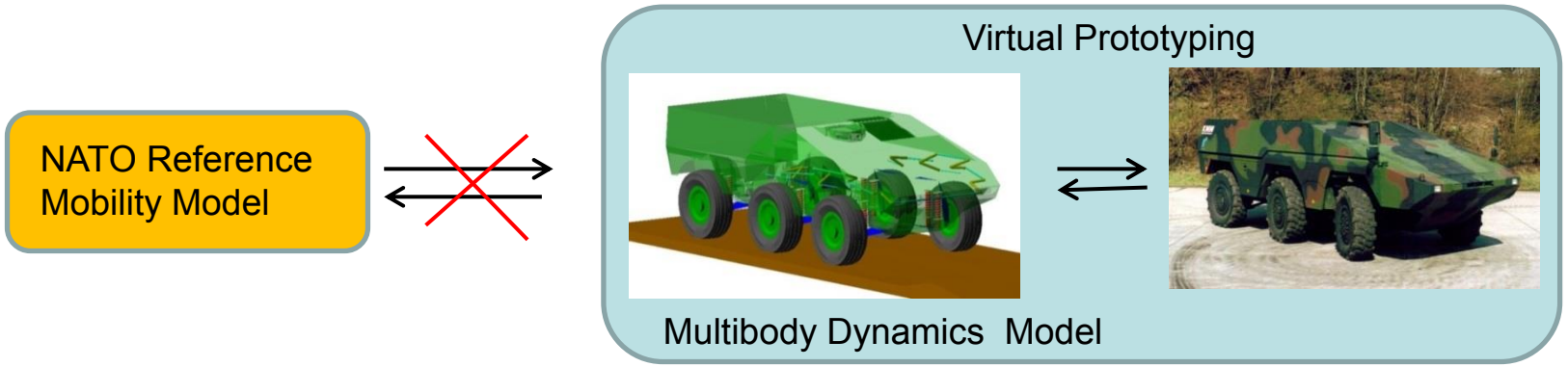
- Controlled tyre inflating system
- Controlled suspension System
- Electronic controlled drive train
- Electronic stability program

Mobility Prediction for Operational Scenario



Empirical Approach: NATO Reference Mobility Model (NRMM)

- NRMM was developed in 1960-1970 by TARDEC and ERDC
- Methodology relied on empirical relationship and is not physics-based
- Is not applicable to contemporary vehicle design methods
- Does not benefit from advances in simulation and computational capabilities

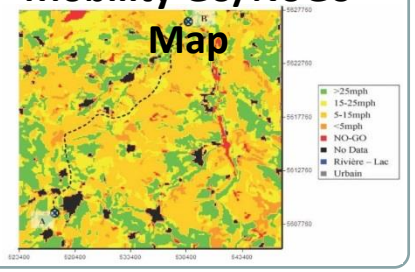


AVT-248 Research Task Group

Next-Generation NATO Reference Mobility Model (NG-NRMM) Development

Activity	**NATO S&T Organization Applied Vehicle Technology Panel** Approved Exploratory Team from April 2014 – December 2015 Approved Research Task Group from Jan. 2016 – Dec. 2018 70 members from 15 nations participating
Goals	Develop and demonstrate NG-NRMM process & technologies Incorporate NextGen NRMM as a NATO Standard
Co-Chairs	Dr. Paramsothy Jayakumar (U.S. Army TARDEC) Dr. Michael Hönlinger (KMW GmbH&Co.KG, Germany)

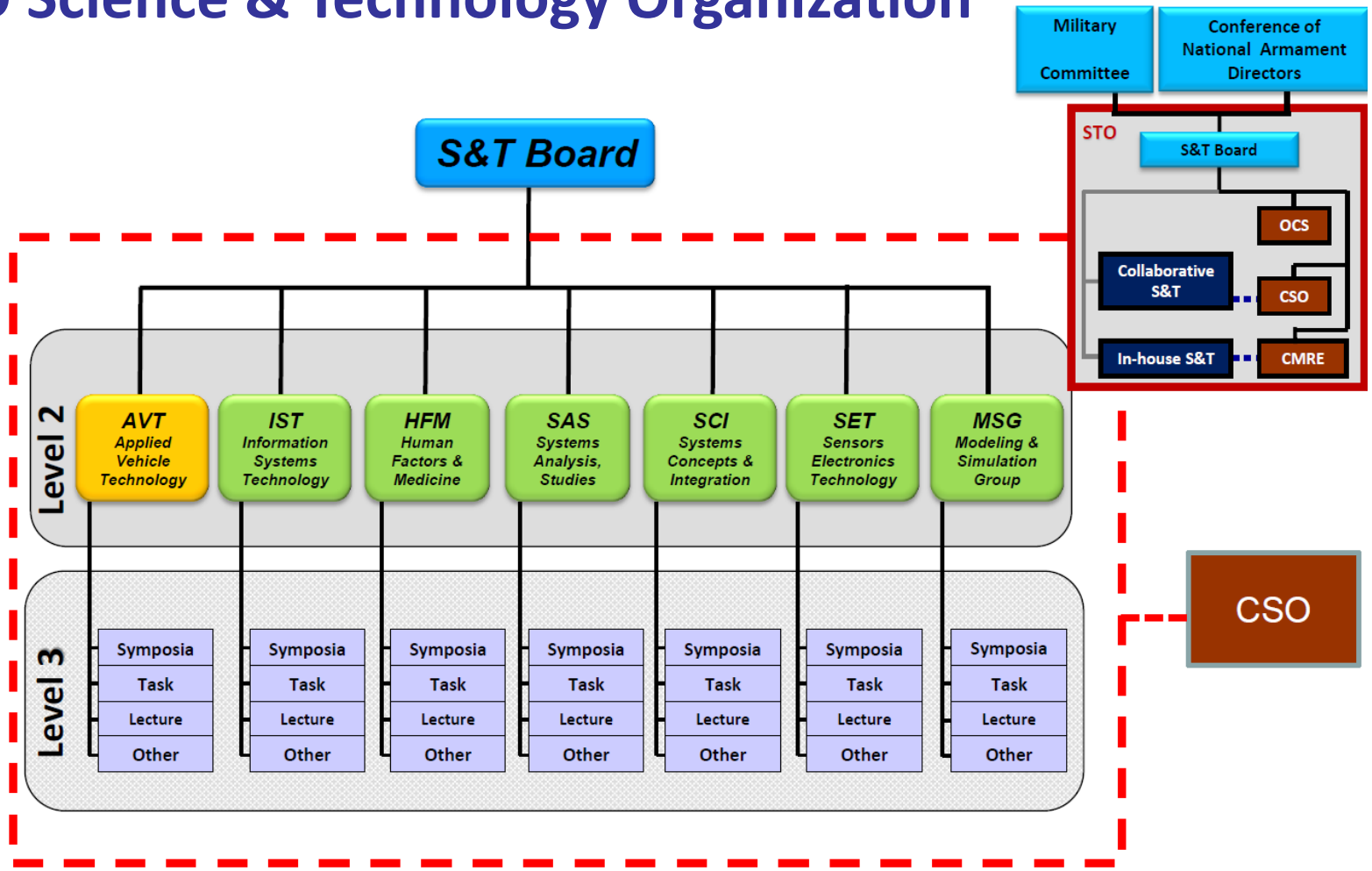
Mobility Go/NoGo Map

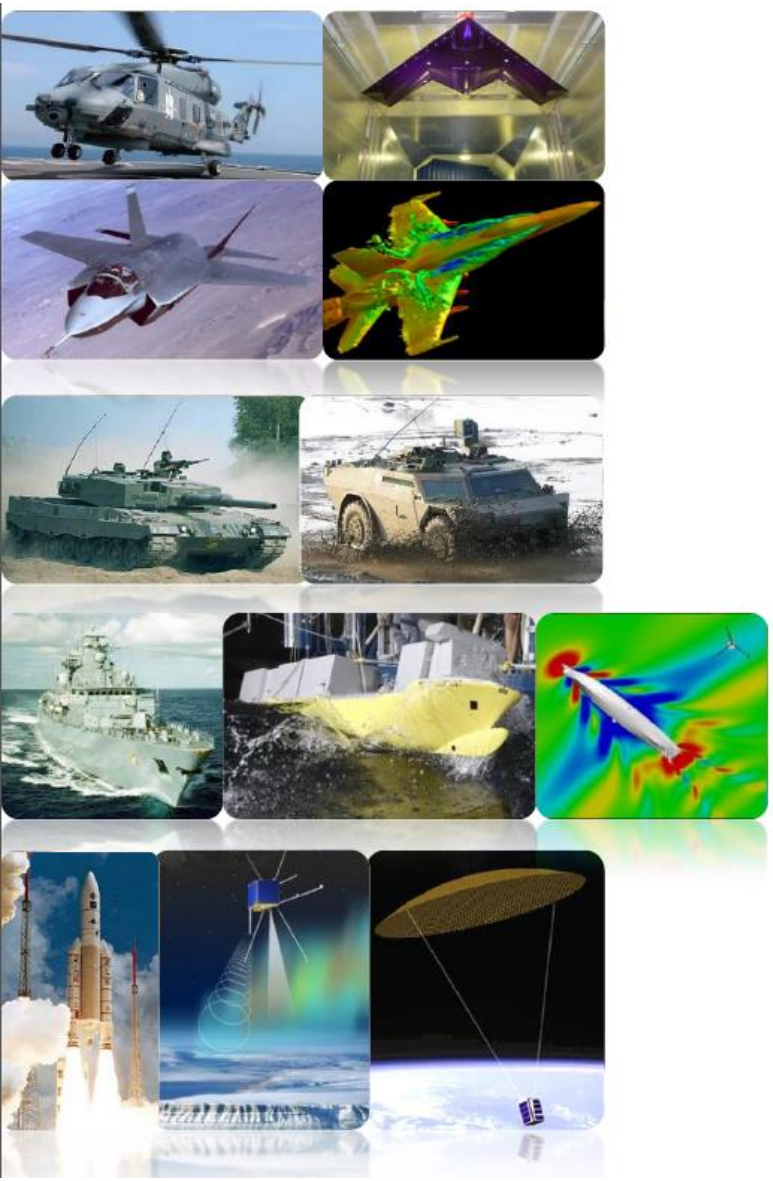


AVT-248 Research Task Group

NATO Science & Technology Organization

Network
of scientists, experts, engineers from
NATO, S&T, Government, Universities, Research Institutes and Industry





NATO Science & Technology Organization

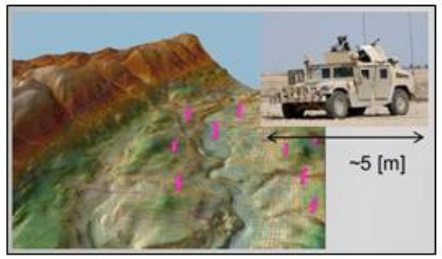
Applied Vehicle Technology Panel (AVT)

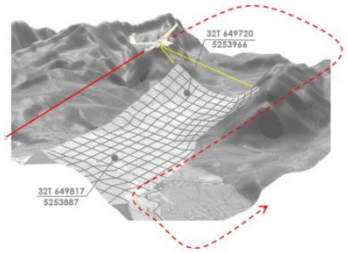
AVT Panel Mission

"Improve performance, affordability, and safety
of vehicle, platform, propulsion and power systems
operating in all environments
for new and ageing systems
through advancement of appropriate technologies"

Next-Generation NATO Reference Mobility Model (NG-NRMM) Development

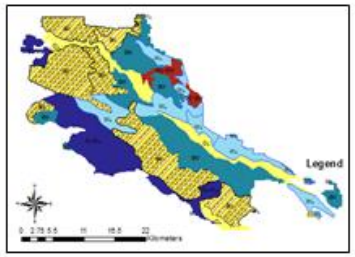
Terrain Elevation Map

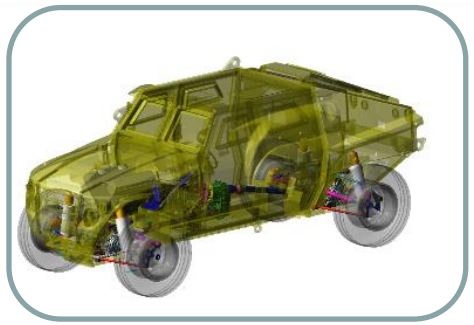




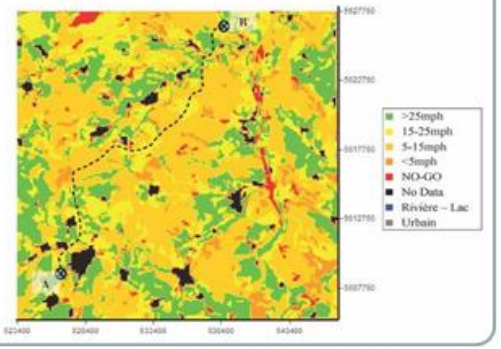
Physics-based M&S

Soil Type Map

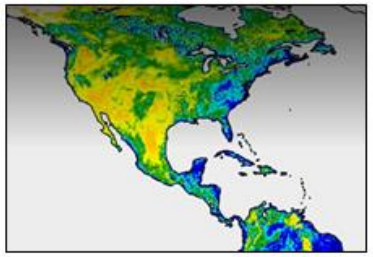




Mobility Go/NoGo Map



Soil Moisture Map



Qualitative | NRMM | NG-NRMM

1970 | 2020

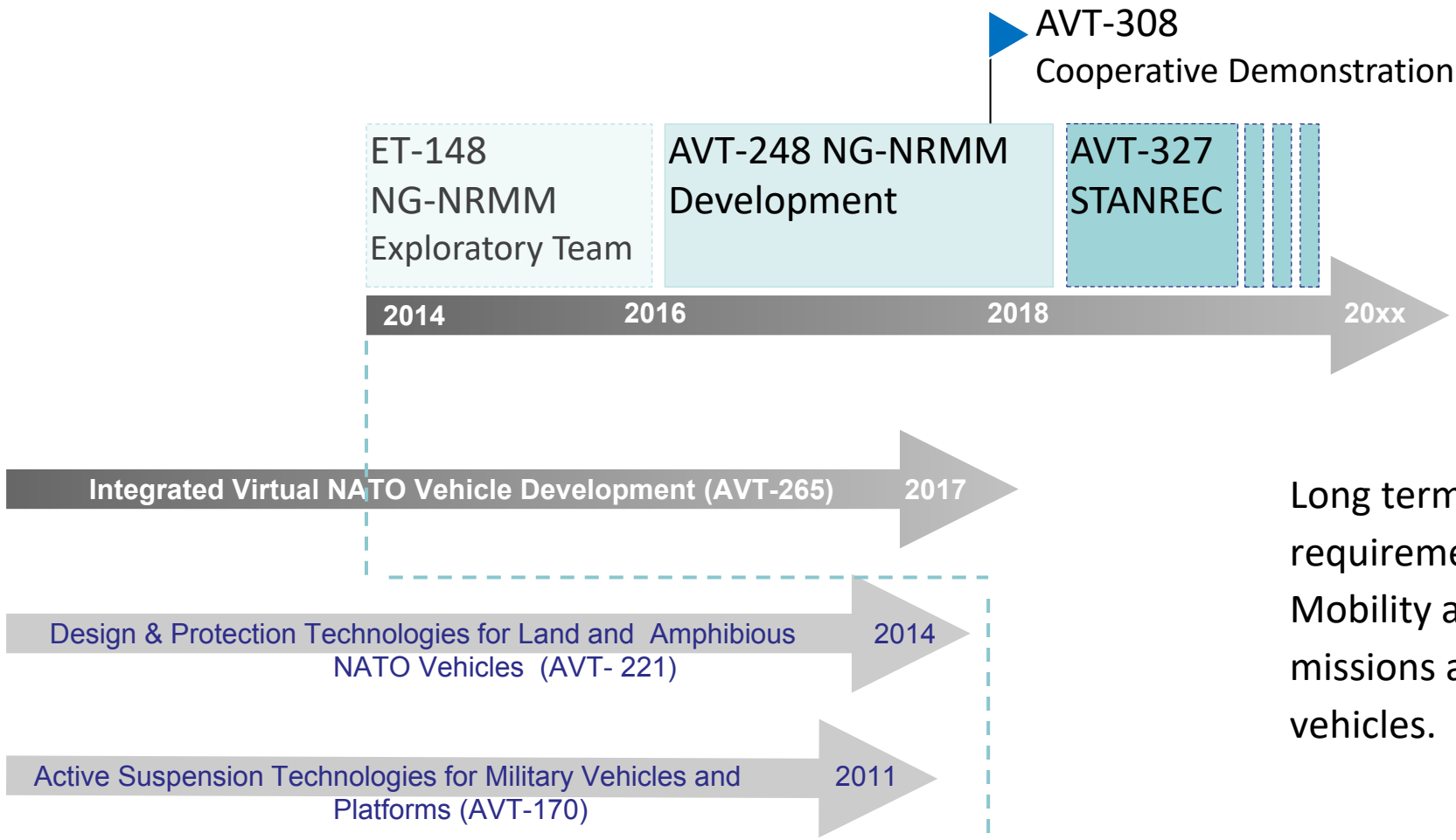
AVT-248 Research Task Group

Mission and Scope

AVT-248 RTG develops and defines the Next Generation NRMM (NG-NRMM) to be any mobility M&S capability that produces map-based probabilistic mobility predictions of land and amphibious vehicles through interoperation of M&S tools that include:

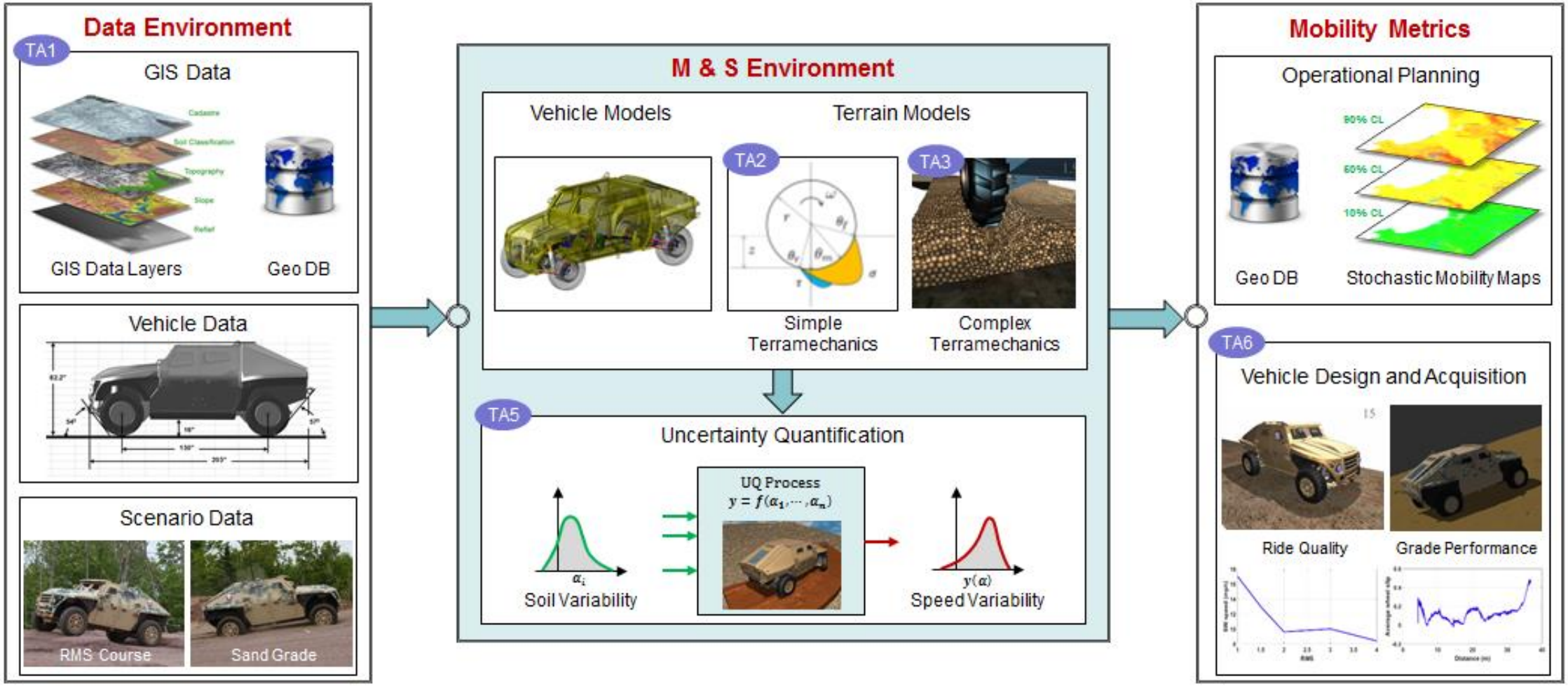
- Geographic information systems (GIS) software,
- 3D Physics based vehicle dynamics,
- Terramechanics models for off-road operations
- Autonomous control M&S software, as well as
- Uncertainty Quantification (UQ) software for probabilistic M&S

NG-NRMM in line with AVT Long Term Strategy



Long term strategy to meet operational requirements by increased Performance, Mobility and Protection capabilities to support missions and the next generation of NATO vehicles.

NG-NRMM Architecture



Interdisciplinary Research Thrusts

The Research Task Group 248 carried forward six research thrusts

TA 1: GIS Terrain and Mobility Map

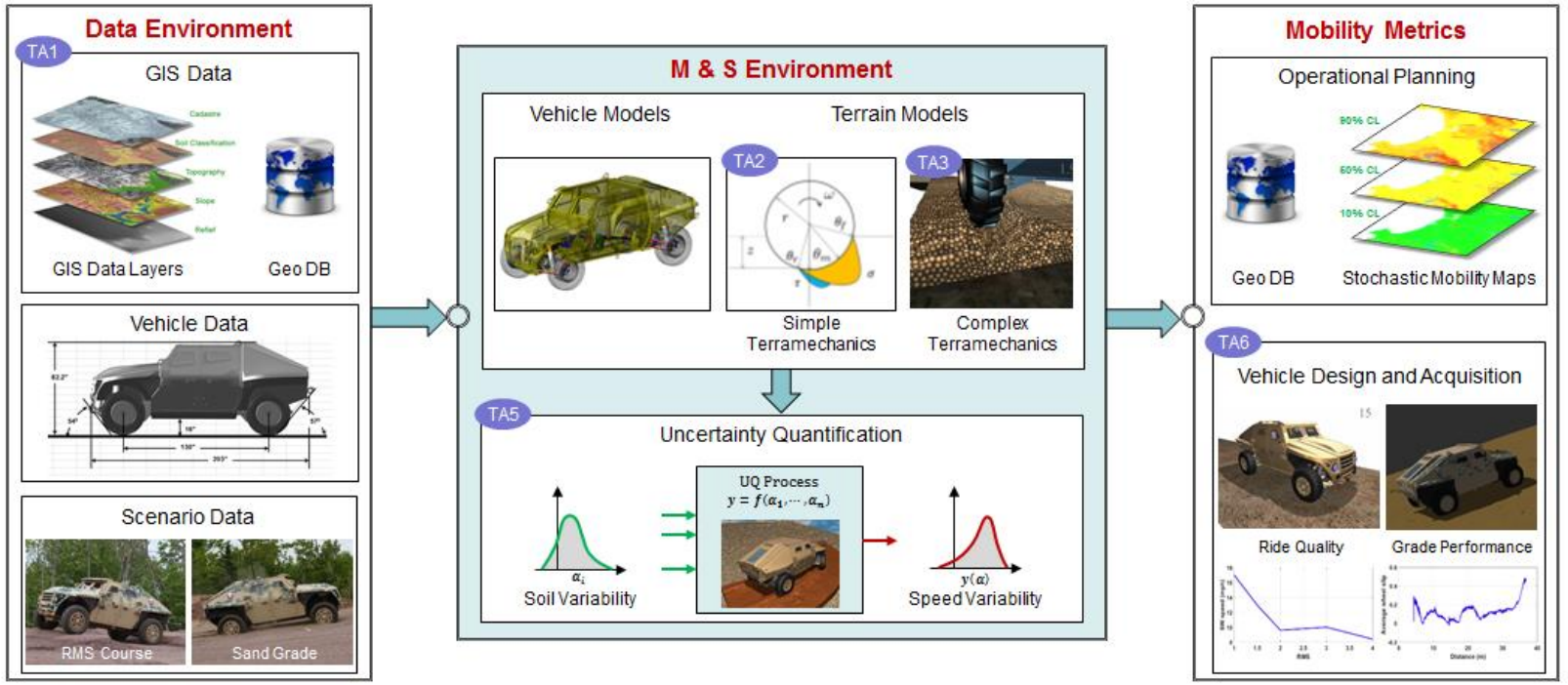
TA 2: Simple Terramechanics

TA 3: Complex Terramechanics

TA 4: Intelligent Vehicle Mobility

TA 5: Uncertainty Quantification

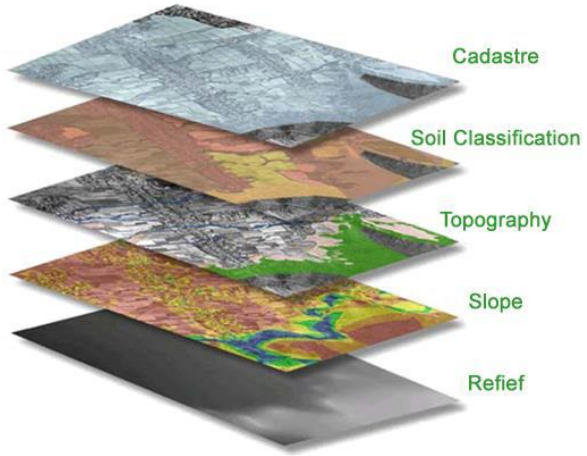
TA 6: Verification & Validation



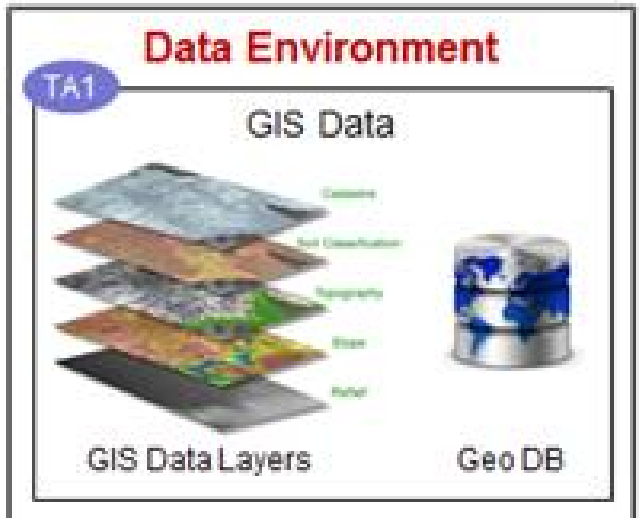
Research Thrust Areas

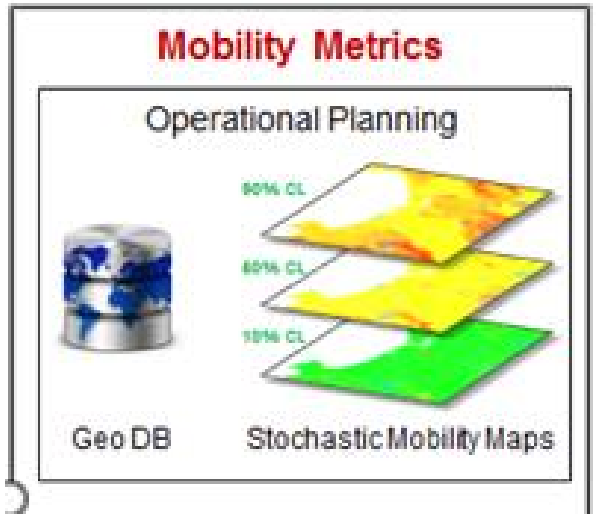
TA1: GIS Terrain and Mobility Map

Identify GIS-based mapping tool that implements and integrates mobility metrics in an open architectured environment



Geographic Information System (GIS) data base





Research Thrust Areas

TA 2: Simple Terramechanics

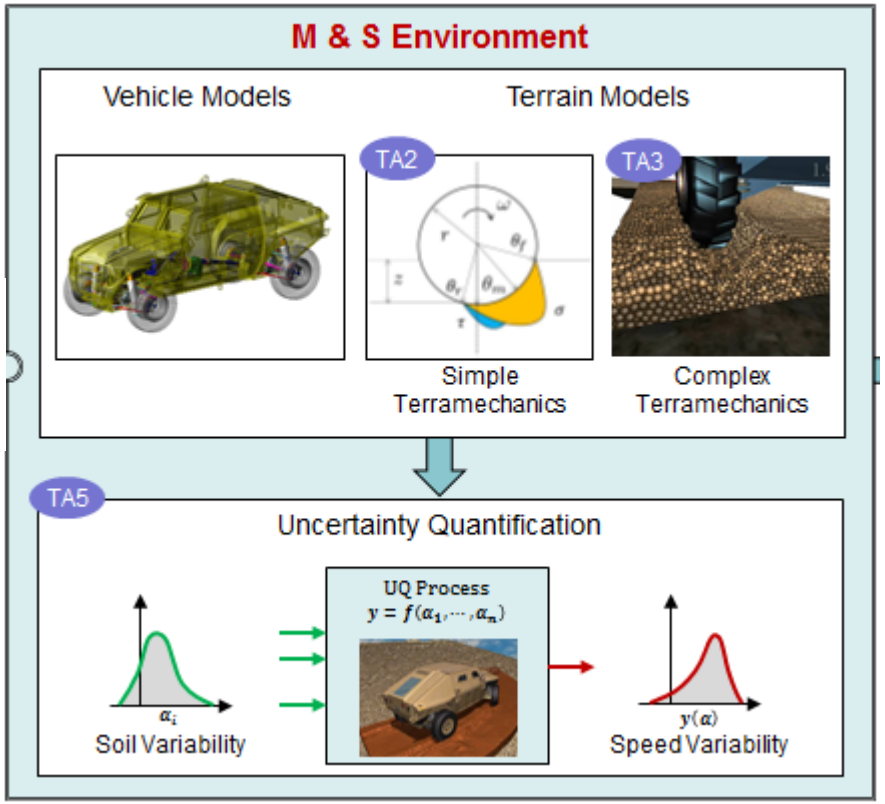
Identify existing terramechanics methods supporting NG-NRMM requirements that provide possible means of correlating the terrain characteristics to remotely sensed GIS data

TA 3: Complex Terramechanics

Establish a vision for the long term terramechanics approaches that overcome the limitations of existing models

TA 5: Uncertainty Treatment

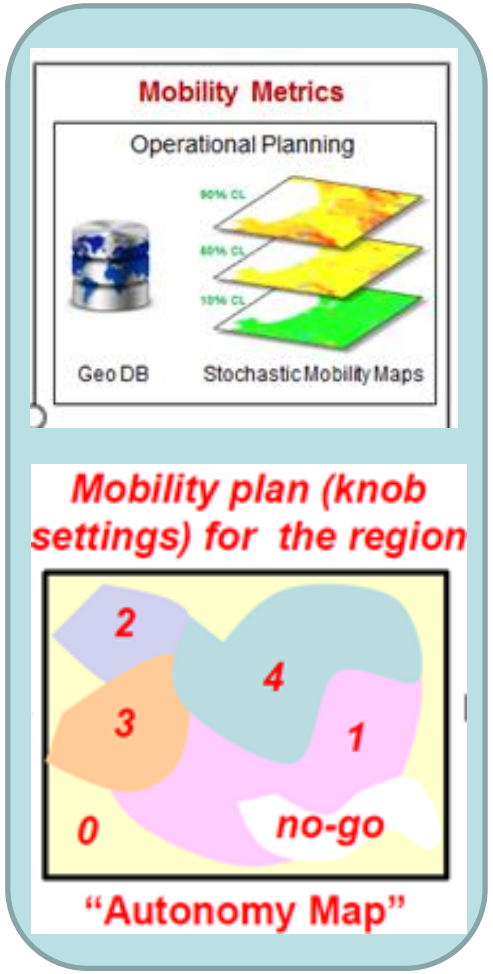
Identify practical steps required to embed stochastic characteristics of vehicle and terrain data to extend and refine the current deterministic mobility metrics



Research Thrust Areas

TA 4: Intelligent Vehicle Mobility

Identify unique mobility metrics and M&S methods necessary for mobility assessments of intelligent vehicles over a sliding scale of data and control systems resolution.



Research Thrust Areas

TA 6: Verification and Validation

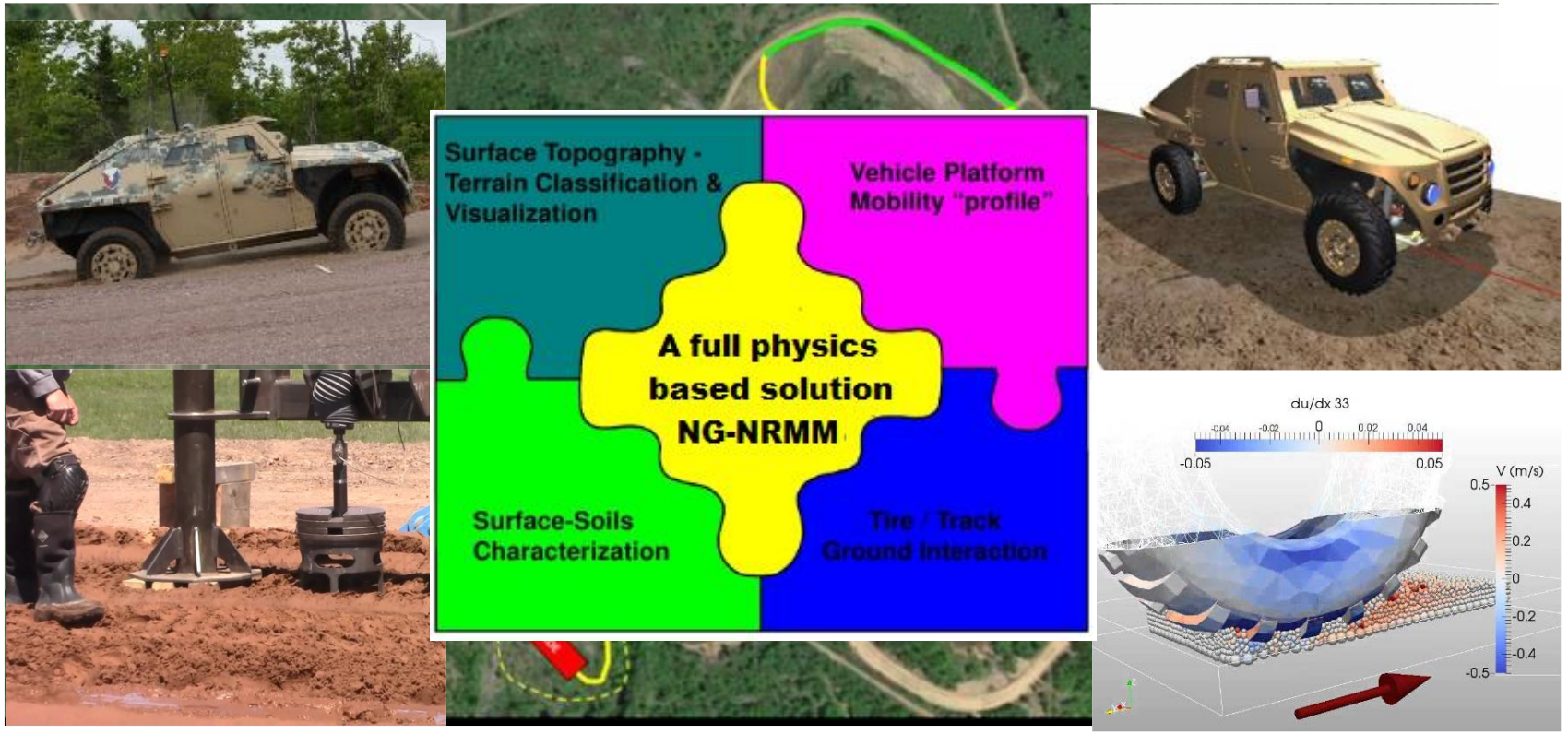
Implement vehicle-terrain interaction benchmarks for verification of candidate NG-NRMM M&S software solutions and

lay the groundwork for long term validation data through cooperative development with test organizations standards committees.

NATO AVT-248 Research Task Group Structure

Research Thrust Areas	Lead	Organization
1. GIS Terrain and Mobility Map	Funk / Wojtysiak	ESRI / AMSAA
2. Simple Terramechanics	McCullough	BAE Systems
3. Complex Terramechanics	Wasfy	ASA Corp.
4. Intelligent Vehicle Mobility	Jain	NASA JPL
5. Uncertainty treatment	Choi / Gaul	U Iowa/RAMDO Solutions
6. Verification & Validation	Balling	Aarhus Univ, Denmark
7. Data Gaps & Operational Readiness	Bradbury	DSTL, MoD, UK
Supplementary Activities		
Collaborative Demonstration of Technology	Hönlinger / Mayda / Jayakumar	NRC, Canada / TARDEC
NATO Standardization NG-NRMM	Hönlinger / McCullough / Jayakumar	KMW, Germany / BAE

AVT-308 Cooperative Demonstration of Technology for Next-Generation NATO Reference Mobility Model



AVT-308 CDT

Mission and Scope

The mission of the AVT-308 Cooperative Demonstration of Technology is to showcase the enhanced mobility prediction capabilities of the NG-NRMM (AVT-248).

Using real world demonstration and advanced physics based modelling, accurate simulation solutions to the complex mobility challenges of today's land based forces are highlighted.

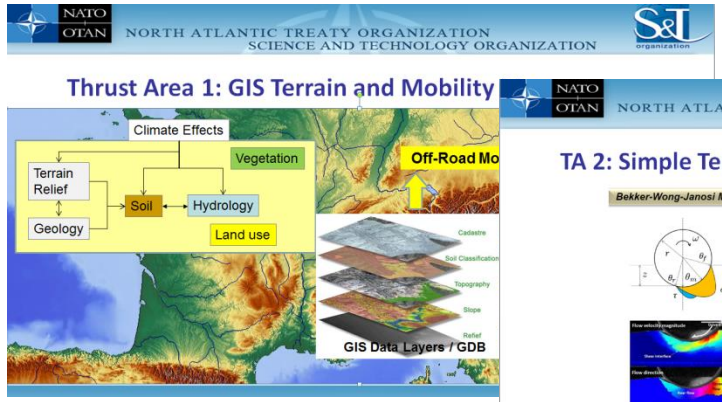
The scope of the AVT-308 CDT includes:

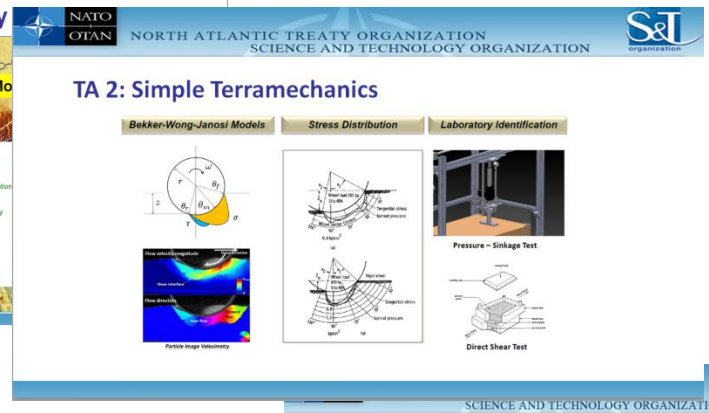
- On-Site training, including technical sessions on simple and complex terramechanics, and software vendor presentations.
- Demonstrations of vehicle mobility performance on representative terrain using both relevant high mobility hardware and virtual simulations.

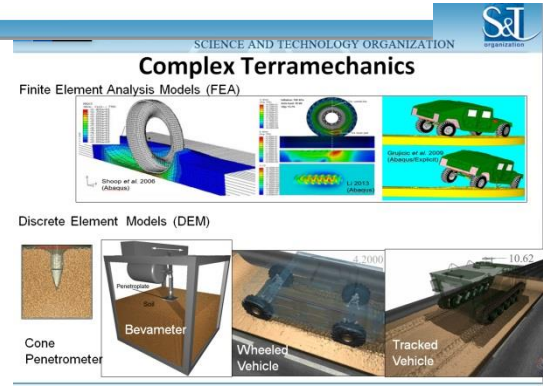
Scientific Topics to be covered

- **The capabilities of NG-NRMM are shown by the following seven scientific thrust areas:**

  1. GIS-Terrain and Mobility Mapping
  2. Simple Terramechanics
  3. Complex Terramechanics
  4. Intelligent Vehicle Mobility
  5. Uncertainty Treatment
  6. Verification and Validation
  7. Data Gaps and Operational Readiness

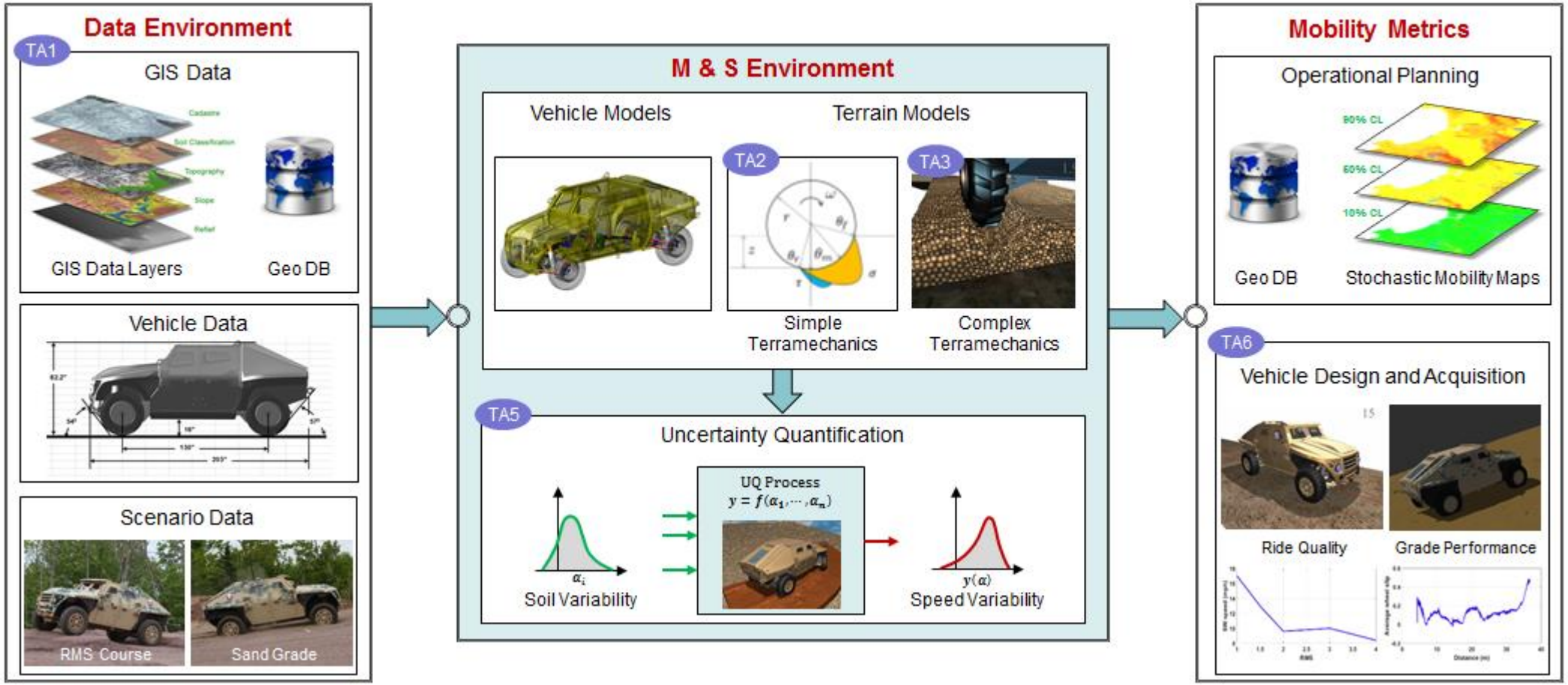




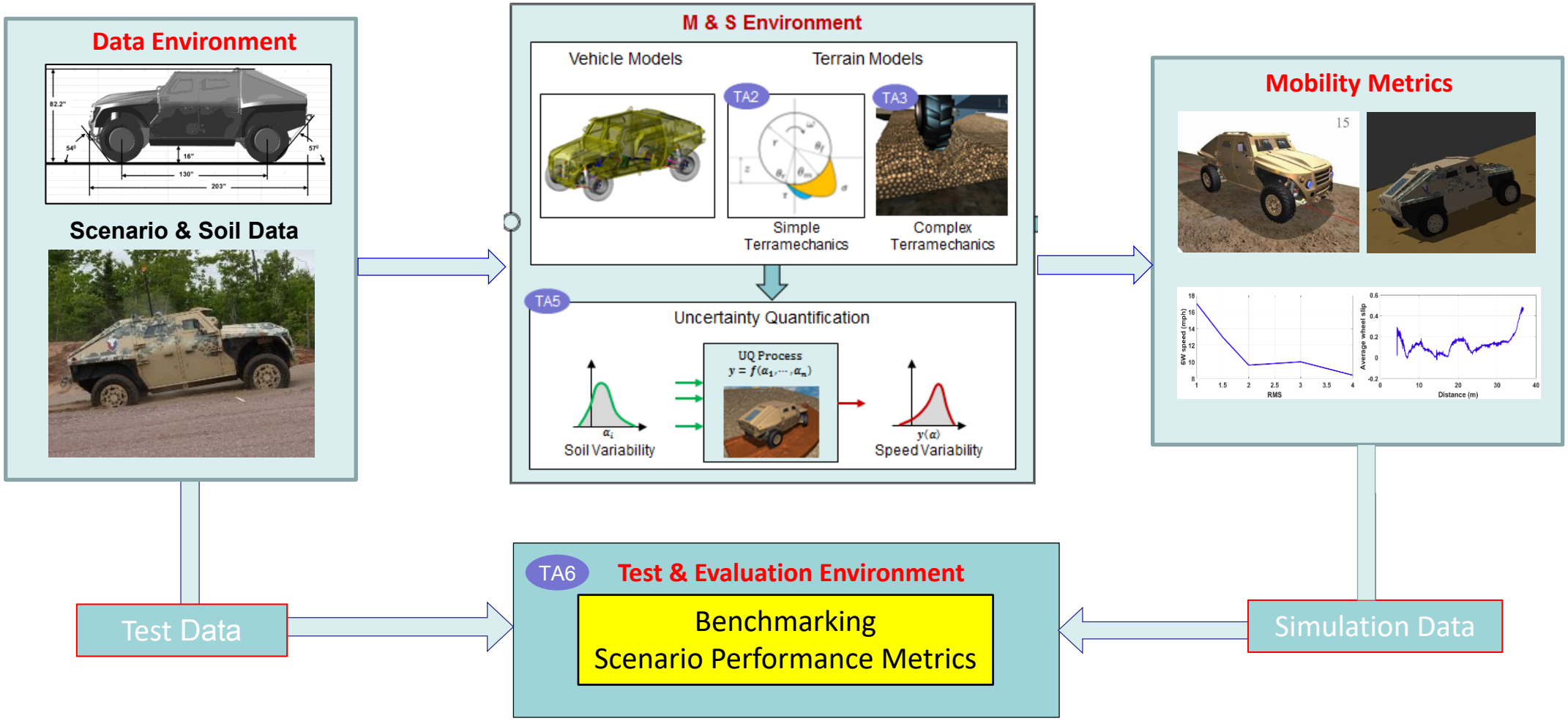


- **The CDT pulls all of these thrust areas together,** coupled with the latest in multi-body physics simulations, to deliver relevant mobility solutions that are then compared and validated against actual vehicle performance.

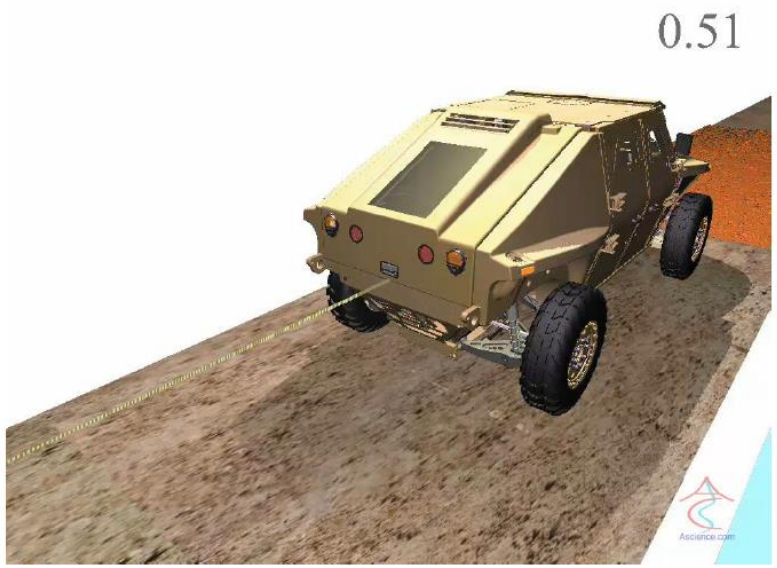
NG-NRMM Architecture



CDT Architecture



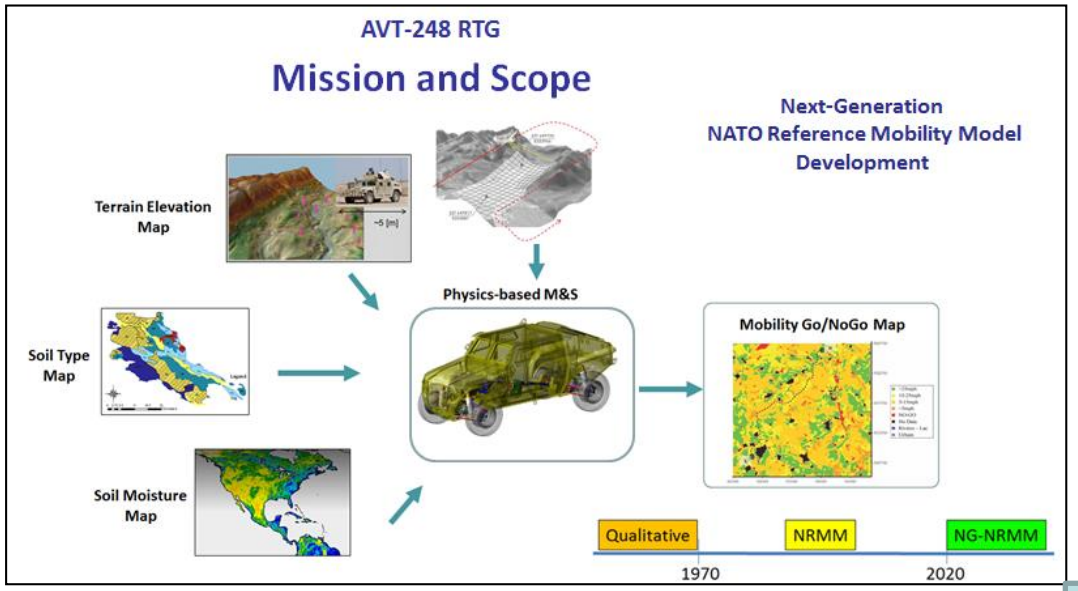
Demonstration NG-NRMM in real Test Environment

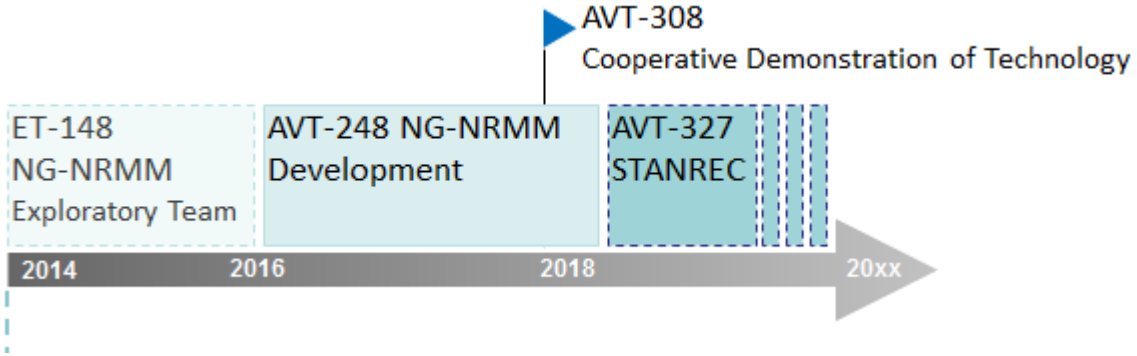


Test Name	Terrain
1 Straight Line Acceleration and Braking (TOP 2-2-602)	Pavement
2 Wall to Wall Turn Circle Radius	Pavement
3 Steady State Cornering (30 m radius) (SAE J2181)	Pavement
4 NATO Double Lane Change (AVTP 03-160 W)	Pavement, Gravel
5 Max. Side Slope with Sinusoidal Steer & Obstacle Avoidance	Hard-Packed Crushed Mine Rock
6 Maximum Longitudinal Grade	Pavement, Coarse Grain Sand
7 Vertical Step: 12", 18", 24"	Concrete
8 V-Ditch	Concrete
9 Half-Round Obstacle: 4", 8", 10", 12"	Pavement
10 Symmetric Random Roads: 1", 1.5", 2", 3", 4" RMS	Hard-Packed Crushed Mine Rock
11 Asymmetric Random Roads: 1", 1.5", 2" RMS	Hard-Packed Crushed Mine Rock
12 Soft-Soil Mobility: Drawbar Pull	Course Grain Sand Fine Grain Organic/ Silty Sand: Dry & Wet
13 Mobility Traverse	Composite of Natural Terrain & Engineered Courses

AVT-248 Task Group and CDT

From basic research in **2014** to showcasing of technology in **2018**





- ✓ Impact on **early stage vehicle designs** as well as **operational decision making**
- ✓ Increased **operational interoperability** and **safety** by predictive mission planning

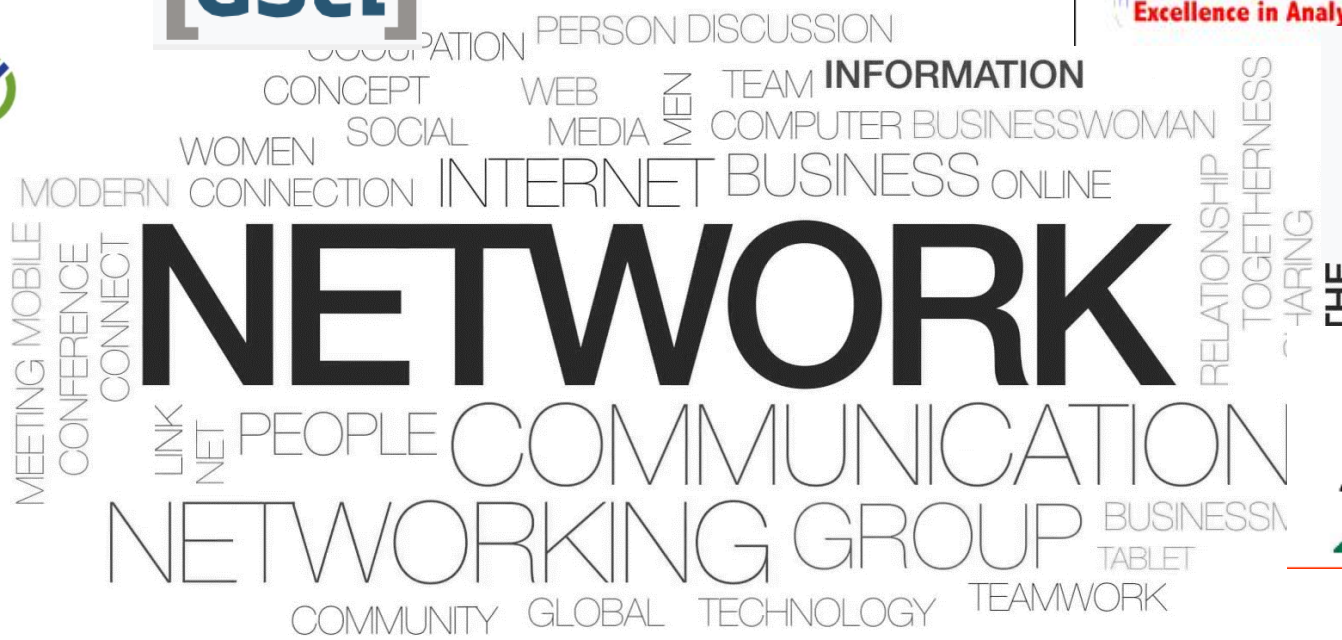
CDT 2018 NG-NRMM

esri

RAMDO SOLUTIONS

[dstl]

AMSAA
Excellence in Analysis



SOLIDUM PETIT IN PROFUNDIS · UNIVERSITAS ARHUSIENSIS ·

ASA Corp.

Canada NRC·CNRC

TARDEC

BAE SYSTEMS

NASA

KMW
A COMPANY OF
KNDS

and others ....

Tuesday Agenda

0730	Registration and Transport to *Tent Site*	*KRC Main Building*
0830	Safety / Logistics Information	Scott Bradley
0845	Welcome	Jay Meldrum
0900	NATO Task Group and CDT Objective	Michael Hoenlinger
0945 **	Break	
1045 **	NG-NRMM Virtual and Physical Demonstration Plan	Ole Balling / Scott Bradley
1145 **	Thrust 1: Geospatial Terrain and Mobility Mapping	Matt Funk / Ryan Williams / Russ Alger
1230 **	Lunch	
1330 **	NG-NRMM Physical Demo / Walk-Around or Visit Booths	Scott Bradley, Lead
1530 **	Break	
1600 **	Thrust 2: Simple Terramechanics Model & Data	Michael McCullough
1645 **	Thrust 3: Complex Terramechanics Model & Data	Tamer Wasfy
1730	Summary and Tomorrow's Preview	Richard Gerth
1800	Transport to *KRC Main Building*	

Wednesday Agenda

0730	Registration and Transport to Tent Site	KRC Main Building
0830	Safety Brief	Jay Meldrum
0845	NATO Welcome	Christoph Mueller
0900	US DOD Welcome	Philip Perconti
0915	TARDEC Welcome	Paul Rogers
0930 **	History, Motivation, and Goals for NG-NRMM	David Gorsich
1000 **	Break	
1030 **	NG-NRMM Physical Demo / Walk-Around or Visit Booths	Scott Bradley, Lead
1230 **	Lunch	
1330 **	NG-NRMM Virtual Demonstration	Radu Serban, Lead
1500 **	Break	
1545	CDT Results and Vision for the Future	William Mayda
1630	Transport to KRC Main Building	
1800	Cocktail Hour	Memorial Union Ballroom
1900	Dinner Reception	
	After-Dinner Speaker	Richard Koubek, President, MTU

Thursday Agenda

0800	Registration and Transport to Tent Site	KRC Main Building
0900	Review of First Two Days and Plans for Today	Paramsothy Jayakumar
0930	Thrust 5: Uncertainty & Stochastic Mobility Maps	Nick Gaul / KK Choi
1015 **	Break	
1045 **	Thrust 6: NG-NRMM Verification and Validation	Ole Balling / Frederik Homaa
1145 **	NG-NRMM Standard	Michael McCullough
1215 **	Lunch	
1315	Software Developer Presentations	

MSC	Military Vehicle Simulation with Adams: Mobility and Beyond
CSIR	South African Mobility Prediction Software MOBSIM
CM Labs	Real-Time Vehicle Simulation using Vortex Studio
VSDC	Wheeled Vehicle Mobility Prediction using NWVPM
AU	ROAMS, a Fast Running Mobility Simulator Utilizing GeoTIFF Terrain Maps
ASA	DIS – A Complex Terramechanics Software Tool for Predicting Vehicle Mobility

1515	Break	
1545	Thrust 7: Gaps and Path Forward	Michael Bradbury / P. Jayakumar
1630	Open Discussion	All
1700	Conclusion of CDT; Transport to KRC Main Building	

Cooperative Demonstration of Technology

Information and Discussion

The exchange of experience with military users, industry, NATO and S&T experts enables a better understanding of the application of NG-NRMM, the potential for further development and thereby influences the support for further development and application.