GEOSPATIAL ANALYSIS FOR MACHINE LEARNING IN TACTICAL DECISION SUPPORT

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GEOSPATIAL ANALYSIS

Tactical military land operations heavily depend on the terrain, therefore terrain (geospatial) analysis is key to decision making.

The Intelligence Preparation of the Environment (IPE) provides terrain information.

Aim: of Geo-analysis is twofold:

1. Direct use of geo-products by planners
2. Use in Machine Learning tools

GEO-PRODUCTS AND TIERS

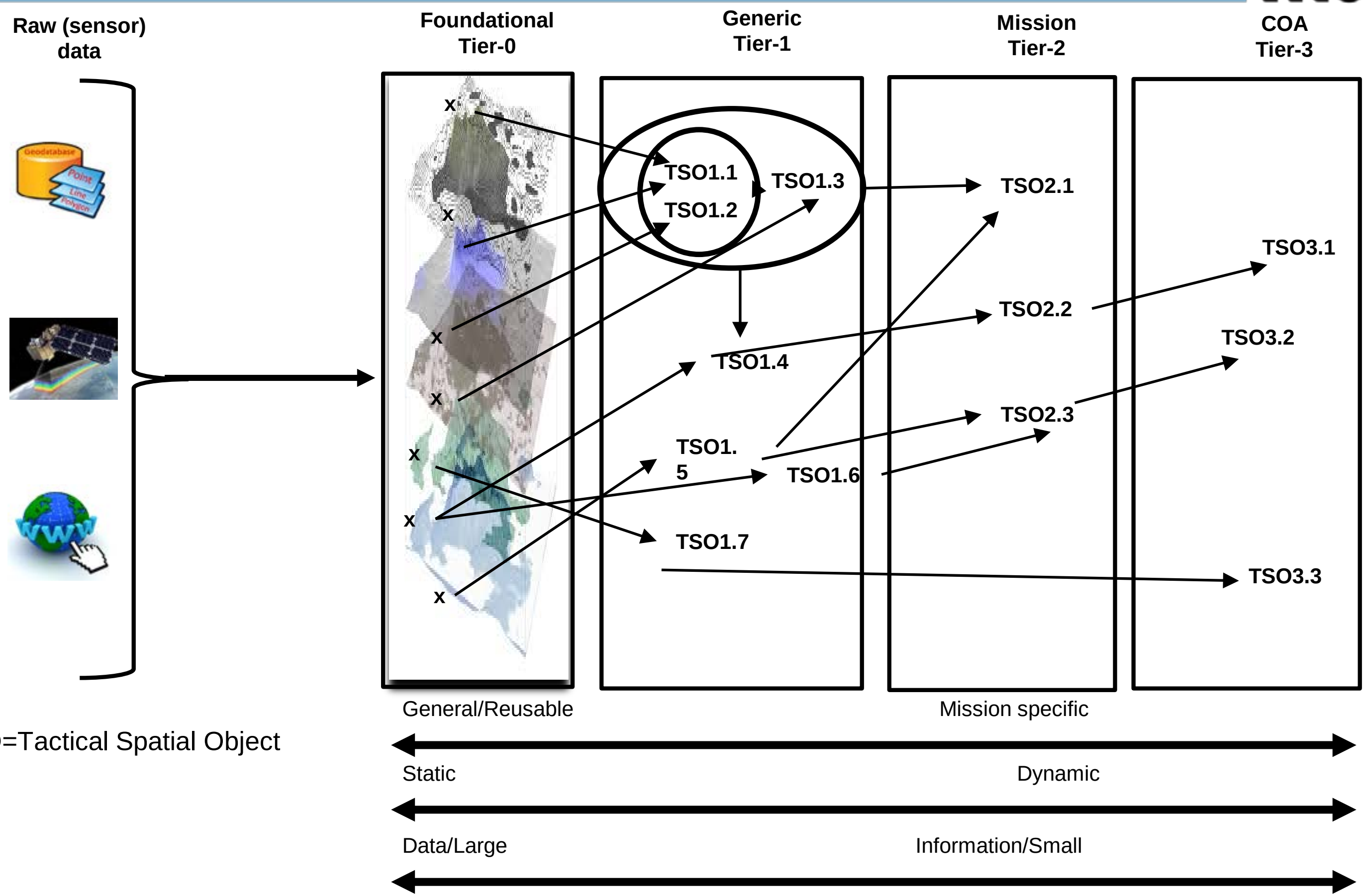
- **Tier-0 products** (foundational) integrated description of terrain characteristics:
  Examples: DTED, hydrology, vegetation, soil, tree-density, ...

- **Tier-1 products** based only upon the Tier-0, can be pre-computed:
  Examples: Cross Country Mobility, Manoeuvre Network, Cover and Concealment, …

- **Tier-2 products** derived from Tier-0 and Tier-1 products. Is mission specific (depend on the tasks that a unit needs to perform in that mission) and cannot be precomputed:
  Examples: Avenues of Approach, Attack by Fire positions, Routes (SWAP), Vantage points (SWAP).

- **Tier-3 products** are specific objects that have been selected to support a specific COA (chosen from the Tier-2 candidate products and possibly further refined based on weather (METTC):
  Examples: Phase lines, Routes, Boundaries.

GEO-PRODUCTS TIERS



TSO=Tactical Spatial Object

DIRECT USE OF GEO-PRODUCTS IN PLANNING

- Planners use geospatial products (TSOs) such as:
  - Routes
  - Obstacles
  - Choke points
  - Water crossings
  - ….etc

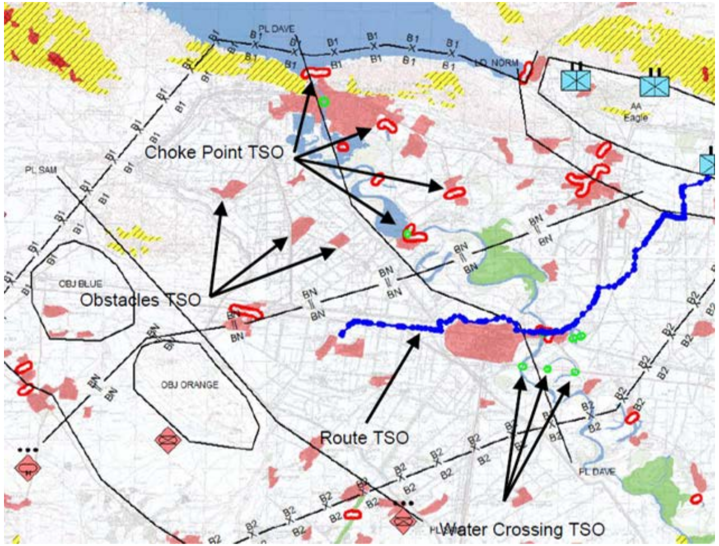
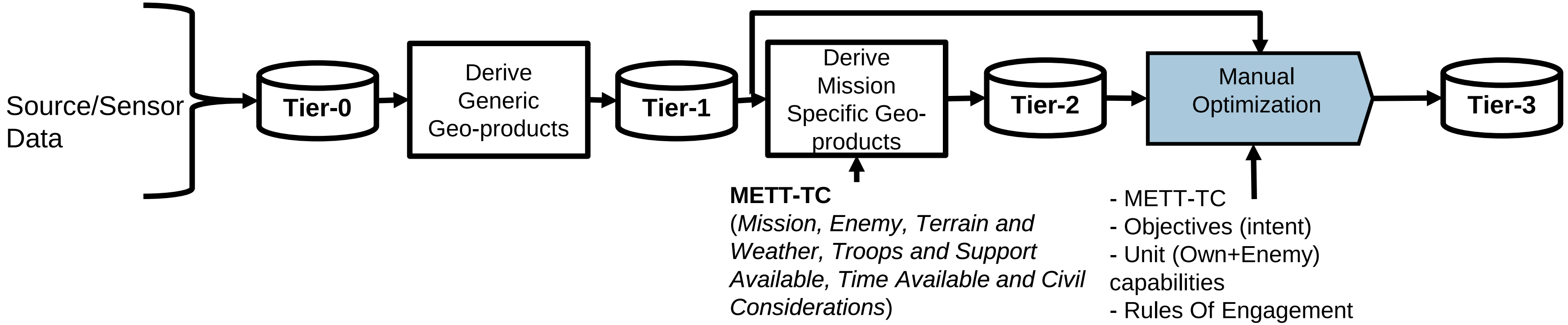


Figure from "Results of an Experimental Exploration of Advanced Automated Geospatial Tools: Agility in Complex Planning" (2009), W.A. Powell

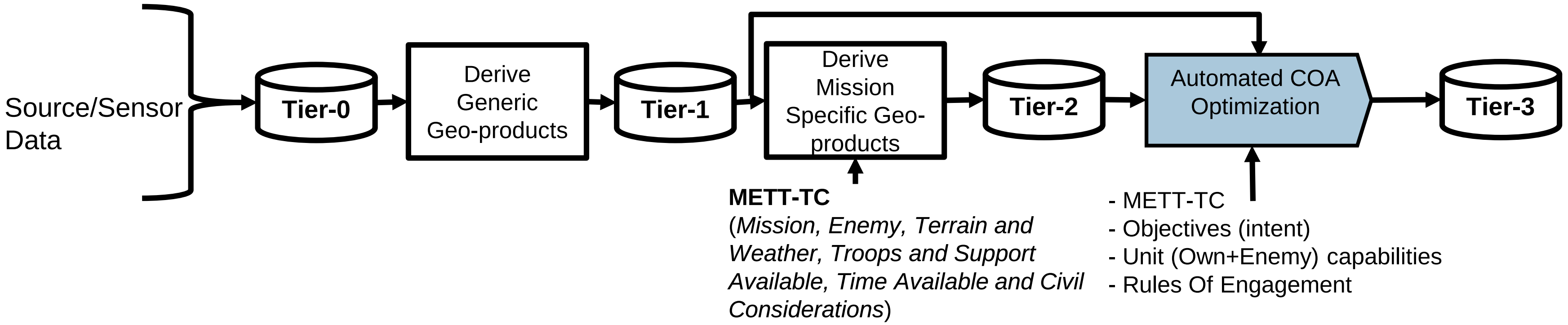
To build an "optimal" plan by selecting the best elements from the above options. This is found by evaluating the draft plan based on experience first and later in a wargaming session.

MANUAL COA GENERATION

Manual optimization steps based on geospatial products:



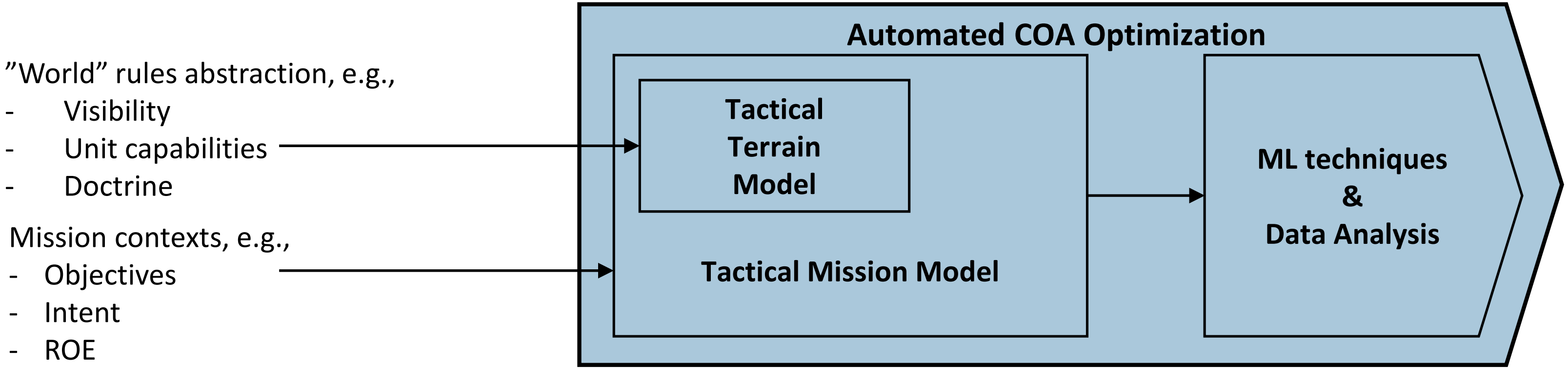
AUTOMATED COA OPTIMIZATION USING ML



Components required for automated COA optimization:

- **Tactical Terrain model**: Abstract model of the terrain with sufficient fidelity to perform optimization with ML techniques.
- **Tactical Mission model**: Abstract model of the mission context.
- **ML optimization method** such as Genetic Algorithms or Reinforcement Learning.

AUTOMATED OPTIMIZATION COMPONENTS REQUIRED



- **Tactical Terrain model**: Abstraction is required because operational use requires (1) ease of modelling and configuration, (2) speed of modelling, (3) execution speed required for ML (order of magnitude: 10^4 – 10^6). Therefore “dirt level” simulations are not feasible.
  Tier-1 and tier-2 geo-products can facilitate this!
- **Tactical Mission model**: Abstract behaviour modelling of units in mission (such as “game rules”, capabilities, objectives) including terrain.
- **ML optimization method** such as Genetic Algorithms or Reinforcement Learning.

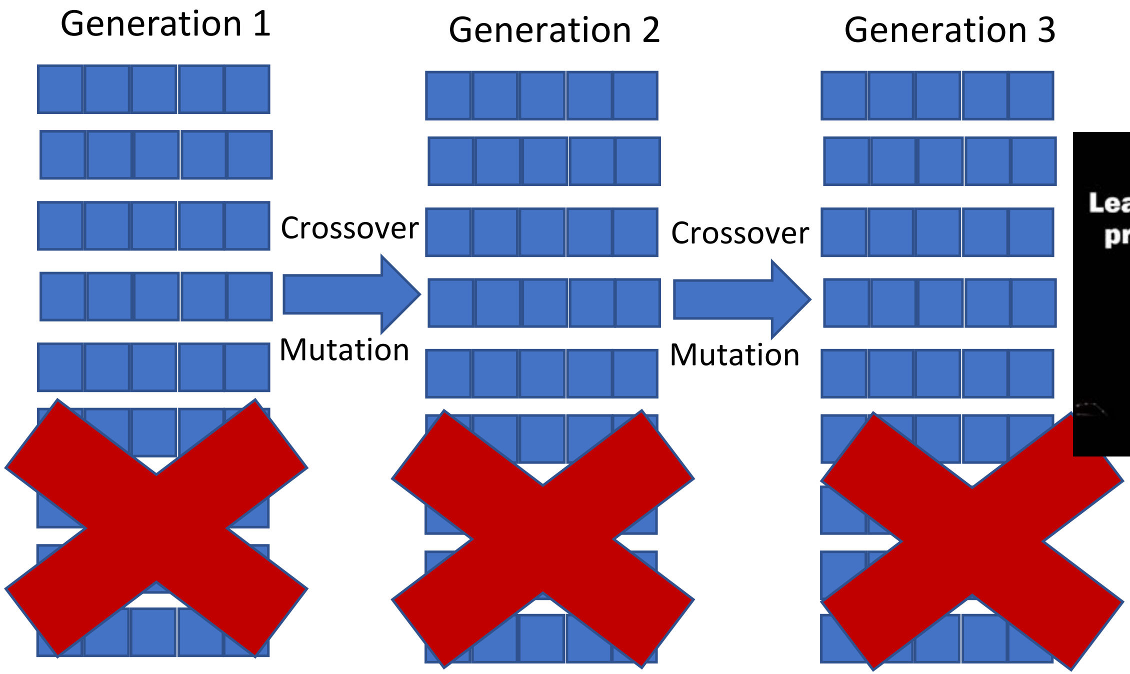
Scenario / Objective

- Find effect (block, fix, disrupt, turn) locations that optimize (maximize) enemy delay.
  - Given limited resources (such as mines, concertina wire, fire support, ..)
  - Given red composition of forces, red objective and many possible enemy COAs
  - Given limited time

Required models

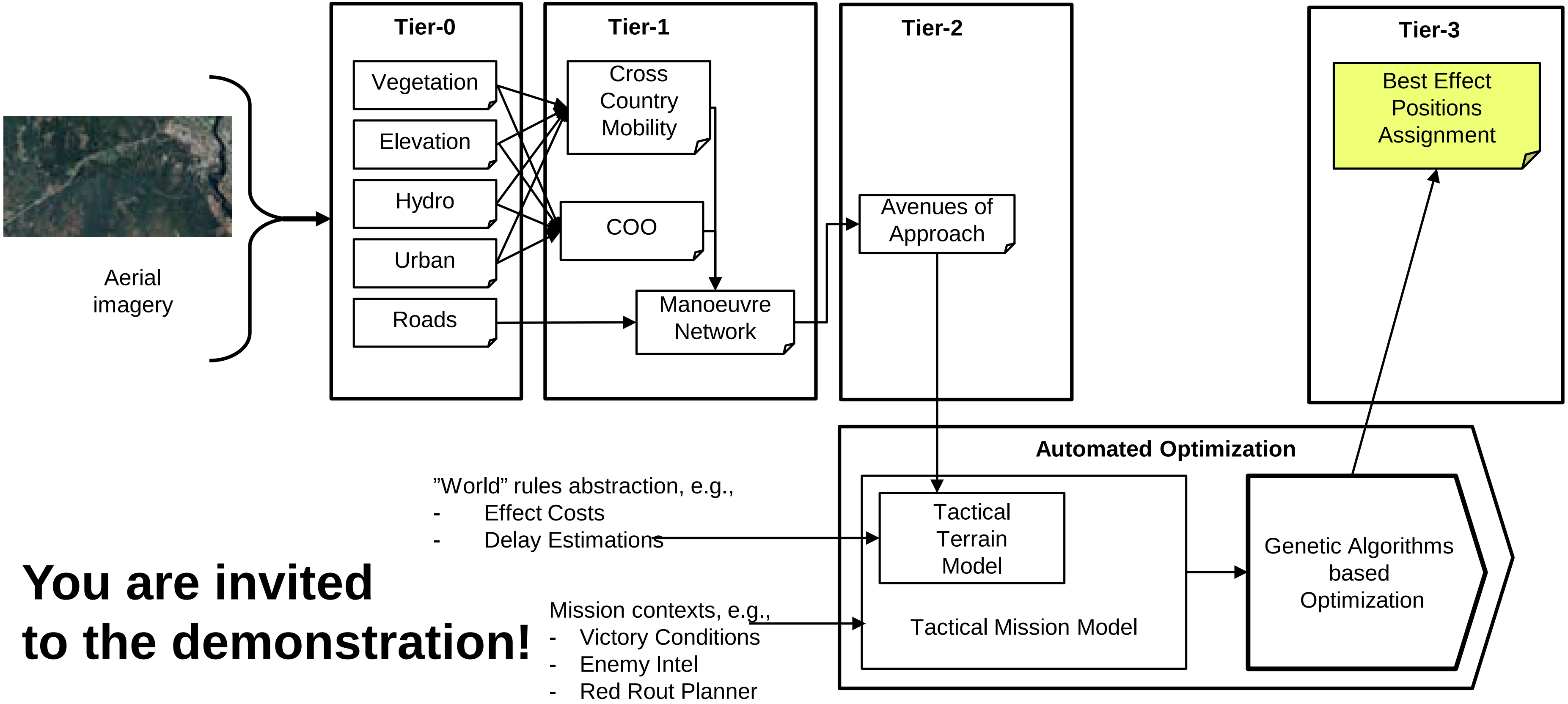
- Tactical Terrain Model (TTM)
  - “Virtual” road network based on Avenues of approach (AA).
    COO,CCM,MN (Tier-1,2) used to find AA as abstract terrain representation
  - Possible delay (block,fix,disrupt) or movement limitation (turn) per node
  - Cost (resoures) to achieve effect per node in the “virtual” road network (tier-1)
- Tactical Mission Model (TMM)
  - Defines (enemy) mission succes (when second unit reaches objective).
  - Defines enemy manoeuvre possibilities (related to enemy knowledge such as reconnaissance capabilities)
  - Enemy route planner

TACTICAL TERRAIN MODEL


Generation 1
Generation 2
Generation 3
Crossover
Mutation
Crossover
Mutation


Learning in progress

EXAMPLE1: PROCESS STEPS



You are invited to the demonstration!

EXAMPLE2: ZEBRA SWORD EXPERIMENT

Scenario / Objective

- Prevent (platoon sized) enemy from manoeuvring to village by placing (remote controlled / robotic) units into ambush positions

- Find best ambush locations taking into account enemy COAs

EXAMPLE2: REQUIRED MODELS

Tactical Terrain Model (TTM)

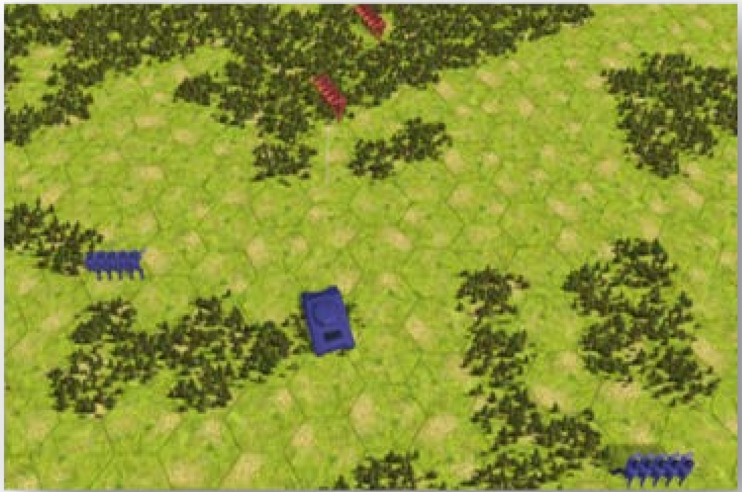
- “Virtual” (Hexagonal, 100 m diameter) world model based on Cross Country Mobility and Manoeuvre Network with terrain type characteristics, such as:
  - Plains, Forest, Water
  - LOS, Cover and Concealment possibilities (eg. forest edges conceals units)
  - Traverse costs

Tier-0 Tier-1 Tier-1

EXAMPLE2: REQUIRED MODELS

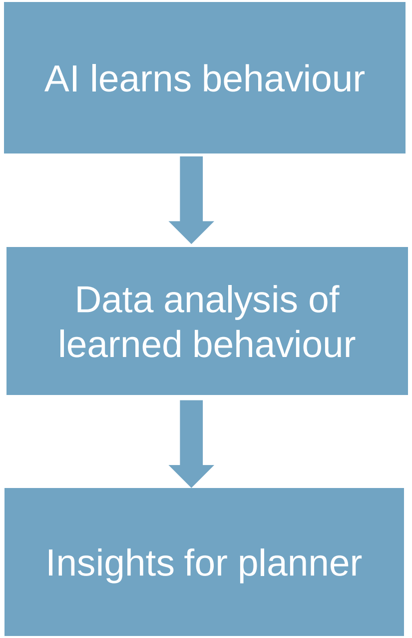
Tactical Mission Model (TMM)

- Unit properties
  - Health, vulnerability for enemy fire, travelling speed (terrain dependent), weapon range, sensor range.
- Game/simulation properties
  - Turn based
- Score functions: **Blue**: damage to opponent, **Red**: arriving at village



OPTIMIZATION WITH REINFORCEMENT LEARNING

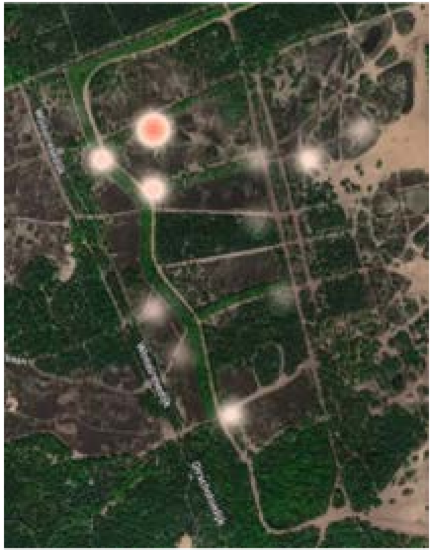
- **Reinforcement learning** finds best strategies (ie best actions, given a state) to achieve optimal score function
- **Co-learning**
  - Blue and Red learn against each other (turn based)
    - Weak spots are found and used
    - Best assault positions
    - Kill zones
- **Analysis** of learned behaviour
  - 500.000 best engagements are saved and analysed
  - Large variations in blue and red COAs
  - Tier-2 (type) results:
    - High probability of contact locations
    - Likely ECOAs
    - Advantageous positions

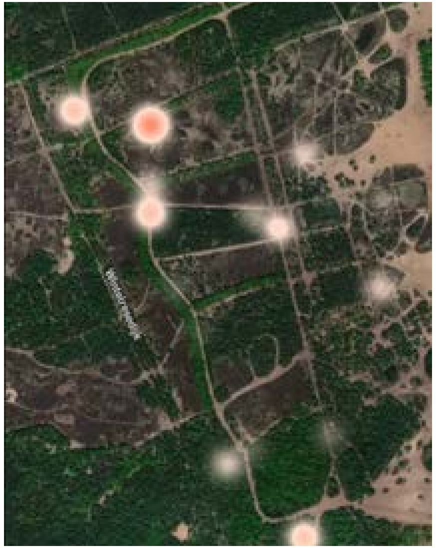


OPTIMIZATION RESULTS

Tier-2 results:
- Likely enemy contact locations heatmap
- Preferred routes towards ambusg locations
- Likely ECOAs

Tier-3 results:
- Optimal Ambush locations





EXAMPLE2: PROCESS STEPS

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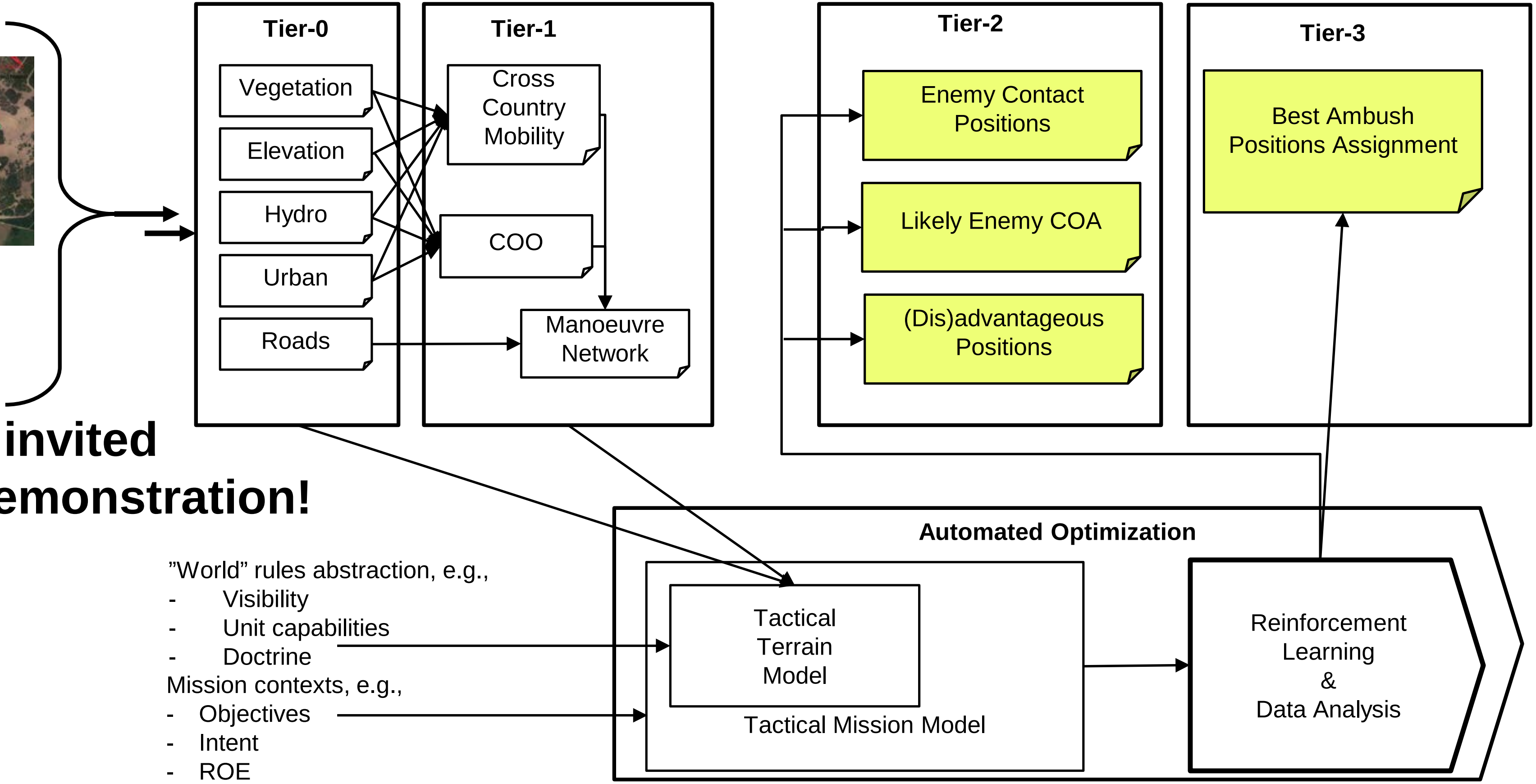

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CONCLUSIONS

Summary

- Machine Learning provides opportunities for tactical decision making
- Abstract models are required for practical use and geospatial type products as produced by the Intel cell can help building these abstract models
- Two example use-cases have been shown, **VISIT OUR DEMO!**

Future work envisioned

- Study into:
  - How to define the best score function (to prevent loopholes) based on the commander’s intent
  - The use of current high fidelity simulators to automatically extract rules for abstract Tactical Mission model game rules, eg by using Neural networks.
  - The effect of uncertainties in the used models on optimization results
- Automization of process steps for building demonstrator prototype tools in the COA genaration process of land operations