Multi-Dimensional Data Farming:

Extending Data Farming for Multi-scale Decision Support by

Integrating Novel AI Technologies

BLUF

Multi-Dimensional Data Farming (MDDF) automates simulation decision-making by the integration of innovative Artificial Intelligence (AI) Techniques and allows improved and fast decisions in highly complex multi-scale, multi-domain, and multi-level hybrid war campaigns.

Data Farming

- Codified by MSG-088 *Data Farming in Support of NATO*

- The Realms of Data Farming (DF) collaboratively connected by the *DF Loop-of-Loops*

- Characterization or Optimization

- NATO: Military Decision-Making

- Improved Situational Awareness

- Develop, analyze & refine COA

- Informed & robust decisions

- Proven and applied decision-support tool

- Limitations for large multi-scale campaigns with many factions and operations interacting at various levels
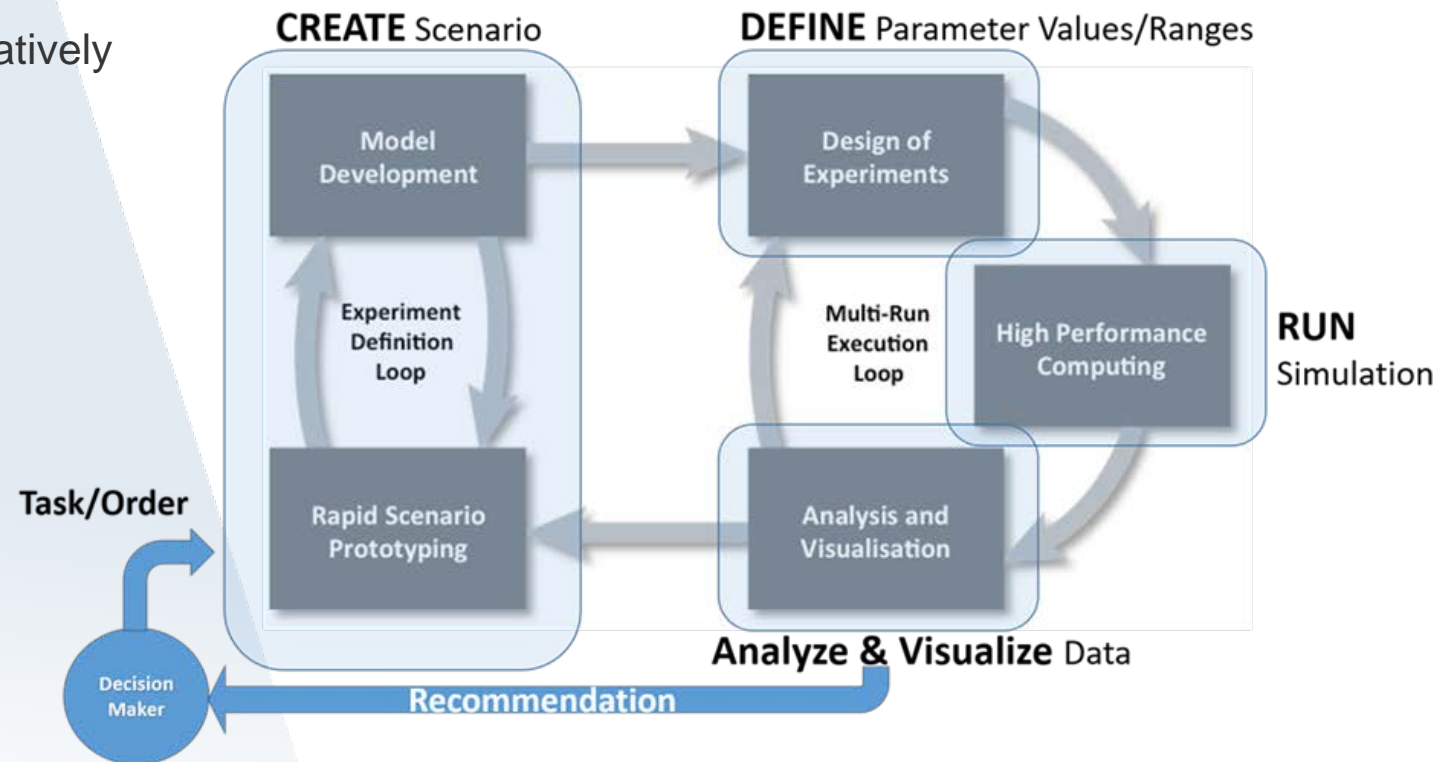
Unconventional Campaign

- Blue & Green armed forces vs. Red fighting in physical & cyber domains (s. RSY MSG-197 in Bath, GBR, 2022)

- Red launches a hybrid operation on Green, triggering a Border Operation, in support of two strategic objectives:
  - force Green to divert resources away from the Campaign
  - lower Green public opinion in favor of the Campaign

- Strategic level: multi-faction multi-domain combat model (Attrition, Cyber, Epidemic – ACE model)

- Tactical level: multi-agent based simulations of the Border Operation (Map Aware Non-uniform Automata, MANA)
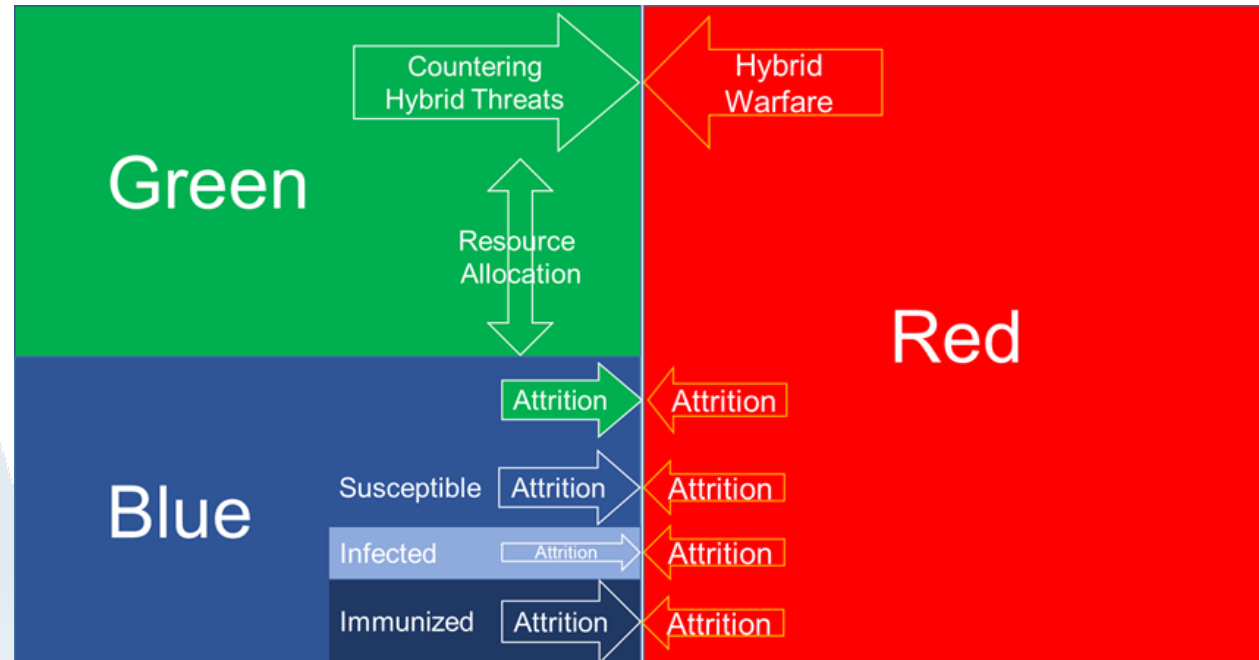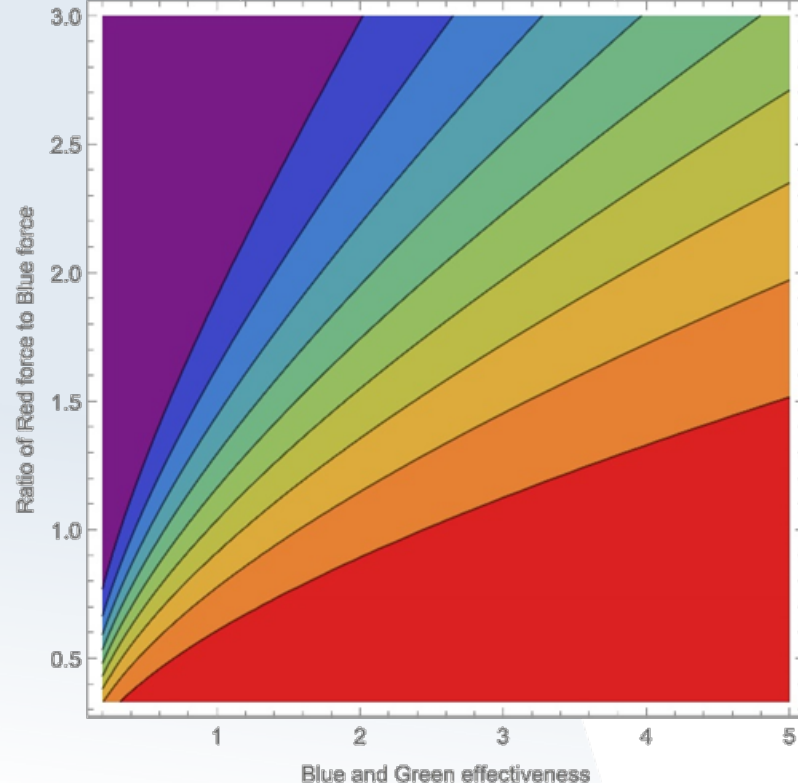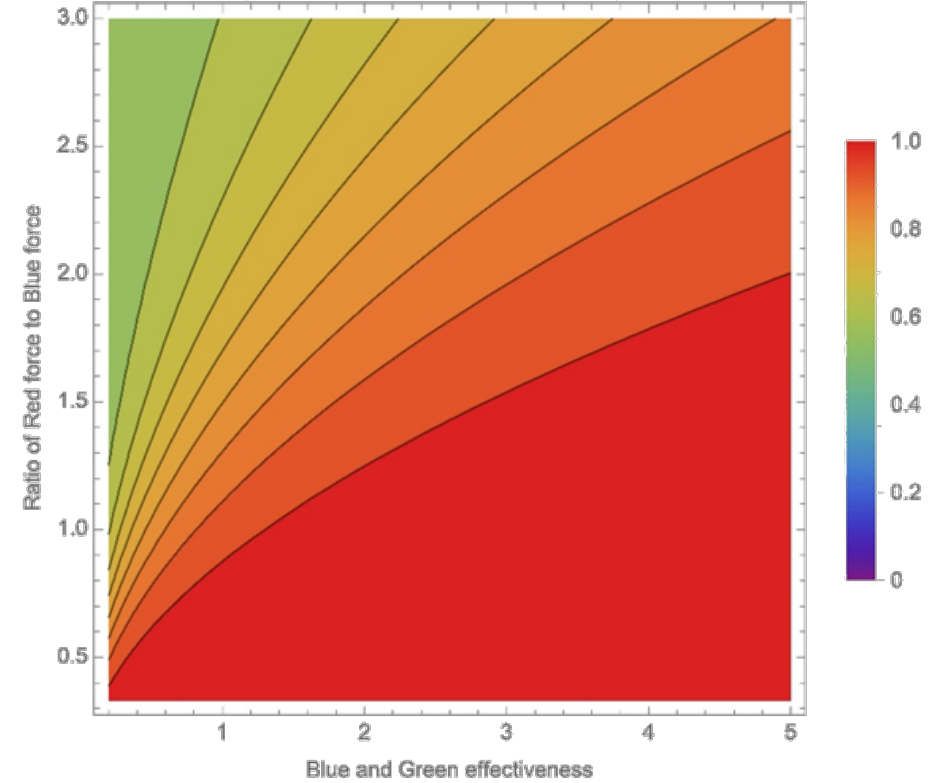
Campaign Probability of Success
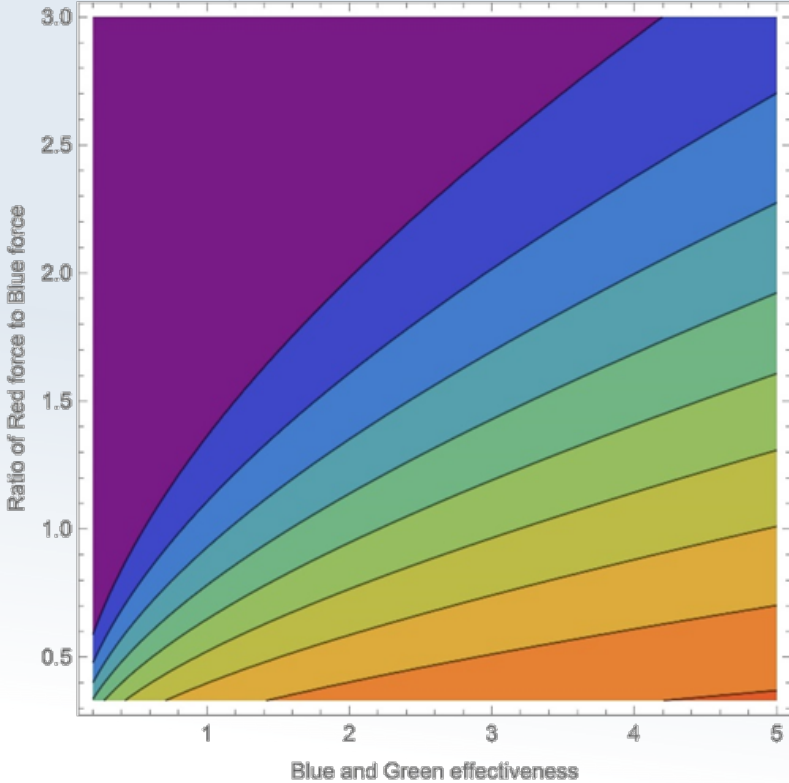
* alpha of supply for BLUE by GREEN

Border Operation
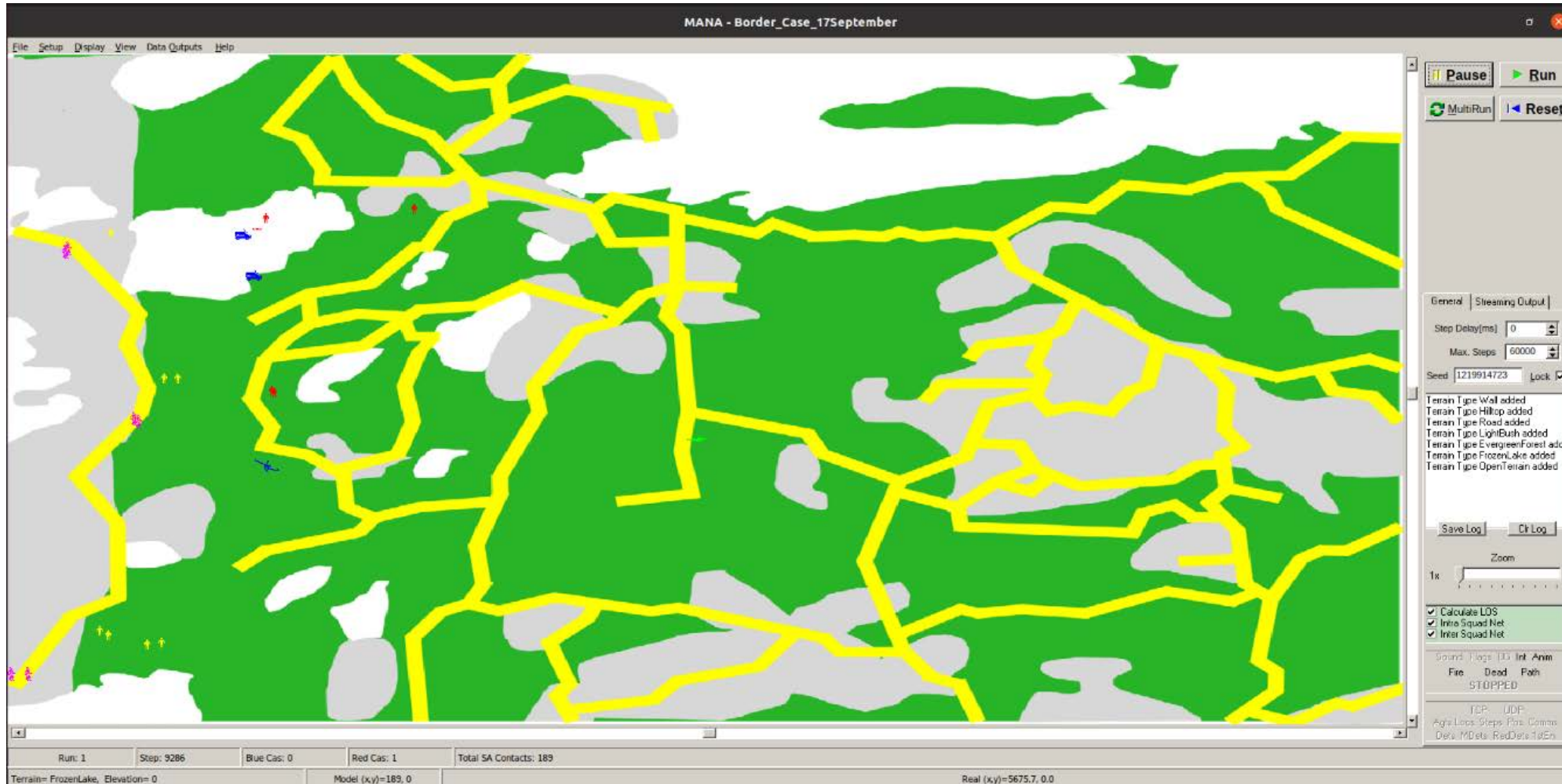
Embedding the Tactical Operation

t^* $t^* + dt$

Unconventional Campaign (UC)

$G_{BO}(t^*)$

$G_{BO}(t^* + dt)$

$\alpha = \alpha(t^* + dt, p_N)$

Border Operation (BO)

When we fail, why do we fail?
What is required to succeed?

t^* is the begin time of the Border Operation
dt is the duration of the Border Operation
$B(t), R(t), G(t)$ are the Blue, Red, Green forces
$B_1(t), B_2(t), B_3(t)$ are susceptible, infected, immunized units with respect to cyber attacks
$G_{BO}(t)$ is the Green resource allocated for the Border operation
α is the rate at which allies supply weapons to Green Force in the Campaign
p_N is the percentage of non-intercepted migrants during the Border Operation

Accelerating Automation with AI

Explainable AI

Allows a broader range of meta-models to be considered without sacrificing interpretability

Automated Machine Learning

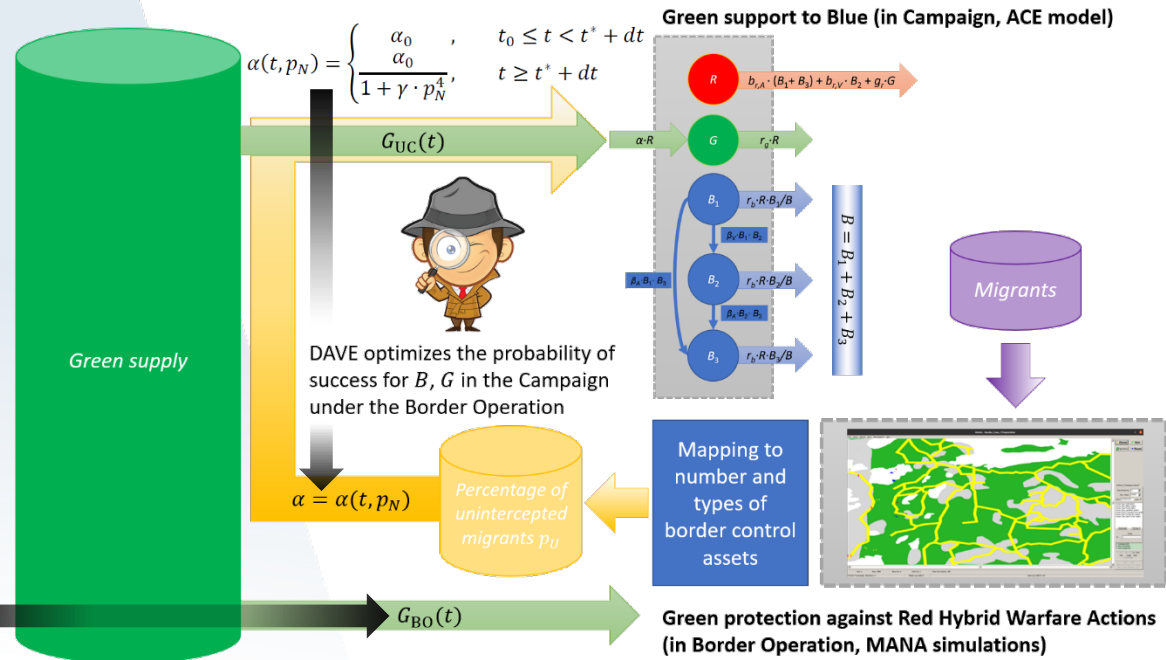Increases the level of automation in building meta-models

Bayesian Optimization with Gaussian Processes

Framework to find optima of black-box functions

# DAVE (Design, Analyze & Visualize Experiments)

- Design of Experiments: Intelligent sequential search through COA space using meta-model predictions

- Analyze: Optimal balance of forces between Unconventional Campaign (UC) and Border Operation (BO)?

- Visualize: Temporal playback of UC, spatio-temporal playback of BO to gain insight

Factor	Cost_Unit	Setting	Cost_Total
UAV Quantity	10	2	30
Sensor Range (km)	1	5	
Speed (km/hr)	0.05	30	
Zone 1 Patrol Quantity	50	1	85.1
Visual Range (km)	1	1	
Speed (km/hr)	0.5	80	
Interception Processing Time (sec)	0.001	3000	
Detected Location Duration (sec)	0.004	3000	
Zone 2 Patrol Quantity	50	2	121.2
Mini-UAV Sensor Range (km)	1	4	
Speed (km/hr)	0.5	40	
Interception Processing Time (sec)	0.001	2000	
Detected Location Duration (sec)	0.004	1500	
Southern Border Fence	200	1	200
			436.3

DAVE optimizes the probability of success for B, G in the Campaign under the Border Operation

$$\alpha(t, p_N) = \begin{cases} \alpha_0 & , \quad t_0 \le t < t^* + dt \\ \dfrac{\alpha_0}{1 + \gamma \cdot p_N^4} & , \quad t \ge t^* + dt \end{cases}$$

Green support to Blue (in Campaign, ACE model)

$G_{UC}(t)$

$B = B_1 + B_2 + B_3$

Migrants

Mapping to number and types of border control assets

Green supply

$\alpha = \alpha(t, p_N)$

Percentage of unintercepted migrants p_U

$G_{BO}(t)$

Green protection against Red Hybrid Warfare Actions (in Border Operation, MANA simulations)

DAVE Architecture & Implementation

- Based on and using Data Farming Services (DFS) from MSG-155

- Dashboard + automized AI modules

- Implemented standalone for PoC/Demonstrator, to be integrated later into service-oriented architecture of DFS

- PoC status in 2023, extended to Demonstrator for CWIX 2024
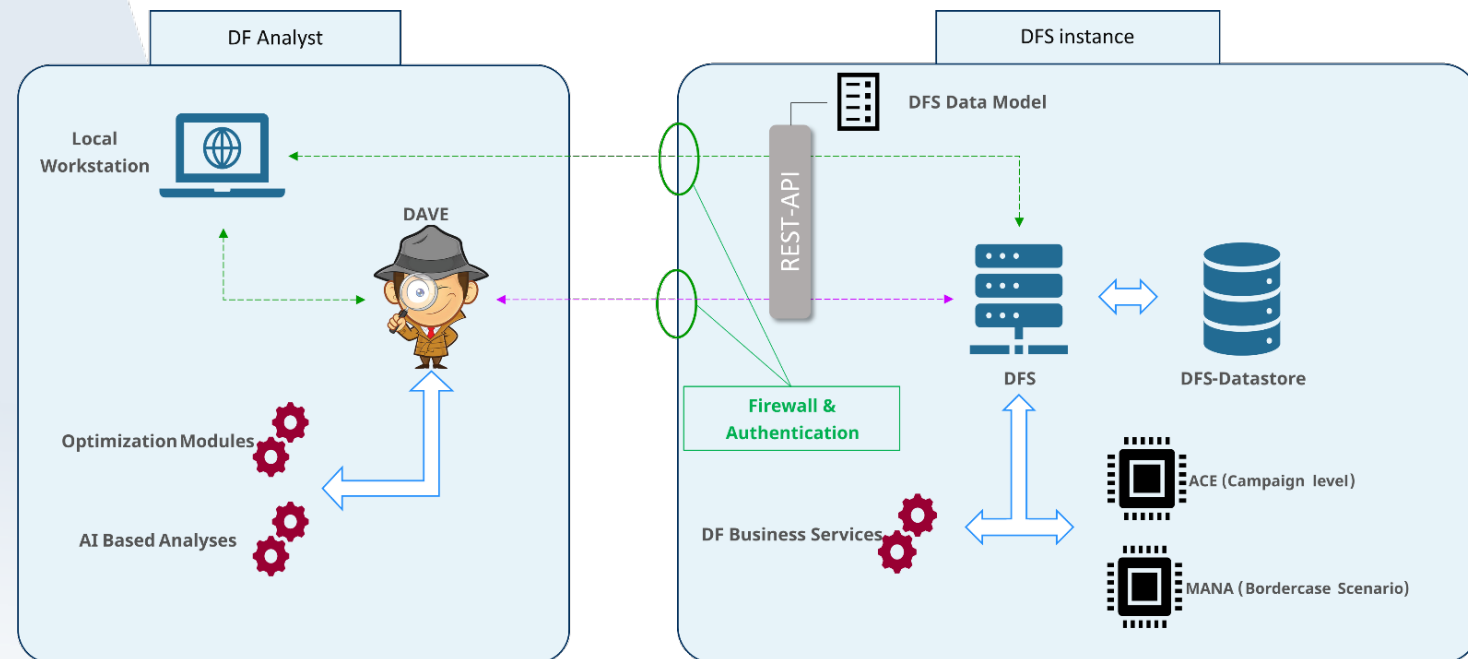
DAVE Demo

Summary

- MDDF models for the first time the interplay of a long-time scale campaign and a short-time scale operation, accounting for the complexity that arises in terms of time, sharing of resources and domains involved.

- MDDF shows how it is possible to combine AI techniques exploring operations at multiple scales (domain, level, time) and optimize the probability of winning the campaign.

- MDDF introduces a new multi-model approach to couple simulation models of different aggregations that allow more comprehensive multi-level military planning and decision-making.

- MDDF allows to accelerate the automation process making it efficient and effective in analyzing large and complex multi-dimensional data spaces.

- MDDF AI driven automation may extend the application of MDDF as a resource and time efficient simulation support for wargaming in domains like mission support or training and education.

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