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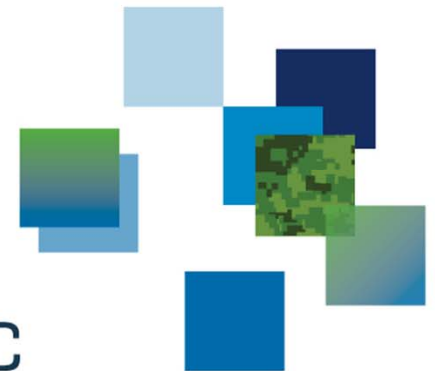
Recherche et développement
pour la défense Canada

Investigating Constraint-based Approaches for the Development of Agile Plans

Nicolas Léchevin, Christian Fricke, Micheline Bélanger,
Mohamad Allouche, Normand Pageau

DRDC | RDDC

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Outline

- Tactical Planning Challenges
- Constraint-based Planning with TPEM*
- Demonstration
- Results
- Future Work

* Tactical Planning and Execution Management
DRDC – Thales Canada

Planning Problems

Context of Operations:

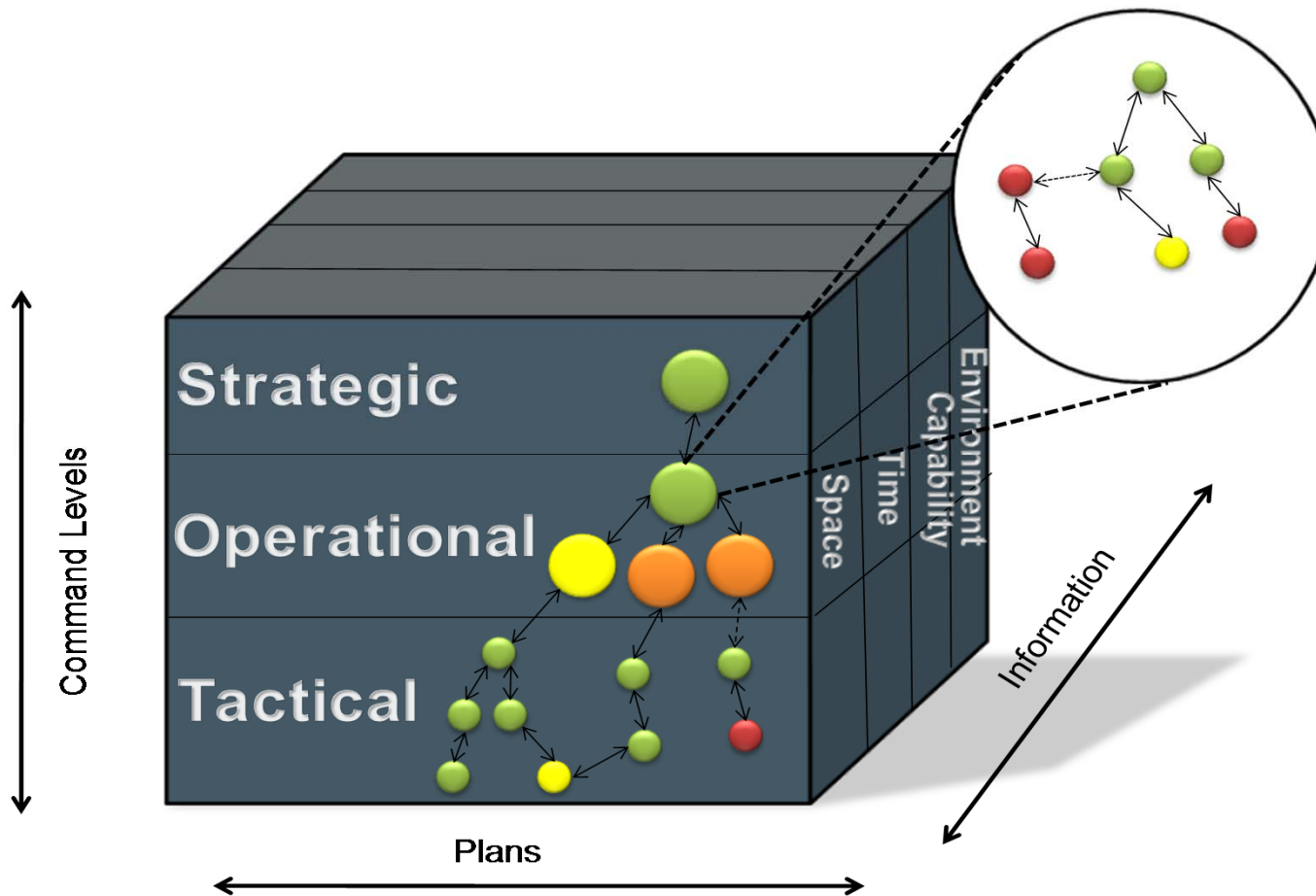
- Highly complex environments
- Time-constrained and uncertain environments
- Highly dynamic (high-tempo) operational situations
- Multi-Level
- Multi-Player
- Multi-Objectives
- Multi-Dimensional



Planning Approach for:

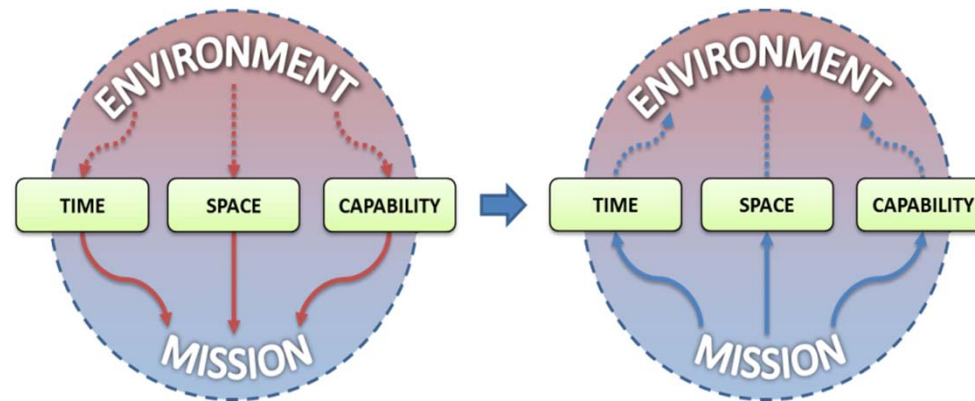
- Highly adaptable tactical forces
- Dispersed: Time, Space, Purpose
- Create & exploit opportunities
- Increase the tempo of ops
- Overwhelm enemy's understanding of the battle space

Information Dimensions for Planning and Monitoring



Concept

- Each plan element has a default context to be visualized along each information dimension (time, space, capability, environment)
- Default context = Set of constraints
- Environment shapes time, space, and capability constraints



- Seamless effort to go from one dimension to any other one

Temporal View

■ Planning: Robust Scheduling

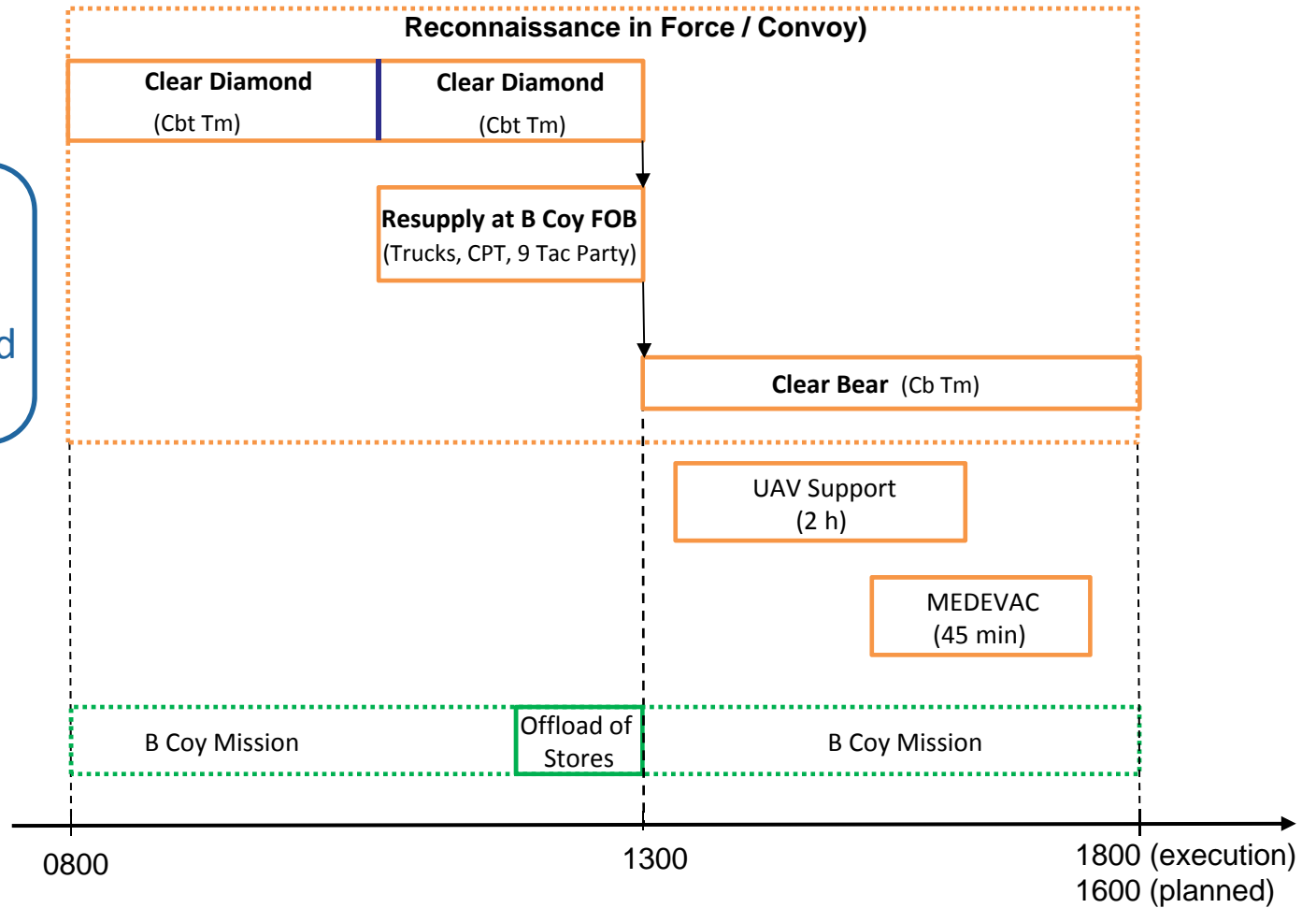
- Based on Time Constraints
- Temporal task boundaries: time intervals instead of time instants

■ Monitoring

- Schedule time evolution
- Notification mechanisms
 - Delay detection: report, task start/end
 - Conflict: Task resource assignment

Typical Schedule

- Crisp task boundaries
- High sensitivity to uncertainties, unexpected events

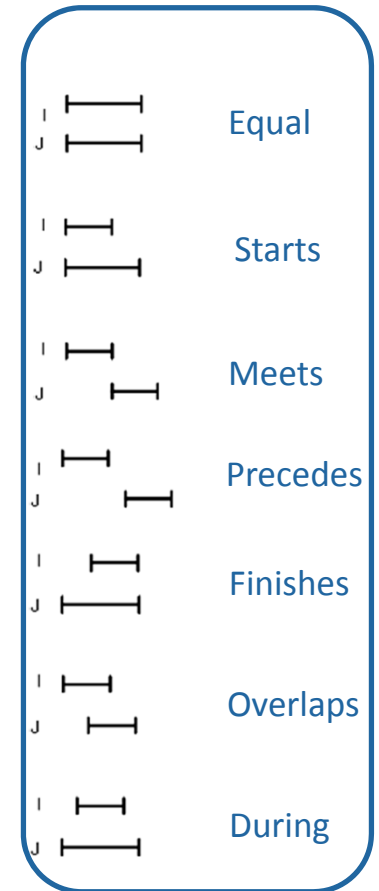
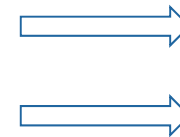


Constrained-based Robust Scheduling

1. Define Tasks: name, qualitative information

2. Define temporal constraints between tasks

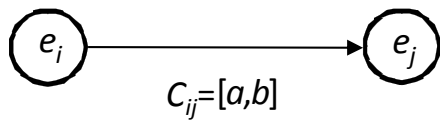
- Mission duration: 8 hours
- Synchronization of resupply tasks at B Coy FOB : 1300
- Dependencies among tasks: e.g. (1)Diamond – (2) Bear
- Task duration estimates
- Delay estimates



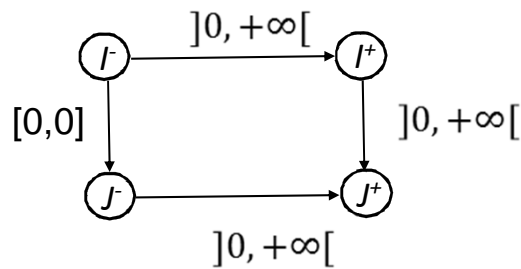
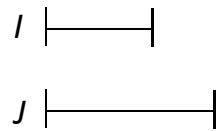
Example of Time Constraints

Time Constraints
'Resupply at B Coy FOB' must start at least 0 seconds after the end of 'Clear Diamond (From Tamayo to B Coy FOB)'.
'Resupply at B Coy FOB' must finish at most 0 seconds after the end of 'Offload of Stores'.
'Clear Diamond (From B Coy FOB to Junction AB)' must start at least 0 seconds after the end of 'Clear Diamond (From Tamayo to B Coy FOB)'.
'Clear Bear' must start at least 0 seconds after the end of 'Clear Diamond (From B Coy FOB to Junction AB)'.
'UAV Support' must last between 0 seconds and 2 hours.
'UAV Support' must start at least 0 seconds after the beginning of 'Clear Bear'.
'MEDEVAC' must last between 0 seconds and 45 minutes.
'Reconnaissance in Force / Convoy Escort' must start 0 seconds after the beginning of 'Security Operations in Bahoruco'.

Robust Scheduling: Graph representation

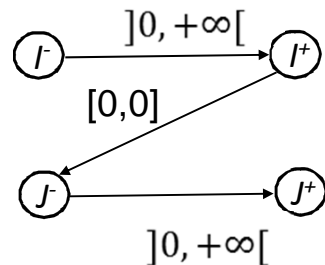
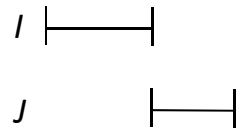


Single task with start/end nodes



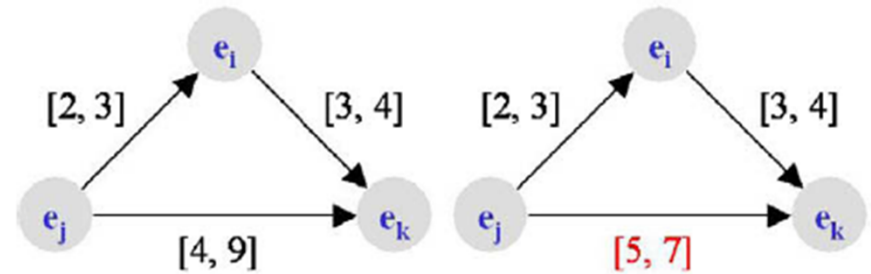
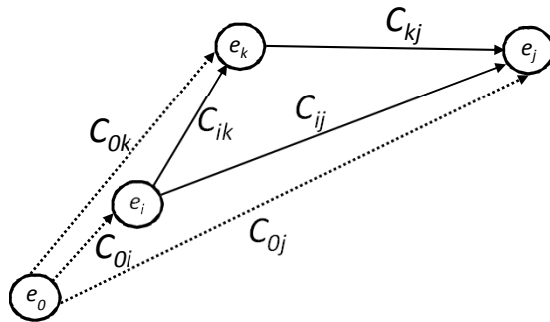
Example 1: Simultaneous starts

- Task durations are not specified
- I^+ and J^+ occurs after I and J
- J^+ occurs after I^+



Example 2: I end meets J start

Minimization of temporal plan



M. Allouche, A. Boukhtouta, "Multi-agent coordination by temporal plan fusion: Application to Combat SAR", Information Fusion, Vol. 11, pp. 220-232, 2012

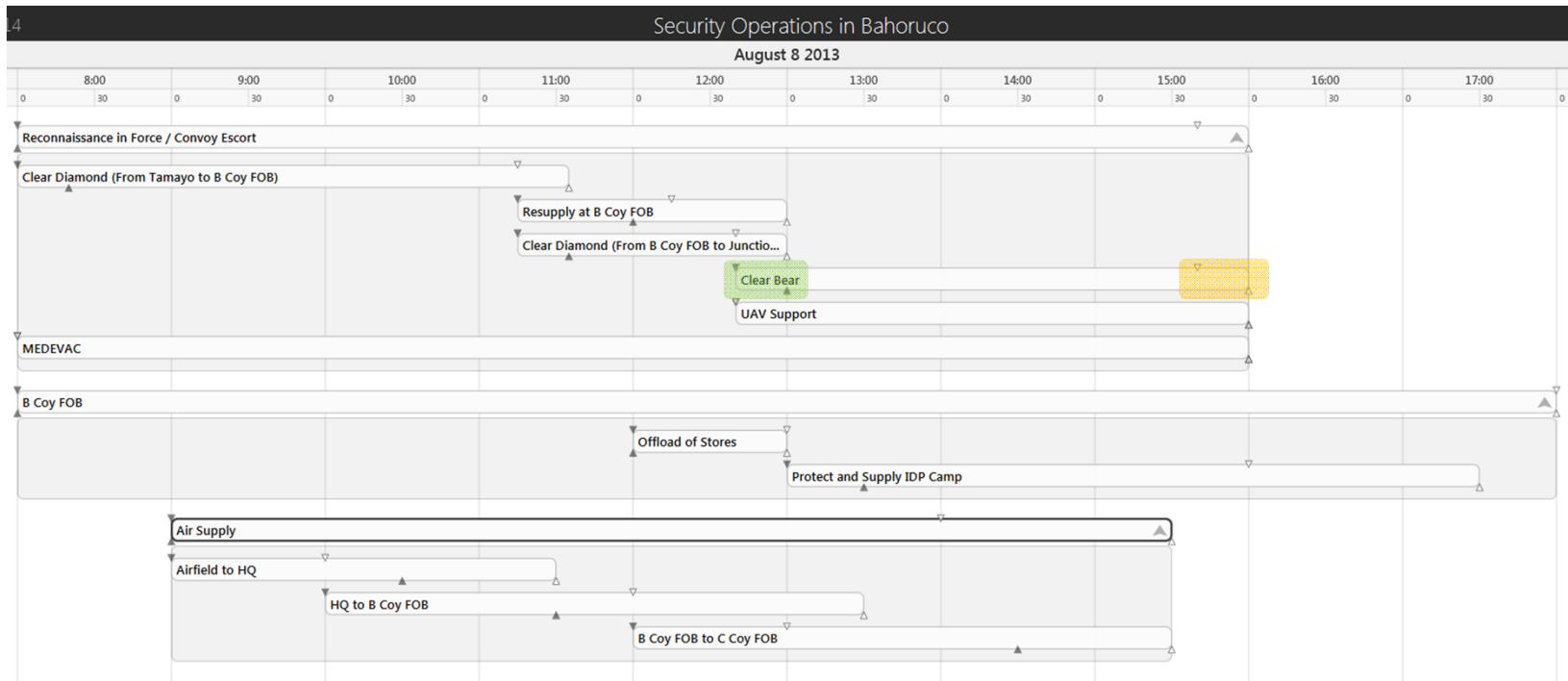
```

For k = 1 to n
  For i = 1 to n
    For j = 1 to n
       $C_{ij} \leftarrow C_{ij} \cap (C_{ik} \oplus C_{kj})$ 
    end
  end
end

```

$C_{ij} = \emptyset$: Inconsistent graph

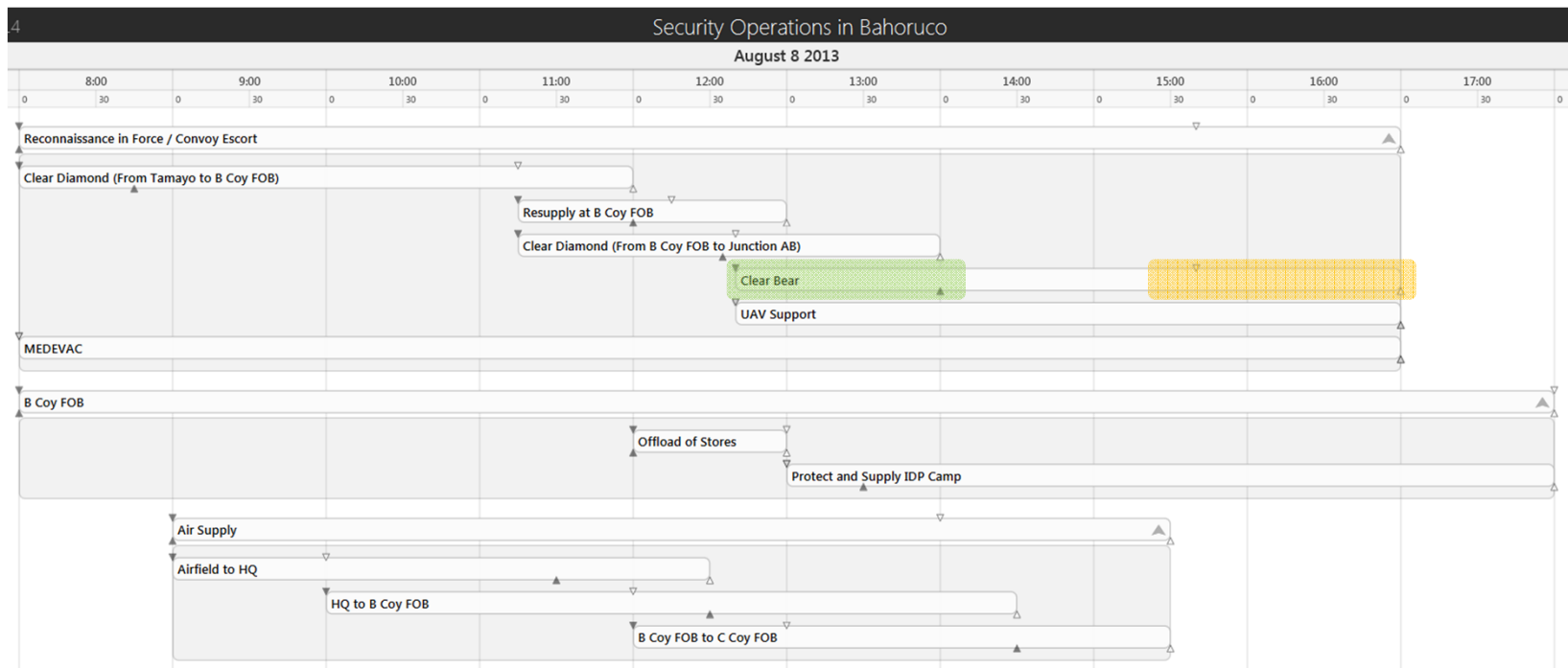
Robust Schedule



Task start buffer 

 Task end buffer

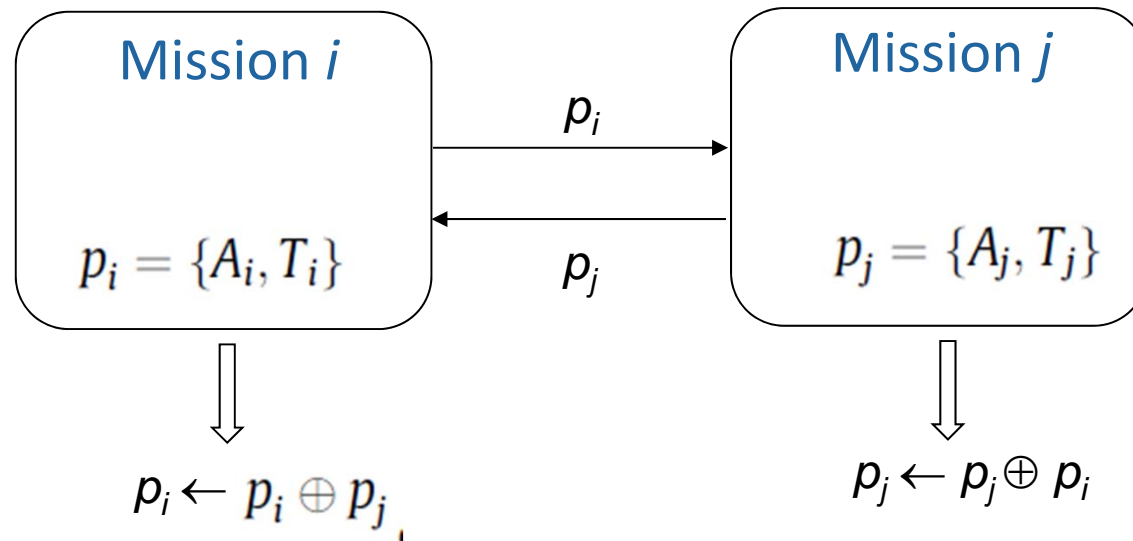
Robust Schedule



Mission replanning may modify start/end interval lengths, and schedule robustness margin

- Mission duration
- Tactical speed
- Route planning

Fusion of Temporal Plans



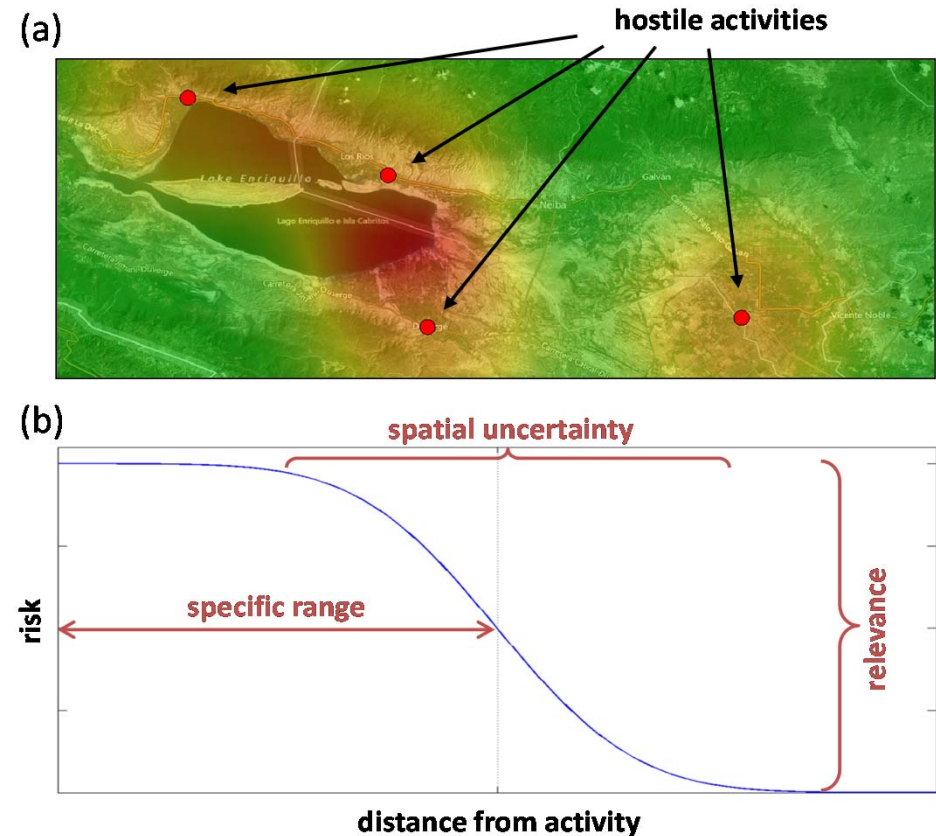
where $p_i \oplus p_j \stackrel{\text{def.}}{=} \min(\underbrace{\text{aug}(p_i, p_j)}_{\text{Union of graphs}} \cap \text{aug}(p_j, p_i))$

Union of graphs

$[-\infty, +\infty]$ when $\text{edge} \in p_j$

Spatial view – Hot spot map

- Known Red threats
 - Route intimidation
 - Weapons
- Risk function (influence, prob. to kill, ...)
- Risk aggregation over the map

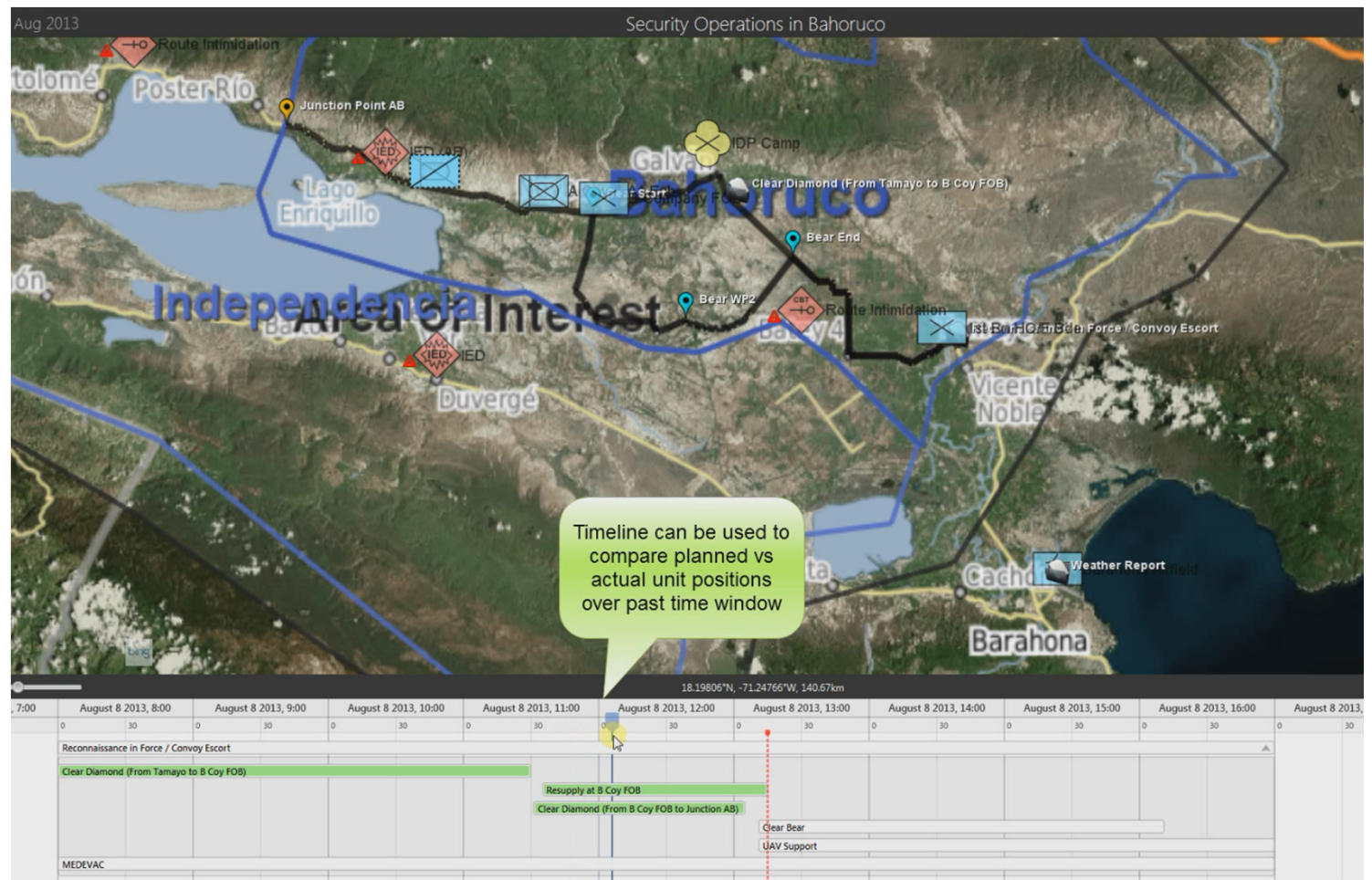


Backward/Forward Simulation

- Veh. dynamics
- State at time T
- Planned route



Simulation of units displacement starting from T backward/forward)



Capability View

- Planning: Capability based planning vs. resource based planning
 - Capability requirements defined for every task of the schedule
 - Definition of resources that must meet the capability requirements
 - Status of requirements

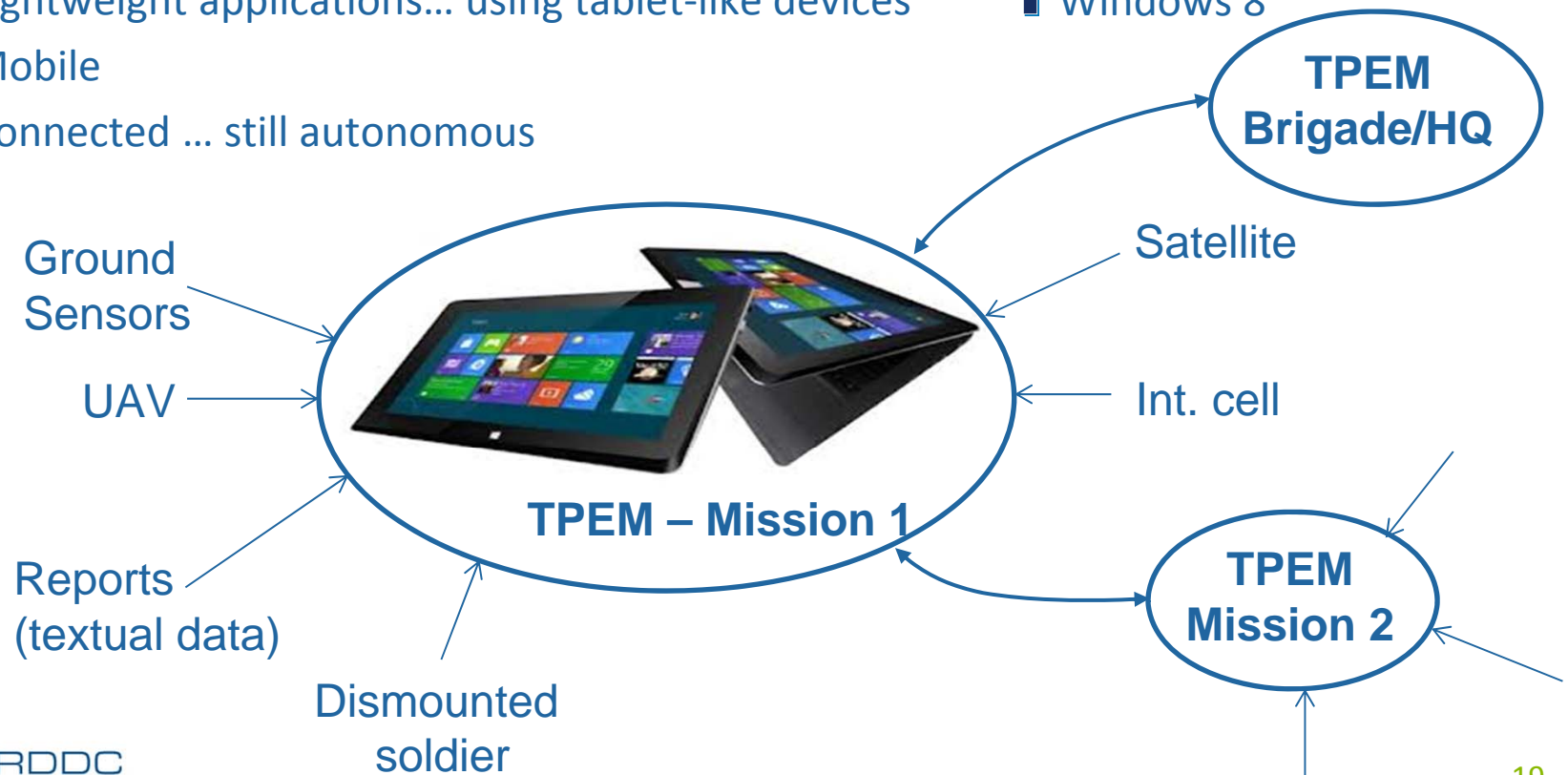
Environment View

- Pre-mission report repositories:
 - Intelligence summary
 - Concept of operation
 - Land Component Campaign Plan
 - Higher echelon order
- Planning/Monitoring: Information sharing: Web-like environment (Web, Defence network)
 - Web-like environment (Web, Defence network)
 - Chat (future development)
- Monitoring: Reception of reports
 - Mission report (INTREP, SITREP, ContactREP, ...)
 - Orders (MEDEVAC)
 - Weather
 - Tracking

From Concepts to Technologies

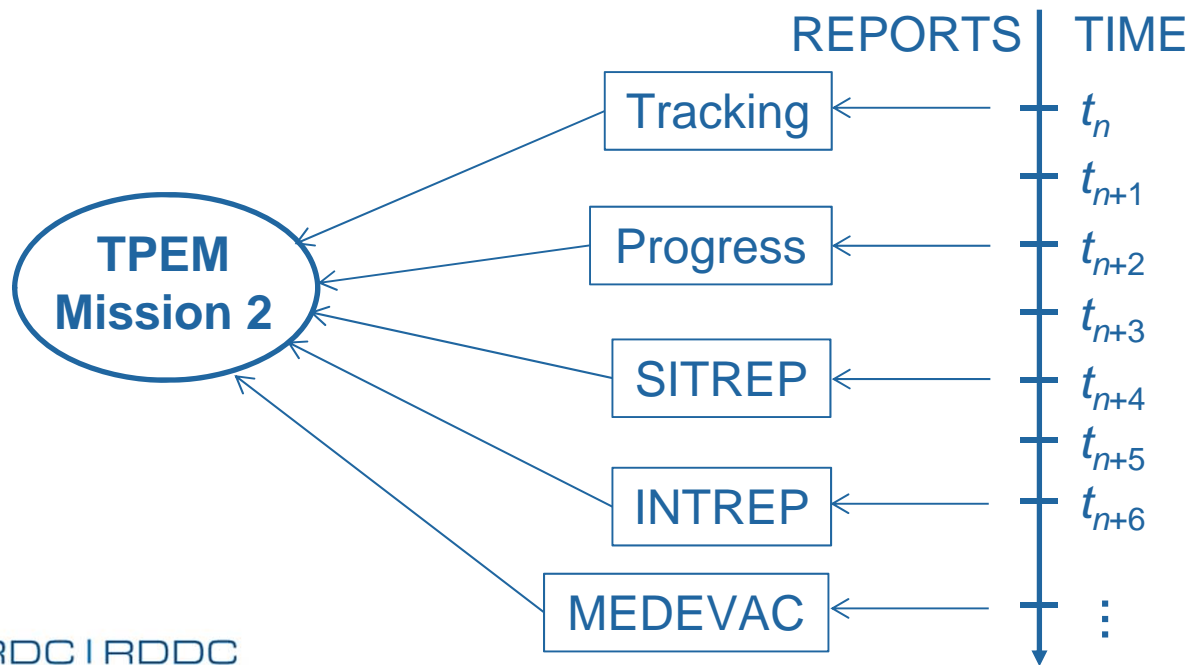
■ We should think of a new way to develop TPEM capabilities

- Lightweight applications... using tablet-like devices
- Mobile
- Connected ... still autonomous
- Windows 8



Stimulation of TPEM

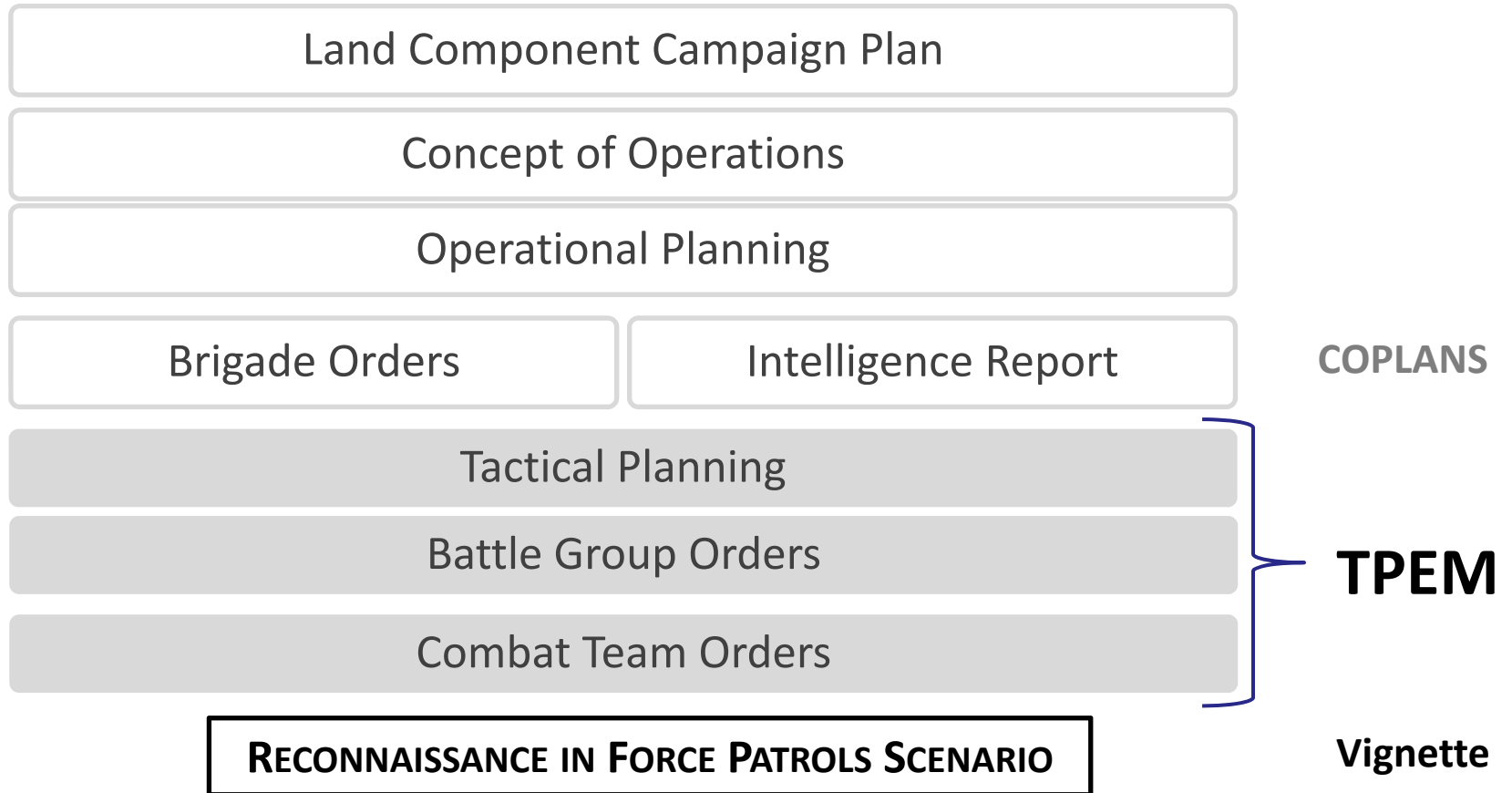
- A stimulator emulates the data that TPEM would receive from sensors, reports, GPS.



Demonstration: Reconnaissance in Force Patrol



Demonstration



OPP (COPlanS) Data Exported to TPEM

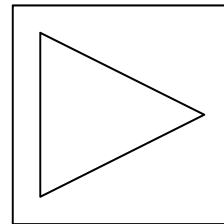
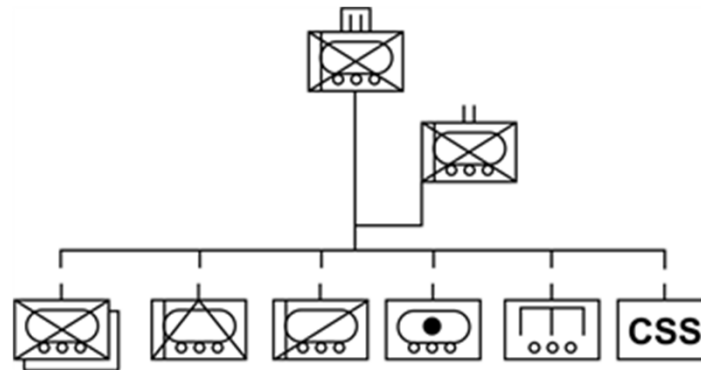
The screenshot displays the COPlanS v1.6.0 alpha software interface, which is used for Course of Action (COA) development and analysis. The main window is titled "COPlanS v1.6.0 alpha - Course of Action Development [Security Operations in Bahoruco - Security Operations in West Isle (Operational)]".

The interface is divided into several panes:

- Course of Action Development:** Shows the current COA being developed, "Security Operations in West Isle". It includes options for "New Own COA" and "New Adversary COA", and a "Development" section with various analysis tools like "COA Properties", "Time Synchronization", "Space Synchronization", "Risk Mitigation", and "COA Viability".
- Time Synchronization:** A Gantt chart showing the timeline of operations from Wednesday, August 07, 2013, to Thursday, August 08, 2013. Operations include "Security Operations in West Isle", "Security Operations in Bahoruco", "Reconnaissance in Force / Convoy Escort", "B Coy FOB", and "Security Operations in Independencia".
- GIS: Security Operations in West Isle (Operational):** A map view showing the geographical area of operations. A red outline indicates the operational area, and a green outline indicates a specific region. The map includes a "Layers" panel with "Plan", "Key Location", "WMS", "World", and "Grid".
- Initial Force Estimate and C&C Structures:** A tree view showing the organizational structure of the forces. It includes "Orbat (Own)", "1 RCR (Canadian Battle Group)", "3 RCR (Canadian Battle Group)", "A Coy (3 RCR (Canadian Ba)", and "B Coy (3 RCR (Canadian Ba)".

The bottom status bar indicates "CLASSIFIED CONFIDENTIAL (EXERCISE)", "COA | Security Operations in West Isle", and the user "admin".

Battle Group (3 RCR - TF 1 and 1 RCR - TF 2)



DEMO: Mission
execution Monitoring

Results

- Demo feedback from: (1) Directorate Land Requirement; (2) CALWC (Army of Tomorrow); (3) 5th Canadian Mechanized Brigade Group
- Improve data input methods / better GPS integration / Automatic Route planner (Spatial view)
- Participants overwhelmed by the amount of data available to tactical users; better suited for Brigade level or higher (Operational level); simplified version for tactical planning/monitoring;
- Need to integrate What-If analysis (temporal view);
- Lack of feedback on decision implication: Need to assess/predict the effect/risk of a plan (spatial view)

Future Work

- Develop what-if analysis and re-planning functionalities with risk-benefit-cost analysis (including all views)
- Dashboard: Monitoring of effect achievement
- Spatial view: GIS-based robust path planner, vehicle dynamics
- Capability view: move planner; real-time notification (e.g. loss of resources)
- Resources synchronization for Adaptive Dispersed Operations