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Investigating Constraint-based Approaches for the Development of Agile Plans

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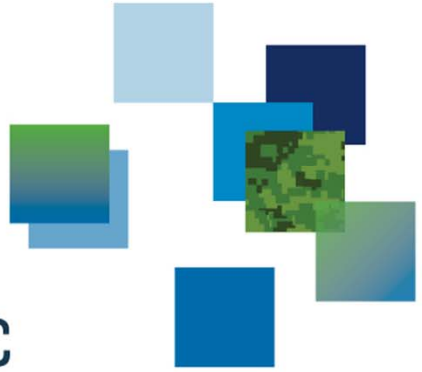

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Outline

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

* Tactical Planning and Execution Management
DRDC – Thales Canada

Planning Problems

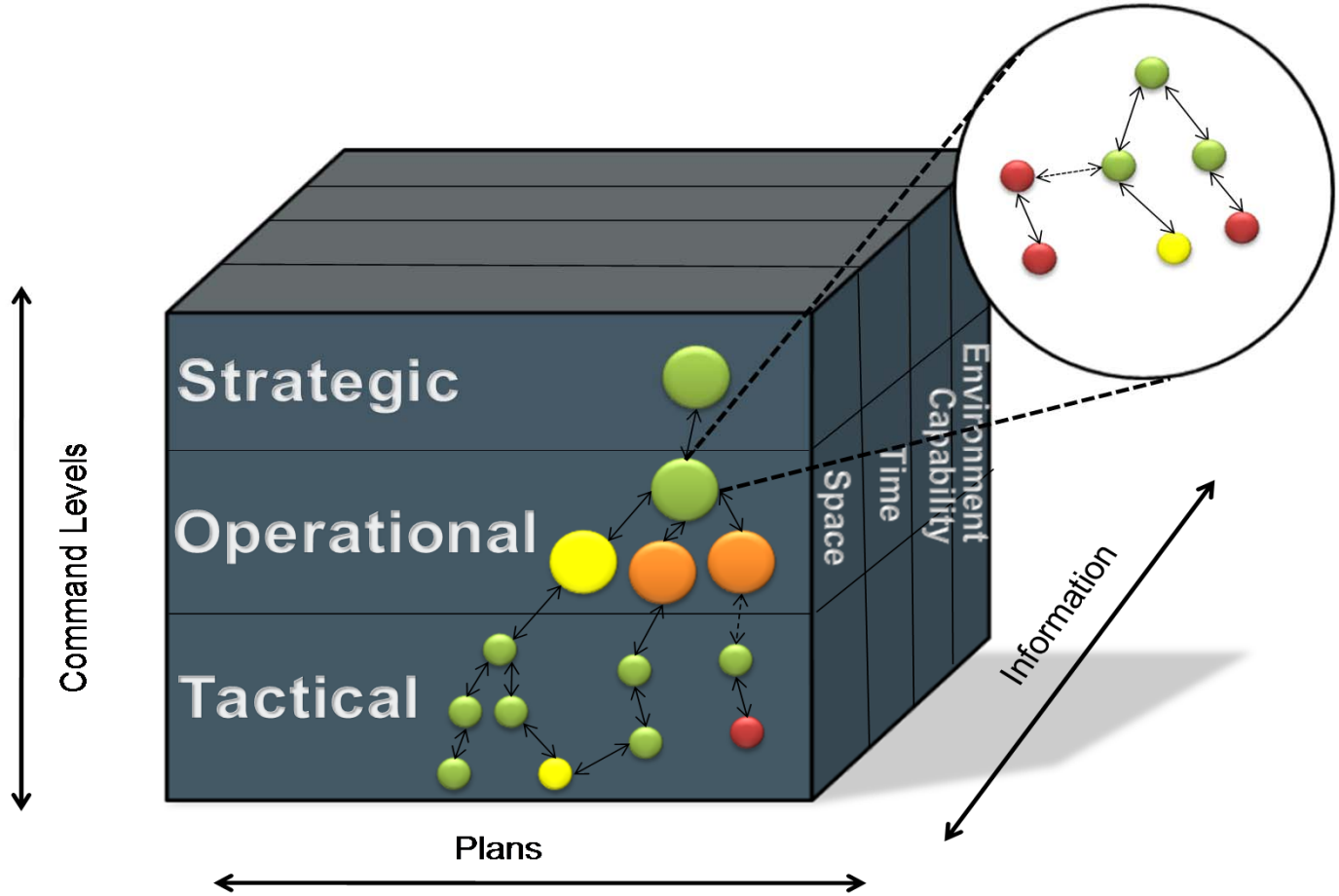
Context of Operations:

- 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:

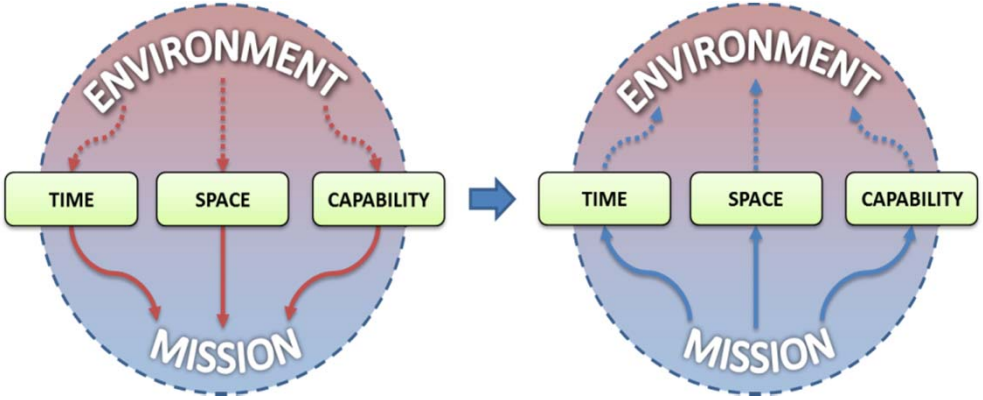
- Highly adaptable tactical forces
- Dispersed: Time, Space, Purpose
- Create & exploit opportunities
- Increase the tempo of ops
- Overwhelm enemy's understanding of the battle space

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



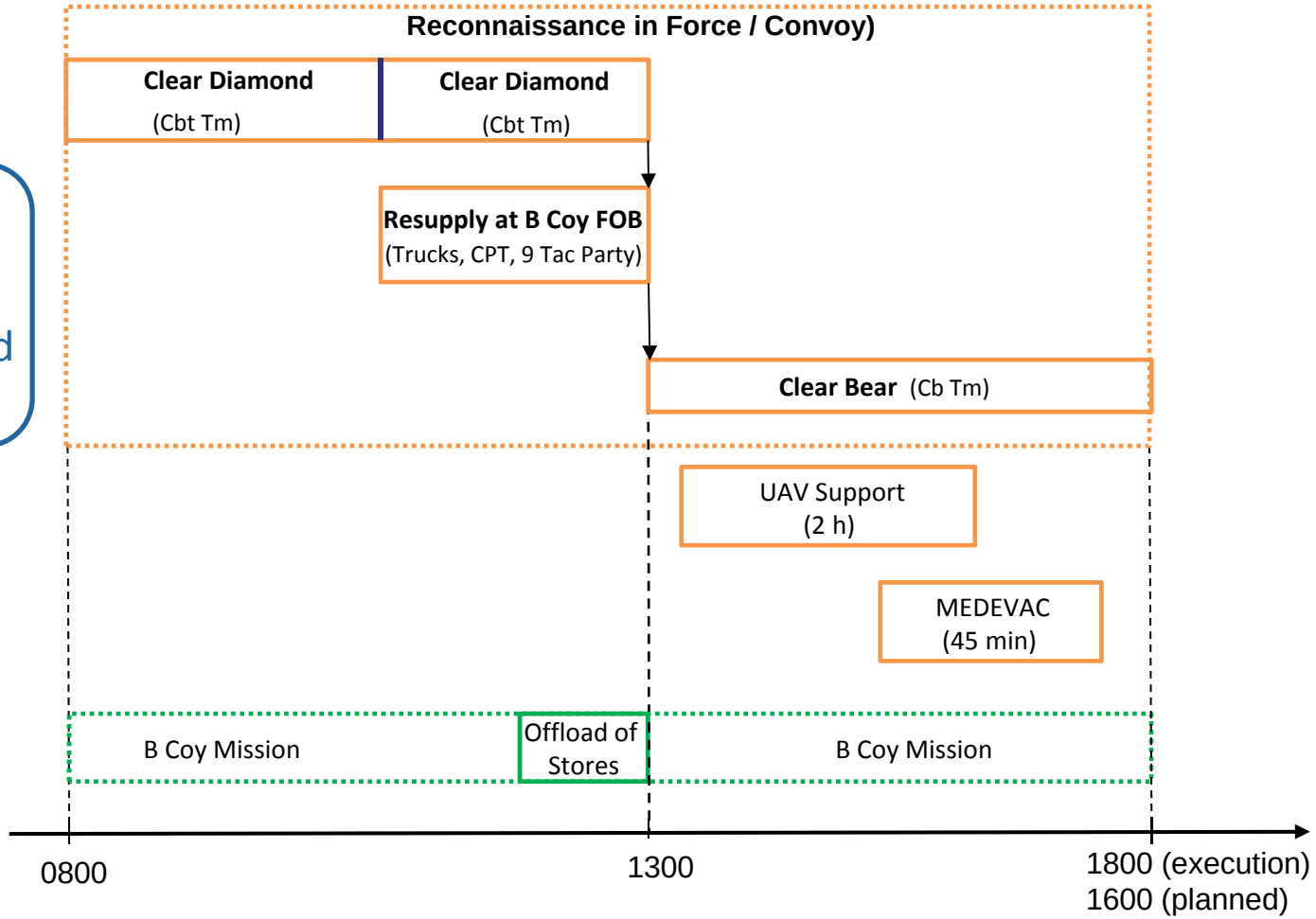
- Seamless effort to go from one dimension to any other one

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

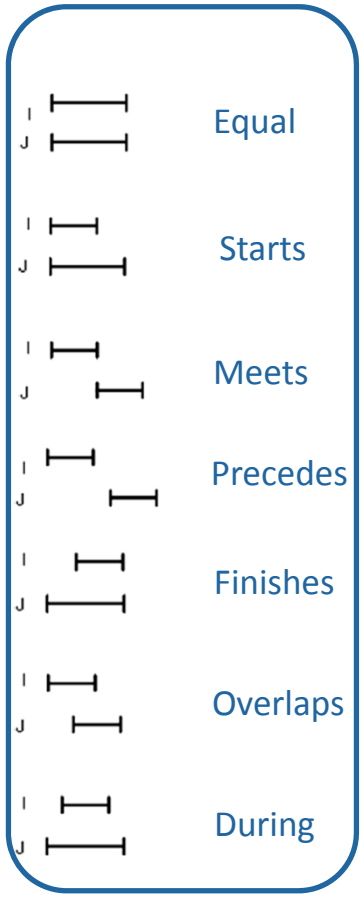


Constrained-based Robust Scheduling

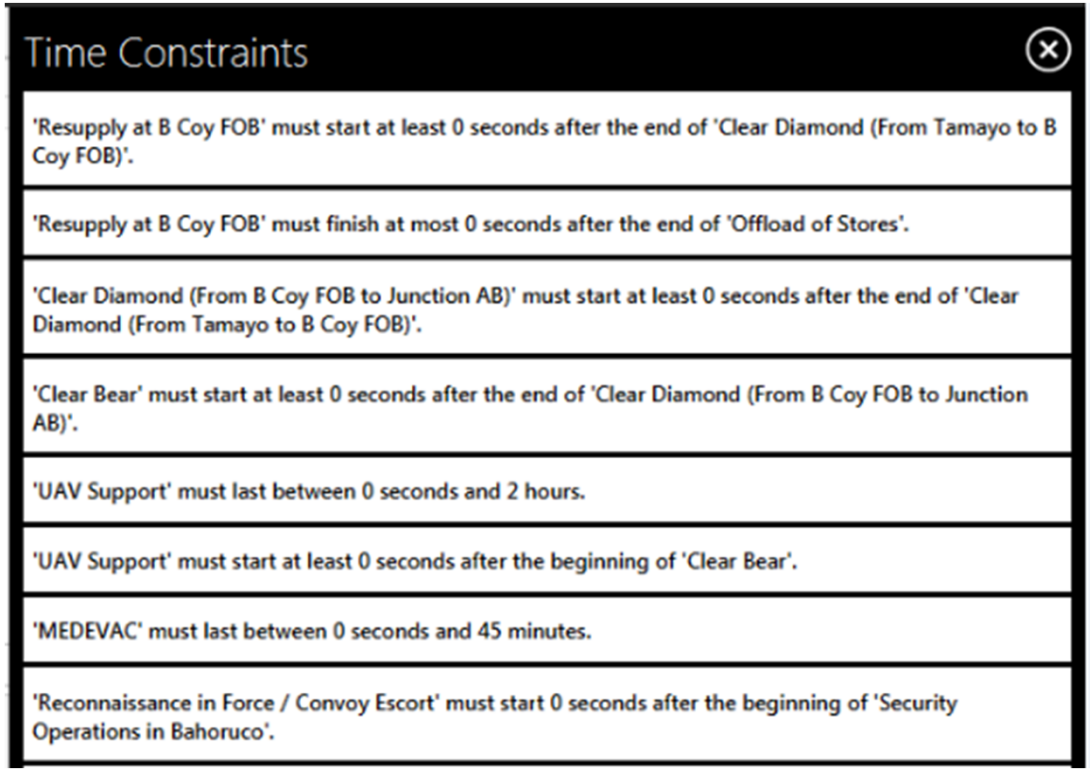
1. Define Tasks: name, qualitative information

2. Define temporal constraints between tasks

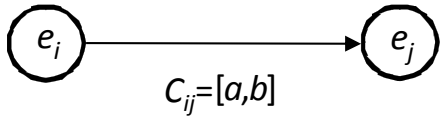
- Mission duration: 8 hours
- Synchronization of resupply tasks at B Coy FOB : 1300
- Dependencies among tasks: e.g. (1)Diamond – (2) Bear
- Task duration estimates
- Delay estimates



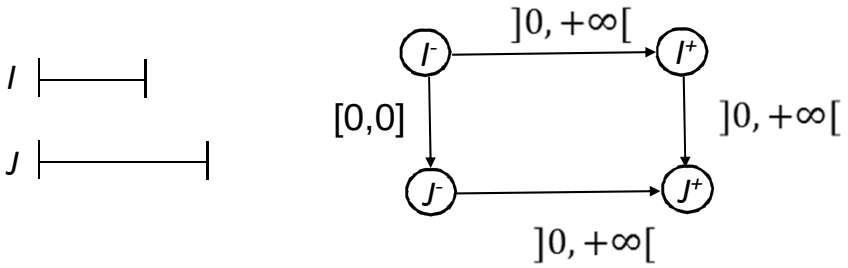
Example of Time Constraints



Robust Scheduling: Graph representation

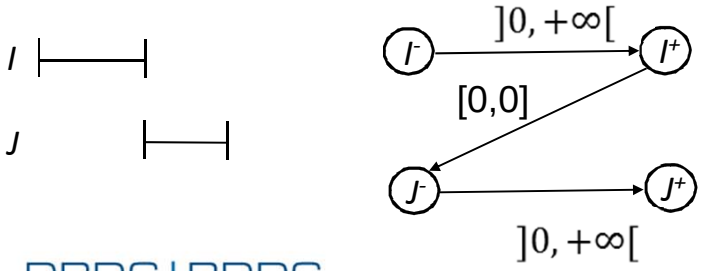


Single task with start/end nodes



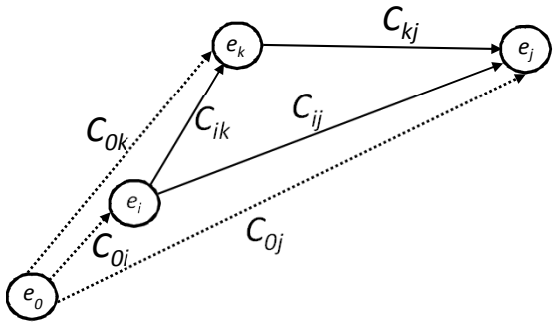
Example 1: Simultaneous starts

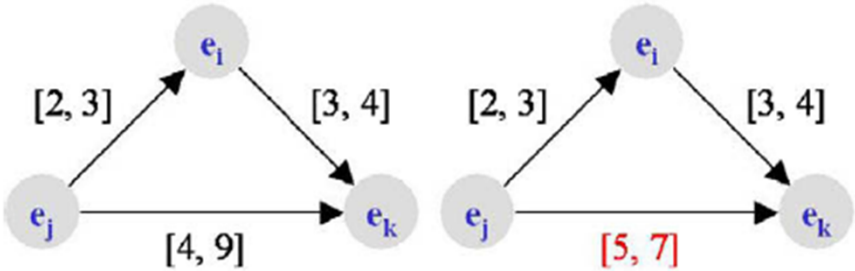
- Task durations are not specified
- I^+ and J+ occurs after I^- and J^-
- J^+ occurs after I^+



Example 2: *I* end meets *J* start

Minimization of temporal plan



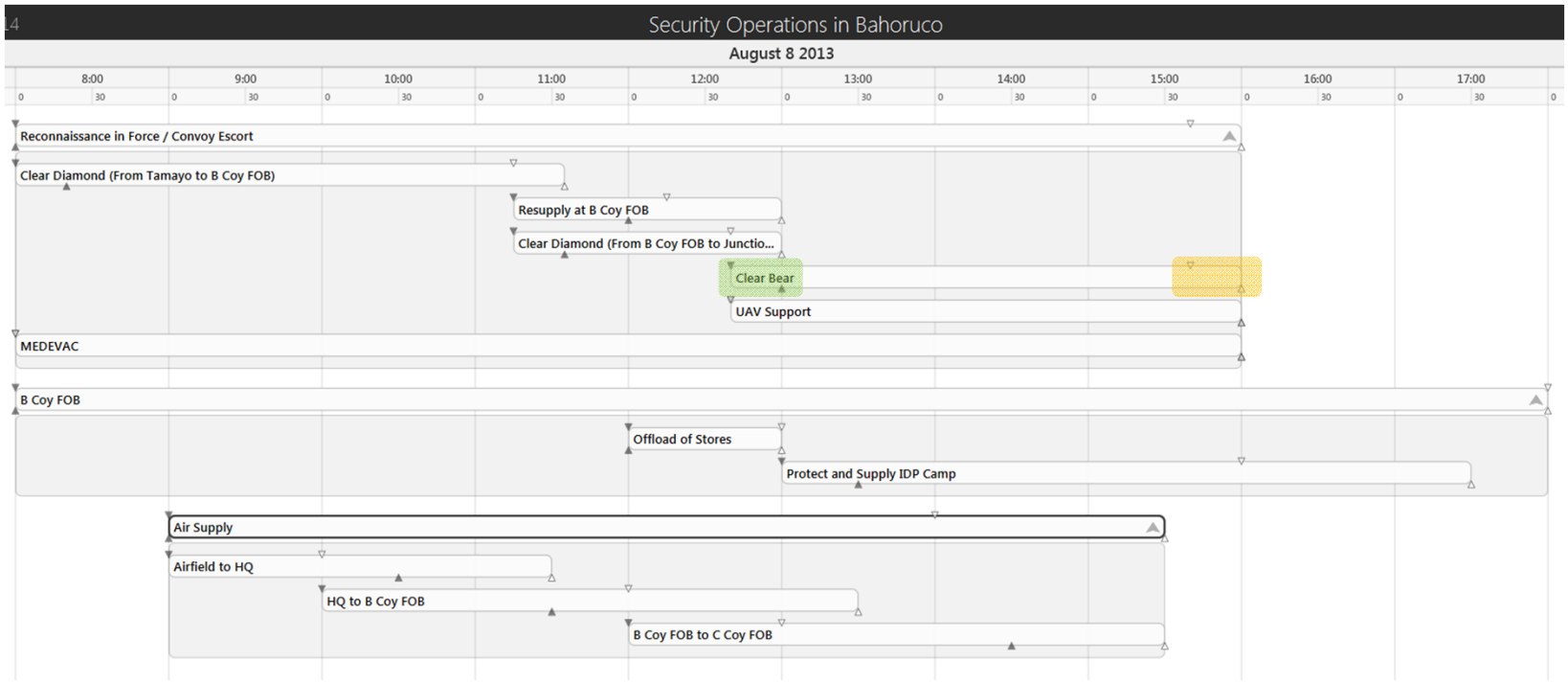


M. Allouche, A. Boukhtouta, "Multi-agent coordination by temporal plan fusion: Application to Combat SAR", Information Fusion, Vol. 11, pp. 220-232, 2012

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

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

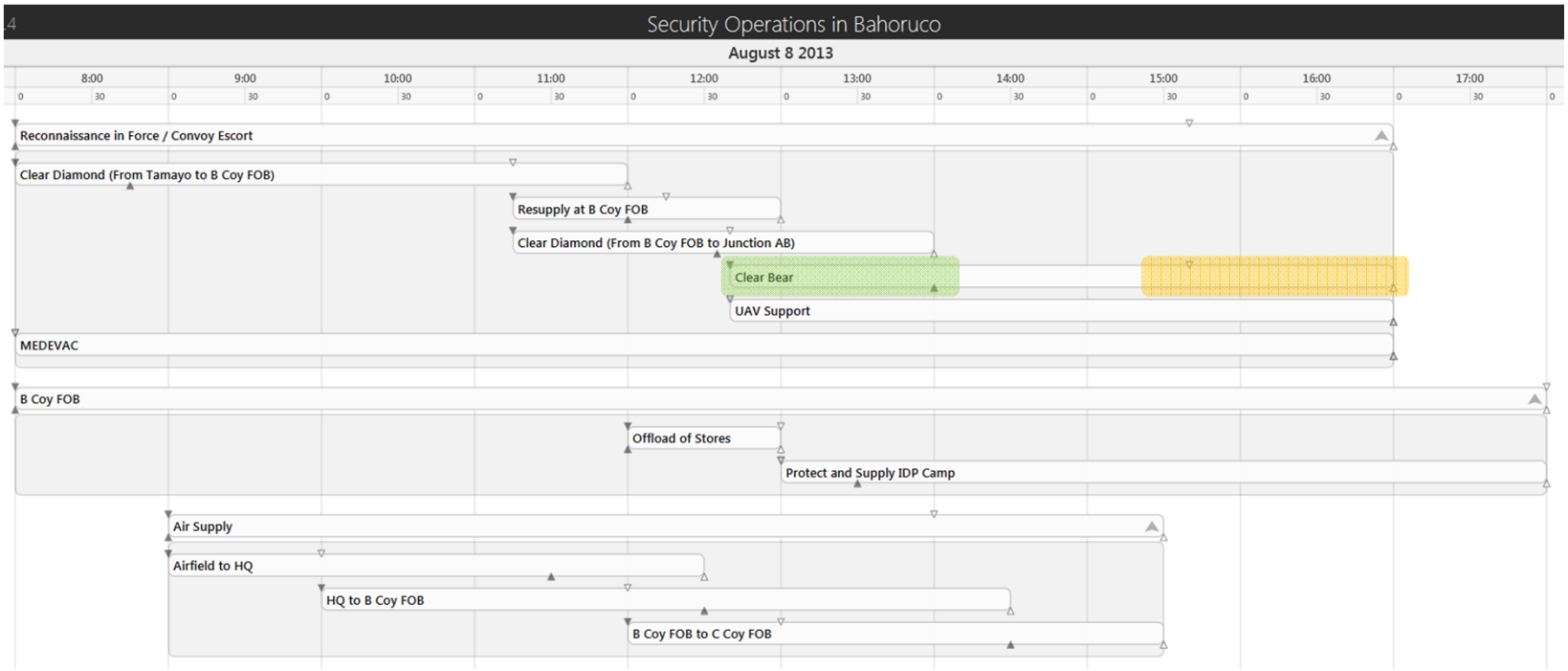
Robust Schedule



Task start buffer

Task end buffer

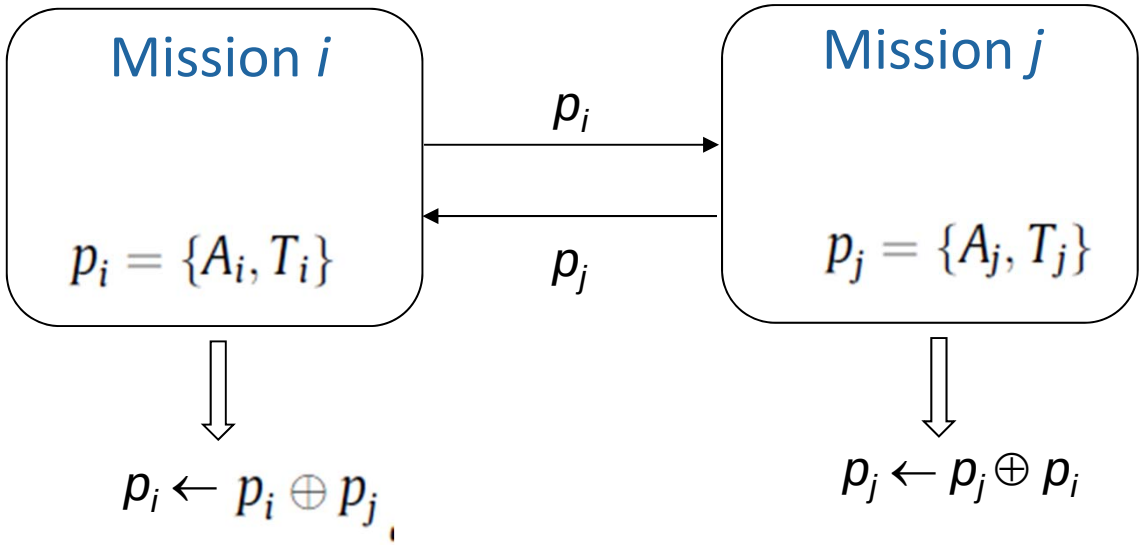
Robust Schedule



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

- Mission duration
- Tactical speed
- Route planning

Fusion of Temporal Plans



where $p_i \oplus p_j \underset{def.}{=} min(aug(p_i, p_j) \cap aug(p_j, p_i))$

Union of graphs

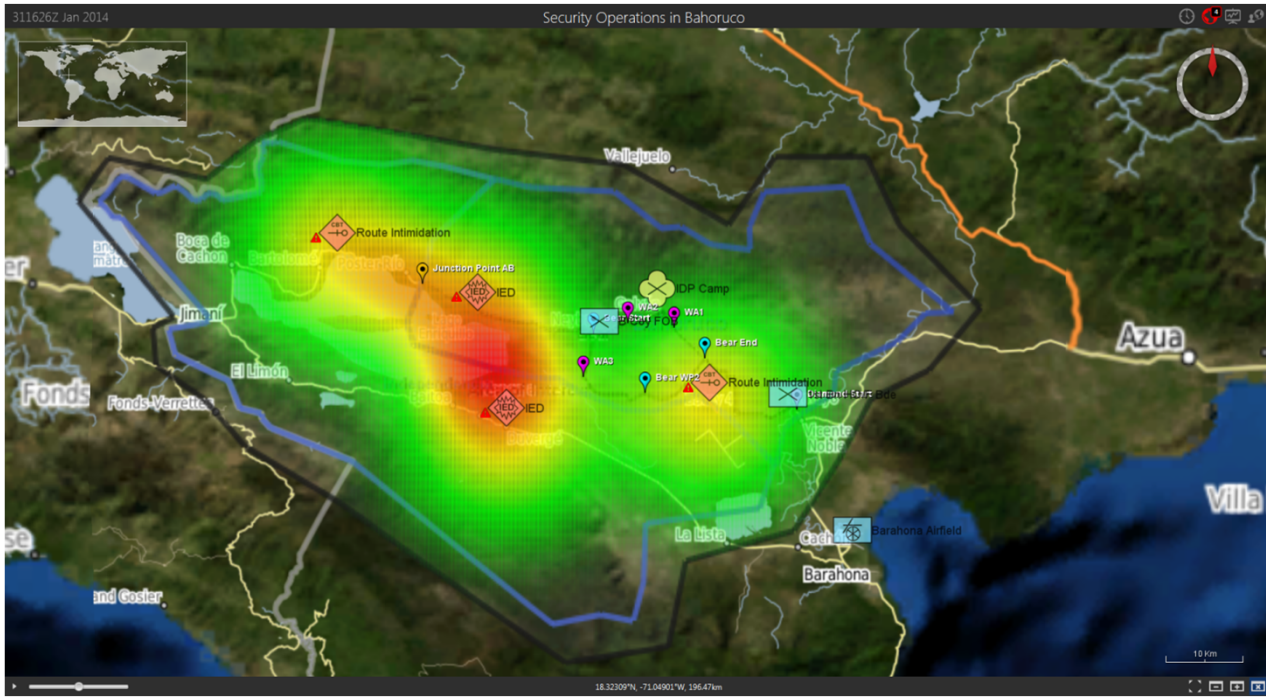
$[-\infty,+\infty]$ when edge $\in p_j$

Spatial View

- Planning

  Map
  - Geo-referenced Locations
  - Multiple layers
    - Maps
    - Waypoints/Checkpoints
    - Infrastructures
    - Zones
  - Assets / Resources
  - Routes
  - Task assignment (actions)

  Hot spot map



- Monitoring:

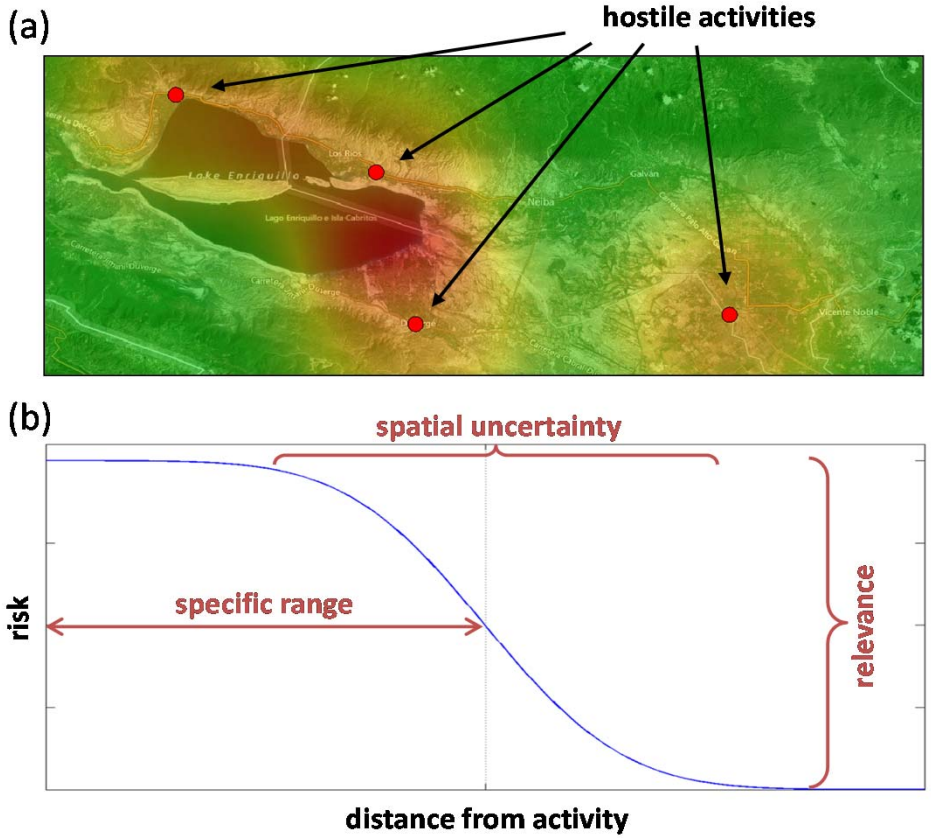
  Tracking of resources

  Notification of hostile event occurrence in area of interest,

  Notification of reports received (INTREP, SITREP, ContactREP)

Spatial view – Hot spot map

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

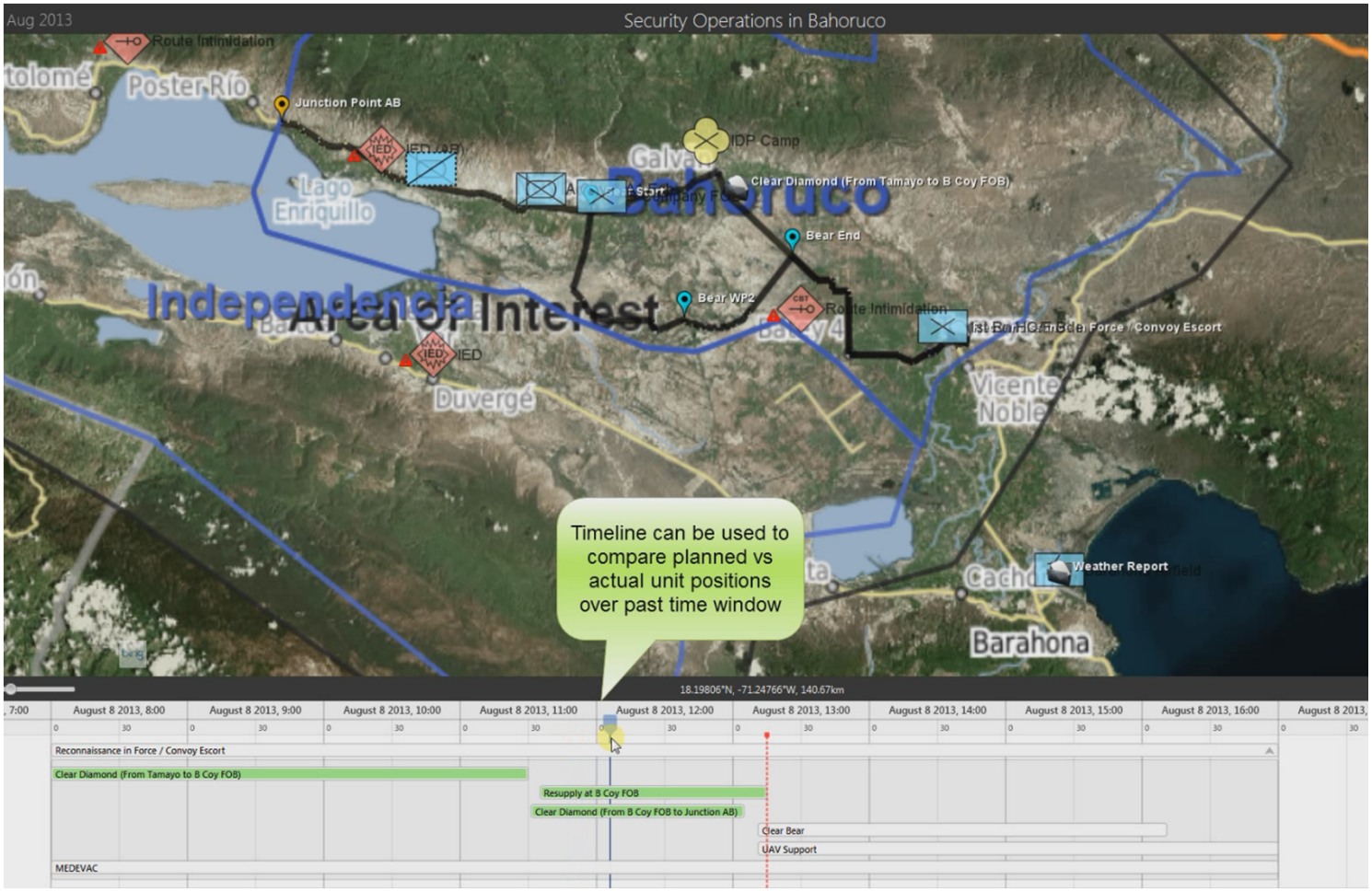


Backward/Forward Simulation

- 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

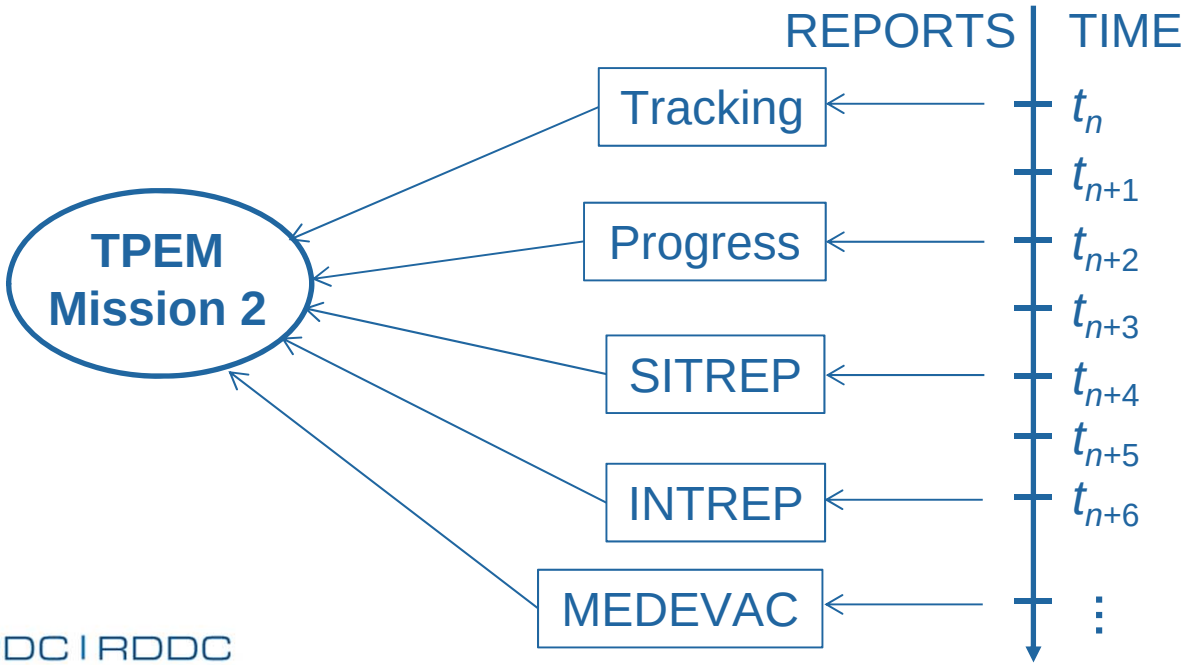
- Pre-mission report repositories:
  - Intelligence summary
  - Concept of operation
  - Land Component Campaign Plan
  - Higher echelon order
- Planning/Monitoring: Information sharing: Web-like environment (Web, Defence network)
  - Web-like environment (Web, Defence network)
  - Chat (future development)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

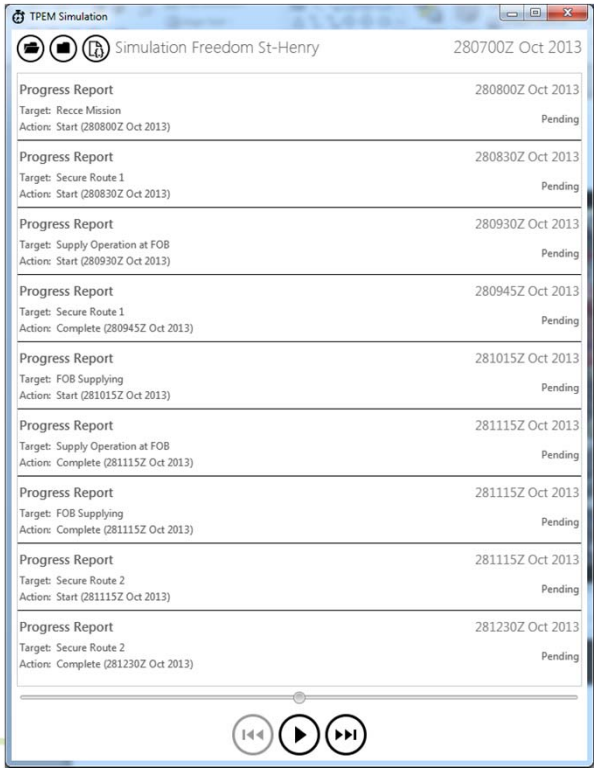
From Concepts to Technologies

- We should think of a new way to develop TPEM capabilities
  - Lightweight applications… using tablet-like devices
  - Mobile
  - Connected … still autonomous
  - Windows 8

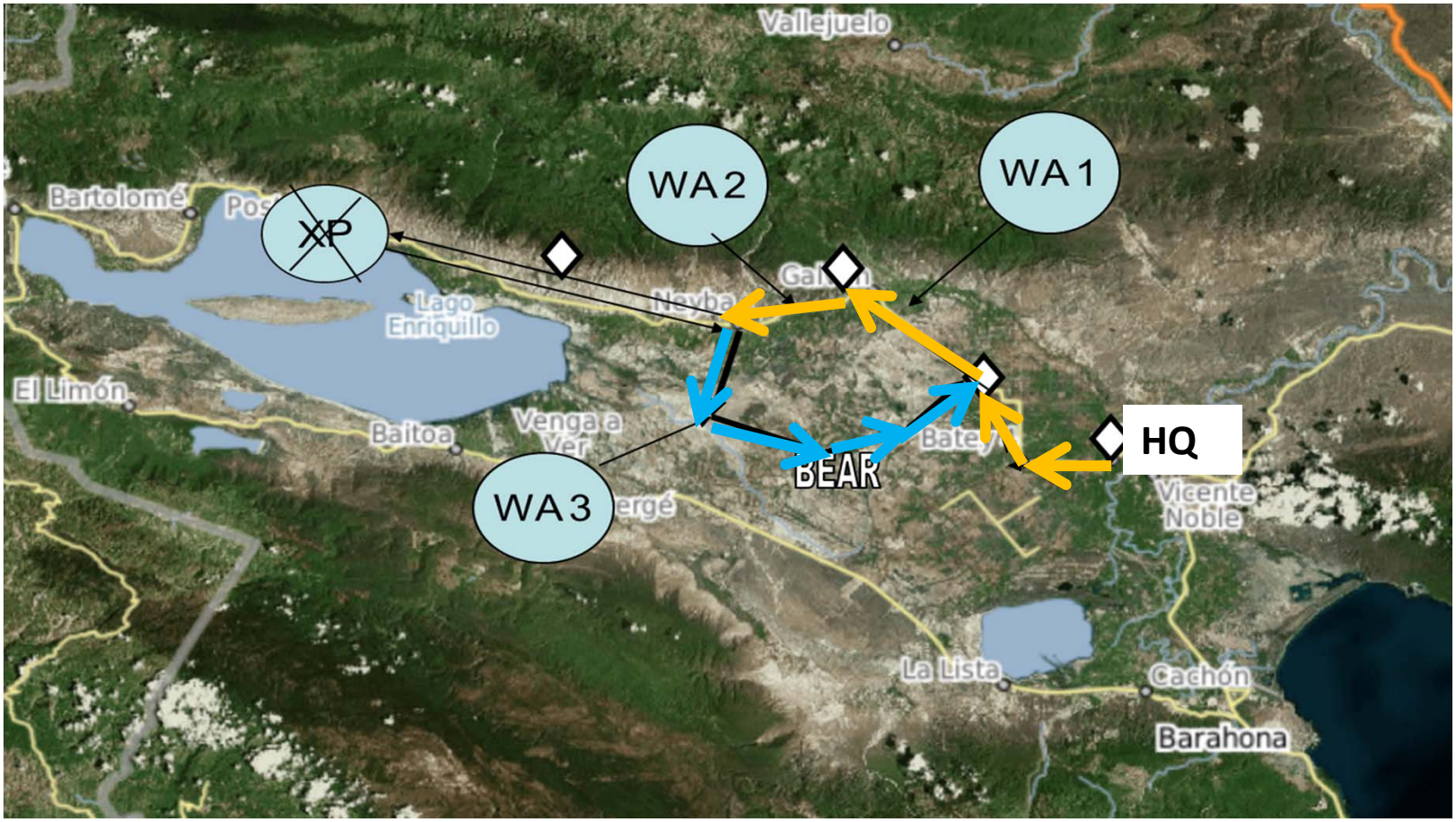
Stimulation of TPEM

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

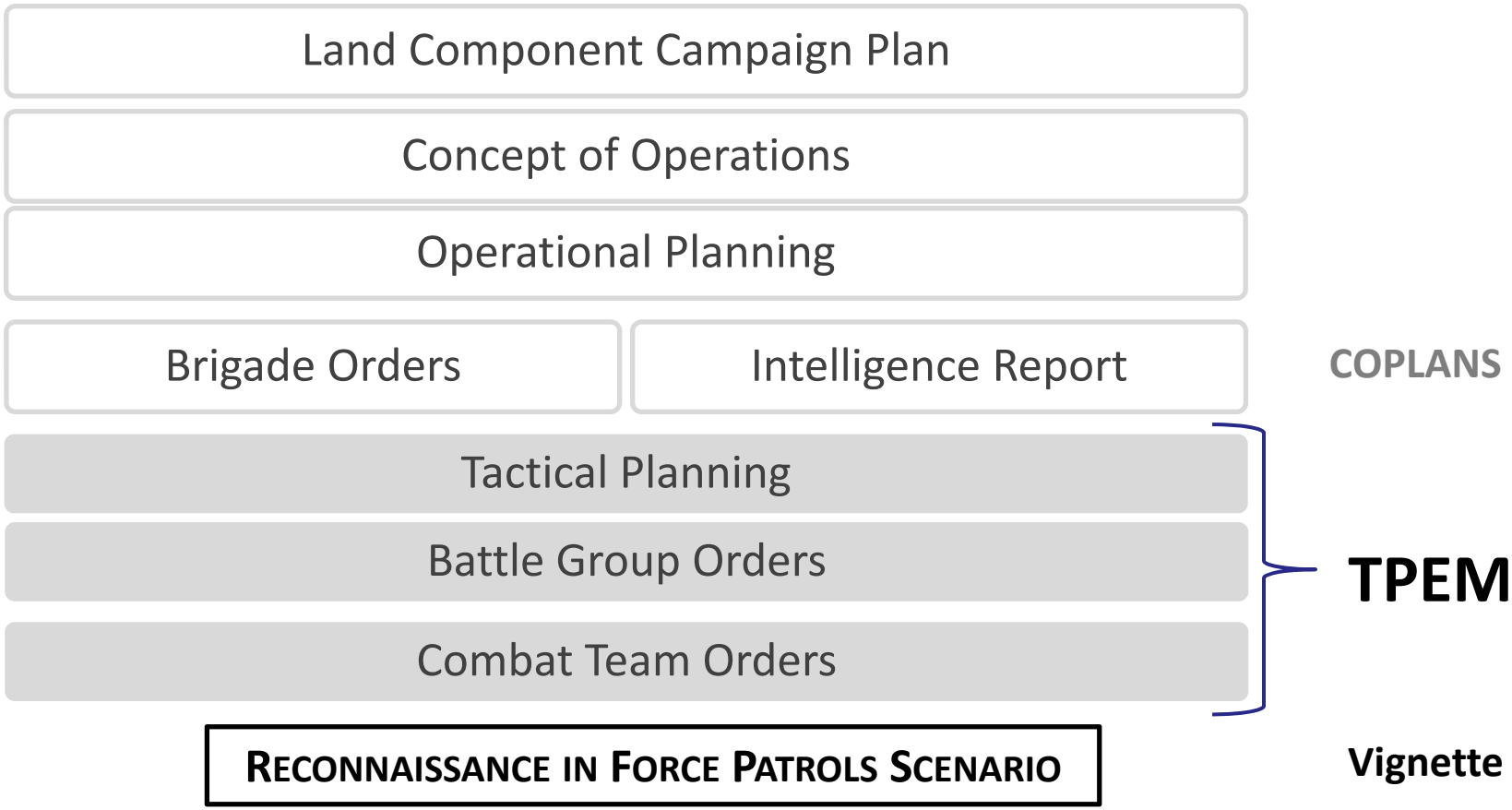




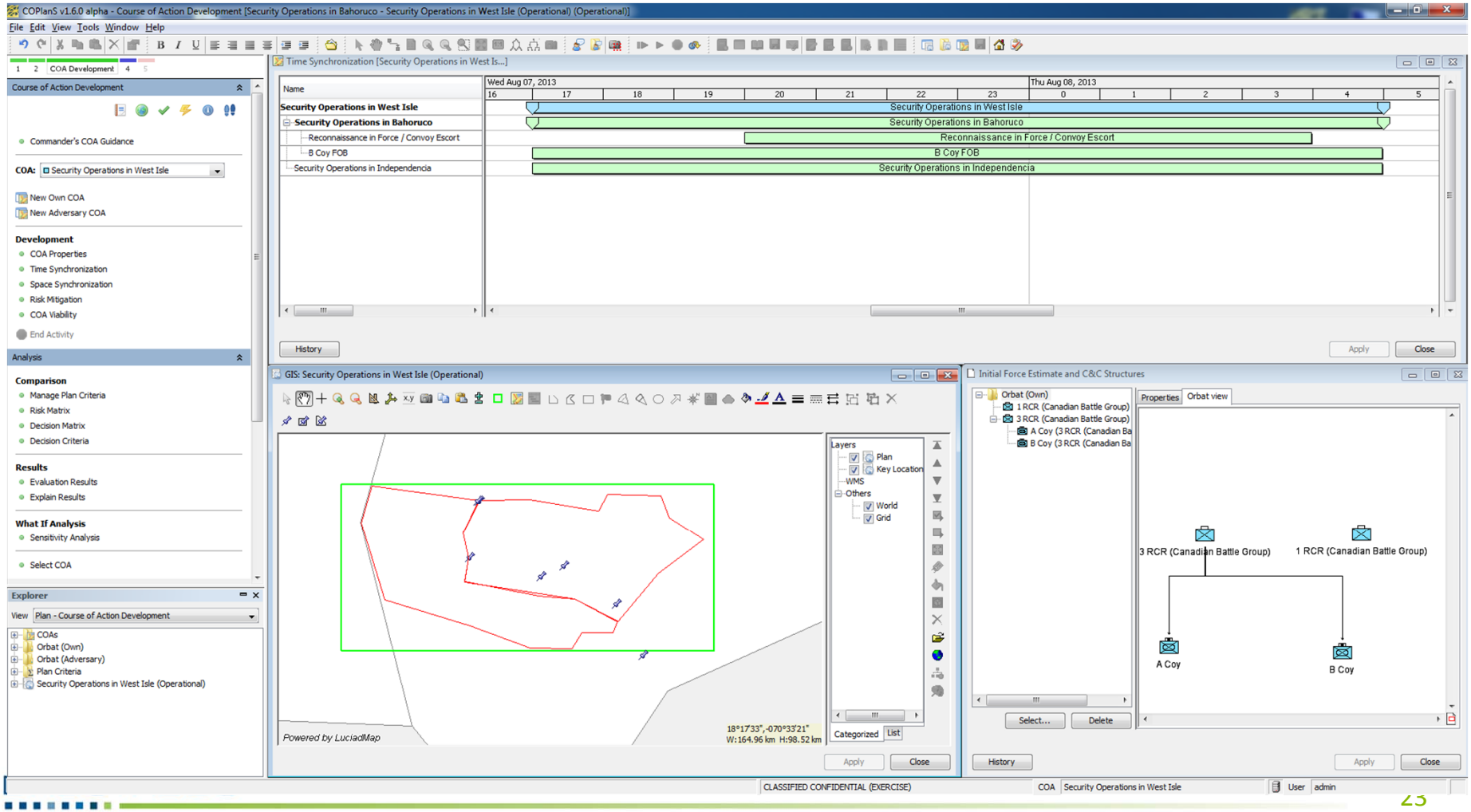
Demonstration: Reconnaissance in Force Patrol



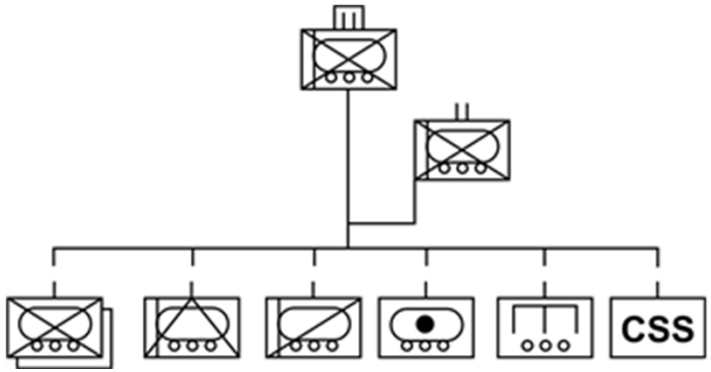
Demonstration

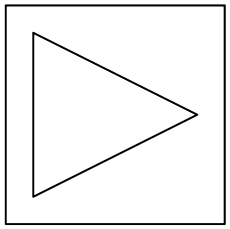


OPP (COPlanS) Data Exported to TPEM



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