Research & Development of Polyfunctional Intelligent Operational Virtual Reality Agents

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MISS

Rome
October 4th 2006

Goals

- **The development of operative Prototypes to be Run in a Federation for completing the Dynamic VV&A and Execution Phase of new generation intelligent CGF.**

- **To develop a new generation of Computer Generated Forces (CGF) PIOVRA (***Polyfunctional Intelligent Operational Virtual Reality Agents),* **to be used both for exercise scope, both for defence planning and support operations in an HLA Federation.**
- **New CGF should be in some extent "Intelligent", meaning that they should demonstrate co-operative and competitive behaviours (co-ordinating units both during operative actions and situation evaluation) based on the current boundary conditions and situation.**

Research Motivations

- To develop a new Generation of CGF able to simulate "Intelligent" behaviour, filling up the gap between user requirements and current available CGF performances
- To create PIOVRA intelligent CGF as effective models to be integrated in HLA Simulation for:
  - Training
  - Operation Planning
  - Operation Support

- To guarantee the possibility to Define/Configure PIOVRA CGF using Libraries and Effective Paradigms in order to guarantee Accreditation, Effectiveness and Usability of PIOVRA developments

PIOVRA Military Relevance

- **Development of a New Generation of Effective Intelligent Units to be used on:**
  - **Exercise**
  - **Defence Planning**
  - **Support to Operations,.**

- **The expected benefits of using PIOVRA CGF are:**
  - **reduction of human personnel operating directly the simulation system**
  - **increasing objectivity degree in the actions and the reactions of any of the simulated entities present in the battlefield (i.e., friend, foe or neutral)**
  - **Availability of "intelligent" PIOVRA CGF able to describe the reasons behind a particular operational behaviour (allowing to verify in an indirect manner, the doctrine, tactics and ROE).**

New CGF Application Areas

PIOVRA developments will be useful in :

- **Exercise functional area:**
  - PIOVRA CGF constitute the ideal "sparring partner" due to the constancy of their reactions and their possibility to reproduce realistic opponent actions and reactions.
- **Defence Planning area:**
  - PIOVRA CGF consents to verify operational plans in less time due to the absence, complete or partial, of human experts employed in the different roles foreseen by the Operational Plan under exam; also in this case the objectivity, the reaction constancy, the CGF decision motivation traceability represent significant advantages.
- **Support to Operations area:**
  - PIOVRA CGF are an essential element in performing realistic verification and ongoing real tactical situations possible progress evaluation by inserting them in the subject operation's simulation. Due to elevated degree of realism and extremely rapid simulation feedback these use become realisable only through the use of intelligent CGF.

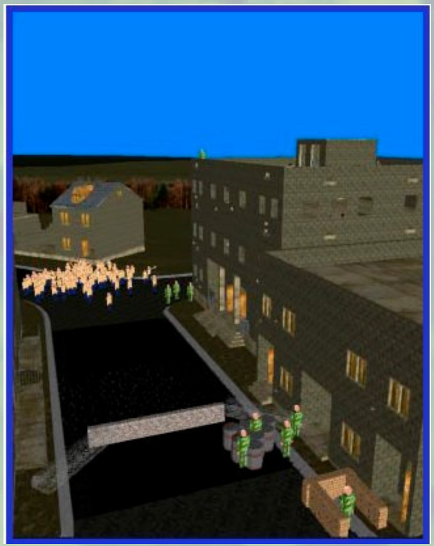
New CGF Characteristics

The PIOVRA CGF includes the following characteristics:

- User-Defined Initialising Parameters
- Analyse Surrounding Environment and React Respectively Capability
- Cooperative Capacity
- Force Aggregating/Desegregating Capability and relevant military hierarchy
- Resultant Aggregation Levels different from aggregating/desegregating elements sum/subtraction
- Limit Proper Autonomy to Achieve Common Objective Capability
- Stress Level Indicator applicable for the entities behaviour definition
- Implementation of Typical Human Behaviour (survival instinct and moral/ethical motivations)
- Distinct Friend, Enemy, Suspect and Neutral Units
- Explicit ROE justifying Proper Behaviour
- Military Reports to Higher Commanders Capability
- Decision Process Traceability
- Feedback capability
- CGF entities simulating various force levels

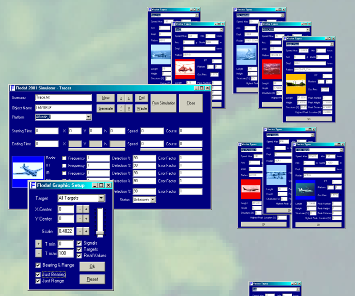
New CGF & Models

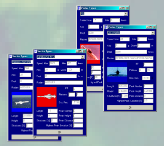
- New CGF need to be designed for incorporating an hierarchical scalable structure in order to be able to reach high level of details (i.e. single persons) without loosing the possibility to model large entities and with autonomous reporting capabilities for justifying their choices to external user.
- G-DEVS/HLA developments of PIOVRA guarantee the possibility to plug such models in PIOVRA CGF respecting consistency and speeding up VV&A processes.



PIOVRA CGF

- PIOVRA is devoted to develop HLA models of three different basic entities
  - Friends
  - Enemies
  - Suspects (including terrorists)
  - Neutrals

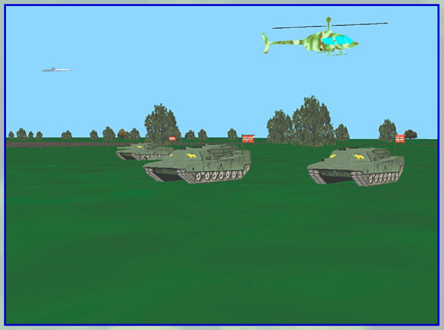




- PIOVRA Units represent different aggregations:
  - Single
  - Team
  - Squad
  - Platoon
  - Company Basic Extension

PIOVRA Units

- PIOVRA pays great attention into modelling Neutral Units representing civilians and their specific behaviours and logic



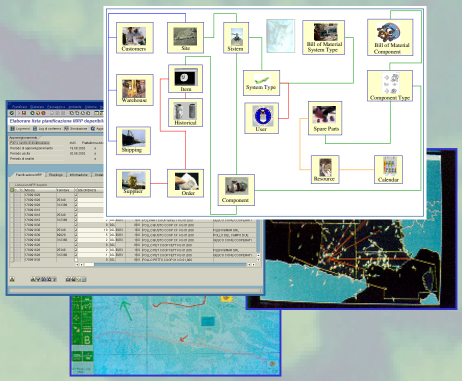
- Modelling special units such terrorist: a significant part of PIOVRA is devoted to create models for reproducing dynamically the human behaviour in complex scenario.
- PIOVRA entities include psychological parameters and models (i.e. "stress level" as aggregation level and of external situation function).
- The capability to reproduce such behaviour is based on the use of Artificial Intelligence directly integrated in the project

PIOVRA Modeling

- **PIOVRA Conceptual models for simulating a cooperative behaviour of PIOVRA CGF allowing their aggregation or separation depending on the situation** (clearly keeping in mind the command hierarchies for military units and managing their dynamic evolution during actions).
- **Modelling all the aspects and parameters for properly define the different units in terms of Rules Of Engagement (ROE); the use of Fuzzy Logic and Artificial Neural Networks allows to extend the validity range of PIOVRA Models**

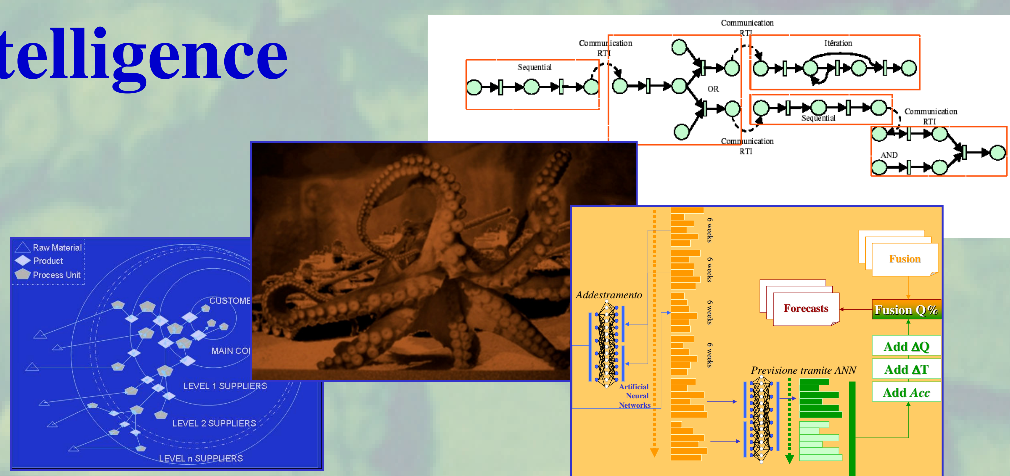
PIOVRA Components

- **PIOVRA Library allows to attribute specific intelligent behaviours to the operative units.**
- **PIOVRA CGF are integrated using High Level Architecture (HLA) in a Federation**
- **PIOVRA Federation as Executable Scenario with extended Capabilities for Testing and Experimenting the Models**
- **PIOVRA Reports and Feed-backs for guaranteeing the dynamic change of Rules of Engagement for PIOVRA CGF**



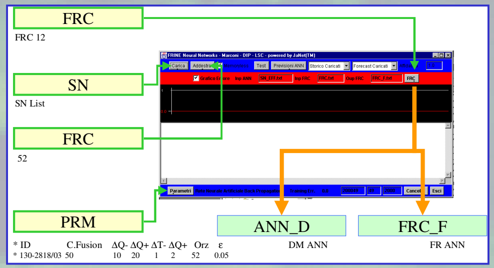
Expertise for New CGF

- Development of New Generation CGF is a quite breakthrough research and need to include real "intelligent" behaviours (in operative term) and able to be used in future simulation.
- This Challenge is enabled by very advanced technologies and strong experiences in their area:
  - Artificial Intelligence
  - G-DEVS
  - HLA



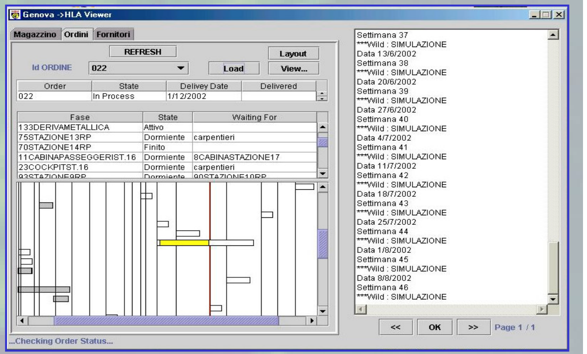
AI & PIOVRA

- The use of AI (Artificial Intelligence) in hybrid hierarchical models request to combine different techniques in order to be successful.
- The PIOVRA project expect to experiment different integration architecture combining:
  - Fuzzy Logic (balancing Boundary Conditions & Scenario)
  - Artificial Neural Networks (self-learning)
  - KBS (behaviour justification)
  - Data Fusion (Situation Assessment, Threat Assessment)
  - Swarm Intelligence (Cooperative Intelligent Behaviour)



Integration & HLA

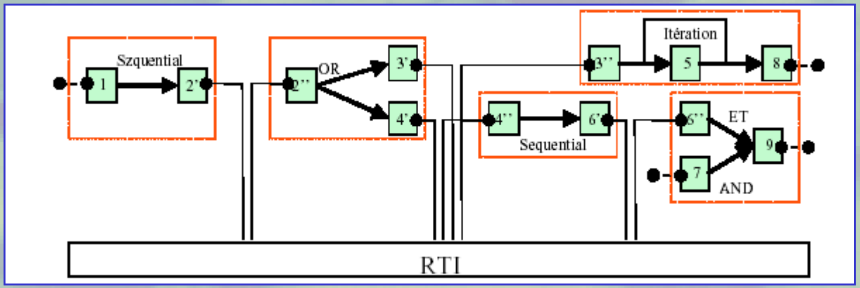
- The interoperability of the PIOVRA components is strictly based on HLA in order to maximise their integration capabilities and improve the efficiency of their hierarchical structure.
- The Development of PIOVRA Units as HLA federates support the accreditation and testing of their performances

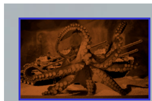


- PIOVRA CGF communicating/cooperating/competing through HLA allows to guarantee potential extensive use of PIOVRA units on complex scenario just by adding federates.

Modeling & G-DEVS HLA

- The design and development of PIOVRA Models is expected to be realised in a G-DEVS/HLA framework, tailored for PIOVRA, able to consider both the continuous components (i.e. movement) and discrete (i.e. events and actions) integrate in High Level Architecture.
- The PIOVRA model repository will be developed as an effective Library based on G-DEVS paradigm in order to guarantee the parameters and behavioural firmware pre-determination very precisely and carefully by expert teams of automated components

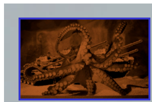




PIOVRA Partners

The use of Excellence Centers with long tradition in research applied to industrial projects and mutual cooperation is a critical issue for guarantee the success of PIOVRA initiative:

- **MISS DIPTEM, Genoa University**
  - **Leader & Coordinator**
- **LSIS, Marseille**
- ***Liophant Simulation***

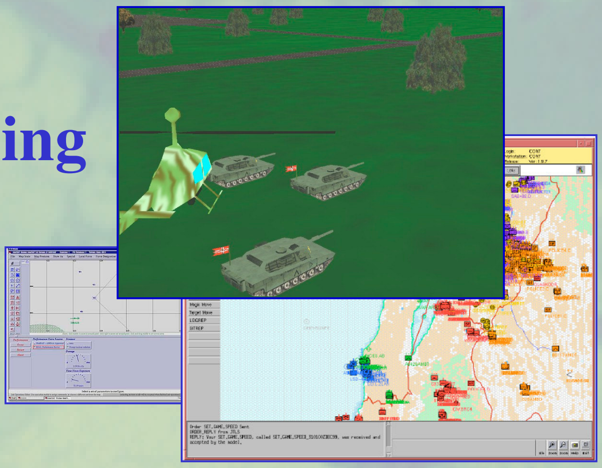


Scenario Definition

- PIOVRA includes a detailed scenario definition to be used for metrics and performance evaluation of the models developed and their fidelity and effectiveness.
- A demonstration phase on a complex scenario is expected to be used as framework for experimenting and analysing the PIOVRA federation; the scenario is expected to be integrated with war gaming systems (i.e. JTLS) in order to simulate/study specific situations.
- PIOVRA VV&A represent a very important and significant task in order to guarantee the success of the initiative.

PIOVRA Prototype

- PIOVRA project main goal is to complete a Prototype for completing Experimental Analysis based on DOE (Design of Experiments) for the VV&A and Execution of PIOVRA models.
- The Project Partner previous experiences guarantee the possibility to benefit from their skills and libraries in order to obtain also with the Budget Requested an Executable System for full Validation of PIOVRA models over Operative Scenarios.
- Prototype integrated with war gaming systems in order to simulate/study specific situations.



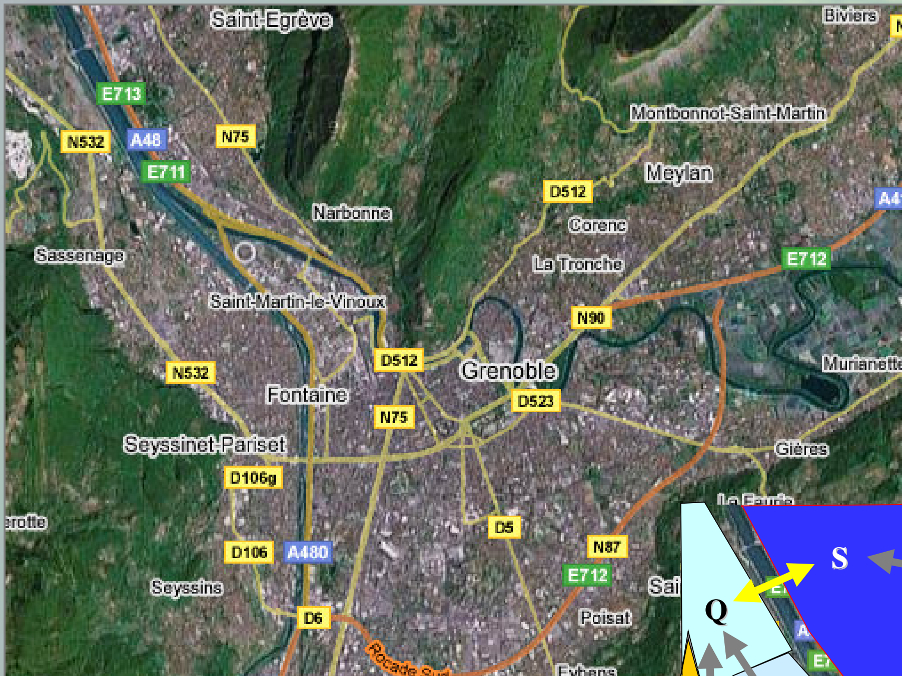
PIOVRA Objects

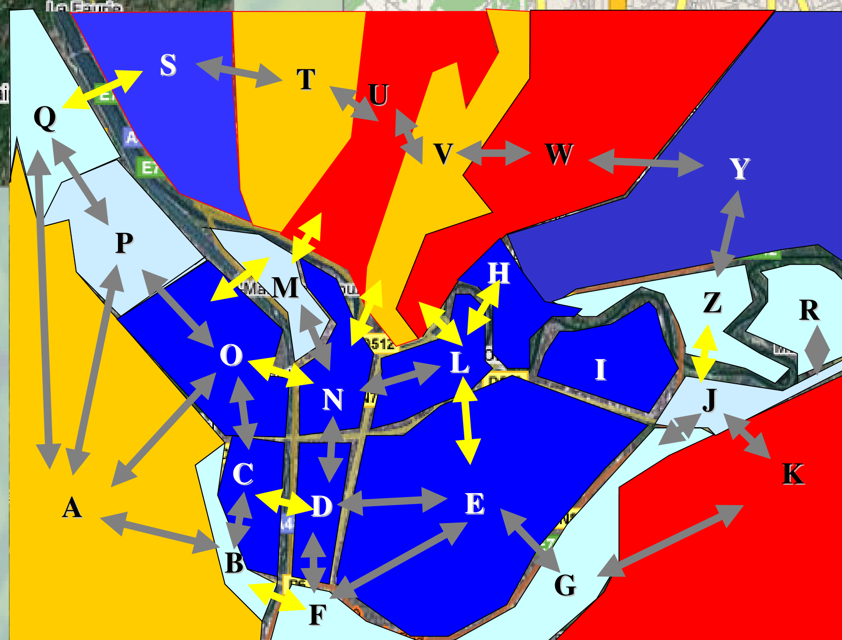
Comportment Objects are dedicated to the simulation of actors that represents behaviors of populations, movements or analog entities to where units on the field belongs.

Action Objects are units that have the task to simulate particular elements acting in the scenario like a military unit, a terrorist, a political representative. They can also simulate particular events like riots, demonstrations, etc. Part of the Action Objects is generated in function of a particular state of one or more Comportment Objects.

Support Objects include all the objects don't representing human actors of the Scenario, but influent phenomena; for instance Support Object List includes Weather Object as well as Zone Objects.

PIOVRA ZONES

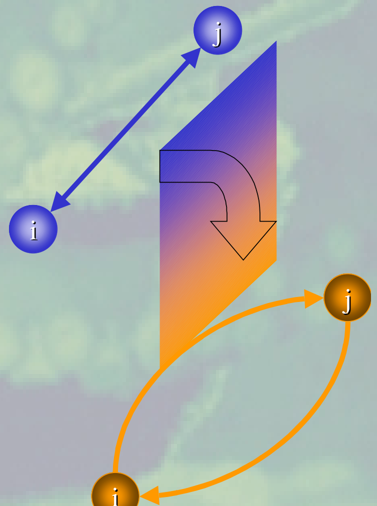


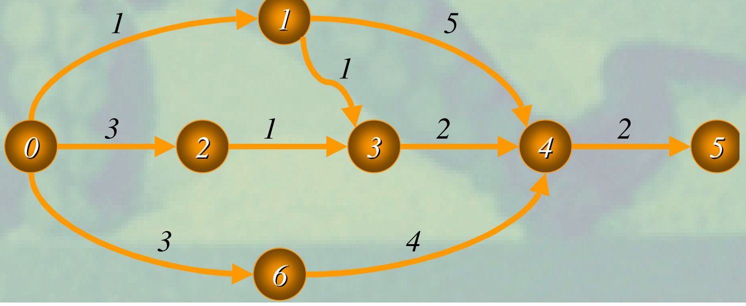


In the proposed context, the movement algorithms are devoted to control any action object which moves inside PIOVRA Zone and each Zone Object is an entity that includes movement links and ground characteristics

PIOVRA Movements

Holonomic Movement	• It is based on Zone Object Characteristics • It is devoted to move entities on the map identifying the Zone where the unit is operating
Vectorial Movement	• Is based on Zone Object Characteristics • It considers the links connections among the Zone Objects and road networks as reference for each movement





Psychological Modifiers

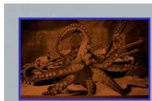
Currently the research is focusing on the Following Psychological Modifiers are under Analysis:

- Fear
- Stress
- Fatigue
- Aggressiveness

PIOVRA

Fear

Event Generating Fear
Montecarlo Technique
Fear Generated Level
Size/Force Vs. Event Impact
List of Object Zones Perceiving the Event
Object Zone
B%+K%+Z%+B%+Y%+X%=1
Fear Effect
Cool Characteristic
0%
100%
B%
X%
K%
Y%
Z%
N%
No Effect
Paralysis
Escape
Aggressive Level Increase
Stress Level Increase
Fatigue Resistance Increase
Stress Level Modifier
Fatigue Level Modifier
Action Object
Action Object
Action Object
Action Object
Action Object
Action Object
List of Action Objects inside the Zone



Fatigue

Fatigue is state corresponding to temporary loss of strength and energy resulting from hard physical or mental work; physical fatigue (equivalent to physical debilitation for Pavlov) is generated by anything that physically weakens the organism, this is supposed to increases the likelihood of crisis (transmarginal inhibition).

$$FL_j(t_{i+1}) = FL_j(t_i) + Dfc\left(SOP_j(t_i), zone_j(t_i)\right)\cdot\left(t_{i+1} - t_i\right)\cdot Hf\left(FL_j(t_i), Dfc\left(SOP_j(t_i), zone_j(t_i)\right)\right)$$

$$Hf(FL_j(t_i), y) = \begin{cases} y \le 0 & Gsf_j \cdot kff_1 \cdot \sqrt{\dfrac{FL_j(t_i)}{bf_1} + 1} \\ y > 0 & Gsf_j \cdot kff_2 \cdot \dfrac{\sqrt{\dfrac{FL_j(t_i)}{bf_2} + 1}}{FL_j(t_i) + 1} \end{cases}$$

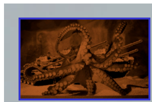
where:

- $FL_j(t_i)$ is the Fatigue Level of the j-th Action Object at i-th event time
- $SOP_j(t_i)$ Status of Operation of the j-th Action Object in i-th event time
- $zone_j(t_i)$ Zone location of the j-th Action Object in i-th event time
- Dfc(x,y) Unitary Continuous Change in Fatigue Level due to Status x in Environment y
- Gff_j Fatigue Factor Characteristics of j-th Action Object
- Hf(x,y) Function for reproducing Hysteresis and Saturation on Fatigue depending on current status as well as current increase
- kff_1, kff_2 Factors for tuning Hf Function Impact
- bf_1, bf_2 Factors for tuning Hf Function Period

$$FL_j(t_i) = FL_j(t_i) + Dfe\left(E_i\right)\cdot Hf\left(SL_j(t_i), Dfe\left(E_j\right)\right)$$

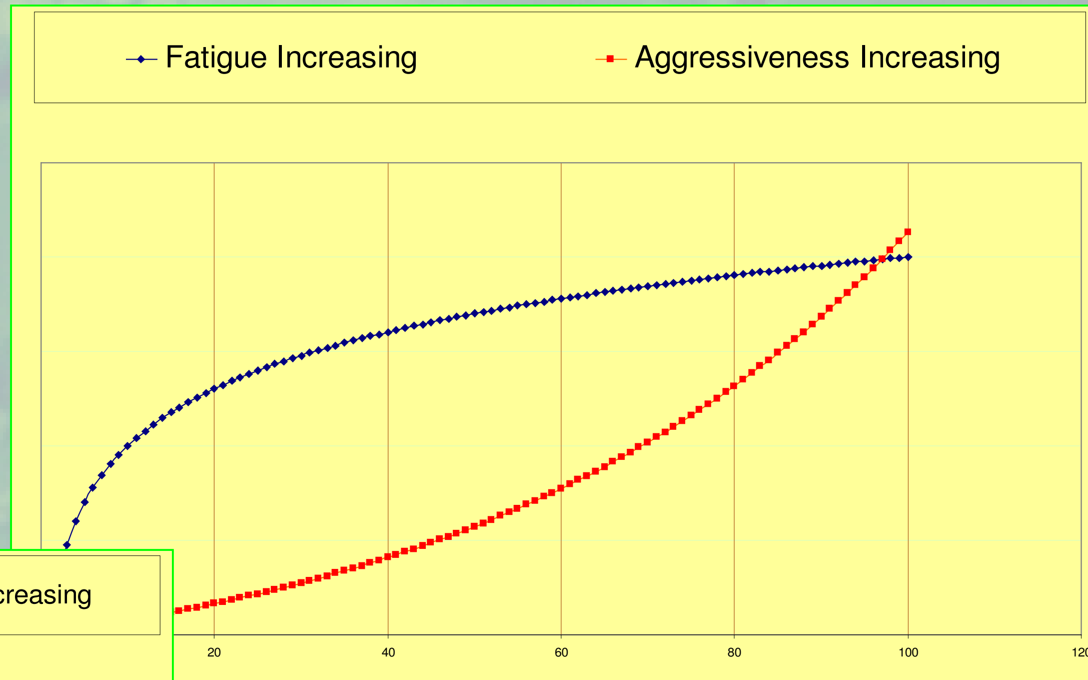
- E_i Event affecting the j-th Object at i-th event time
- Dfe(x,y) Event Discrete Change in Fatigue Level due to Status x in Environment y

- **Fatigue Continuous Variance**
- **Event Affecting Fatigue**



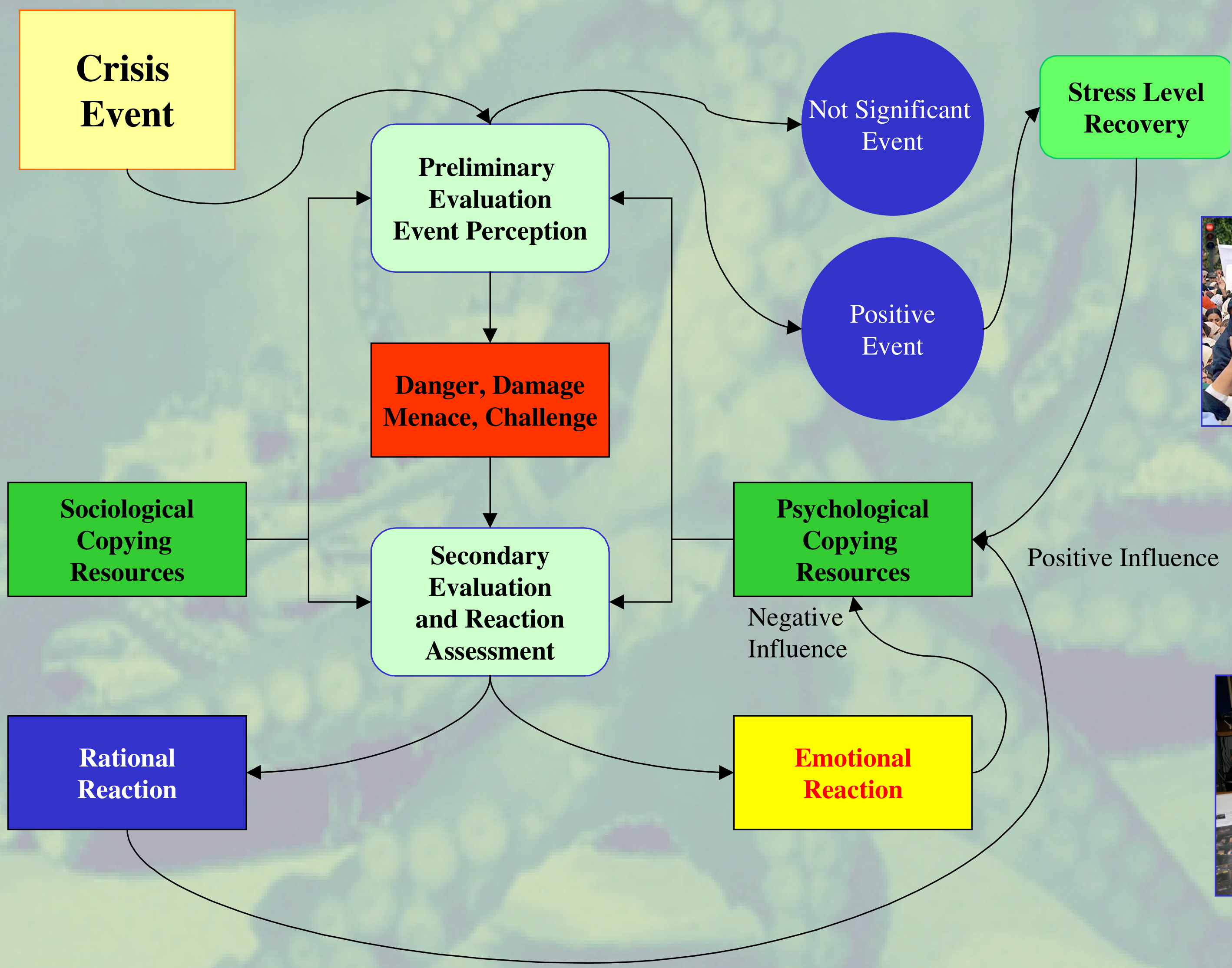
Different Evolution Trends

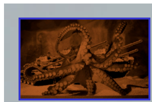
Fatigue is characterized by saturation in increasing and faster recovery during early phases in our range of analysis



Aggressiveness increases based on exponential escalation and relaxes back slowly

Stress Reaction





PIOVRA

Aggressiveness

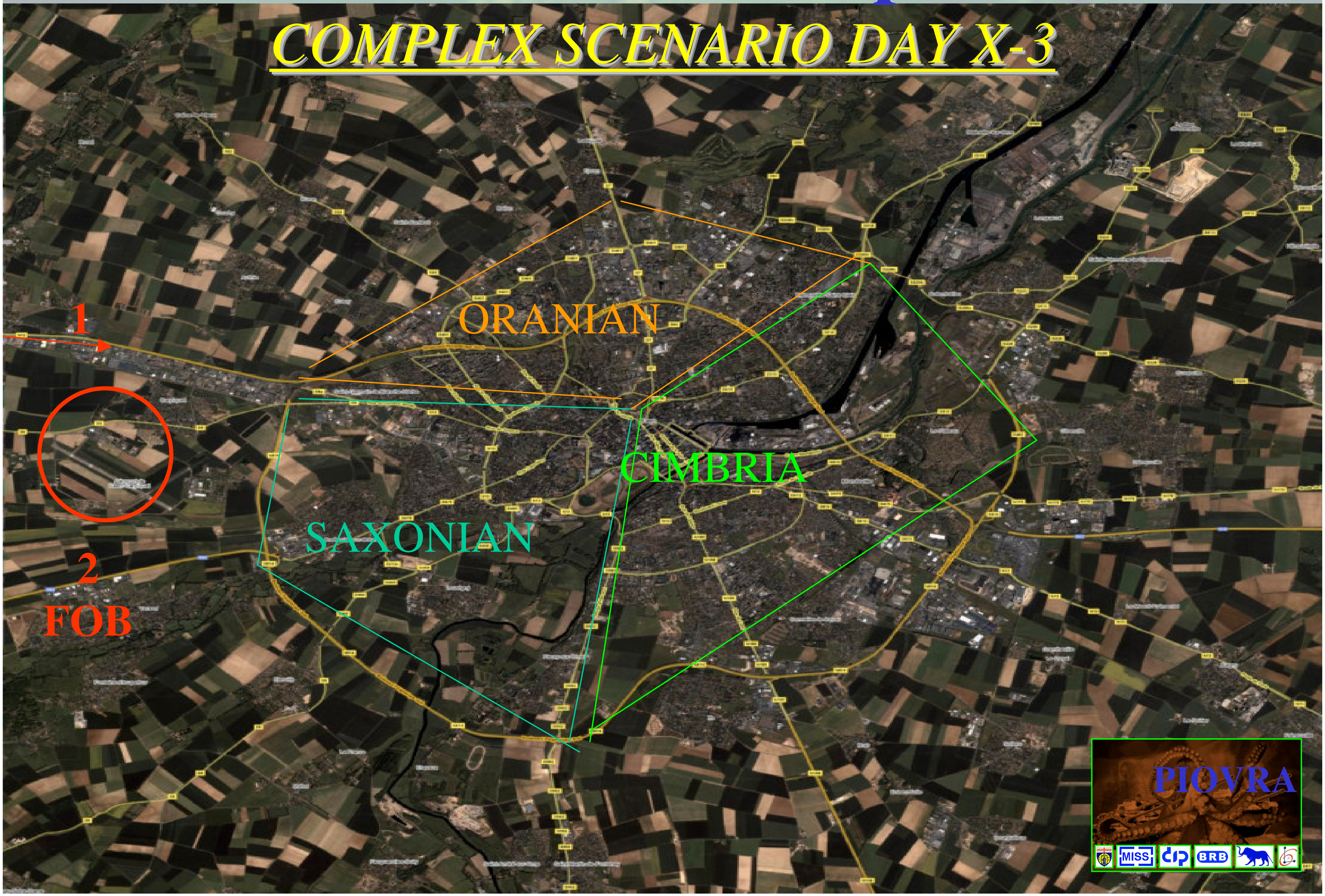
The aggressiveness emerges usually as result of:

- Benefit Opportunity Perception (rational aggressiveness); this is influenced by individual aggressive capacity, gender difference and behavioral models
- Negative Emotions (hostile aggressiveness): this is related to a provocation (perception of an hostile attitude), personality difference and other emotion and negative feeling including physical pain, weather stress factor (hot) and irritation.

Aggressiveness is heavily influenced by sociological conditions in term of size of the group, cultural models, media influence etc.

Scenario Example

PIOVRA



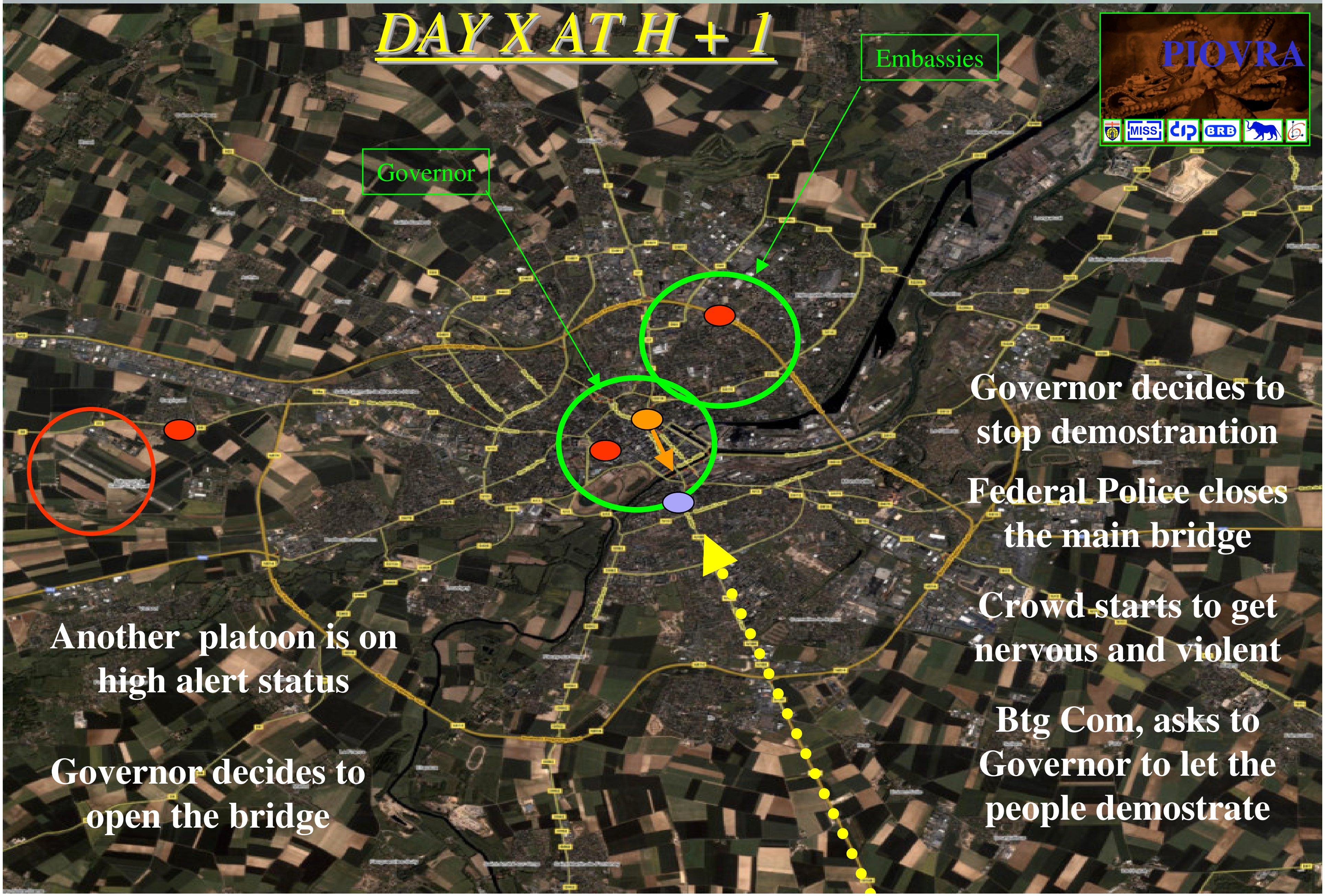
Scenario Example

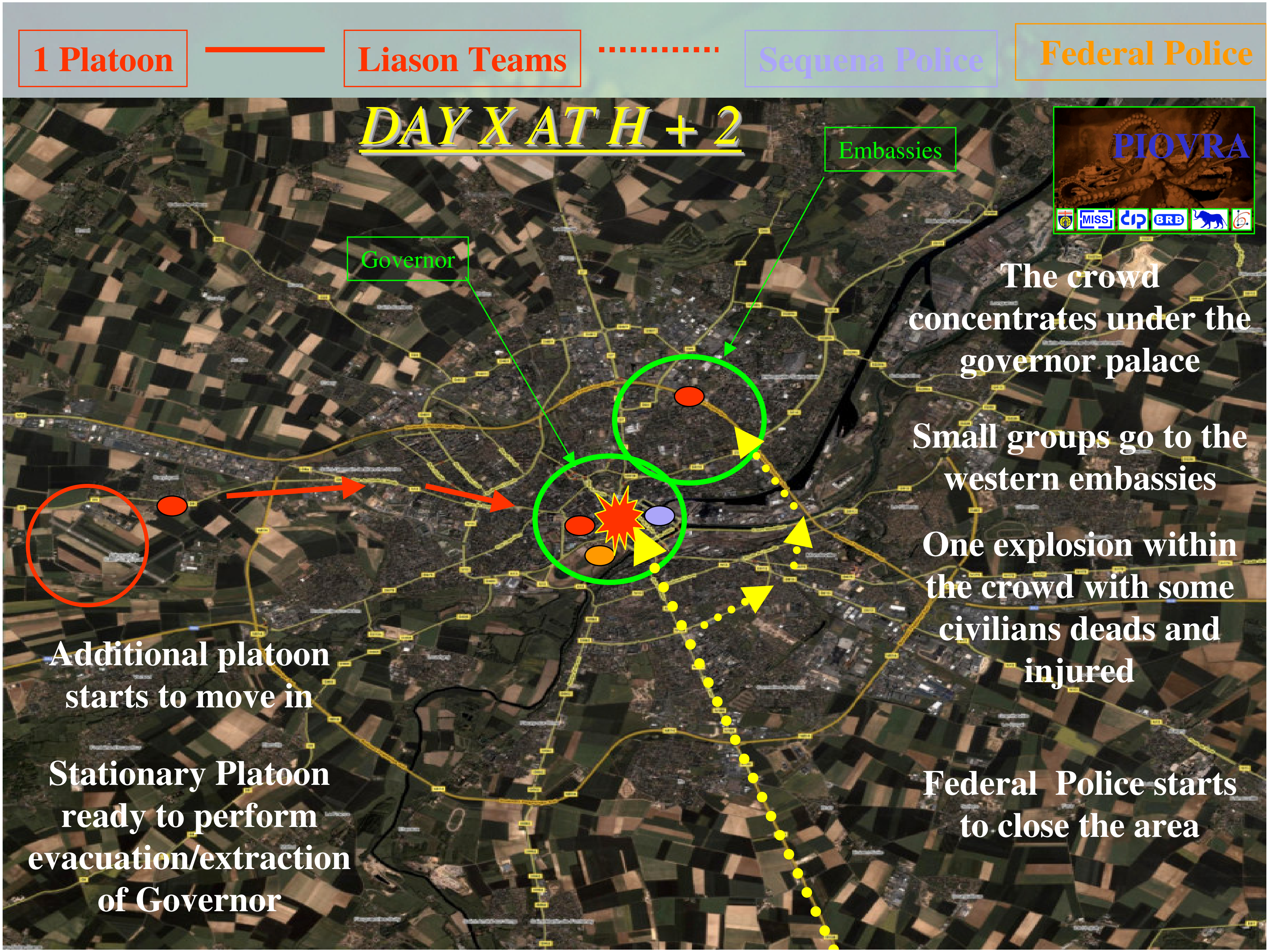
PIOVRA


1 Platoon
Liason Teams
Sequena Police
Federal Police
DAY X AT H
Embassies
Demonstration
Governor
PIOVRA
MISS
BRB

1 Platoon | Liason Teams | Sequena Police | Federal Police

DAY X AT H + 1




1 Platoon
Liason Teams
Sequena Police
Federal Police
DAY X AT H + 2
Embassies
PIOVRA
Governor
The crowd concentrates under the governor palace
Small groups go to the western embassies
One explosion within the crowd with some civilians deads and injured
Additional platoon starts to move in
Stationary Platoon ready to perform evacuation/extraction of Governor
Federal Police starts to close the area

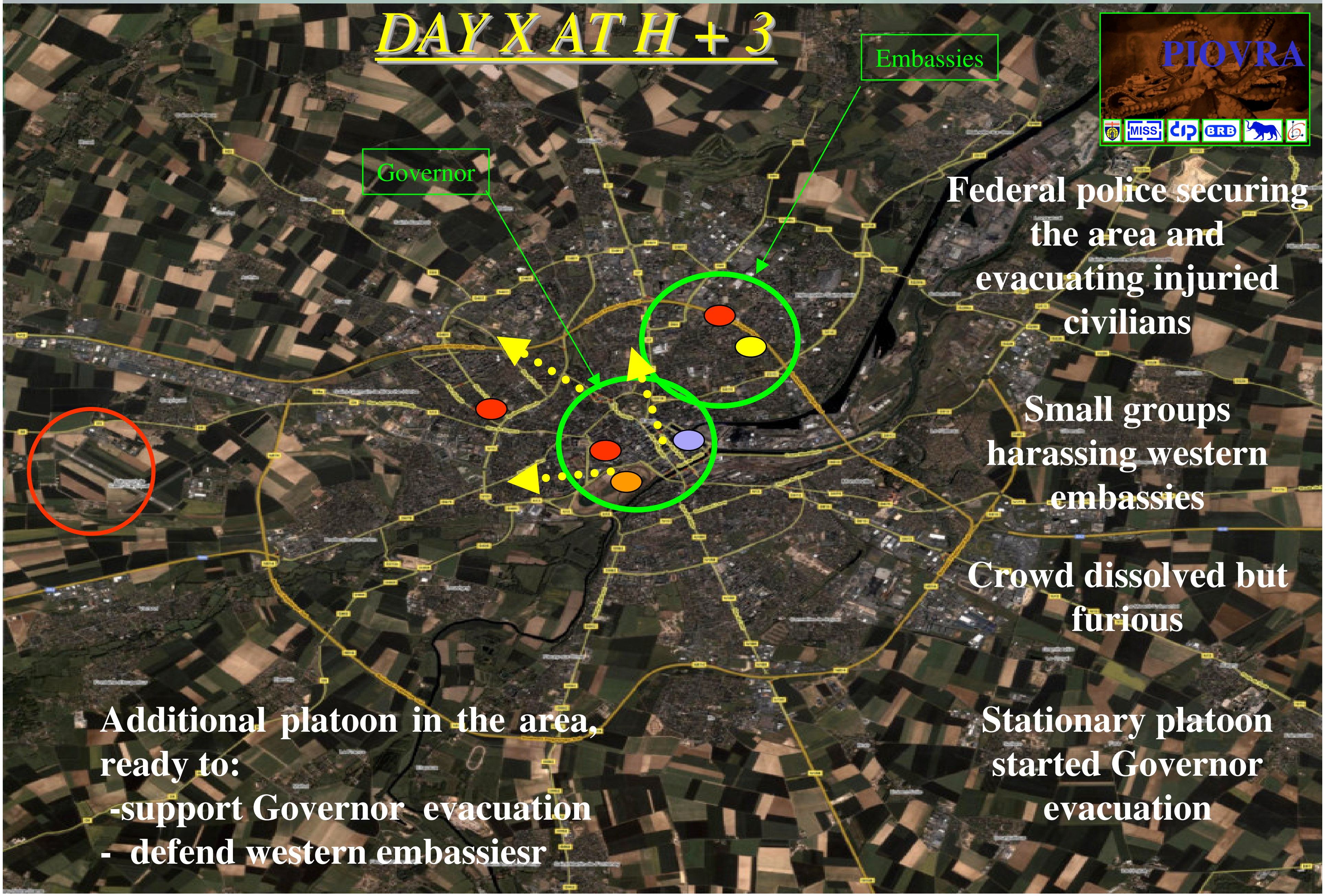
1 Platoon

Liason Teams

Sequena Police

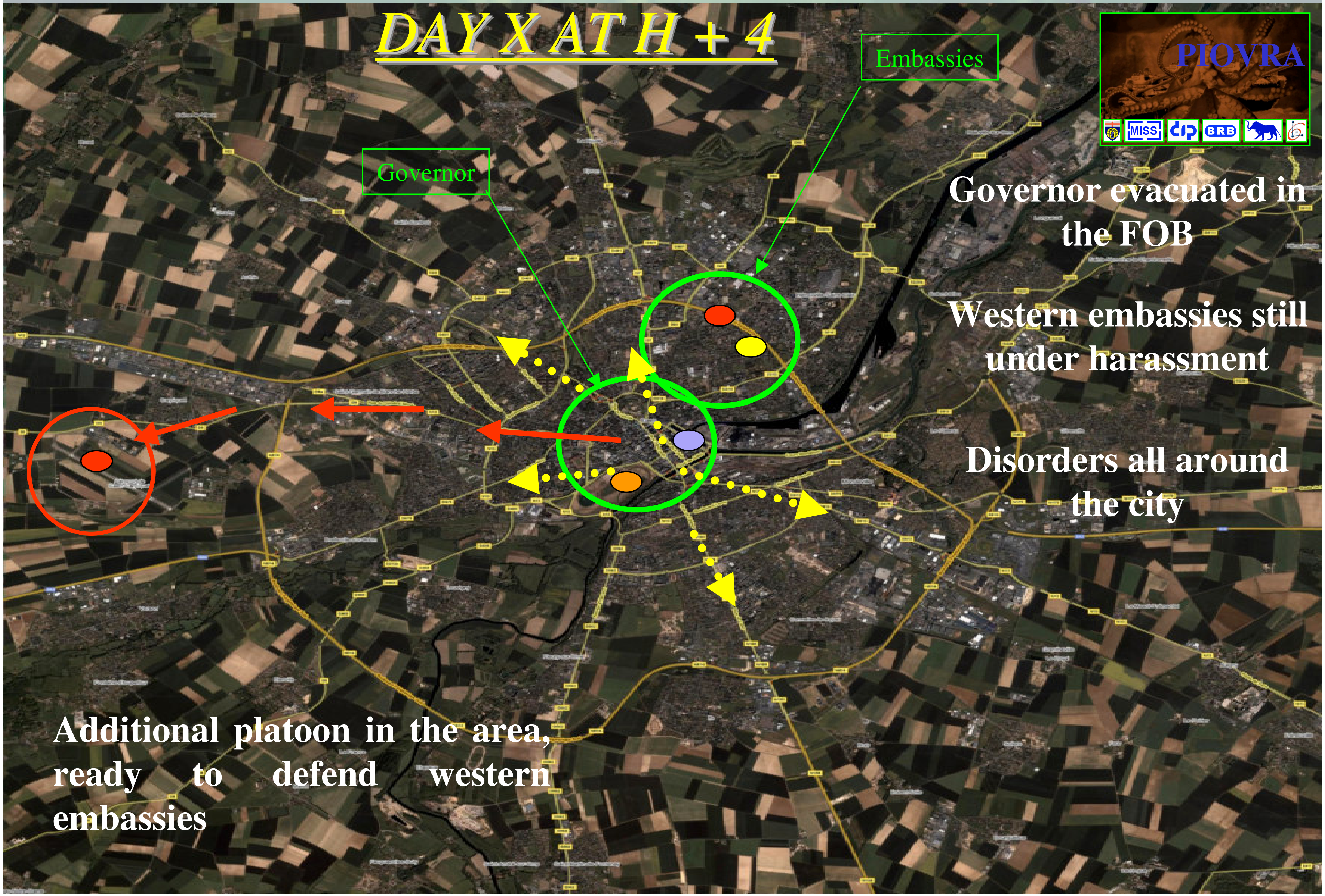
Federal Police

DAY X AT H + 3



1 Platoon | Liason Teams | Sequena Police | Federal Police

DAY X AT H + 4

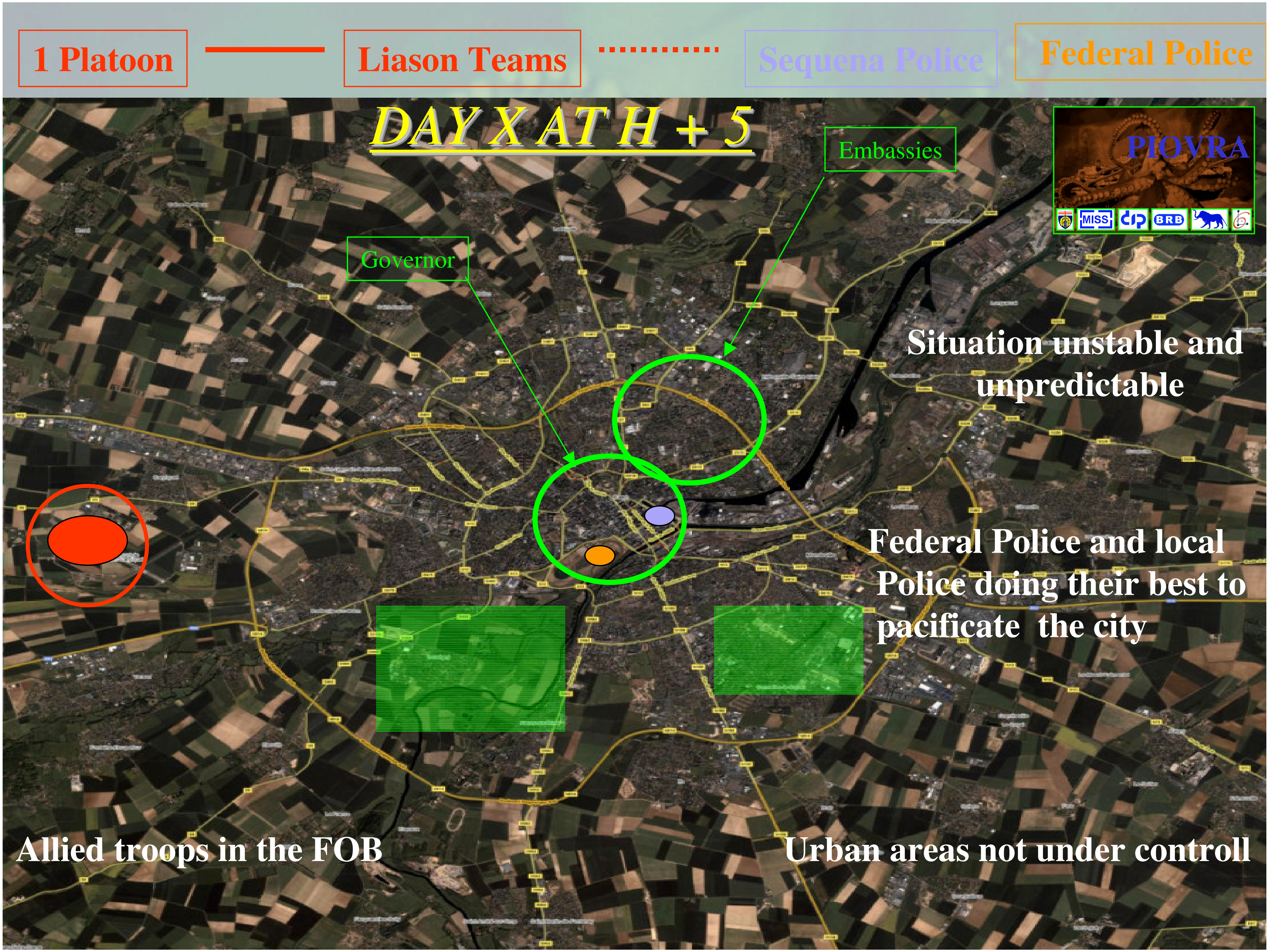


Governor evacuated in the FOB

Western embassies still under harassment

Disorders all around the city

Additional platoon in the area, ready to defend western embassies


1 Platoon
Liason Teams
Sequena Police
Federal Police
DAY X AT H + 5
Embassies
PIOVRA
Governor
Situation unstable and unpredictable
Federal Police and local Police doing their best to pacificate the city
Allied troops in the FOB
Urban areas not under controll

SIMULATION DAY X AT H00

SIMULATION AT COI 18 May 2006

SIMULATION DAY X AT H16

SIMULATION AT COI 18 May 2006

Summarizing

- **PIOVRA Project is devoted to Create New CGFs that introduce innovative characteristics in Simulation Scenarios**
- **PIOVRA CGFs introduce a Competitive Advantage for using Simulation in Exercise/Planning & Operation Support respect existing tools and packages**
- **PIOVRA results will be completely validated and verified as well as integrated in a Prototype representing at least a very advanced stage of development of a full capable Simulation Federate**

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