Computational Red Teaming for Correction of Traffic Events in Real Time Human Performance Studies

Never Stand Still

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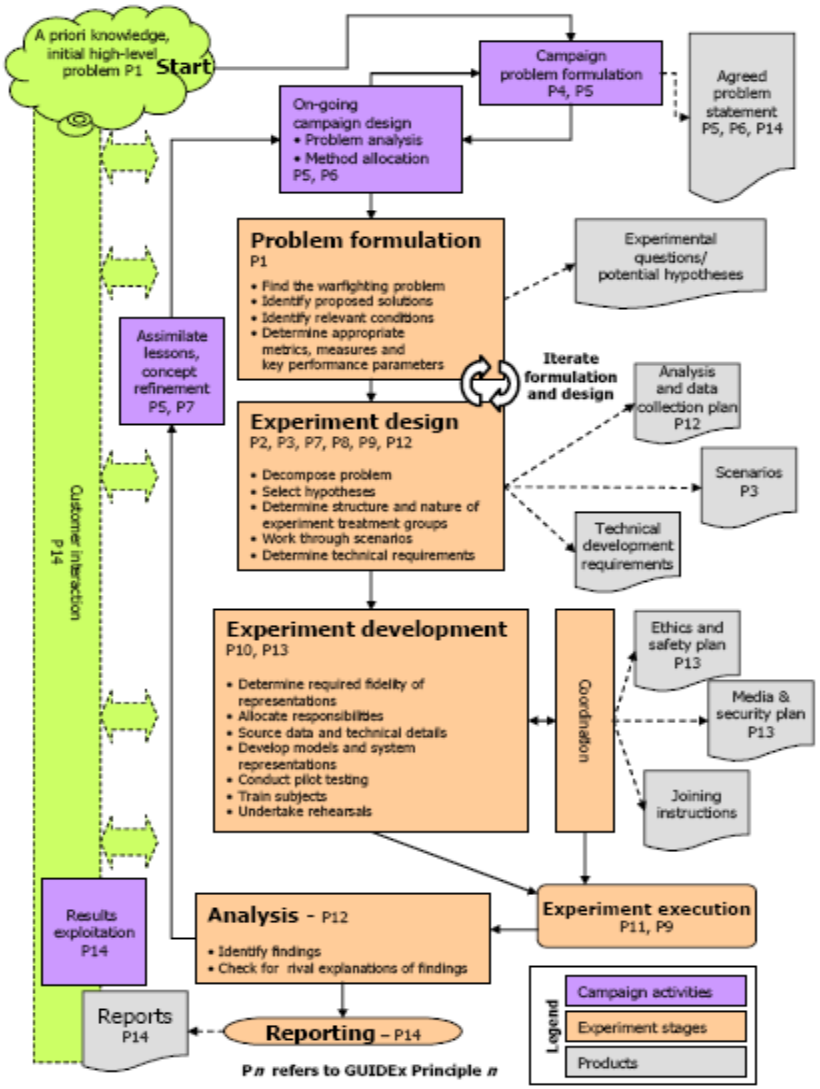
Outline

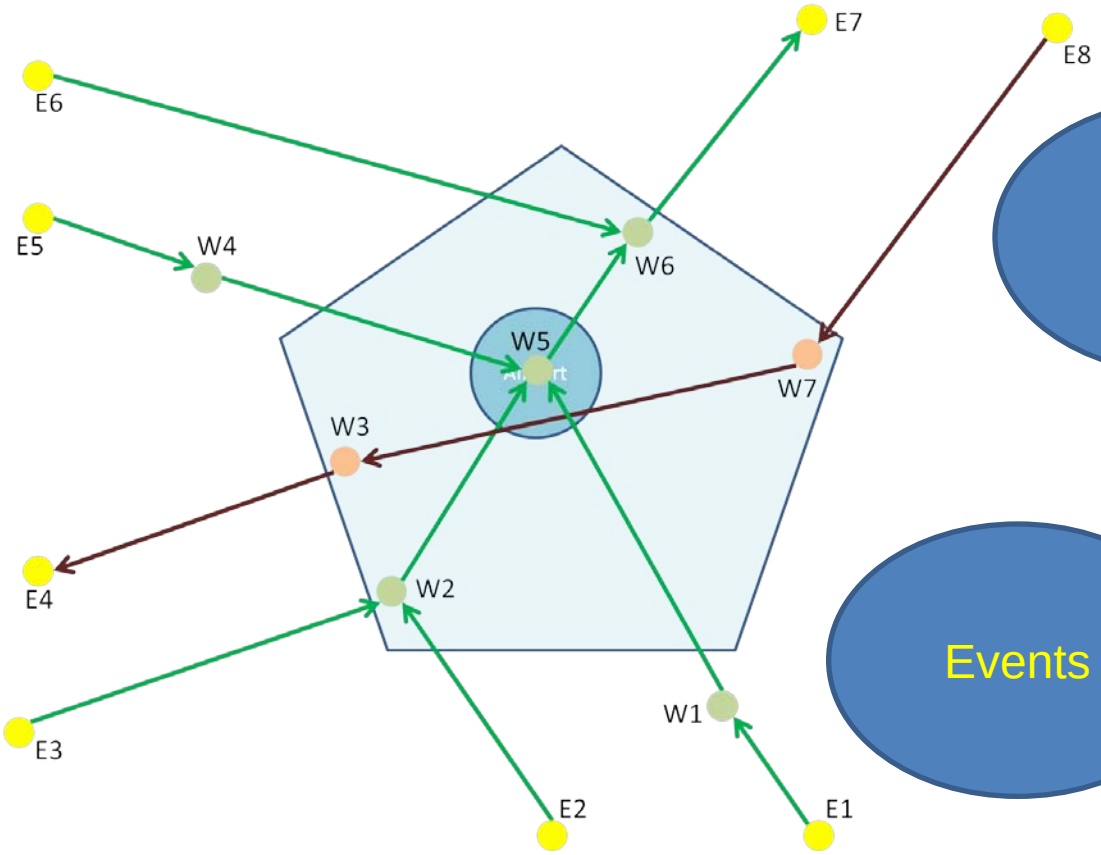
- Motivation
- The Concept
- Problem Definition
- Approach
- Results
- Future Work

Motivation



Source: GUIDEx, 2011

Motivation



Routes

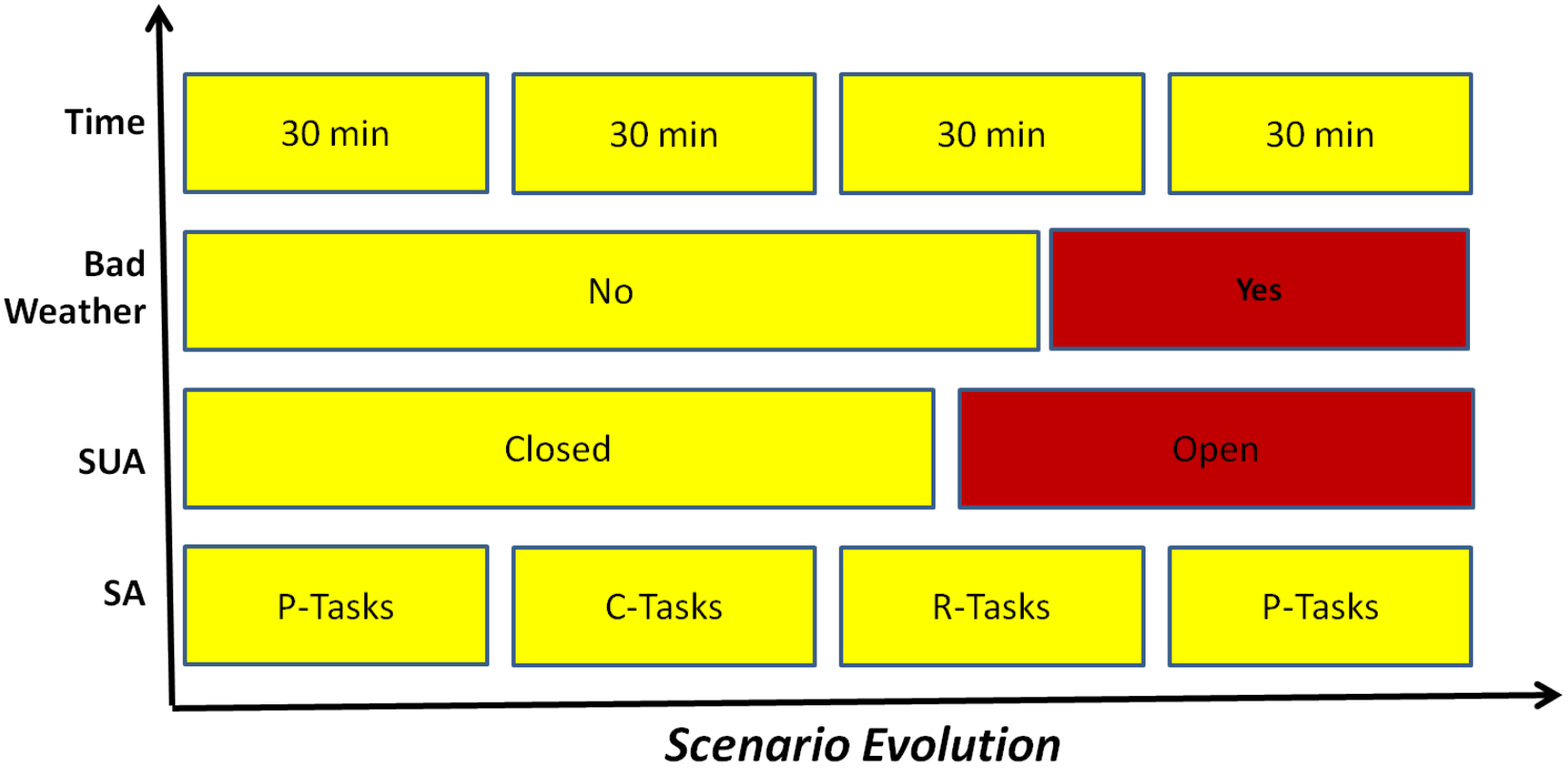
Fleet Mix

Airspace

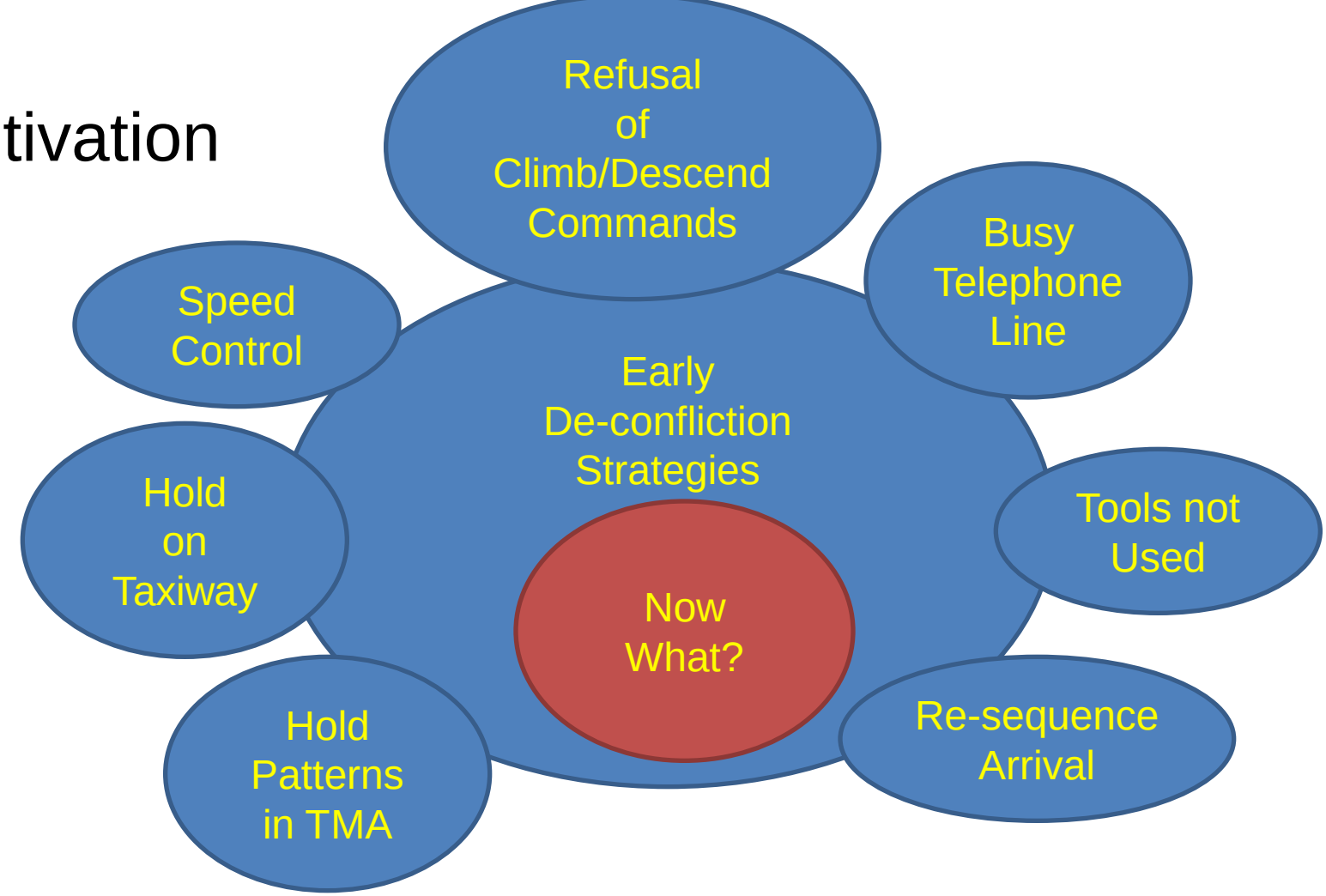
Events

Scheduling

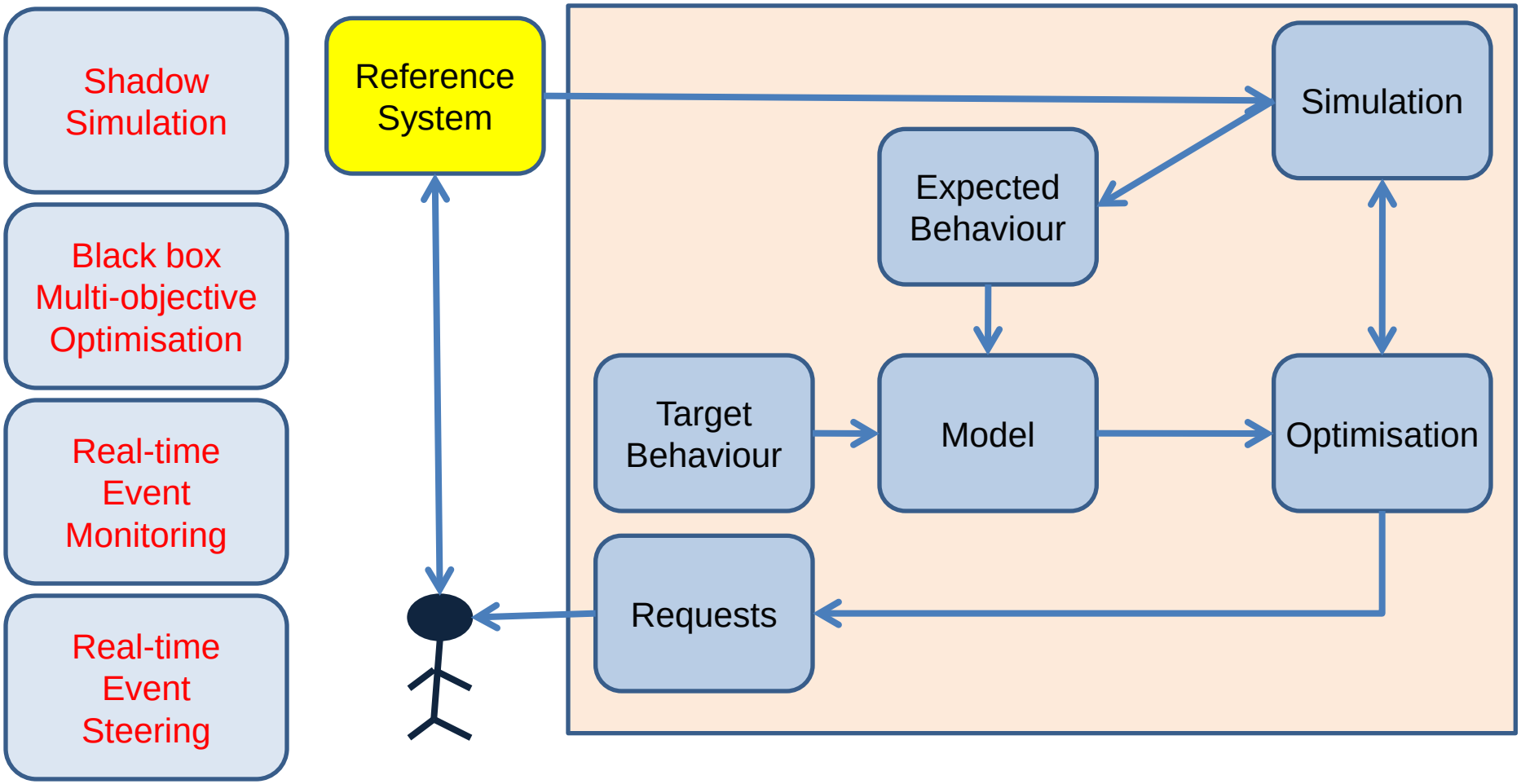
Motivation


Time
30 min
30 min
30 min
30 min
Bad Weather
No
Yes
SUA
Closed
Open
SA
P-Tasks
C-Tasks
R-Tasks
P-Tasks
Scenario Evolution

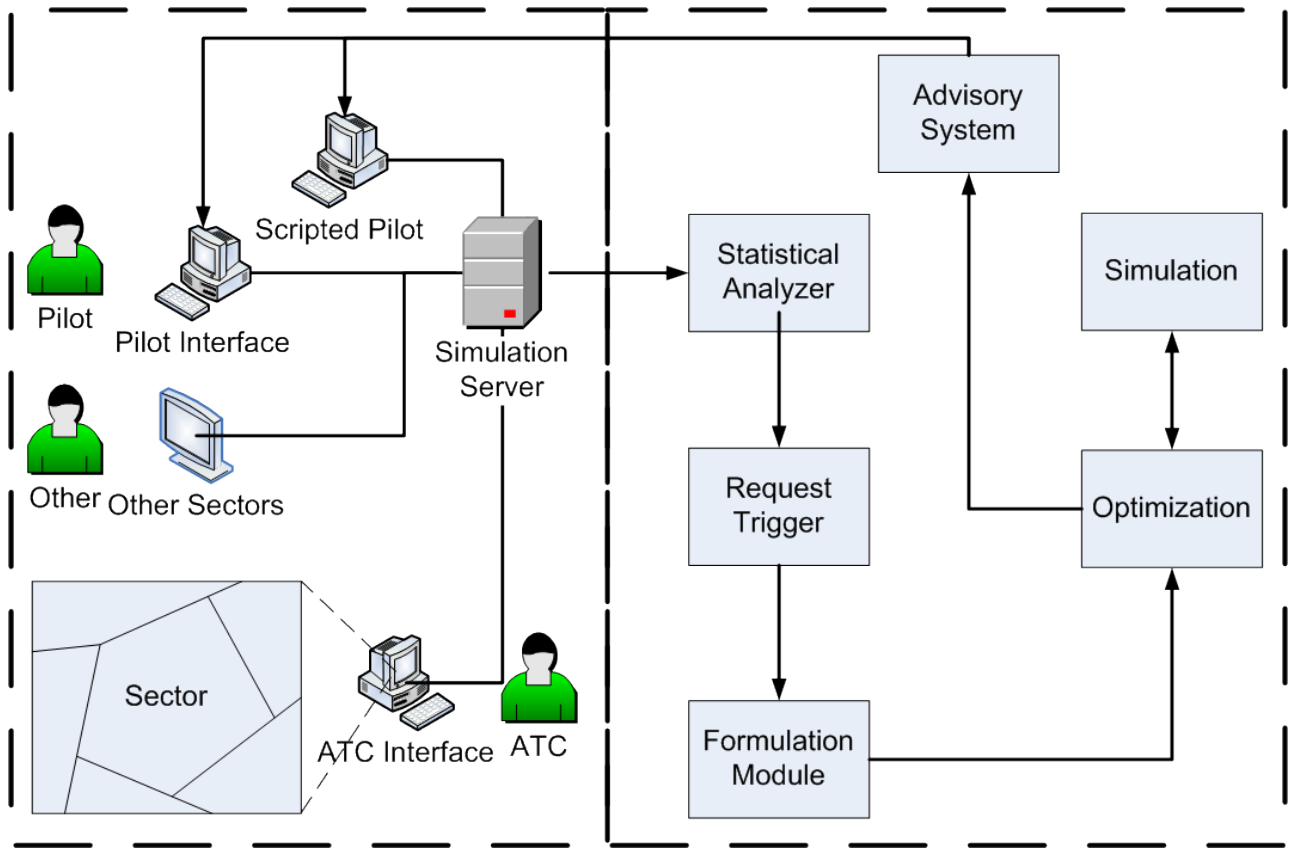
Motivation


Refusal of Climb/Descend Commands
Busy Telephone Line
Speed Control
Early De-confliction Strategies
Hold on Taxiway
Tools not Used
Now What?
Hold Patterns in TMA
Re-sequence Arrival

The Concept – Computational Red Teaming for Human Experiments



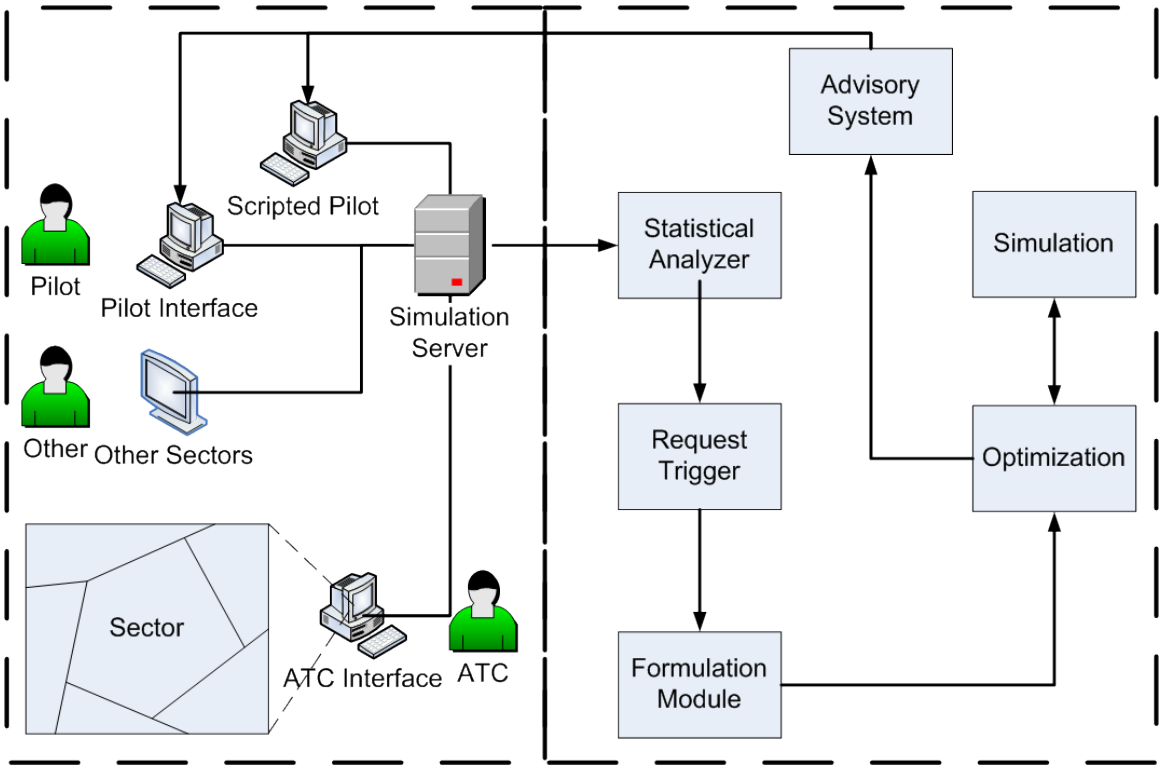
The Concept – Computational Red Teaming for Human Experiments



Aim

- Develop a Computational Red Teaming (CRT) environment to run in parallel to the real time simulation
- The CRT environment will monitor real time simulation and detect deviations from designed effects
- If deviation is detected, simulation and optimisation engine will run to find actions to counteract the actions causing the deviations

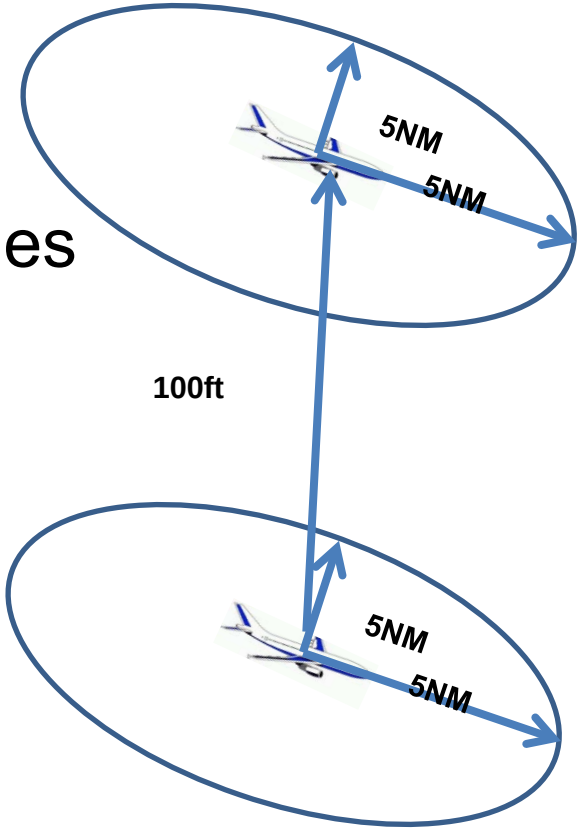
Meeting the Aims



- Types of events
- Detection of deviations
- Type of requests
- Frequency of requests
- Efficiency of optimisation

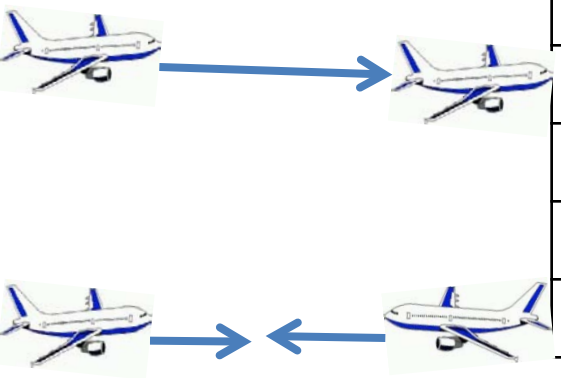
Simulation: Conflicts

- Horizontal separation ≤ 5 Nautical Miles
- Vertical separation ≤ 1000 feet

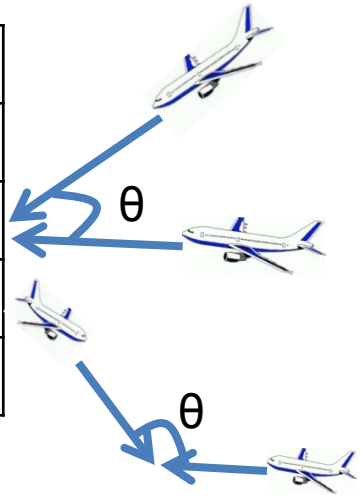


Simulation: Conflicts

- Classification of conflicts



Category	Criteria
In-Trail	θ ≤ 0° + t
Crossing Narrow	0° + t < θ ≤ 90° + t
Crossing Wide	90° + t < θ ≤ 180° - t
Head-On	180° - t < θ ≤ 180°



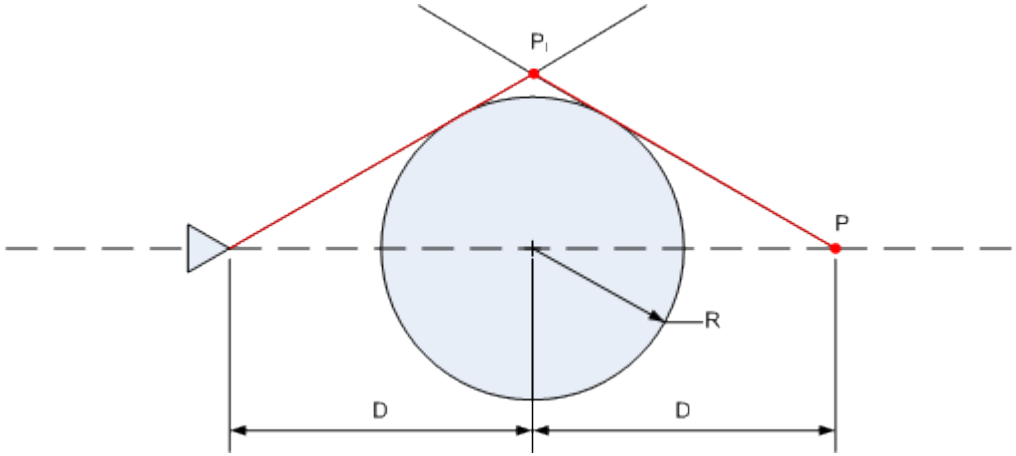
$$\min\left((|\alpha-\beta|),(360-|\alpha-\beta|)\right)$$

Simulation: Detection of deviations

- Could be done in many ways
  - Time-based
  - Event-based
  - Human trigger

Requests

1. Change flight level
2. Reschedule overfly time
3. Avoid an area ahead on the route
4. Skip an upcoming waypoint



Requests: Time & Probabilities

- Requests are made at random times within 5 minutes of the most recent request
- Probability of requests are determined from input data from the optimisation component

$$P(r_n) = \frac{R_n}{\sum_{i=1}^{N} R_i}$$

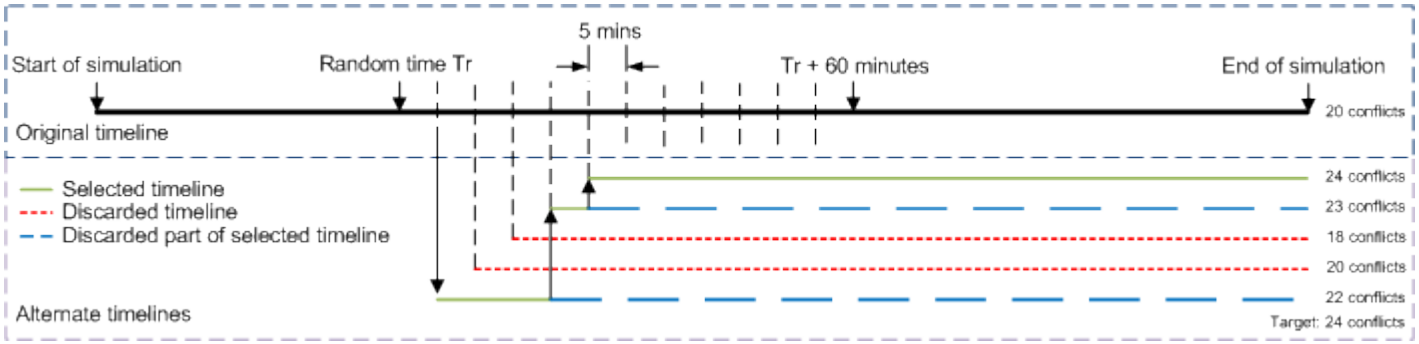
$$P(a_m) = \frac{A_m}{\sum_{j=1}^{M} A_j}$$

Real time correction of traffic events

- A time is chosen and it is decided if the scenario requires modification
- Multiple lists of probabilities are generated using differential evolution
- Each list is used as input for the simulation to produce a list of requests
- The requests cause the number of conflicts to increase or decrease

Real time correction of traffic events

- Each simulation is evaluated using goal programming
- Limited to five minutes
- If objective is not met then continue cycle in 5 minute intervals



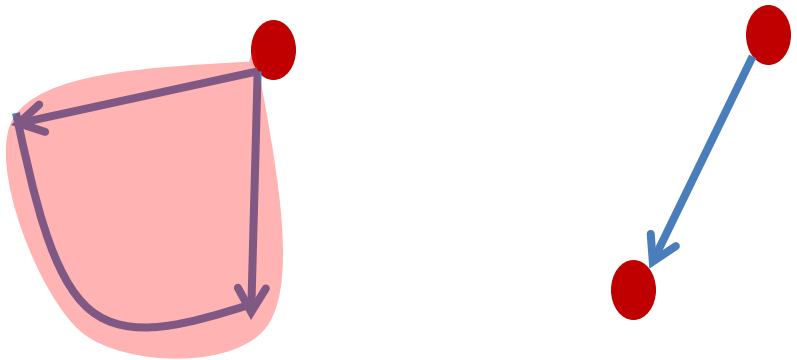
- Insert best list of requests into real time simulation

Optimisation: Differential evolution

- What is evolutionary computation?
  - Population-based stochastic optimisation methods
  - Combines the power of Monte Carlo Simulation with Optimisation
- Why evolutionary computations for this problem?
  - Black box optimisation
  - Stochastic optimisation → variations in response

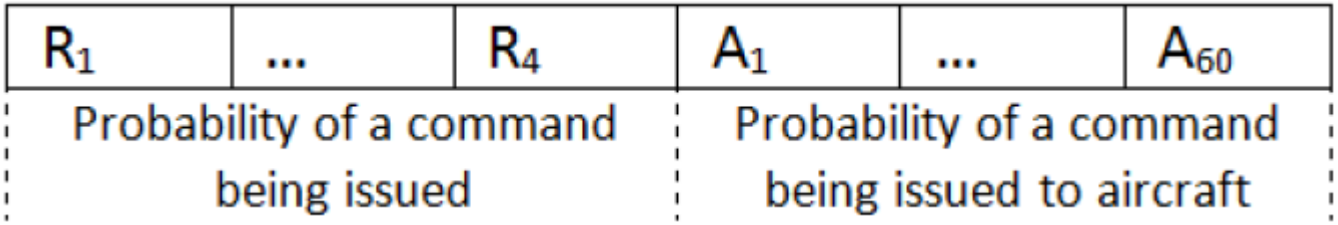
Optimisation: Differential evolution

- Why differential evolution?
  - One of the fastest EC methods
  - Relies on approximate stochastic gradients for black-box optimisation



Optimisation: Differential evolution

- Produces a list of un-normalised probabilities (solutions) which are used as input for the simulation



- Uses the fitness of each solution to decide on possible directions where the fitness function will improve

Optimisation: Fitness

- For each group:

$$x_n - d_i^+ + d_i^{-1} = T$$

Where: x_n = number of conflicts in group n

T = target number of conflicts for group n

d_i^+ and d_i^- = deviation from target

- Fitness for simulation:

$$f = \sum_{i=1}^{N} d_i^+ + d_i^-$$

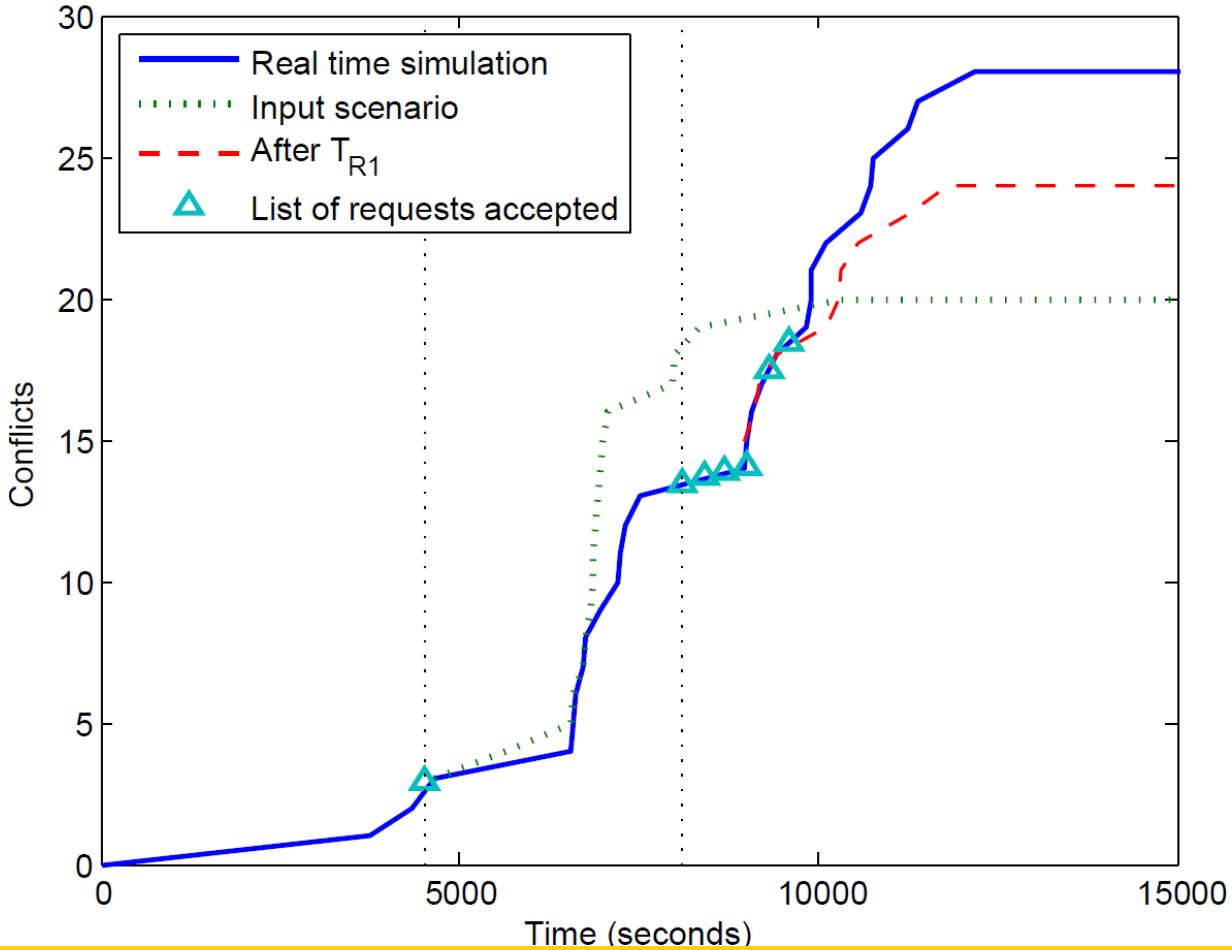
Experimental setup

Experiment	Event at T_{R1}	Event at T_{R2}
I	Increase	
D	Decrease	
I-I	Increase	Increase
I-D	Increase	Decrease
D-I	Decrease	Increase
D-D	Decrease	Decrease

- 4 different input scenarios for each experiment
- Each scenario consisted of similar characteristics:
  - Same route structure with 6 routes
  - 10 aircraft for each route
  - 20 conflicts with 5 conflicts in each conflict group

Results

- Experiment I-I with scenario 3 as input



Results: Number of conflicts in simulation after the insertion of requests

Experiment	Scenario 3		
	Input	T_{R1}	T_{R2}
I	20	24	
D	20	16	
I-I	20	24	28
I-D	20	24	21
D-I	20	16	19
D-D	20	16	13

Results: Deviation of the number of conflicts from the target for each conflict group

Experiment	Scenario 3							
	TR1				TR2			
	IT	CN	CW	HO	IT	CN	CW	HO
I	-1	+1	0	0				
D	0	0	0	0				
I-I	-1	+1	0	0	0	+1	-1	0
I-D	-1	+1	0	0	0	0	0	0
D-I	0	0	0	0	0	0	0	-1
D-D	0	0	0	0	0	0	0	+1

Conclusion

- A computational red teaming approach for the correction of air traffic events in real time human performance studies was developed
- Problem was modelled as a goal programming model, where deviations from goals are minimized
- Objectives met with benefits that can be applied to other safety critical simulations

Thank You!

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