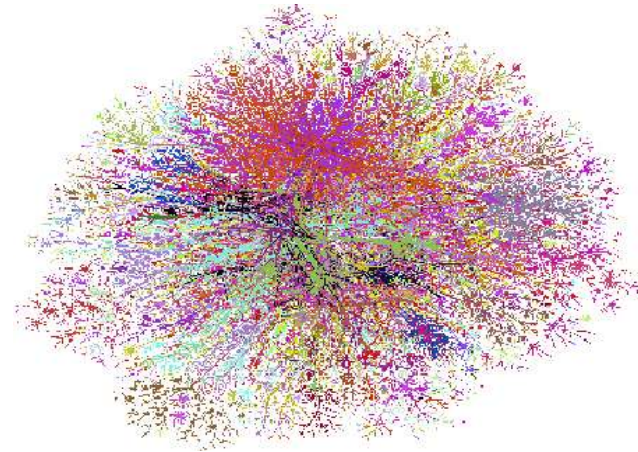




Eric Rigaud

Centre de recherche sur les Risques et les Crises

24 octobre 2012 ■ ■

A framework for modeling the consequences of the propagation of automation degradation: application to Air Traffic Control systems

E. Rigaud³, E. Hollnagel³, C. Martinie¹, P. Palanque¹, A. Pasquini², M. Ragosta¹⁻², S. Silvagni², M. Sujan⁴

¹ University Paul Sabatier - ICS-IRIT, ² DeepBlue Srl, ³ Mines-Paristech / ARMINES, CRC,

⁴ Warwick Medical School - University of Warwick

Technological assessment

To consider in a systematic way, the potential consequences of new technologies in order to anticipate wanted and both potentially reversible and not reversible unwanted effects (adapted from Westrum 1991).

Automation
description

Consequences
Inventory

Risks and
Opportunities
assessment

Interpretation

How will the
technology evolve?

What will the
technology be used
for?



Who will the
technology users be?

Who will decide how
the technology will be
used?

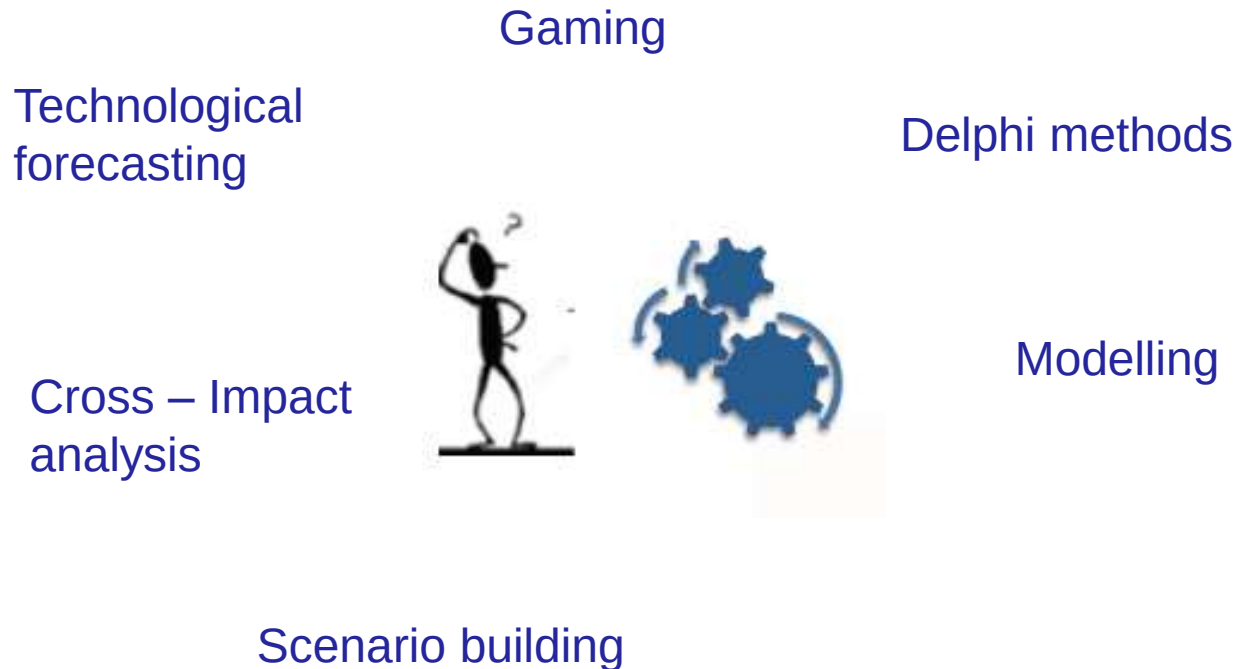
What will be the
consequences of technology
degradations ?

Ecology of action

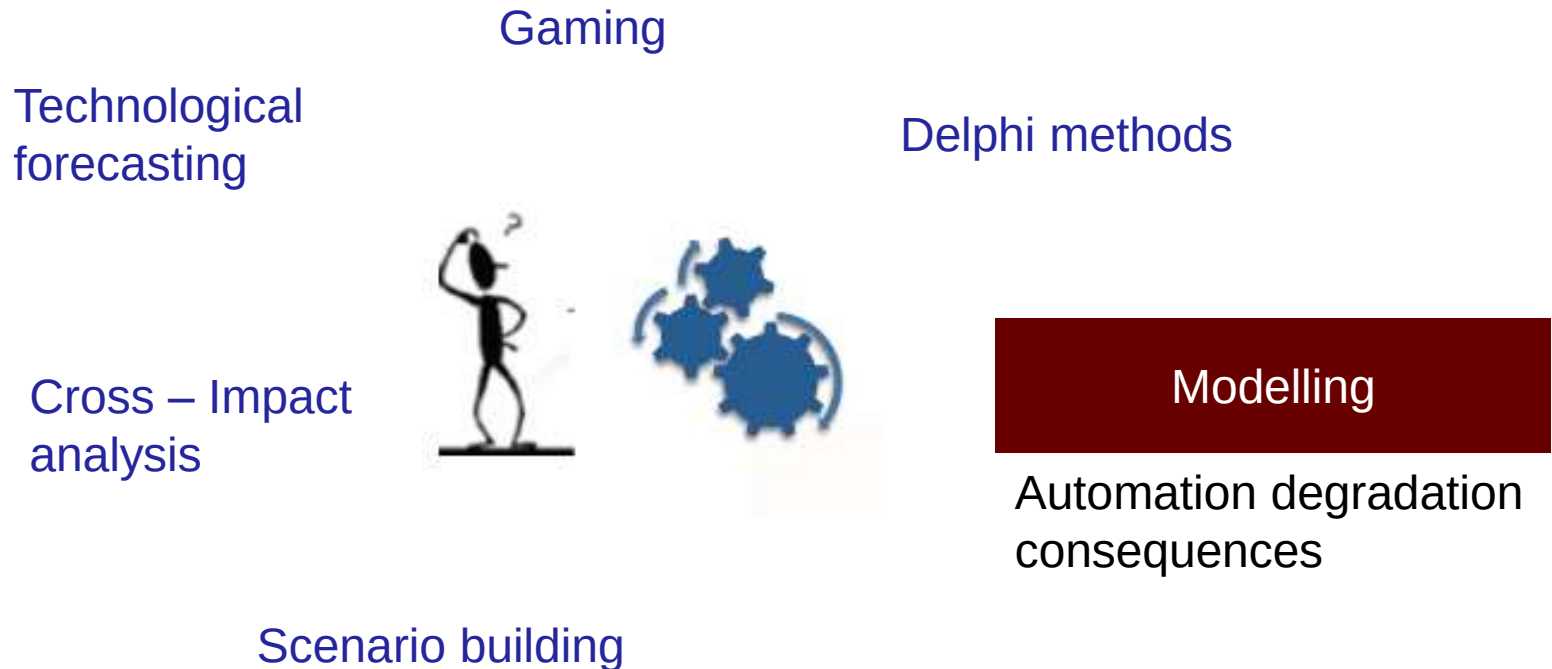
Given the multiple interactions and feedbacks within the environment in which they take place, action, once started, often beyond the control of the actor, causing unexpected and sometimes even contrary effects to those expected (Morin 1990).

- Perverse effect (the unexpected adverse effect is greater than the expected beneficial effect)
- Futility of innovation (the more things change, the more they stay the same)
- Threat of achievements (we want to improve system, but only succeeded in removing the freedoms and safety).

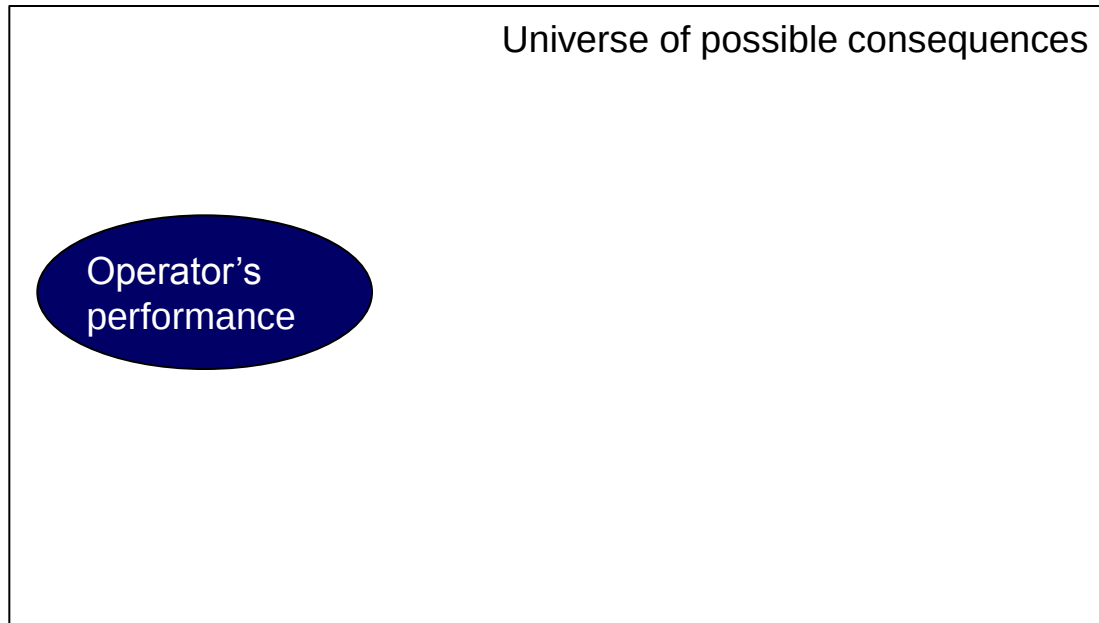
Consequences assessment



Consequences assessment



Automation degradation propagation in LSSTS

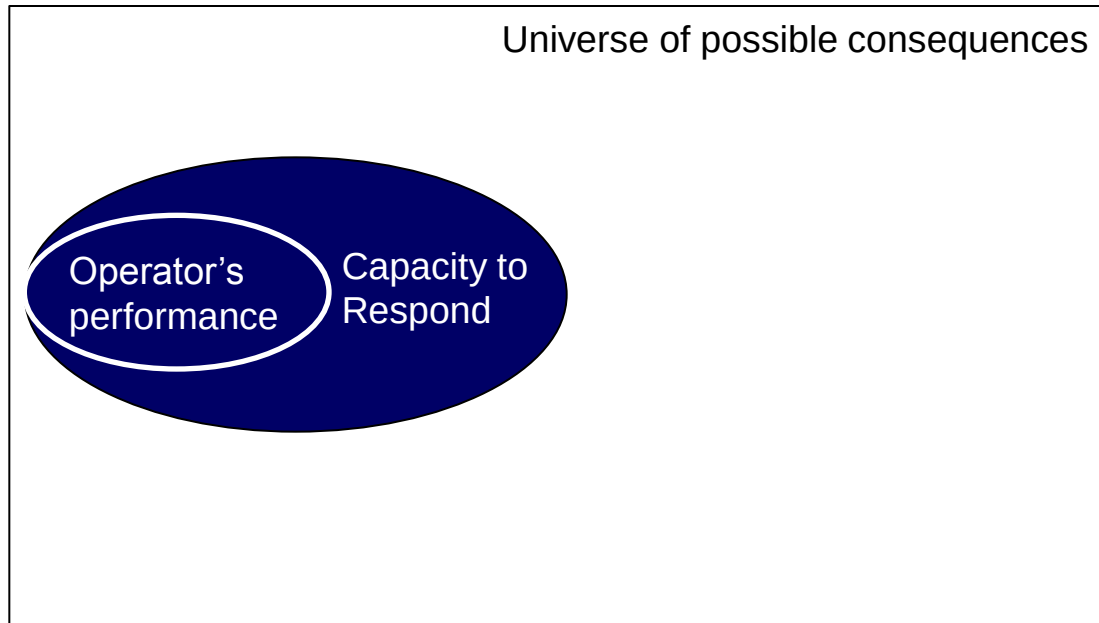


Level 1 Consequences

How automation degradation affects operator's performance ?

- Performance delay and/or precision
- Non technical skills (stress, fatigue, communication, etc.)
- Etc.

Automation degradation propagation

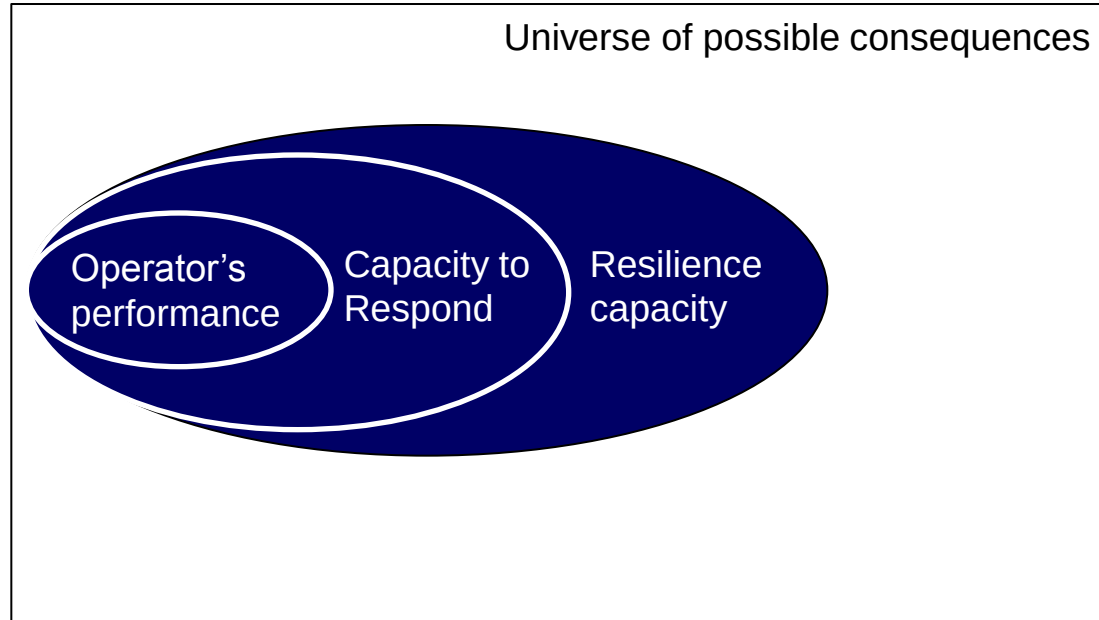


Level 2 Consequences

How automation degradation and operator's performance variability affect capacity to respond ?

- Respond function delay and/or precision
- Operators non technical skills
- Situation to be responded evolution and / or escalation

Automation degradation propagation

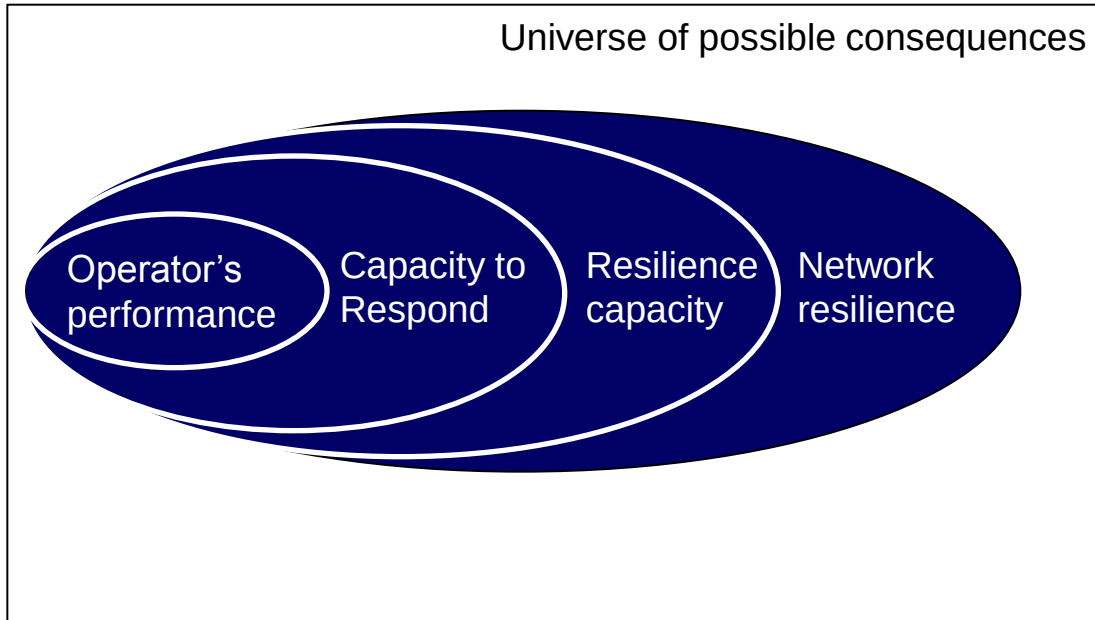


Level 3 Consequences

How automation degradation, operator's performance variability and capacity to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions ?

- Regular and Irregular respond functions delay and/or precision
- Operators non technical skills
- Regular and Irregular situations to be responded evolution and / or escalation

Automation degradation propagation

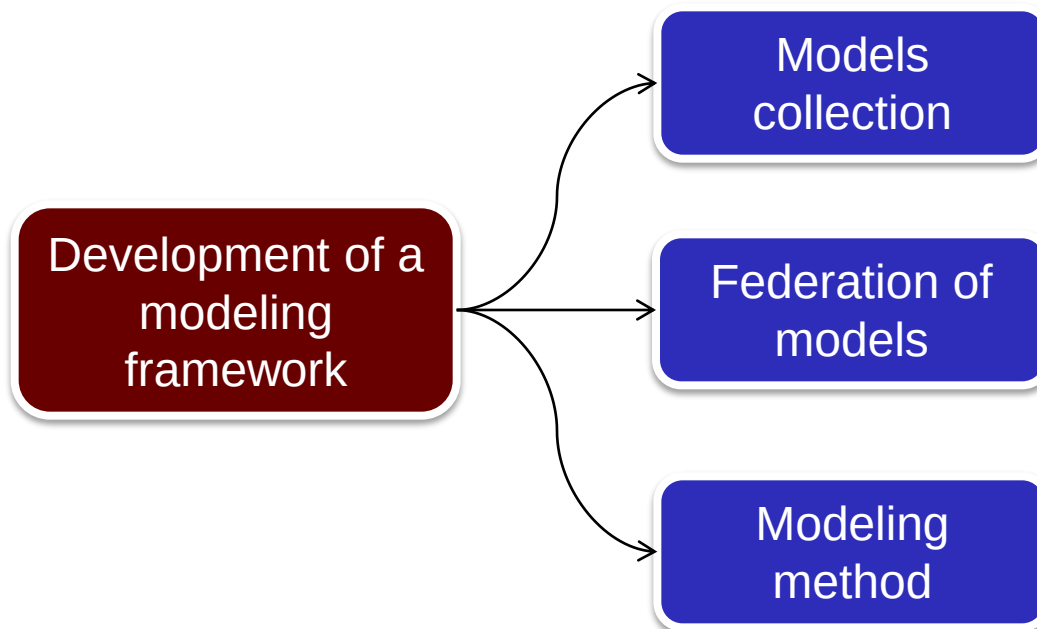


Level 4 Consequences

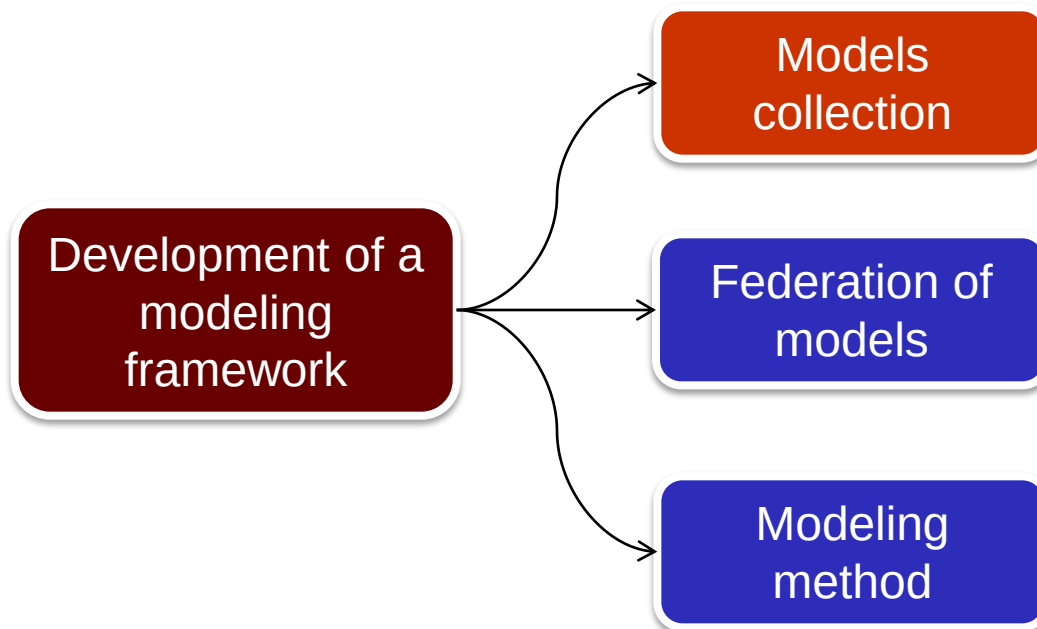
How automation degradation, operator's performance variability, resilience capacity affect network performance?

- Network's node resilience capacities
- Situations to be responded evolution and / or escalation
- Network resilience

Research and development objectives



Research and development objectives



Models Collection

How model automation degradation impacts on operator's performance?

Automation diversity, automation degradation modes, human performance variability.

Automation functions and level of automation typologies, CREAM method phenotypes and Common performance conditions, HAMSTERS task analysis method, Non technical skills, etc.

Models Collection

How model automation degradation impacts on operator's performance?

Automation diversity, automation degradation modes, human performance variability

How model automation degradation impacts on system resilience capacity?

System resilience capacity, system performance trade-offs, lose of control factors.

COCOM model, Organisational resilience analysis grid, Socio technical systems trade-offs

Models Collection

How model automation degradation impacts on operator's performance?

Automation diversity, automation degradation modes, human performance variability

How model automation degradation impacts on system resilience capacity?

System resilience capacity, system performance trade-offs, lose of control factors, etc.

How model automation degradation on a Large Scale Socio Technical System?

Network performances, socio-technical interdependencies.

Network interdependencies typologies, Network models.

Models Collection

How model automation degradation impacts on operator's performance?

Automation diversity, automation degradation modes, human performance variability.

How model automation degradation impacts on system resilience capacity?

System resilience capacity, system performance trade-offs, lose of control factors, etc.

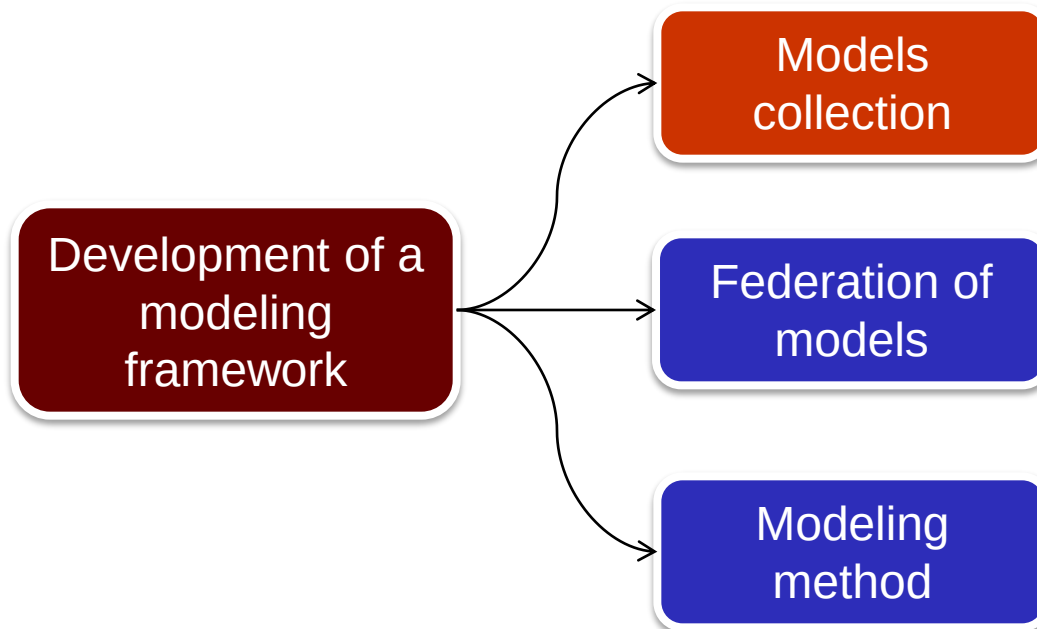
How model automation degradation on a Large Scale Socio Technical System?

Network performances, socio-technical interdependencies, etc.

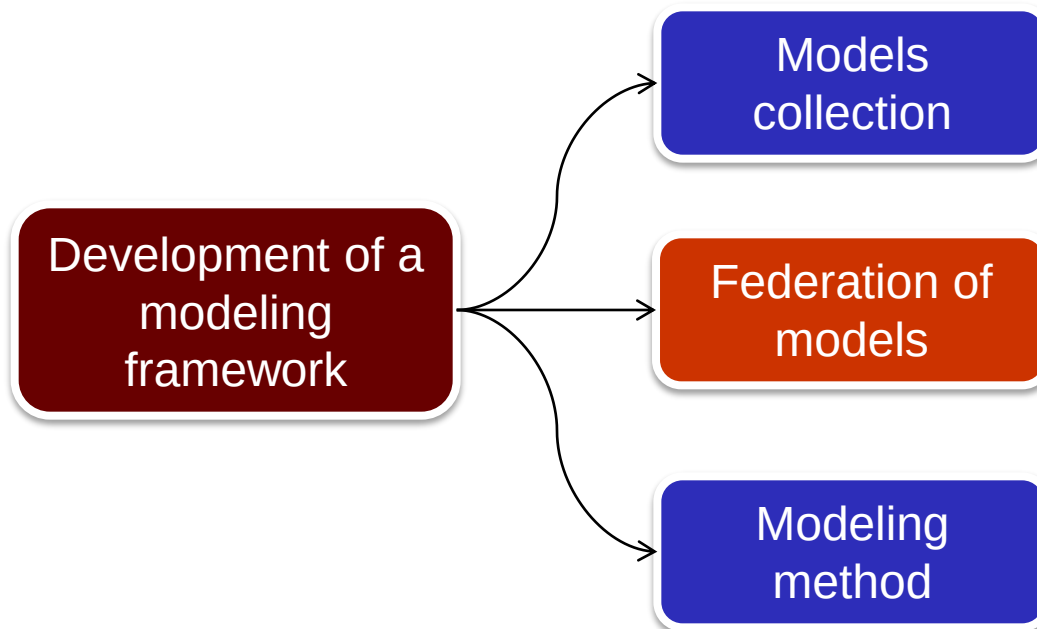
How integrate models as a federation of models?

Modelling models and methods. **FRAM**

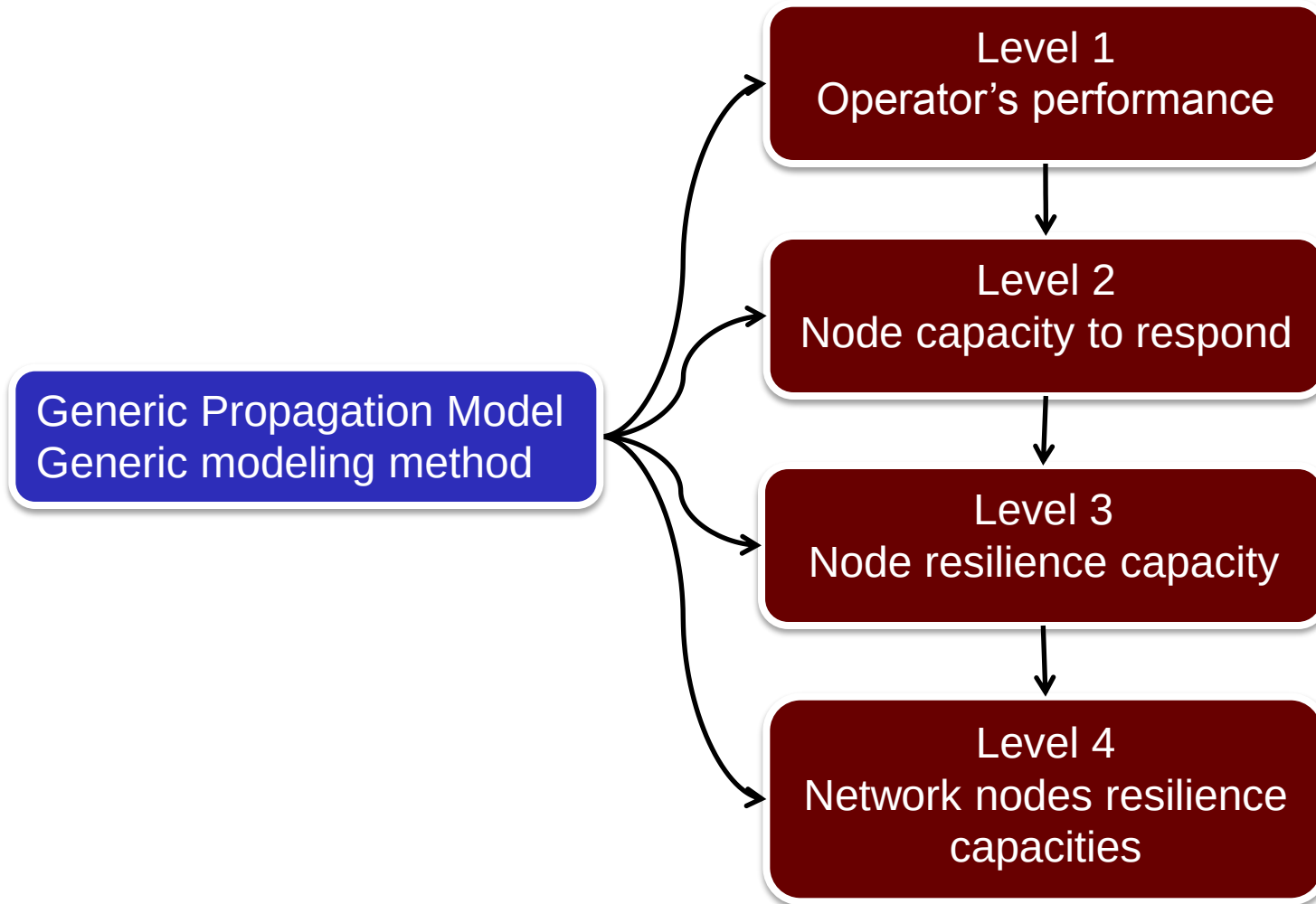
Research and development objectives



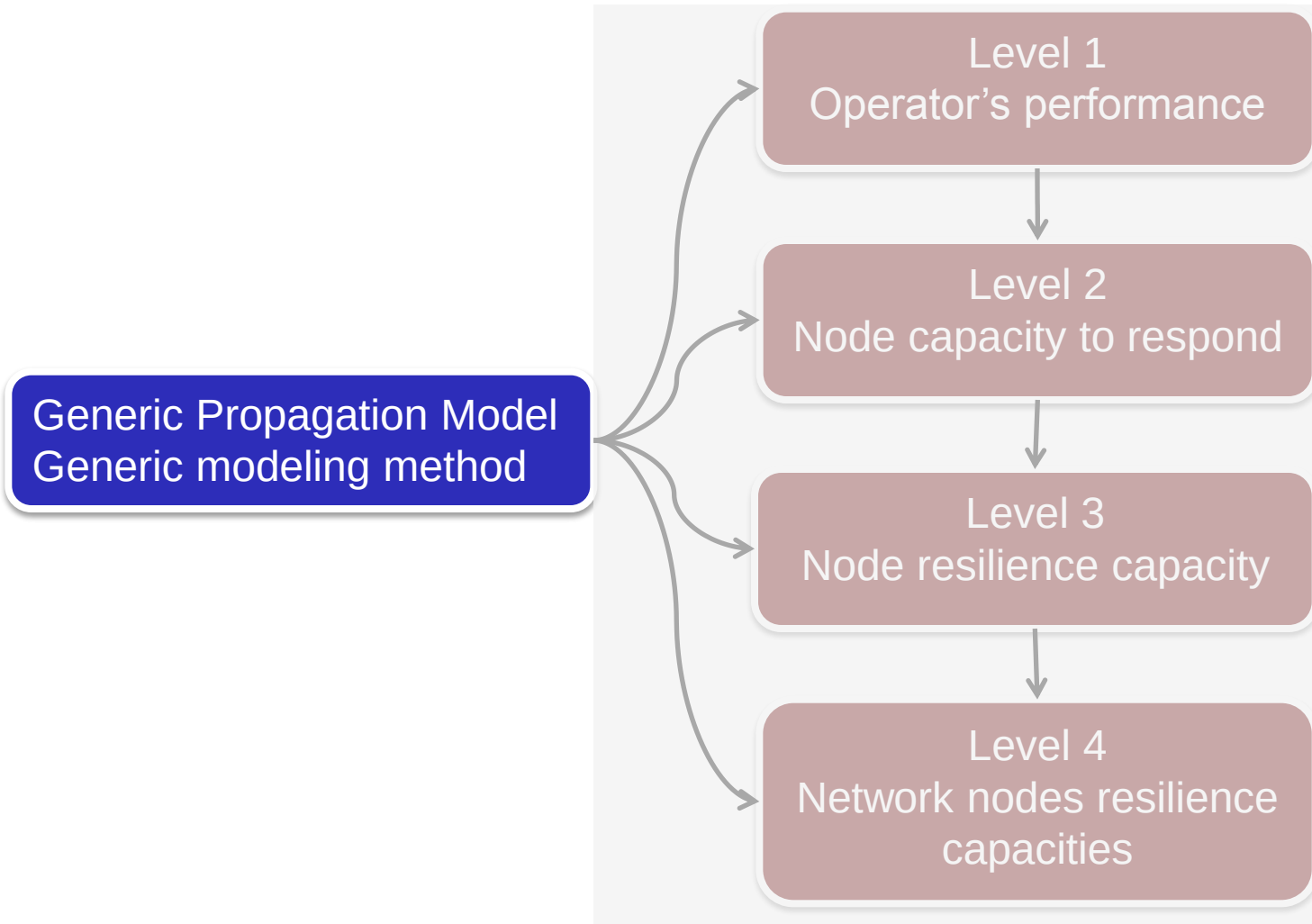
Research and development objectives



Federation of models

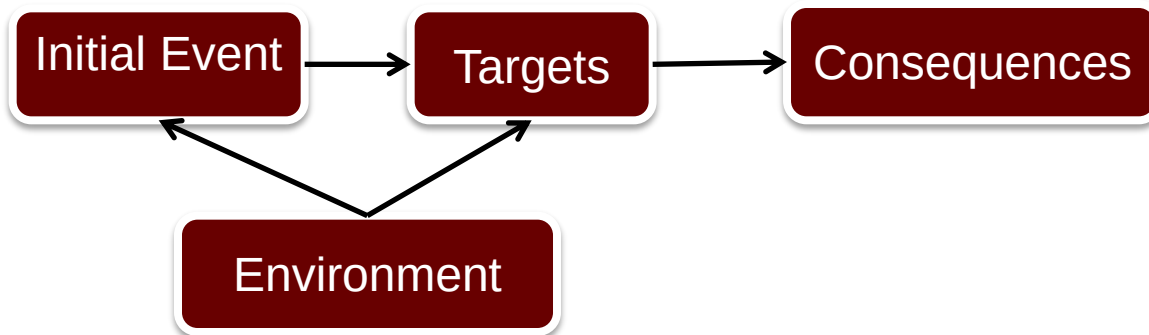


Federation of models



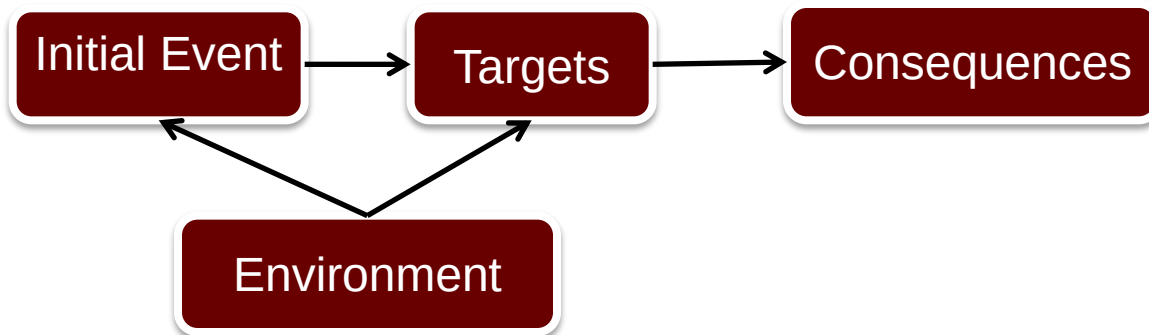
Federation of models

Generic Propagation Model



Federation of models

Generic Propagation Model



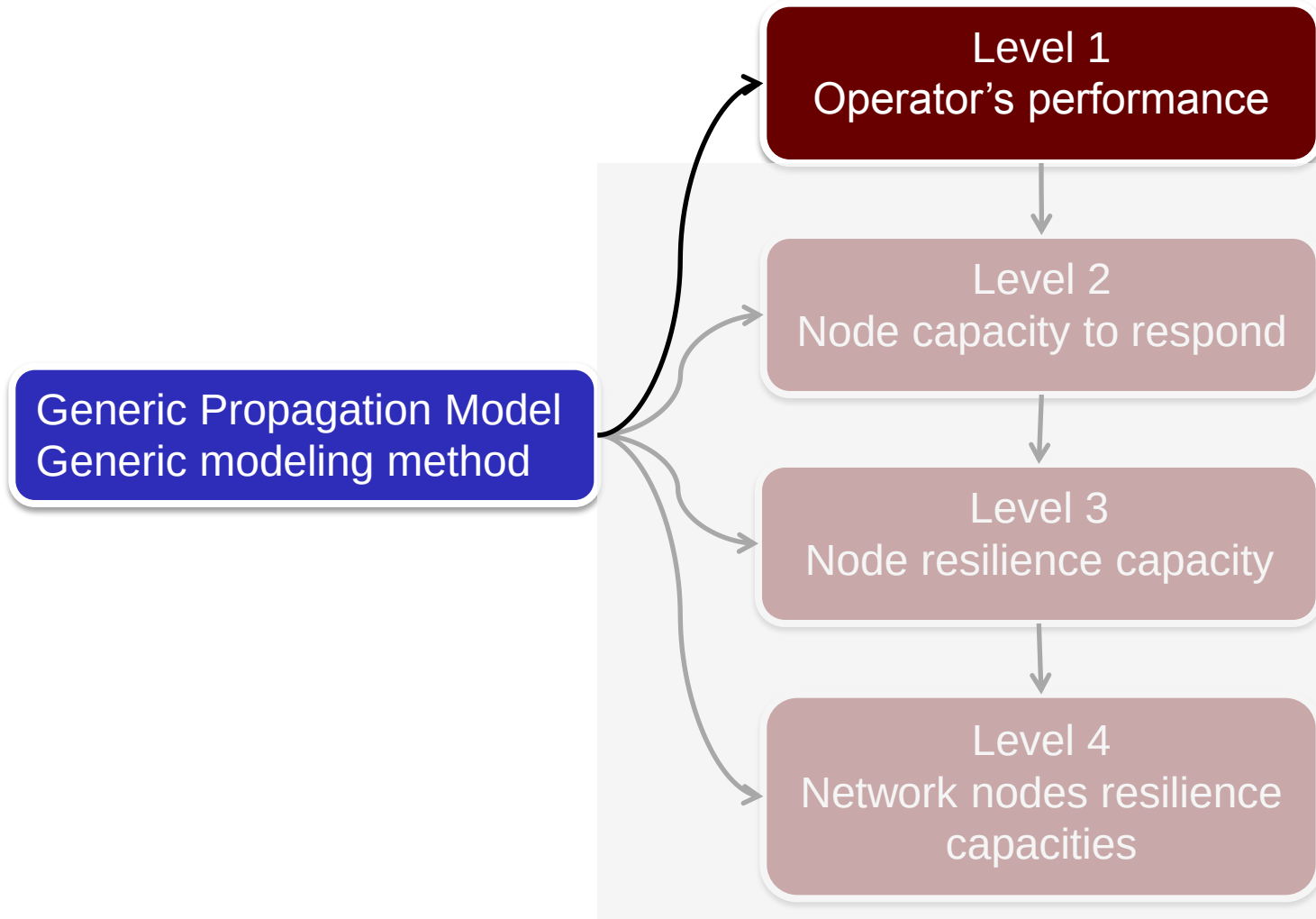
FRAM based generic modeling method

Context definition

Functions definition

Propagation model definition

Federation of models



Federation of models

Level 1. Operator's performance

Initial Event

Automation degradation modes

Targets

Operator's adaptation modes

Environment

Endogenous and exogenous factors that influence operator's behaviours

Consequences

- Precision and duration of the realisation of both automation and operators functions
- Operator's non technical skills

Level 1. Operator's performance

Context definition

Automation
description

Operators
description

Environment
description

Level 1. Operator's performance

Context definition

Automation
description

Name :
Functions performed :
Level of automation :
Degradation modes :

Operators
description

Environment
description

Level 1. Operator's performance

Context definition

Automation
description

Name : **AMAN**

Functions performed : **Display SEQ_LIST and Advisories**

Level of automation : **Semi-Autonomous**

Degradation modes : **Normal, Malfunction, Misleading information provided**

Operators
description

Environment
description

Level 1. Operator's performance

Context definition

Automation
description

Name :
Functions performed :
Level of automation :
Degradation modes :

Operators
description

Name :
Functions performed :
Endogenous variability factors :
Adaptive modes :

Environment
description

Level 1. Operator's performance

Context definition

Automation description

Name : **AMAN**

Functions performed : **Display SEQ_LIST and Advisories**

Level of automation : **Semi-Autonomous**

Degradation modes : **Normal, Malfunction, Misleading information provided**

Operators description

Name : **EXC_ACC**

Functions performed : **Control adequacy between flight planned trajectory and flight actual trajectory**

Endogenous variability factors : **Experience in using AMAN, Training, Workload, Stress, Focus of attention, Number of task to achieved**

Adaptive modes : **Strategic, Tactic, Opportunistic, Scrambled**

Environment description

Level 1. Operator's performance

Context definition

Automation
description

Name :
Functions performed :
Level of automation :
Degradation modes :

Operators
description

Name :
Functions performed :
Endogenous variability factors :
Adaptive modes :

Environment
description

Exogenous factors impacting operators
performance

Level 1. Operator's performance

Context definition

Automation description

Name : **AMAN**

Functions performed : **Display SEQ_LIST and Advisories**

Level of automation : **Semi-Autonomous**

Degradation modes : **Normal, Malfunction, Misleading information provided**

Operators description

Name : **EXC_ACC**

Functions performed : **Control adequacy between flight planned trajectory and flight actual trajectory**

Endogenous variability factors : **Experience in using AMAN, Training, Workload, Stress, Focus of attention, Number of task to achieved**

Adaptive modes : **Strategic, Tactic, Opportunistic, Scrambled**

Environment description

Exogenous factors impacting operators performance

Working conditions, Complexity of traffic, Amount of traffic, Weather

Level 1. Operator's performance

Functions definition

Initial event
functions

Automation functions

Level 1. Operator's performance

Functions definition

Initial event
functions

AMAN.Compute and display SEQ_LIST(),
AMAN.Compute and display advisories()

Level 1. Operator's performance

Functions definition

Initial event
functions

Automation functions

Target
functions

If Automation is semi-Autonomous : Operators
functions that required the use of automation

Level 1. Operator's performance

Functions definition

Initial event
functions

AMAN.Compute and display SEQ_LIST(),
AMAN.Compute and display advisories()

Target
functions

EXC_ACC. Control adequacy between flight
planned trajectory and flight actual trajectory

Level 1. Operator's performance

Functions definition

<i>Name of the function</i>	
Description	
Aspects	
Input	
Output	
Preconditions	
Resources	
Control	
Time	

Level 1. Operator's performance

Functions definition

Control adequacy between flight planned trajectory and flight actual trajectory	
Description	Executive monitor AMAN in order to identify if needed manoeuvre to be cleared to pilot
Aspects	
Input	AMAN Advisories displayed
Output	Difference identified Manoeuvre to be cleared defined
Preconditions	Traffic in an advanced state
Resources	AMAN, CWP, EXC_TMA
Control	Procedures
Time	

Level 1. Operator's performance

Variability model definition

Relation between automation degradation modes and automation functions output aspects value

Relation between Operator's functions endogenous, exogenous and coupling dimensions of variability and adaptation mode

Relation between Operator's functions adaptive modes values and output aspect and endogenous dimensions of variability values

Level 1. Operator's performance

Variability model definition

Relation between automation degradation modes and automation functions output aspects value

Degradation mode

Normal,
Malfunction,
Misleading information
provided

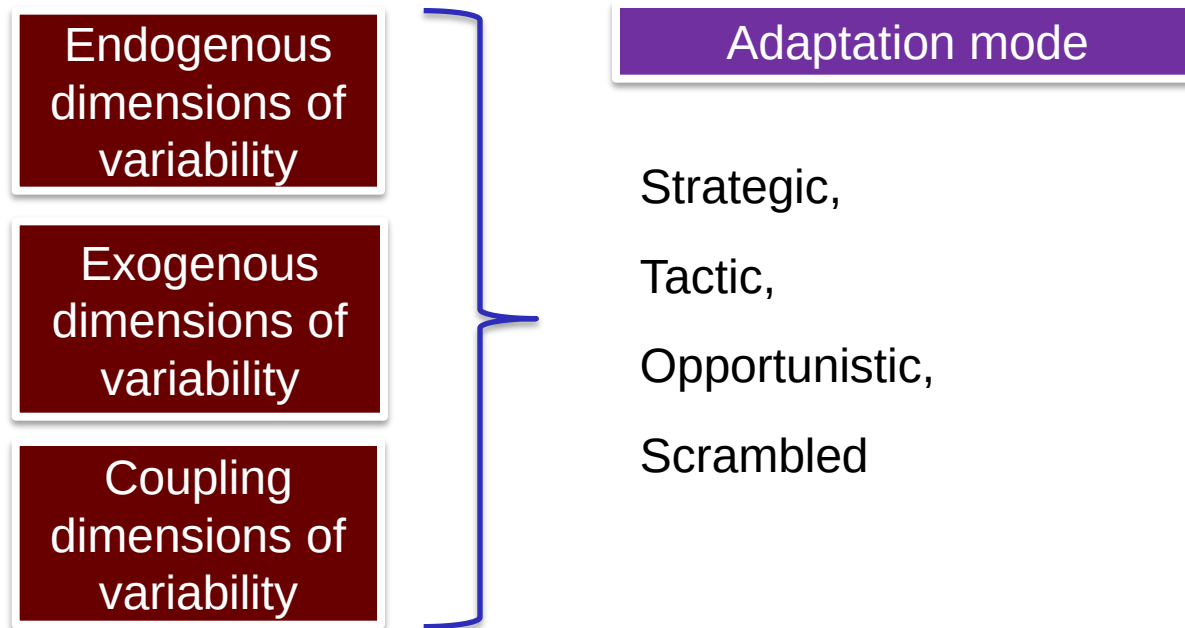
Outputs aspects variability

Precision [Precise, Imprecise]
Duration [Optimum, Average, Long]

Level 1. Operator's performance

Variability model definition

Relation between Operator's functions endogenous, exogenous and coupling dimensions of variability and adaptation mode



Level 1. Operator's performance

Variability model definition

Relation between Operator's functions endogenous, exogenous and coupling dimensions of variability and adaptation mode

Strategic

In strategic control mode time required to perform functions is much superior to available time :

EXC_TMA variability factors are optimum

EXC_TMA is focusing half of it's activity on *Monitor traffic functions*

AMAN is available

Complexity of traffic and amount of traffic is low

Tactical

In tactical control mode time required to perform functions is just superior to available time :

EXC_TMA variability factors are not optimum

OR

EXC_TMA is focusing less than half of it's activity on *Monitor traffic function*

OR

Complexity of traffic and amount of traffic is medium

AND

AMAN is available

Level 1. Operator's performance

Variability model definition

Relation between Operator's functions endogenous, exogenous and coupling dimensions of variability and adaptation mode

Opportunistic

In to opportunistic control mode time required to perform functions is inferior to available time :

AMAN is not available and other conditions are optimum or average
AMAN is available and others conditions are negative

Scrambled

In to scrambled control mode time required to perform functions is much inferior to available time :

AMAN is not available and other conditions are negative

Level 1. Operator's performance

Variability model definition

Relation between Operator's functions adaptive modes values and output aspect and endogenous dimensions of variability values

Adaptation mode

Strategic,
Tactic,
Opportunistic,
Scrambled

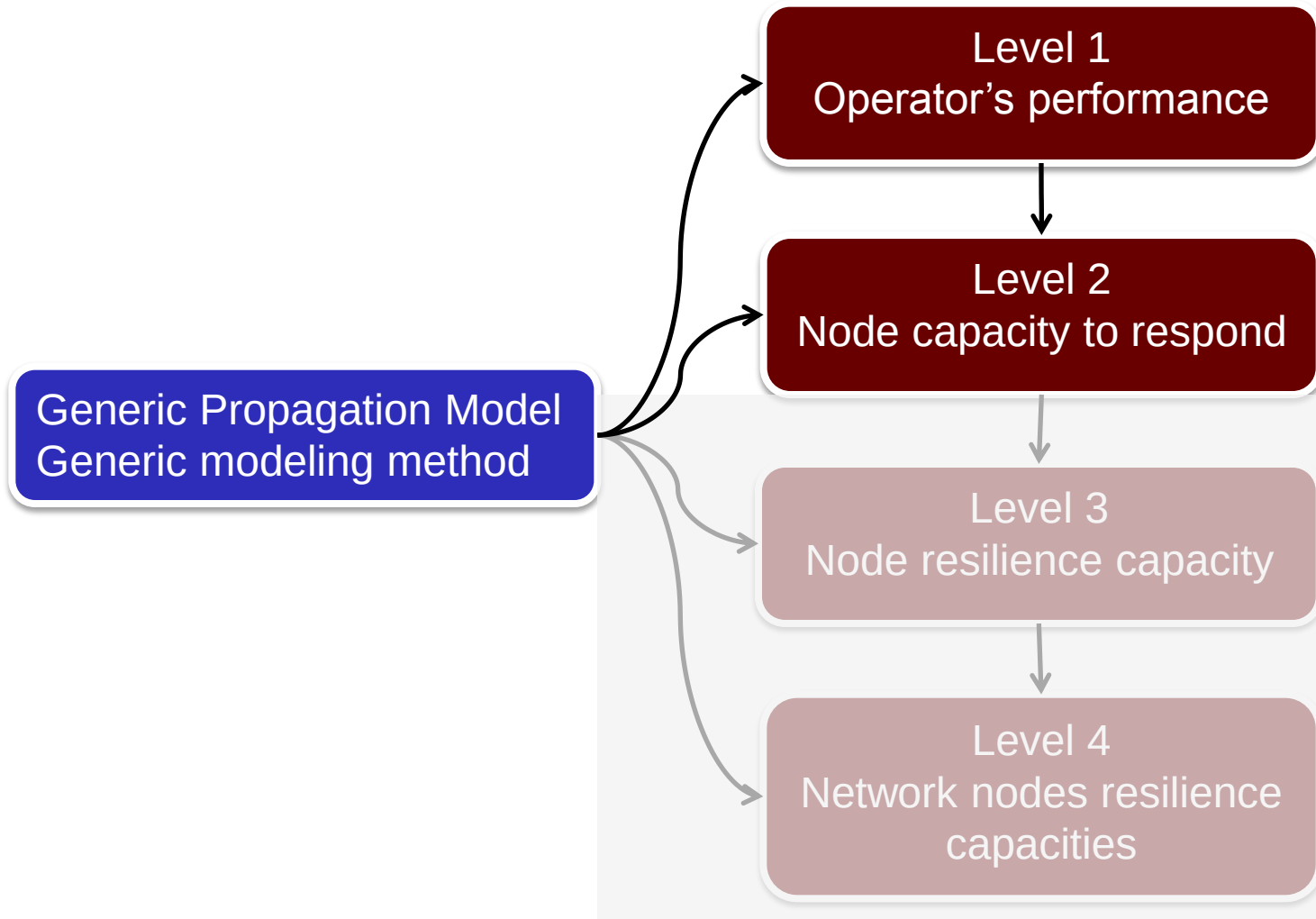
Outputs aspects variability

Precision [Precise, Imprecise]
Duration [Optimum, Average, Long]

Exogenous aspects variability

Stress [Low, Medium, High]
Workload [Low, Medium, High]

Federation of models



Level 2. Node capacity to respond

Initial Event

- Precision and duration of the realisation of both automation and operators functions
- Operators non technical skills

Targets

Respond capacity performance variability factors

Environment

- Endogenous and exogenous factors influencing operators and situation to be respond variability.
- Area of responsibility of operators variability

Consequences

- Respond action consequences
- Situation to be respond consequences
- Operators non technical skills

Level 2. Node capacity to respond

Context definition

Situation to be
controlled

Capacity to
respond

Level 2. Node capacity to respond

Context definition

Situation to be
controlled

Name :
States, performance profile and consequences

Capacity to
respond

Level 2. Node capacity to respond

Context definition

Situation to be
controlled

Name : Flow of traffic variability

States, performance profile and consequences

- Minor / (Time : Few, Resources : No, Competence : Novice, Knowledge No) / Increase of number of task to perform
- Significant / (Time : average, Resources : Available space in sector, Competence : Experience, Knowledge Availability place in sector) / Increase of number of task to perform, stress, workload and decrease sector availability
- Serious / (Time : High, Resources : Available space in sector and airports, Competence : Expertise, Knowledge Availability place in sector and airport) / Increase of number of task to perform, stress, workload and decrease sector and airport availability

Level 2. Node capacity to respond

Context definition

Situation to be
controlled

Name :
States, performance profile and consequences

Capacity to
respond

Name :
Processes : Detect, Identify, Recognize
situation, Define response, respond
Respond modes : Strategic, tactical,
Opportunistic, Scrambled

Level 2. Node capacity to respond

Context definition

Situation to be
controlled

Name : Flow of traffic variability

States, performance profile and consequences

Minor, Significant Serious

Capacity to
respond

Name : Respond to flow of traffic variability

Processes : Detect, Identify, Recognize

situation : Delays, congestion, conflicts,
emergency,

Define response : early descent, speed reduction,
re-routing, etc.

respond : Clear tactical operation

Level 2. Node capacity to respond

Functions definition

Initial event
functions

Level 1. functions

Level 2. Node capacity to respond

Functions definition

Initial event
functions

AMAN.Compute and display SEQ_LIST(),
AMAN.Compute and display advisories()

EXC_ACC. Control adequacy between flight
planned trajectory and flight actual trajectory

Level 2. Node capacity to respond

Functions definition

Initial event
functions

Level 1. functions

Target
functions

Respond capacity functions

Level 2. Node capacity to respond

Functions definition

Initial event
functions

AMAN.Compute and display SEQ_LIST(),
AMAN.Compute and display advisories()

EXC_ACC. Control adequacy between flight
planned trajectory and flight actual trajectory

Target
functions

EXC_ACC. Respond to flow of traffic variability

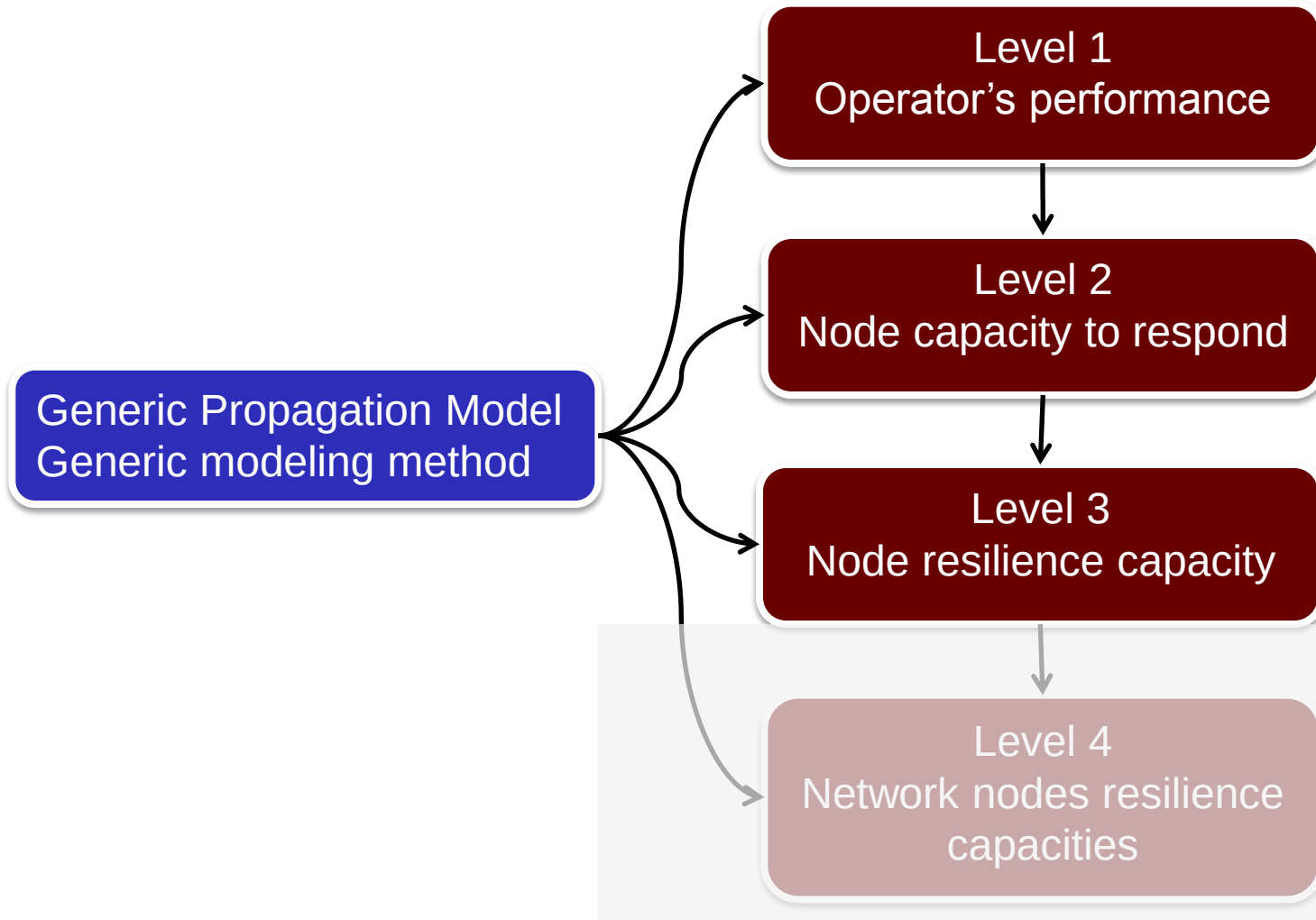
Level 2. Node capacity to respond

Variability model definition

Relation between Capacity to respond functions endogenous, exogenous and coupling dimension of variability and their control mode

Relation between Capacity to respond control modes values and output aspects, endogenous dimensions of variability values and situation to be responded states and consequences

Federation of models



Level 3. Node resilience capacity

Initial Event

- Respond actions consequences
- Situation to be responded consequences
- Operators non technical skills

Targets

Node Regular and irregular situations respond capacities

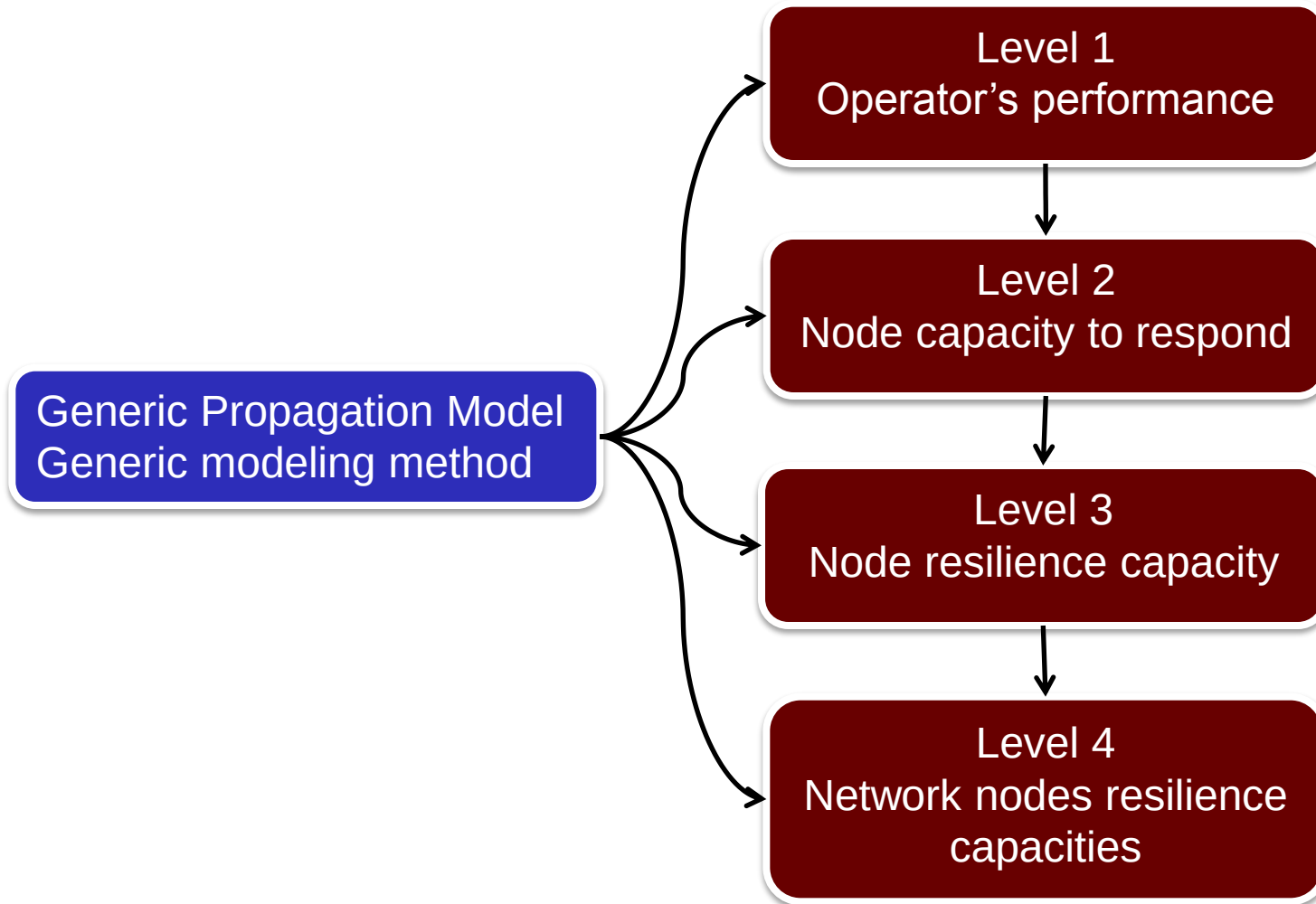
Environment

- Endogenous and exogenous factors influencing operators performance and regular and irregular situations to be responded.
- Container nodes capacities

Consequences

- Node resilience capacity
- Situations to be responded consequences
- Operators non technical skills
- Container nodes capacities

Federation of models



Level 4. Network nodes resilience capacity

Initial Event

- Node resilience capacity
- Situations to be respond consequences
- Operators non technical skills
- Container nodes state

Targets

Interconnected nodes resilience performance

Environment

Environment variability
Nodes responsibilities area zone

Consequences

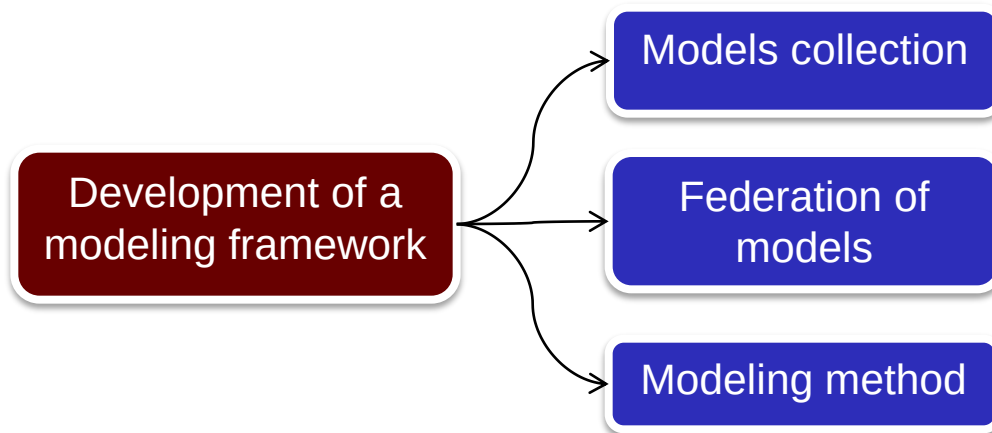
- Nodes resilience capacity
- Situations to be responded consequences
- Operators non technical skills
- Container nodes capacities

Define a modeling framework for automation degradation consequences identification

Four scales of analysis : Operator's performance, Node capacity to respond, Node resilience, Network Resilience

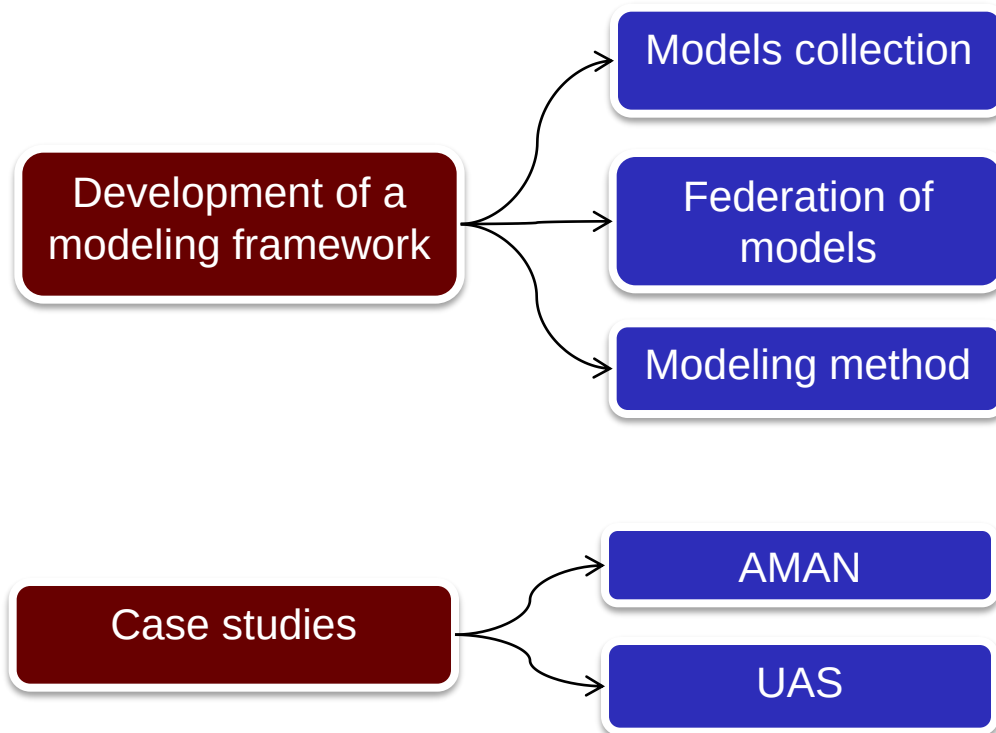
Define a modeling framework for automation degradation consequences identification

Four scales of analysis : Operator's performance, Node capacity to respond, Node resilience, Network Resilience



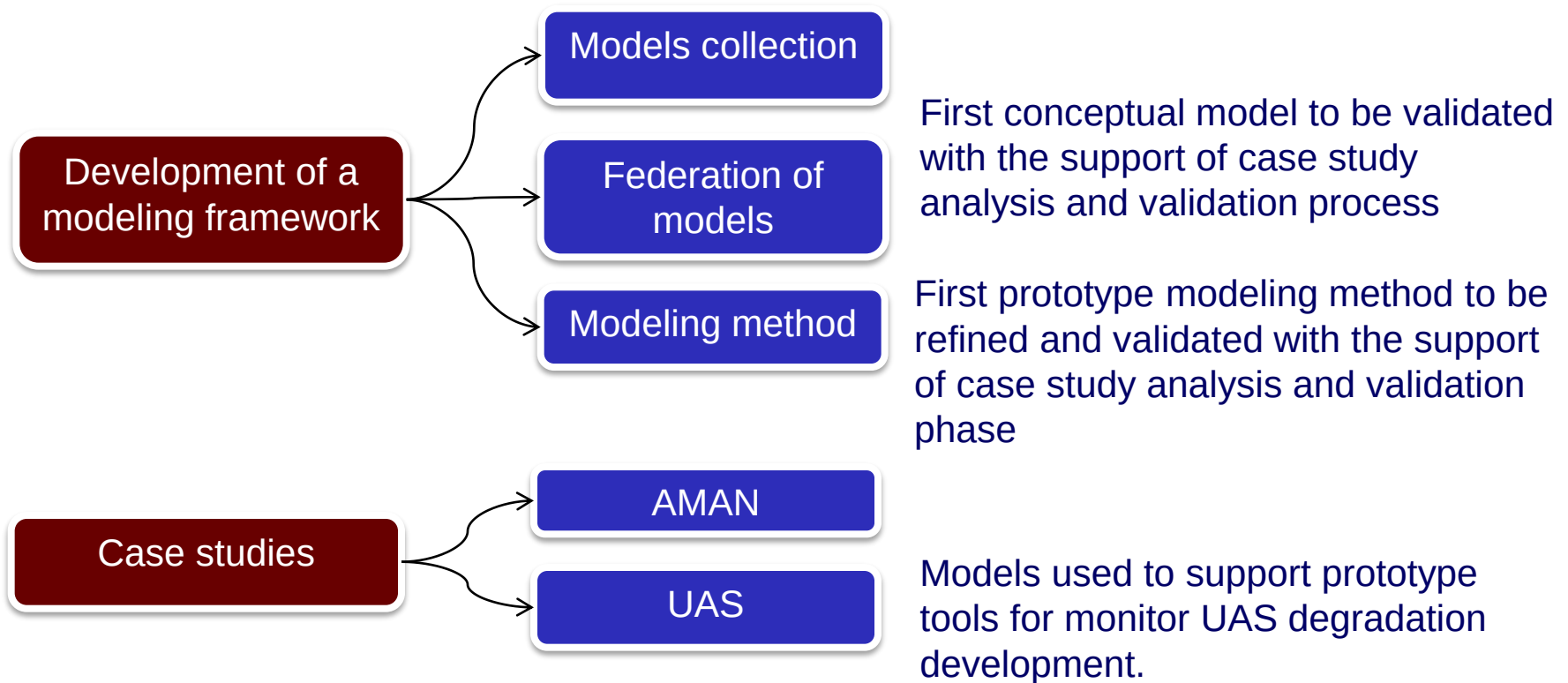
Define a modeling framework for automation degradation consequences identification

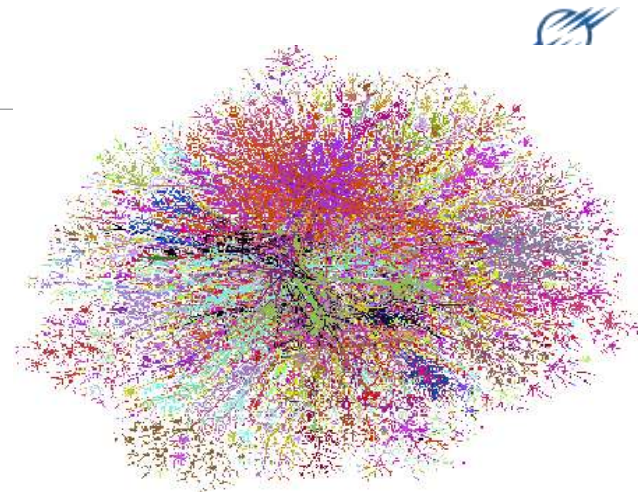
Four scales of analysis : Operator's performance, Node capacity to respond, Node resilience, Network Resilience



Define a modeling framework for automation degradation consequences identification

Four scales of analysis : Operator's performance, Node capacity to respond, Node resilience, Network Resilience





Eric Rigaud

Centre de recherche sur les Risques et les Crises

24 octobre 2012

A framework for modeling the consequences of the propagation of automation degradation: application to Air Traffic Control systems

E. Rigaud³, E. Hollnagel³, C. Martinie¹, P. Palanque¹, A. Pasquini², M. Ragosta¹⁻², S. Silvagni², M. Sujan⁴

¹ University Paul Sabatier - ICS-IRIT, ² DeepBlue Srl, ³ Mines-Paristech / ARMINES, CRC,

⁴ Warwick Medical School - University of Warwick