Sociotechnical systems resilience

Jean-René Ruault[1, 2], Frédéric Vanderhaegen[1], Dominique Luzeaux[2]

1) UVHC, LAMIH, F-59313 Valenciennes, France
2) DGA, 7-9 rue des Mathurins, F-92221 Bagneux, France
jean-rene.ruault@dga.defense.gouv.fr
frederic.vanderhaegen@univ-valenciennes.fr
dominique.luzeaux@dga.defense.gouv.fr

Summary

- Issues and aims
- About sociotechnical systems
- About resilience
- Factors enhancing or reducing resilience capacity
- Impacts upon systems engineering foundations
- Conclusion and perspectives

Beacon

- **Issues and aims**
- **About sociotechnical systems**
- **About resilience**
- Factors enhancing or reducing resilience capacity
- Impacts upon systems engineering foundations
- Conclusion and perspectives

Issues & aims

Resilience: capability of sociotechnical systems

- To cope with unpredictable, unforeseeable events
- To adjust faced with disturbing events,
- To adapt and learn adequate rules of adaptation,

➔ Disturbances out of the system's adaptation mechanisms

Impacts of resilience upon sociotechnical systems:

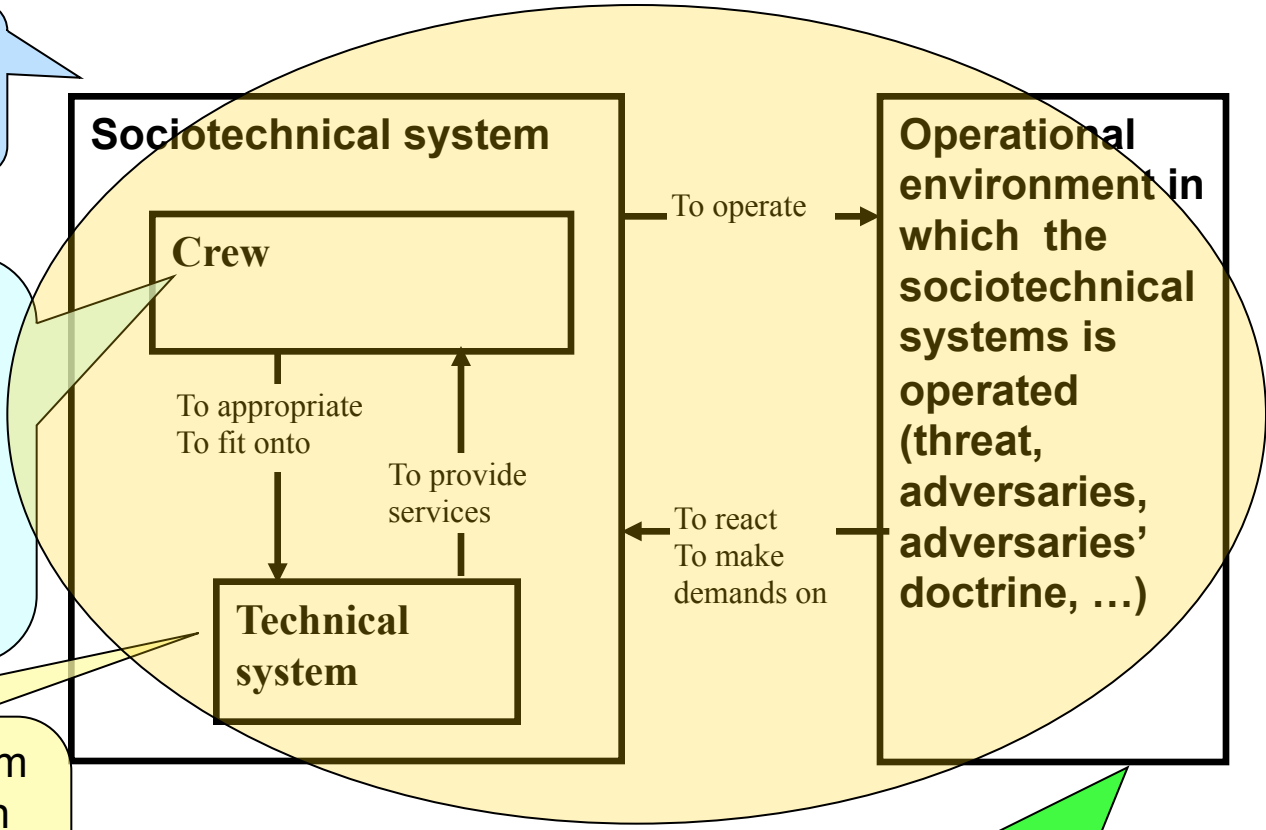
- Systems engineering processes
- Systems engineering models
- Systems architecture
- Systems utilization processes

Complex sociotechnical Systems

A sociotechnical systems ➔a human part and a technical one ……

… the human part appropriates the technical system, to fit it onto missions in which users operate it, function of operational environments and constraints ...

... the design technical system is modelled and specified in order to be operated by users in a reference operational situation



The actual operational environment is different from the reference one (unpredictable events).

Resilience definitions

- "*safety and risks in complex organizations are emergent, not resultant properties: safety and risk cannot be predicted or modeled on the basis of constituent components and their interaction*" (1)

- "*we can only measure the potential of resilience, but not resilience itself*" (2)

- resilience as a "management at the border of the domain of application…" (3)

1. S. Dekker: Resilience engineering: chronicling the emergence of confused consensus ; in E. Hollnagel, D. Woods & N. Levenson (eds), Resilience Engineering. Concepts and precepts, Ashgate, Hampshire, Great Britain, 2006
2. E. Hollnagel & D. Woods: Epilogue – Resilience engineering precepts; in E. Hollnagel, D. Woods et N. Levenson (eds), Resilience Engineering. Concepts and precepts, Ashgate, Hampshire, Great Britain, 2006
3. D. Luzeaux: Engineering Large-scale Complex Systems in D. Luzeaux, J.-R. Ruault & J.-L. Wippler, Complex Systems and Systems of Systems Engineering, ISTE Ltd and John Wiley & Sons Inc, 2011

Four main resilience functions [1]

1. Avoidance (capacity for anticipation)
2. Resistance (capacity for absorption)
3. Adaptation (capacity for reconfiguration)
4. Recovery (capacity for restoration)

This paper deals with:

1. Avoidance
2. Adaptation

1. D. Luzeaux: Engineering Large-scale Complex Systems in D. Luzeaux, J.-R. Ruault & J.-L. Wippler, Complex Systems and Systems of Systems Engineering, ISTE Ltd and John Wiley & Sons Inc, 2011

Avoidance function decomposition

Acquiring information at the operators' level ➔ anticipate and avoid accidents

- Obtain a representation of the environment
- Obtain a representation of the dynamic system
- Identify the environment states that were not envisioned
- Evaluate the instantaneous or trend drifts
- Evaluate the proximity of the state of the system compared to the zones of danger

Adaptation function decomposition

Adaptation of rules, operational procedures, as well as system functional architecture

- Institute and systematize operators' training
- Allow the operators to evolve procedures to take account the environment evolutions
- Generalize good practices from procedures evolutions
- Design an evolutionary system architecture

About resilience (1/3)

- Resilience characteristics
  - Reserve (buffering capacity)
  - Margin
  - Multilevel interactions
  - Flexibility
  - Tolerance
- Among factors of context
  - Crew's training and experiment
  - Human-system interfaces (HSI) quality
  - Methods and procedures accessibility and availability
  - Work conditions
  - Availability of the resources
  - Team collaboration quality
- Mechanisms dealing with resilience
  - Migration phenomenon (omerta)
  - Compensation/decompensation mechanism
  - Threats and appropriate responses
  - Barriers removal (costs; benefits)
  - Dynamic process of "visual piloting"

About resilience (2/3)

- Positive / negative effects of the observance / non-observance specified procedures (Hollnagel's dark matter[1])

		Consequence	
		Positive (no accident)	Negative (accident)
Procedure	Observance	Sociotechnical system functioning in its specified domain	Actual environment different from the reference situation. Procedure observance generates a failure.
	Non-observance	Sociotechnical system adaptation to the actual environment Compensation mechanism Enhance vigilance because decompensation risks	Unsuited adaptation mechanism Failure of a compensation mechanism Signal indicating the probability of an accident

1. E. Hollnagel: Resilience – The challenge of the Unstable; in E. Hollnagel, D. Woods et N. Levenson (eds), Resilience Engineering. Concepts and precepts, Ashgate, Hampshire, Great Britain, 2006

About resilience (3/3)

Capability dimensions

- Doctrine: operating mode, rules, habits, culture, ethos
- Organization: enterprise and team structured
- Training: operators prepared and trained to do their work
- Materiel: all technical components needed to operate
- Leadership: managers prepared to lead and make decision
- Personnel: availability of qualified and skilled
- Facilities: installations and industrial facilities

Beacon

- Issues and aims
- About sociotechnical systems
- About resilience
- **Factors enhancing or reducing resilience capacity**
- Impacts upon systems engineering foundations
- Conclusion and perspectives

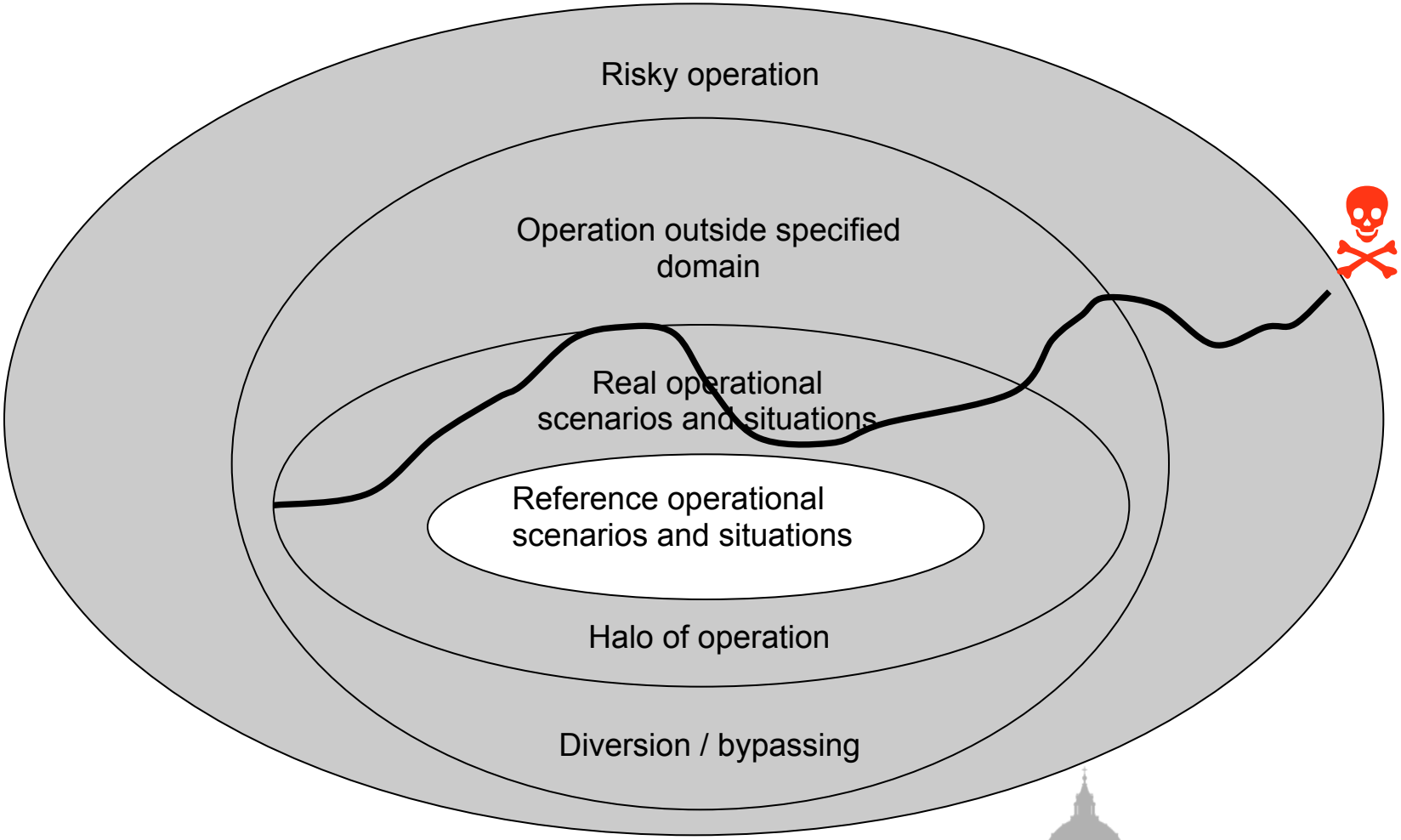
Factors of context and capability dimensions

Capability dimensions Factors of context	Doctrines	Organization	Training	Material	Leadership	Personnel	Facilities
Resources availability	* *	* * *	* *	*	* * *	* * *	* * *
Communications quality	* *	* * *	* * *	* *	*	* *	*
HSI quality	*	*	* * *	* * *	*	*	*
Methods and procedures accessibility and availability	* * *	* * *	* * *	* *	*	*	*
Work conditions	* *	* * *	* *	* * *	*	* * *	*
Number of simultaneous goals	* *	* * *	* *	*	*	* * *	*

Resilience characteristics and capability dimensions

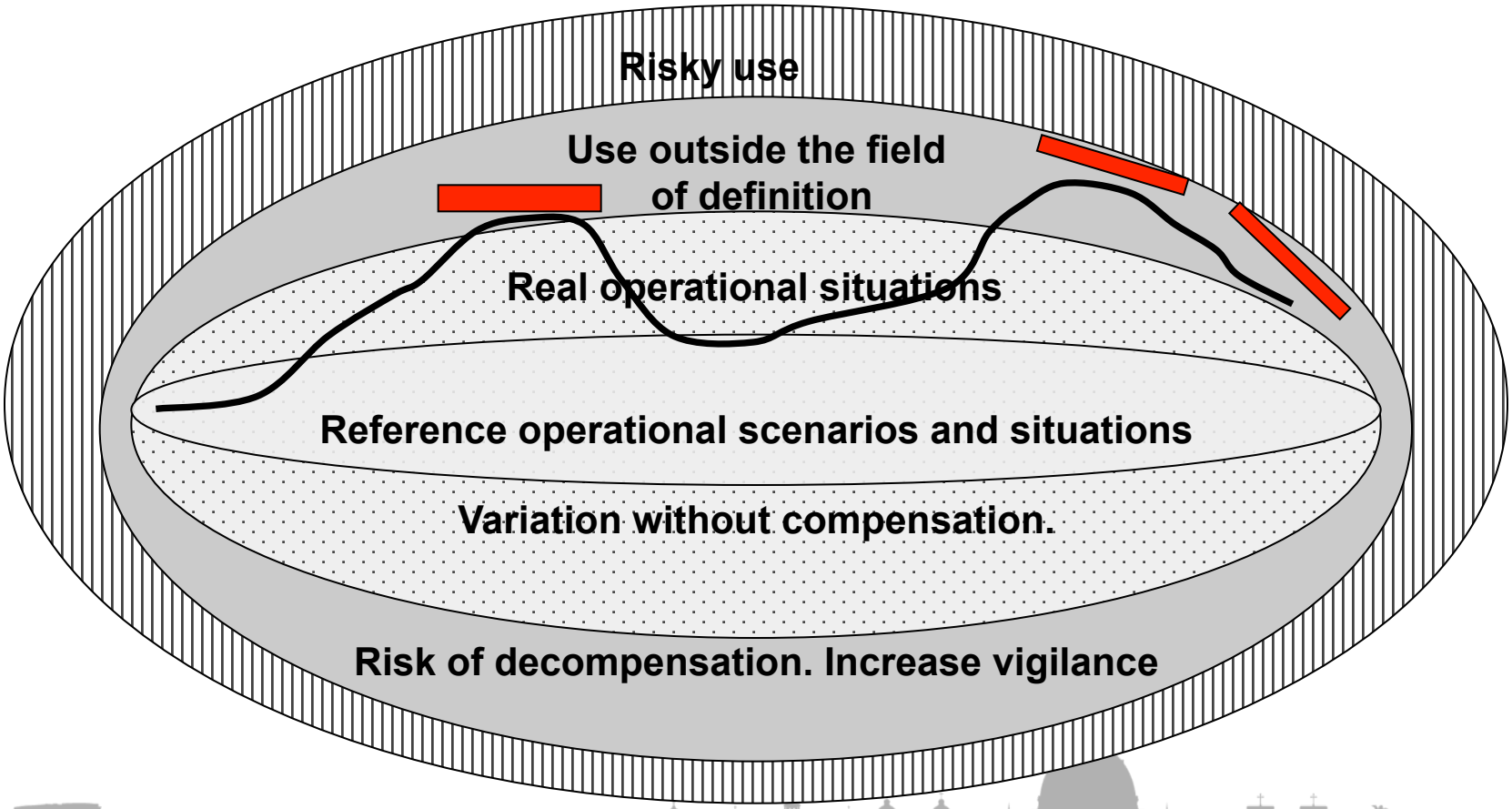
Capability dimensions / Resilience characteristics	Doctrines	Organization	Training	Material	Leadership	Personnel	Facilities
Reserve	* * *	* * *	* *	* * *	* *	* * *	* * *
Flexibility	* * *	* * *	* *	* * *	* * *	* *	* *
Margin	* * *	* * *	*	* * *	* *	* * *	* * *
Tolerance	* * *	* * *	* *	* * *	* * *	* * *	* *
Multilevel Interactions	* *	* * *	* *	* * *	* * *	* *	*

Actual operational situation; blind zone



Visual piloting

- **Control between the situation of reference and the risky use of the system**

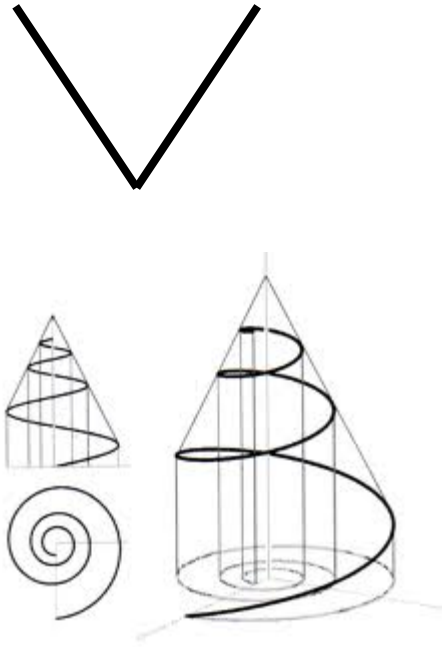


Beacon

- Issues and aims
- About sociotechnical systems
- About resilience
- Factors enhancing or reducing resilience capacity
- **Impacts upon systems engineering foundations**
- **Conclusion and perspectives**

Impacts upon systems engineering processes

- Integrate human-centred processes within systems engineering (appropriation and adaptation processes)
- Carry out experience feedback from actual operational situations
- Take care of the necessary evolutions of the technical system



Impacts upon engineering models

- Model the factors of context and the associated variability
- Model complexity, non-linearity, non-monotony, phase transition
- Capture and model actual operators' activities

Impacts upon system architecture

- Make trade-off between resilience and performance
- Design relevant and efficient human-system interface allowing situation awareness
- Specify introspection capability
- Design flexible architecture

Impacts upon enabling system architecture

- Use high fidelity prototype and evaluate human-system interfaces
- Trace and report current system states and evaluate the gap against reference ones
- Trace and report experience feedback
- Support training

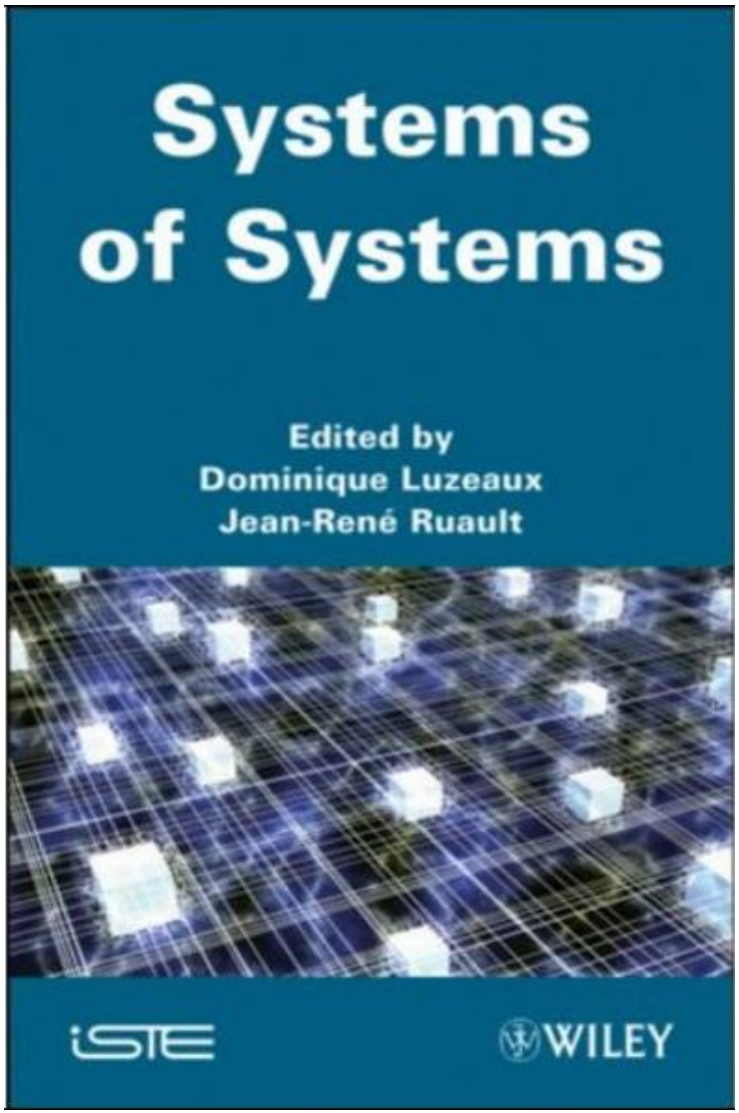
Impacts upon operational processes

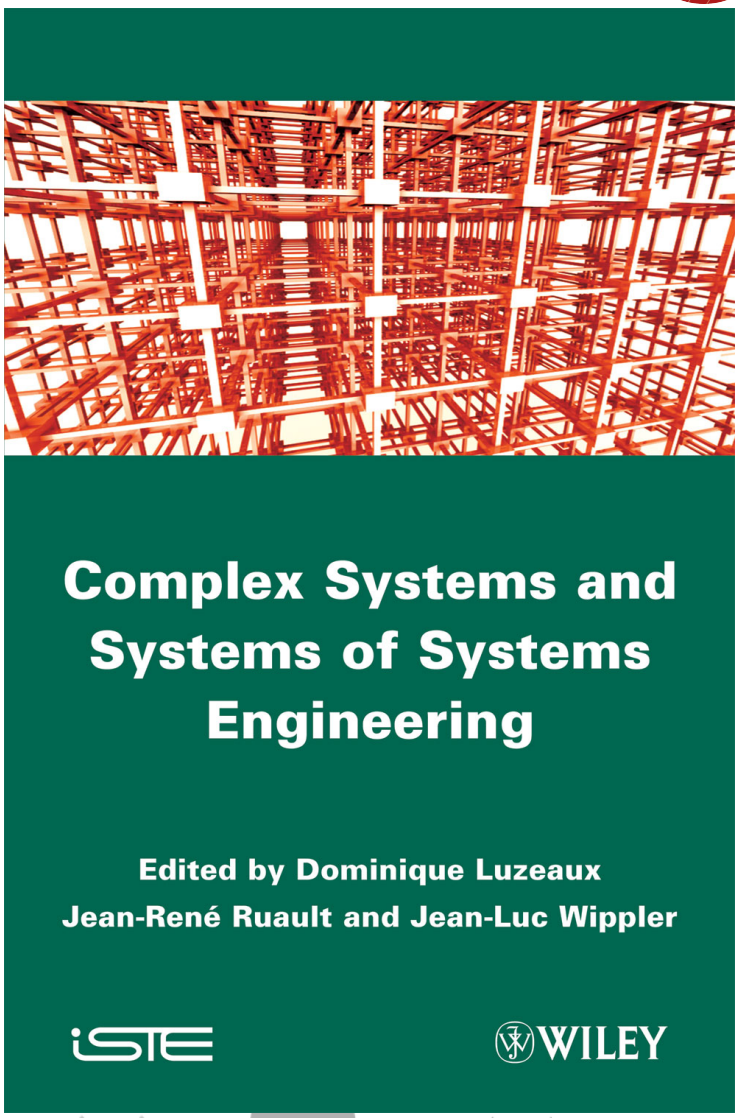
- Develop collective learning and experience feedback
- Set up a management which supports, institutionalizes and gratifies these practices
- Deploy adapted procedures to unforeseen events management and train operators
- Work out the virtuous loop of the control of execution, the drift measurement, the training and change management
- Privilege regulated safety instead of controlled safety

Conclusion and perspectives

- Resilience encompasses safety and is larger since it takes into account unforeseeable situations and exceptional occurrences
- Resilience is a dynamic process which cannot be *a priori* evaluated
- Impacts on the systems engineering processes, the operational processes, the system of interest architecture and the enabling system architecture
- This is the first article of my PhD. We details these impacts in further articles
- Resilience has impacts also on other processes, such as recruitment, training, team building, these will be the issues of further articles

Books


Systems
of Systems
Edited by
Dominique Luzeaux
Jean-René Ruault
ISTE
WILEY


Complex Systems and
Systems of Systems
Engineering
Edited by Dominique Luzeaux
Jean-René Ruault and Jean-Luc Wippler
ISTE
WILEY

Thank you very much for Your attention