IAEA International Conference on
Human and Organizational Aspects of
Assuring Nuclear Safety
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Exploring 30 years of Safety Culture
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WHAT THE NUCLEAR SECTOR COULD LEARN FROM RESILIENCE ENGINEERING

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Resilience…

- Itnrnisic alibtiy of a sytesm to mantiain its struructal idetnity, its (mian) fetuares, and at lesat patrilaly its pefromrnace, in the prensece of disutrabnces, inlucding l, unsuual, or unteexpecd oens, gonig beoynd tshoe for wcihh the steysm had been dsigneed for, or thsoe to wihch it is adptead.

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What?

Preparing the system to be unprepared

- Enhanced capabilities to react and adapt, before, as well as beyond, boundaries of safe operations envelope
  - 'graceful extensibility' (capacity to stretch near and beyond boundaries)
  - 'sustained adaptability' (capacity to manage adaptive capacities)
- Less predetermination, tighter coupling to reality. Shifting control ...
  - from past to present,
  - from prevention to recovery
  - and from the top to the bottom (front line) of organizations

How?

- Staying in control
  - Monitor, respond, anticipate, learn (Hollnagel)
- Staying in control of the degree of control
  - Develop, display, monitor, maintain, teach "margins of maneuver" (Woods)
  - Develop meta-knowledge
  - Manage trust and confidence
- Preparing to adapt to the unpredictable

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Preparing for the unpredicted/unknown

- Slacks, buffers, stocks, extra resources...

- Redundancies, diversity, vicariance,

- Repertoire of generic strategies responding to generic threats

  - Identify basic states, "vital" actions independent from scenarios

- Capacities to reorganize, to shift priorities, to redefine goals (sacrificing decisions)

- Collective sense-making capabilities, collective mindfulness, shared goals and values, shared risk perception

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WHY WOULD RESILIENCE ENGINEERING BE RELEVANT FOR NUCLEAR SAFETY MANAGEMENT?

Signs of strategic weakness

Fukushima

Air France 447

Deep Water Horizon
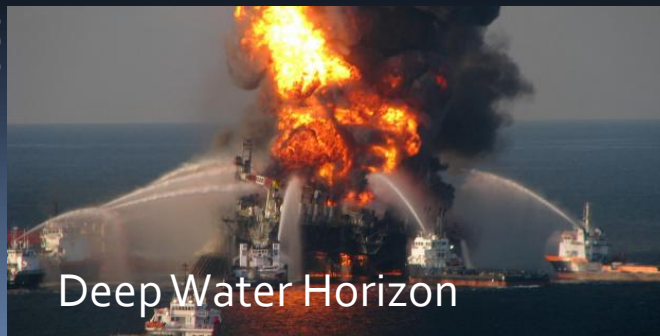
- Demonstrated vulnerability to unexpected, extreme, unexampled events

- Do we need to do better, and more intensively, what we already do…

- Or is the current safety paradigm itself challenged?

From prediction to reality

|	Catastrophic accidents	Minimum target	Predicted value	Observed value	90% Confidence interval
Space Shuttle	Loss of crew		10^{-4}	$1{,}5.10^{-2}$	
Nuclear PWR	Core melt / reactor/year	10^{-5}	7.10^{-6}	$1.\,10^{-4}$	$[0.5\,10^{-5},\ 4.7\,10^{-4}\,]$
Off-shore	Fatal accident/rig/ year	$[10^{-6},\ 5.10^{-4}]$	$[10^{-5},\ 10^{-4}\,]$	$1.7.10^{-3}$	$[\,0.5.10^{-3},\ 4.4.10^{-3}\,]$
Aviation IATA, Jets, 2009/ 2013	Hull loss/sector	10^{-6} ?	-	$2{,}26.\,10^{-6}$	
	Fatal/sector	10^{-6} ?	-	$0{,}5.10^{-6}$	
	Fatal/AC/Year	-	-	$6{,}5.10^{-4}$	

Most of the adaptation is "black matter" to the current safety paradigm

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The Defence in Depth (DiD) concept in nuclear safety

- Initially a physical concept:
  - a series of physical barriers against radioactivity

- Evolved into a safety strategy
  - From normal operations to accidental situation
  - A series of progressively degraded levels of control on the situation
  - From known to ... less known

= the framework of a resilience strategy!
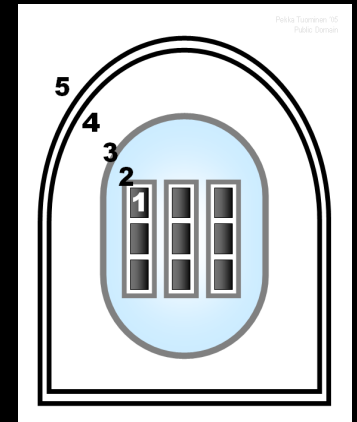
5- Emergency plan

4- Control of severe accidents

3- Control of design basis accidents

2- Control of failures

1- Prevention of failures

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Side comments about DiD

Reconstruction of the city of Tell Al-Rawda (Syria), circa -2500 BC

- To design the defence lines, one must have an idea of what the 'enemy' looks like. But there are possibilities for some genericity.

- The defence concept shapes daily life within the city, and may generate or augment other risks (e.g. epidemic)

- Reversely, daily life influences the efficiency of predefined defences (e.g. need for sentinels, closing doors, storing food…)

- And this daily « safe way of life » is heavily influenced by the belief that the enemy will come (chronic unease) and the trust in protections

How much predetermination?
# How much adaptation?

- Decreasing levels of predetermination
  - From proactive to reactive control

- Increasing levels of functional abstraction
  - From means to goals
  - From 'event based' to 'state based' control

The more detailed the procedures, the less adaptability
- "completeness removes genericity" (J. Rasmussen)

Adaptation is not needed only outside the boundaries of the safe envelope
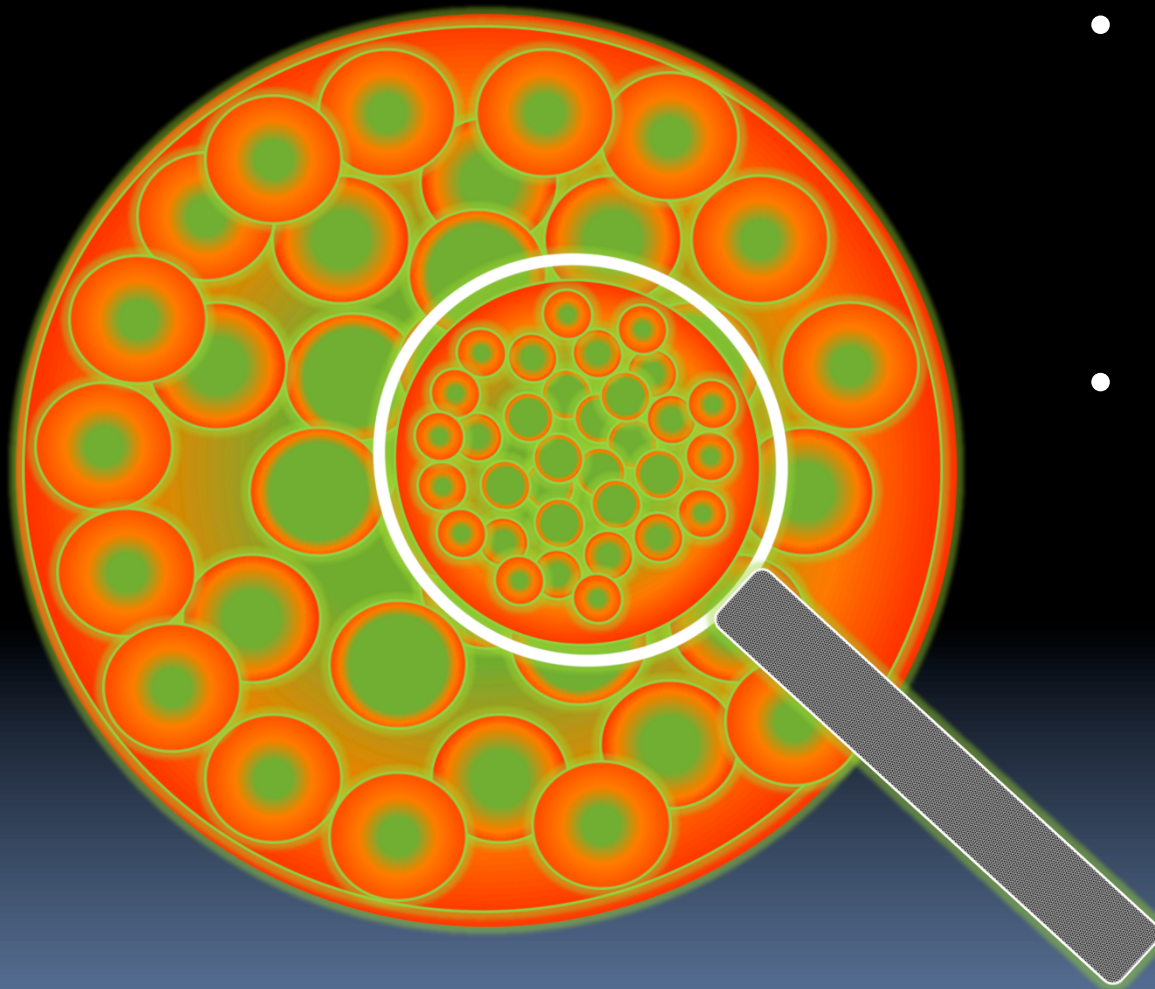
- The adaptation domain is actually of a fractal nature.
- From any point within that domain, a jump to outside the "boundary" can occur

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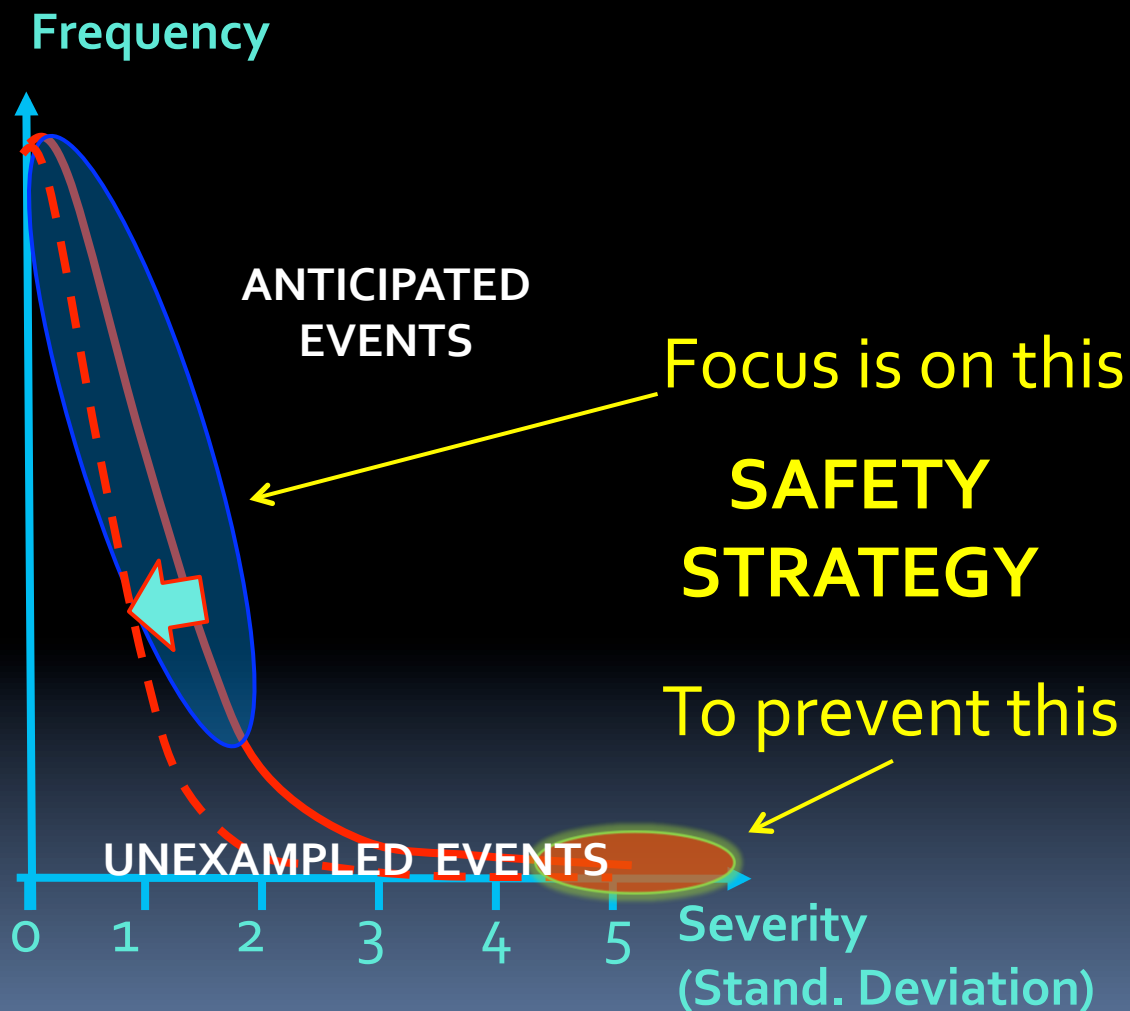
Safety paradigm/ideology/ model/culture

- The core of the safety model is the deterministic and/or probabilistic anticipation of all potential situations
    - And predetermination of all the expected (safe) responses
- Safety is warranted by the real world's conformity to this designed-to-be-safe world
    - Top-down command-and-control model
- The current 'safety culture' is emphasizing predefined responses
    - Procedures are properly covering all situations
    - Compliance is the necessary and sufficient condition for safety
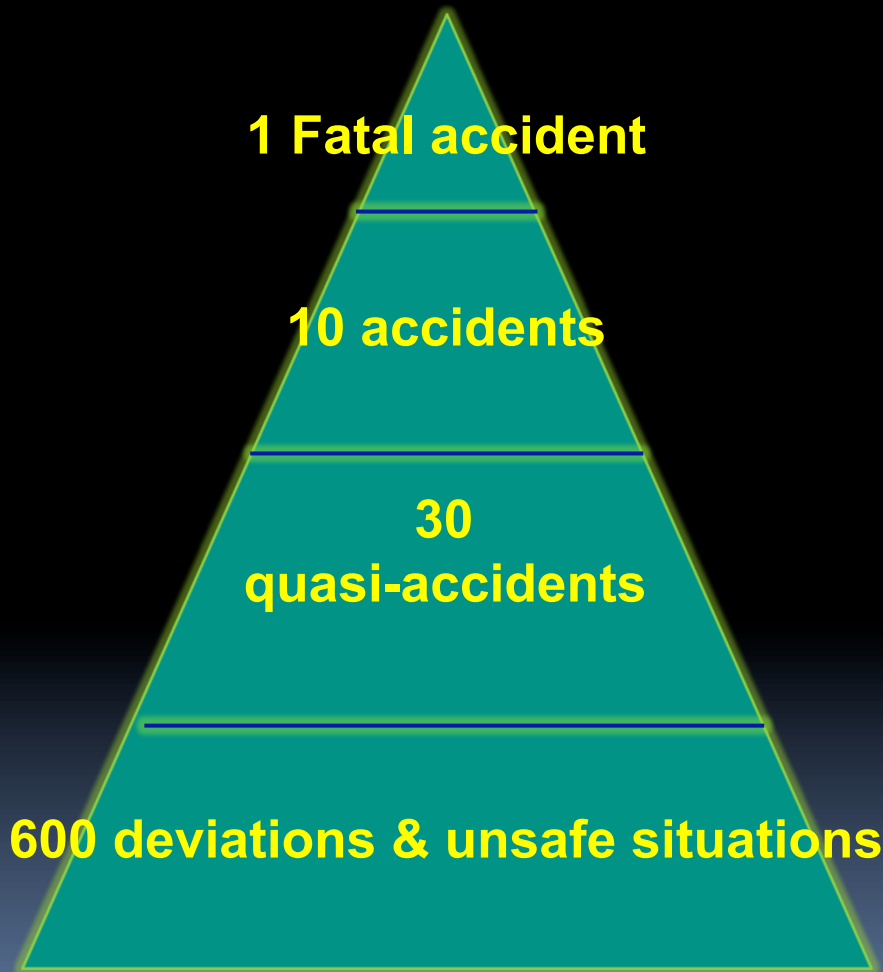
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Challenges…

- Life is "complex", even in normal situations
- Linear simplification (and the correlated top-down "command and control" vision) has done a good job but…
- … it fails to acknowledge the limits to predictability inherent to a complex adaptive (and self generated) system
- The current 'safety culture' is over-emphasizing predefined responses and underestimating the need for adaptation to the unknown
  - Including within the range of 'normal' operations
- We need a « shift from reducing uncertainty about the future to managing uncertainty as events unfold » (K. Suttclife)

A linear vision of risk

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- Bell curve: thin tail illusion

- Linearity illusion: the frequency of low severity events is perceived as a good assessment and driver of disaster probability

- Rationality illusion: the distant elephant syndrome

  - Severity should be the key parameter for rare events

Frequency

ANTICIPATED EVENTS

Focus is on this

SAFETY STRATEGY

To prevent this

UNEXAMPLED EVENTS

0   1   2   3   4   5   **Severity (Stand. Deviation)**

The Henrich/Bird pyramid

1 Fatal accident

10 accidents

30
quasi-accidents

600 deviations & unsafe situations

- Henrich, Fletcher & Bird (1974)
- Insurance company
- 175'000 occupational accidents
- 297 companies

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All Injury Frequency Rate (Month Rolling Average) and Fatality Rate
2000.12 - 2008.08

4.06

0.054

All Injury frequency rate

Fatality rate

bhpbilliton

MAERSK

PotashCorp Helping Nature Provide

Cargill

ADM

ExxonMobil

AIFR   Fatality Rate   Linear (Fatality Rate)

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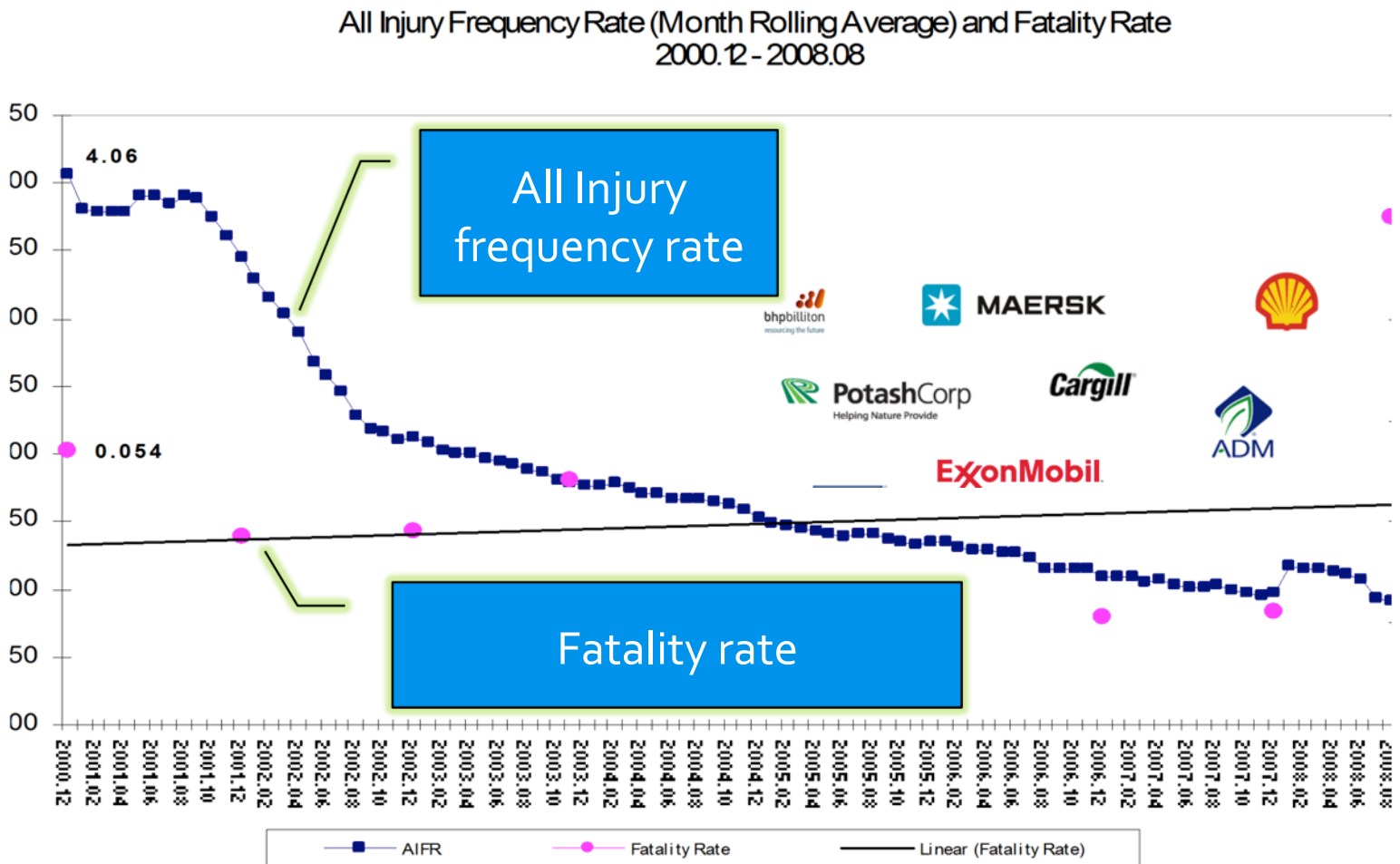
The vicious circle of predetermination and vulnerability

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Most capacities needed to cope with the unexpected are eroded in the continuous attempt to prepare for the expected.

More

Perceived vulnerability to the unexpected → Attempts to increase predictability → Simplification Anticipation Predetermination → Surprises more 'surprising' ↑

From known to unknown

- The degree of overall potential control decreases
- The efficiency of normative control decreases even faster
- The proportion of needed adaptive control increases

Degree of control

Normal situation

Abnormal situation

Known

Unknown

Adaptive control

Normative control
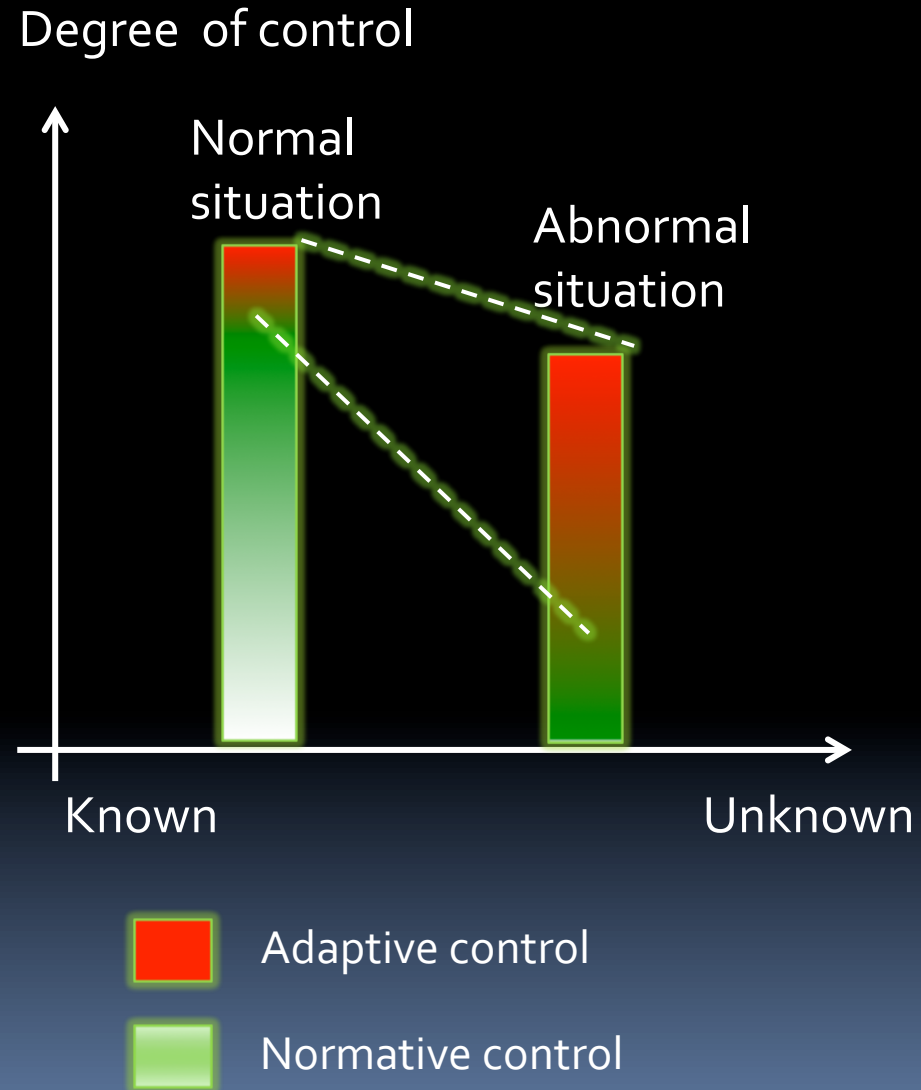
The influence of autonomy

Decreasing staff autonomy (higher compliance to predefined responses)

- Increases the odds that a normal situation stays normal

- But decreases the odds for recovery in case of unexpected events

Degree of control

Normal situation

Abnormal situation

Degree of autonomy
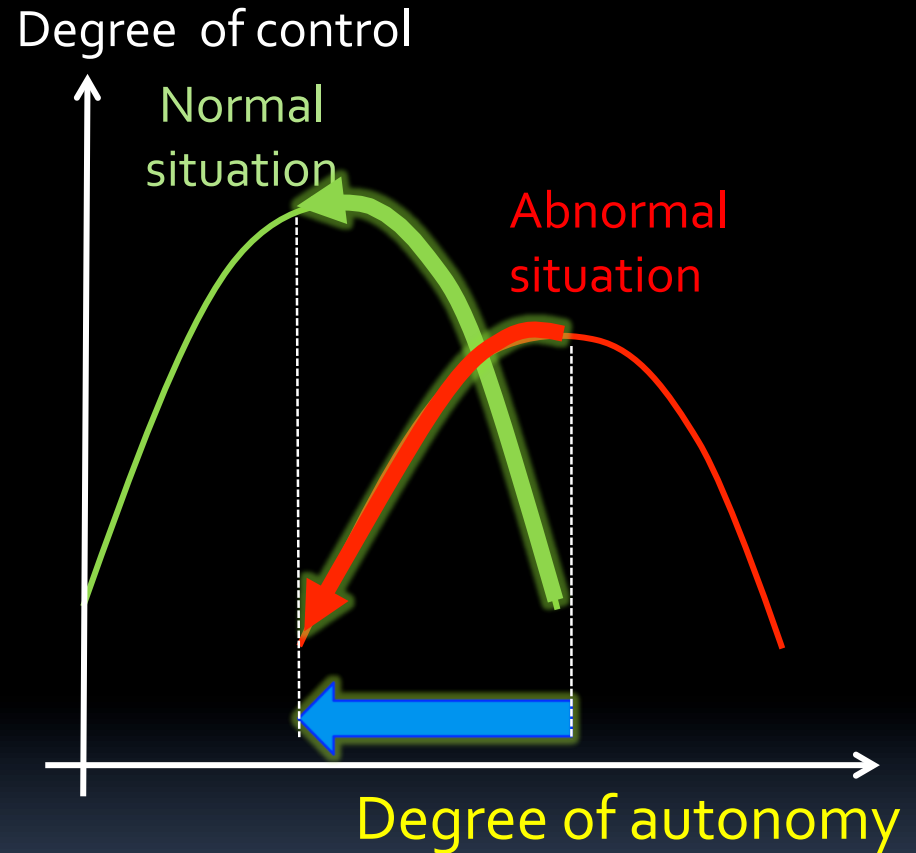
A key question : what are the consequences of 'losing control' in normal vs abnormal situations?

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A different vision of…

- Management
  - Trust
  - Margins of maneuver, dynamic re-planning, priority shifts, reallocation of roles; sacrificing decisions
  - Adaptive competences, redundancy, diversity, vicariance
  - Oversizing, slack, buffers, stocks, back-ups, bunkers…
- Design
  - Simplification !
  - Include operational flexibility
  - Show 'Margins of Manœuver' within safe operations envelope , augmented monitoring
  - Adaptive automation

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A different vision of…

- Procedures
  - Objectives rather than means
  - Express the why's, indicate alternative ways
  - Identify basic states, "vital" actions independent from scenarios
- Training
  - Introduce uncertainty, "fundamental surprises"
  - Reintroduce a proper account of adaptive skills
  - Train uncertainty management skills
  - Address the taboos (e.g. blind procedural adherence)
  - Clearly separate training vs checking
- Learning from experience
  - Understand how Humans handle the unexpected
  - Understand success as well as failures

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Conclusion

- Current safety strategy seeks anticipation of all potential threats, eradication of variations, standardization, linearity, conformity.
  - Makes the system more and more efficient and reliable within its envelope of designed-for uncertainties, and more and more brittle outside it.
- Safety strategies should rather recognize real world complexity (unpredictability) and develop outmaneuvering capacities
  - Means resilience features

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Thank you

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