PREDICTING THE FATAL FLAWS

THE CHALLENGE OF THE UNPREDICTABLE...

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DETECTING? THE FATAL FLAWS

- *« The 'Fatal Flaws' are caused by increasing complexity and decreasing transparency in complex systems.»*

- What is "complexity"?
- What are the main implications of complexity on safety management?

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PREDICTING THE FATAL EVENTS?

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PREDICTING THE FATAL FLAWS

(FUTURE!)

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COMPLEXITY…

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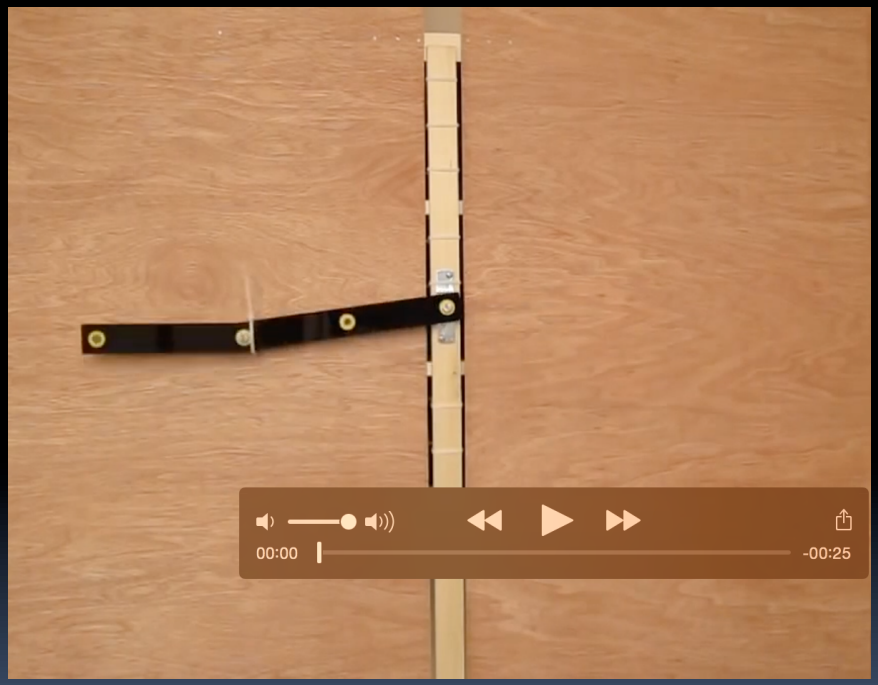
From simple to complex

- Double pendulum



https://www.youtube.com/watch?v=AwTokogw-jw

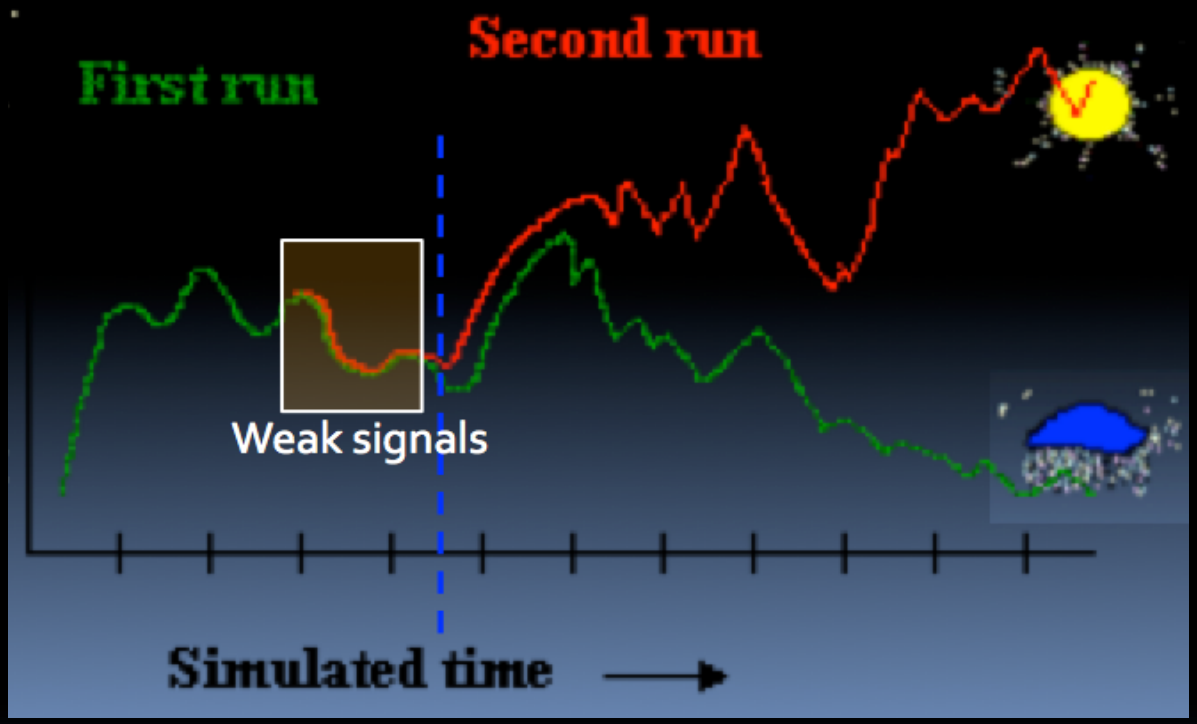
- The interaction between two periodic (totally predictable) components makes a chaotic (unpredictable) system
- A key feature of complex systems: their behavior results from components' **interactions**, not from their (average) behavior

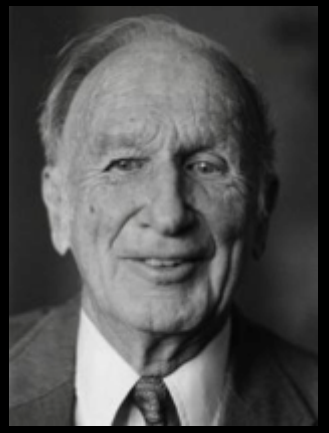
Large population systems

- Simple ("more is similar"):
  - Interactions tend to annihilate individual differences (the noise)
  - Mean values determine large-scale system's behavior

- Complex ("more is different"):
  - Interactions tend to amplify individual differences
  - The amplified noise determines the system's large-scale behavior
  - Nearby states diverge from each other exponentially fast
    - Non linearity
    - Sensitivity to initial conditions
  - The system is then unpredictable
  - Emerging properties cannot be derived from analytical decomposition (they can only be observed, e.g. via simulation)

Chaos theory

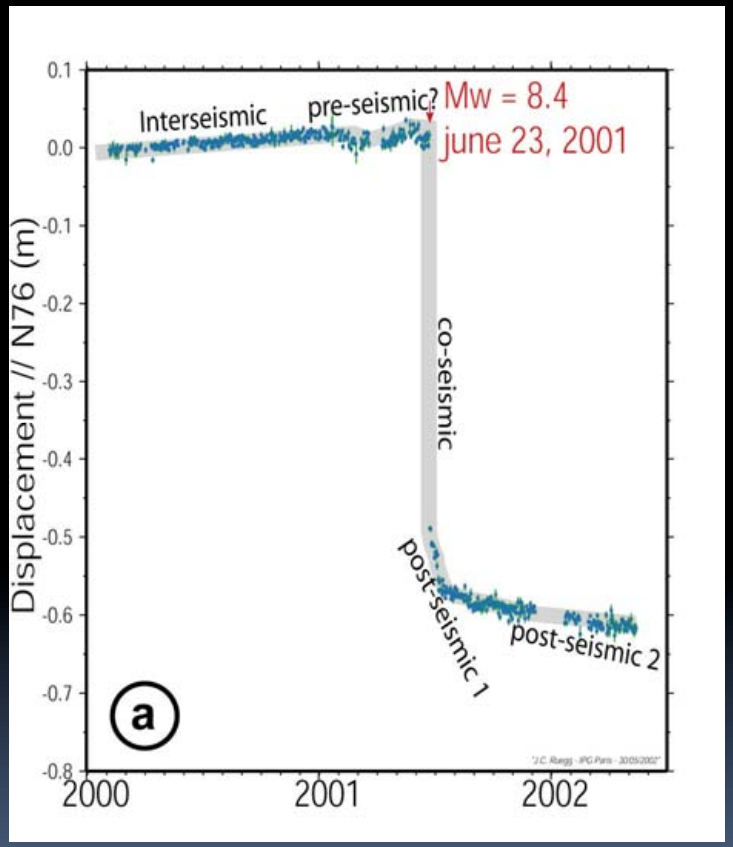




Edward Lorentz

- "*When the present determines the future, but the approximate present does not approximately determine the future*"
- Past is obvious, future unpredictable

The rise and fall of ‘precursors’



- About 15% of earthquakes are preceded by precursors (“Foreshocks”)
- Usually identified AFTER, but not identifiable before
- The difficulty is to discriminate meaningful signals from background noise
  - The key question: what is normal variation?
- To be able to see, we need a model of what we are looking for!

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CURRENT SAFETY PARADIGM

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The current vision of aviation safety

- More reliability, automation, protections
- More specifications, rules, procedures
- More situations covered
- More training for the expected
- More compliance demanded
- More standardization (interchangeable operators)
- More “safety culture” (internalized constraints)
- More reporting, more and more “data”
- More control on people, less and less autonomy

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A "simple" world: linear, predictable, fully controllable

- Deterministic and/or probabilistic anticipation of all potential situations
- 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
  - Risk is seen as generated by deviations and variations
- The modern 'Holy Grail': a world where nothing goes wrong, a perfect world (organizations, processes, teams, behaviors)

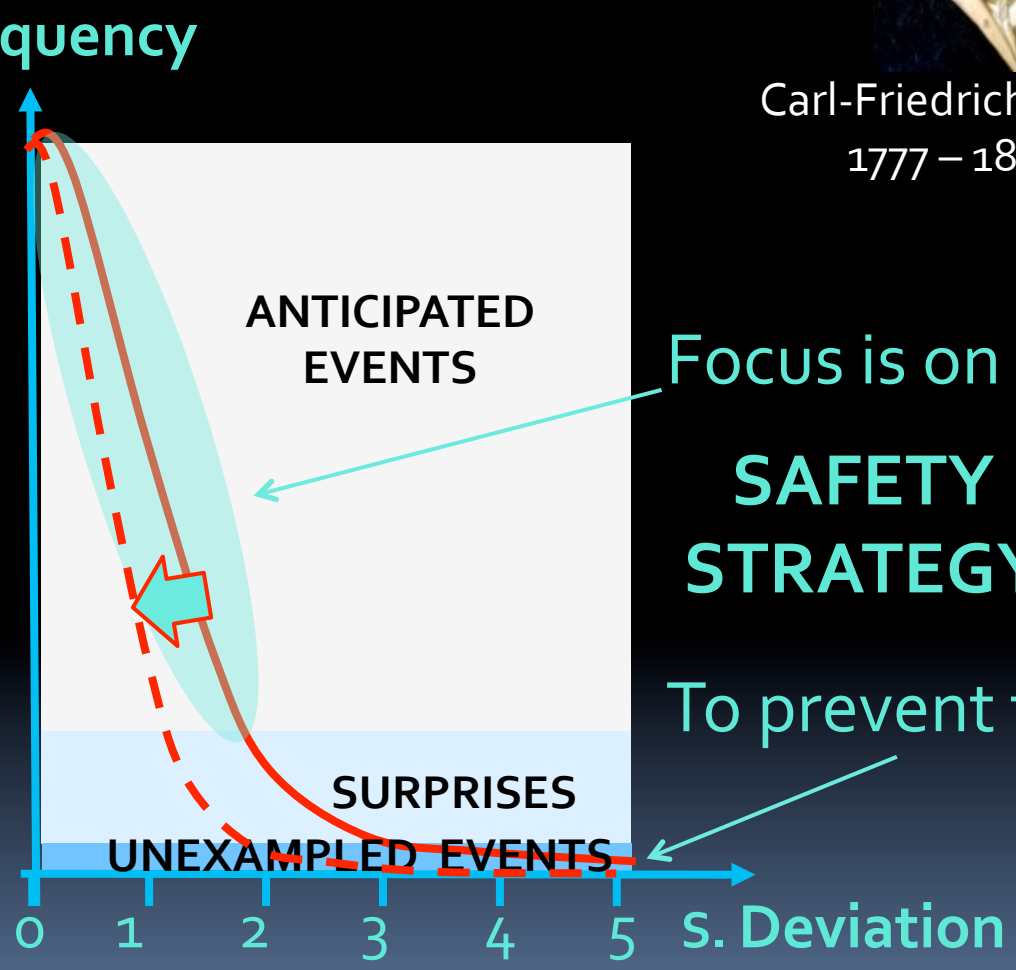

René Descartes 1596-1650)


Pierre-Simon Laplace (1749-1827)

A linear vision of risk

Carl-Friedrich Gauss
1777 – 1855

- Normal distribution
- The frequency of low severity events is perceived as a good assessment of disaster probability



Focus is on that

SAFETY STRATEGY

To prevent this

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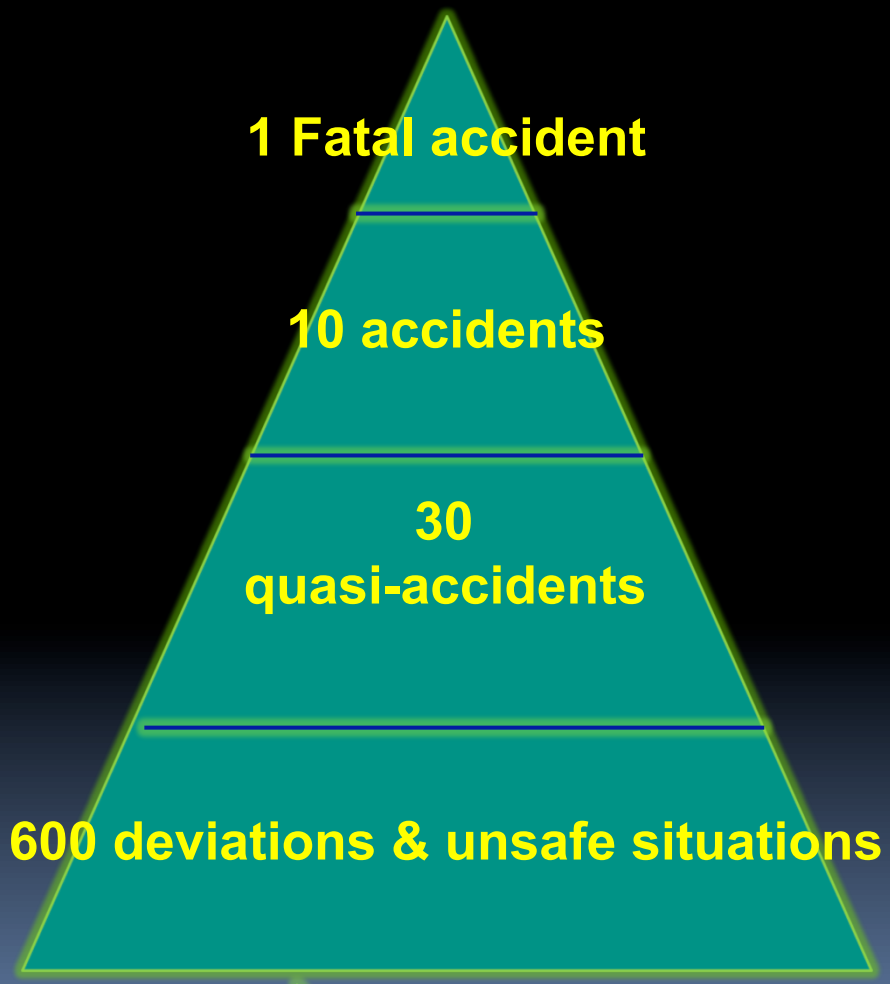
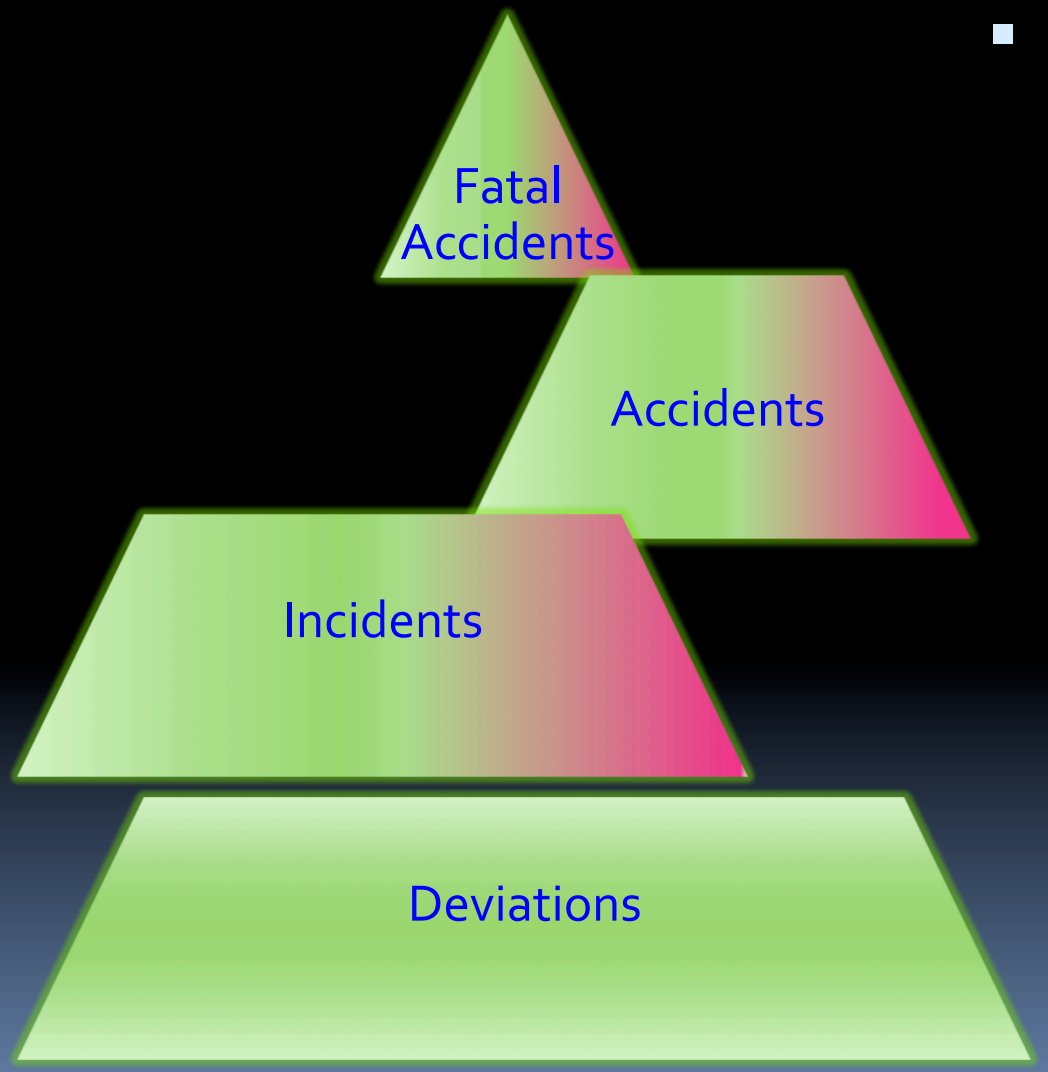
The Henrich/Bird pyramid



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

The pyramid myth



- In a complex system, the frequency of rare & catastrophic events does not react in a simple way to changes in the frequency of day to day incidents

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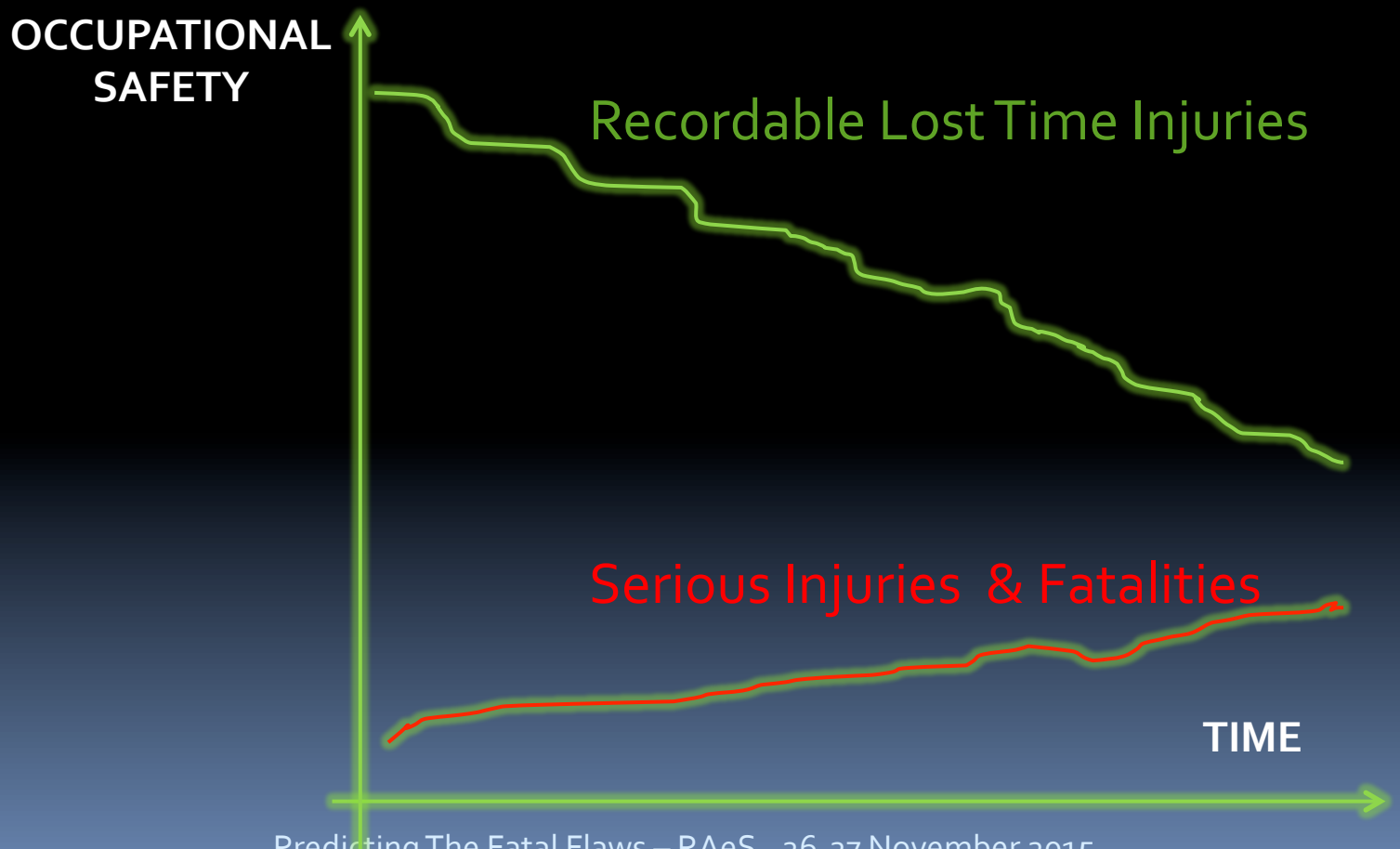
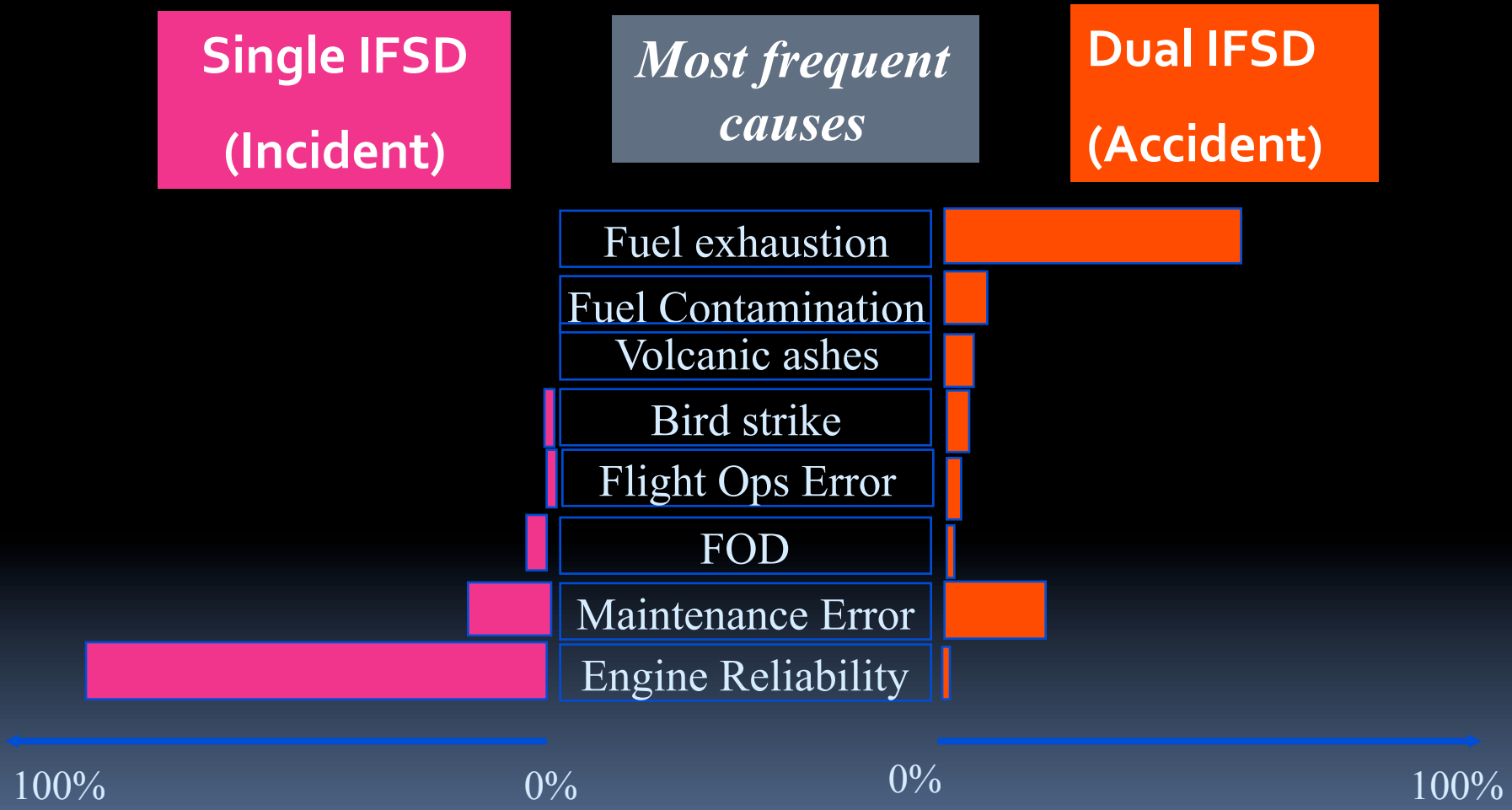
BST and Mercer ORC study (2011), along with seven global companies



From single to dual failure…



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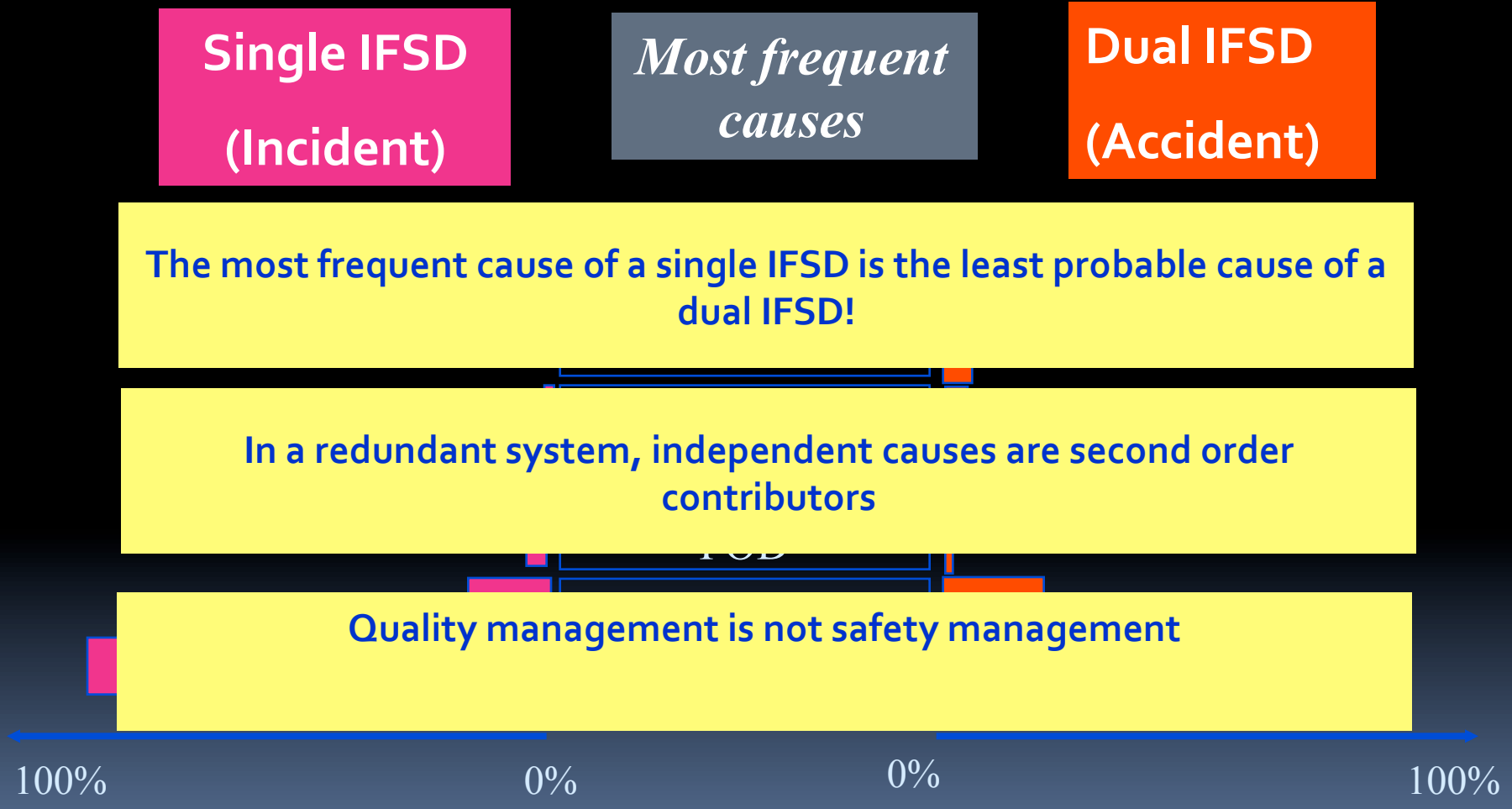

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MIT study (Barnett 2003)

- Seeking correlation between incident rates and passenger death risk, across Major US jet airlines, 1990-1996
- Significant negative correlation found!
- *" Taken literally, the data suggest that a passenger would have reduced his airborne death risk over this period by preferring mishap-prone airlines"*
- *" Data analysis fails to support the conjecture that, the greater an airline's involvement in mishaps, the greater its propensity to suffer the disasters that passengers fear "*.

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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In other words…

- Life is "complex", even in normal situations (and even in aviation)
  - Changing, ambiguous, uncertain
- 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 system
- « Things that have never happened before, happen all the time » (S. Sagan- The Limits of Safety)

A paradigm shift?

- Do we need to do better, and more intensively, what we already do?
- … or is the current safety paradigm itself to be challenged?

- We need a « shift from *reducing* uncertainty about the future to *managing* uncertainty *as events unfold* » *(Kathleen Suttclife)*

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Two main strategies against complexity

- Reducing complexity

- Outmaneuvering complexity

RESILIENCE…

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- 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.

Preparing to be unprepared

- Enhanced capabilities to react and adapt
  - Far from, as well as near boundaries of safe operations envelope
- Less predetermination, tighter coupling to reality
  - Shifting control from past to present,
  - And from the top to the bottom (front line) of organizations
- Proactively developing a repertoire of generic strategies responding to generic threats
  - Identify basic states, "vital" actions
- Developing sense-making capabilities

Resilience as adaptive capacity (D.Woods)

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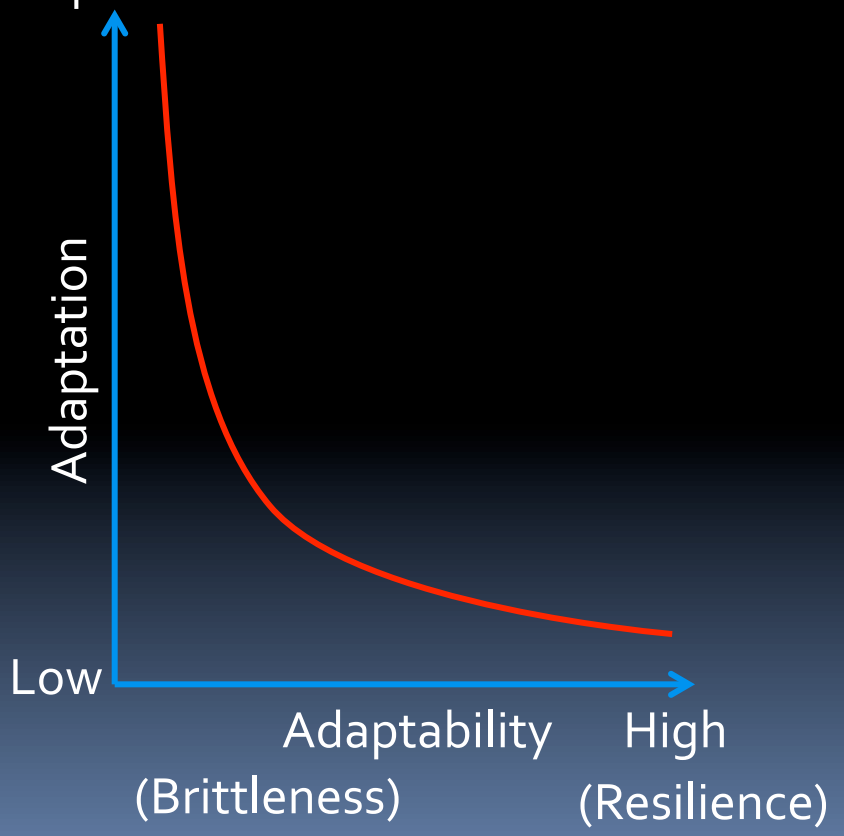
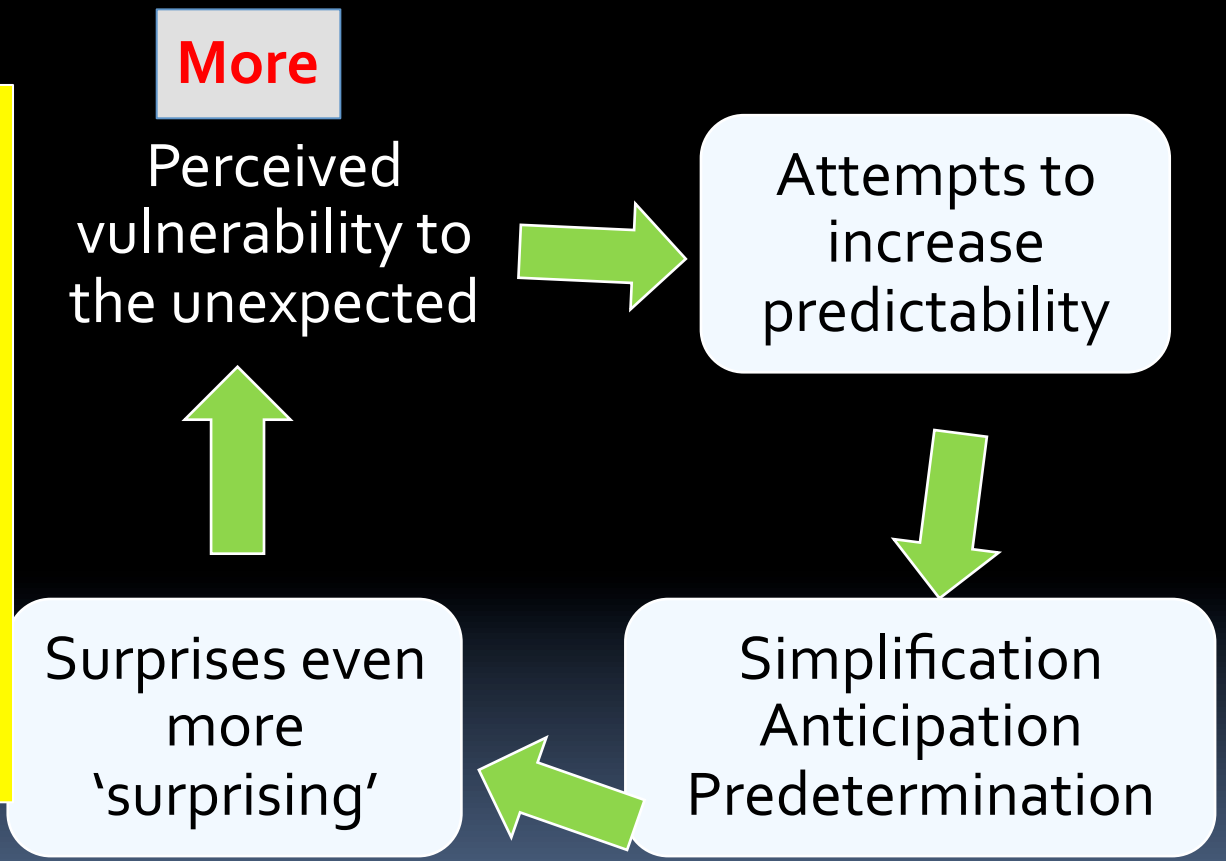
- The more is a system "fit" (optimized for a given environment), the more sensitive it will be to disturbances.
- An inescapable trade-off between optimality and fragility.



The vicious circle of predetermination and vulnerability

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



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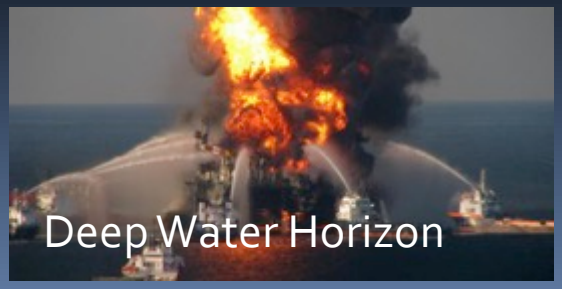
Contemporary fatal flaws

Demonstrated vulnerability to the unexpected, at all scales



- Simple model for a complex world:
  - Denying complexity, missing adaptability needs, missing what produces success
- Lack of margins of maneuver:
  - Productivity pressures, Lean functioning, Faster Better Cheaper
- Lack of control:
  - Tight coupling, escalation, cascading effects, common mode failures, resonance
  - Lack of competence, lack of margins visibility
- Lack of synergy:
  - Silos, fragmentation, working at cross purposes,
  - Local optimums, tragedy of commons
- Lack of adaptability:
  - Hysteresis, stuck in obsolete schemes & behaviors
  - Inability to learn proactively

Future flaws?

• Simple model for a complex world: • Denying complexity, missing adaptability needs, missing what produces success	Complexification of real world, increasing uncertainty Oversimplification of models, linear thinking
• Lack of margins of maneuver: • Productivity pressures, Lean functioning, Faster Better Cheaper	Increased optimization pressure
• Lack of control: • Tight coupling, cascade effects, common mode failures, resonance • Lack of competence	Tighter coupling, interdependencies, networks of networks Decreasing competence/complexity ratio in operations
• Lack of synergy: • Silos, fragmentation, working at cross purposes, • Local optimums, tragedy of commons	Increasing fragmentation, local logics
• Lack of adaptability: • Hysteresis, stuck in obsolete schemes & behaviors • Inability to learn proactively	Paralyzing impact of social, economical, political logics (e.g. financial, judicial constraints) on safety management

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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 (resilience features).

Thank you

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