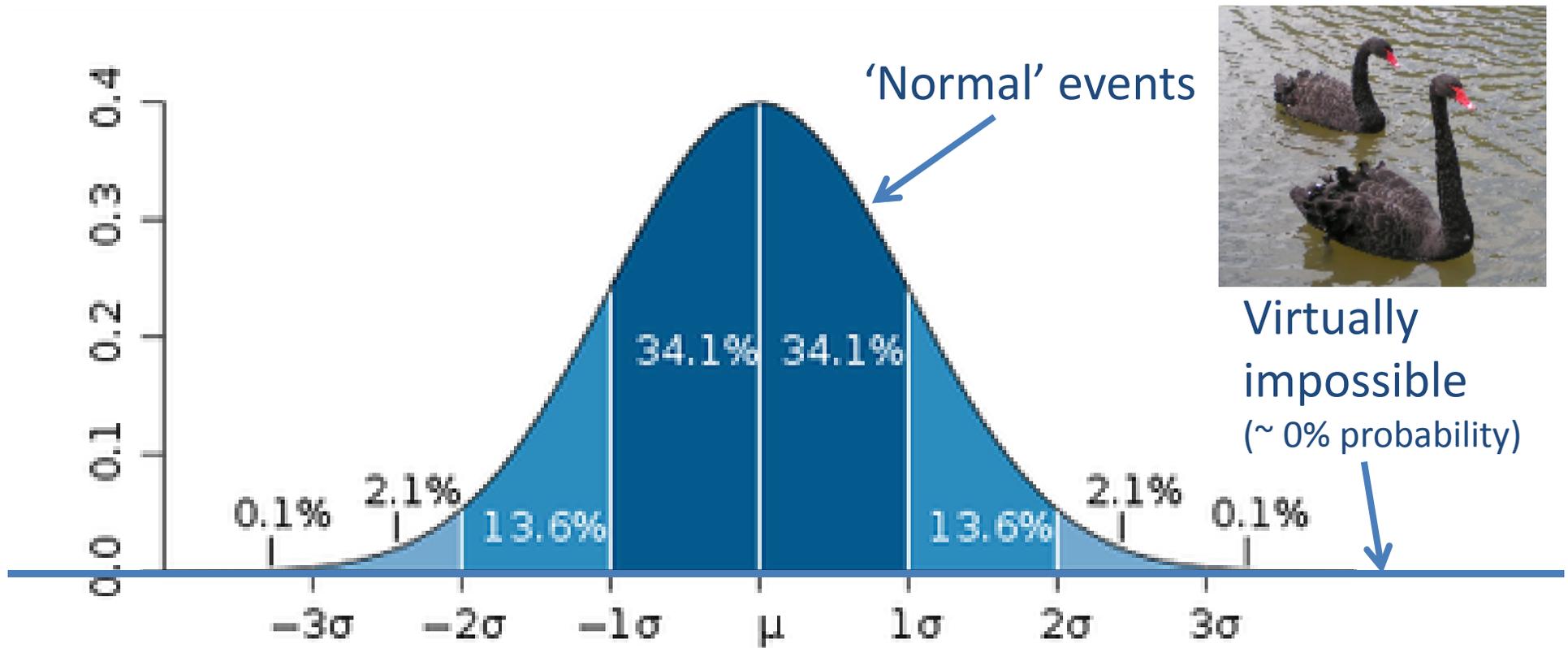


BE



Normal/Gaussian/Bell Curve Distribution

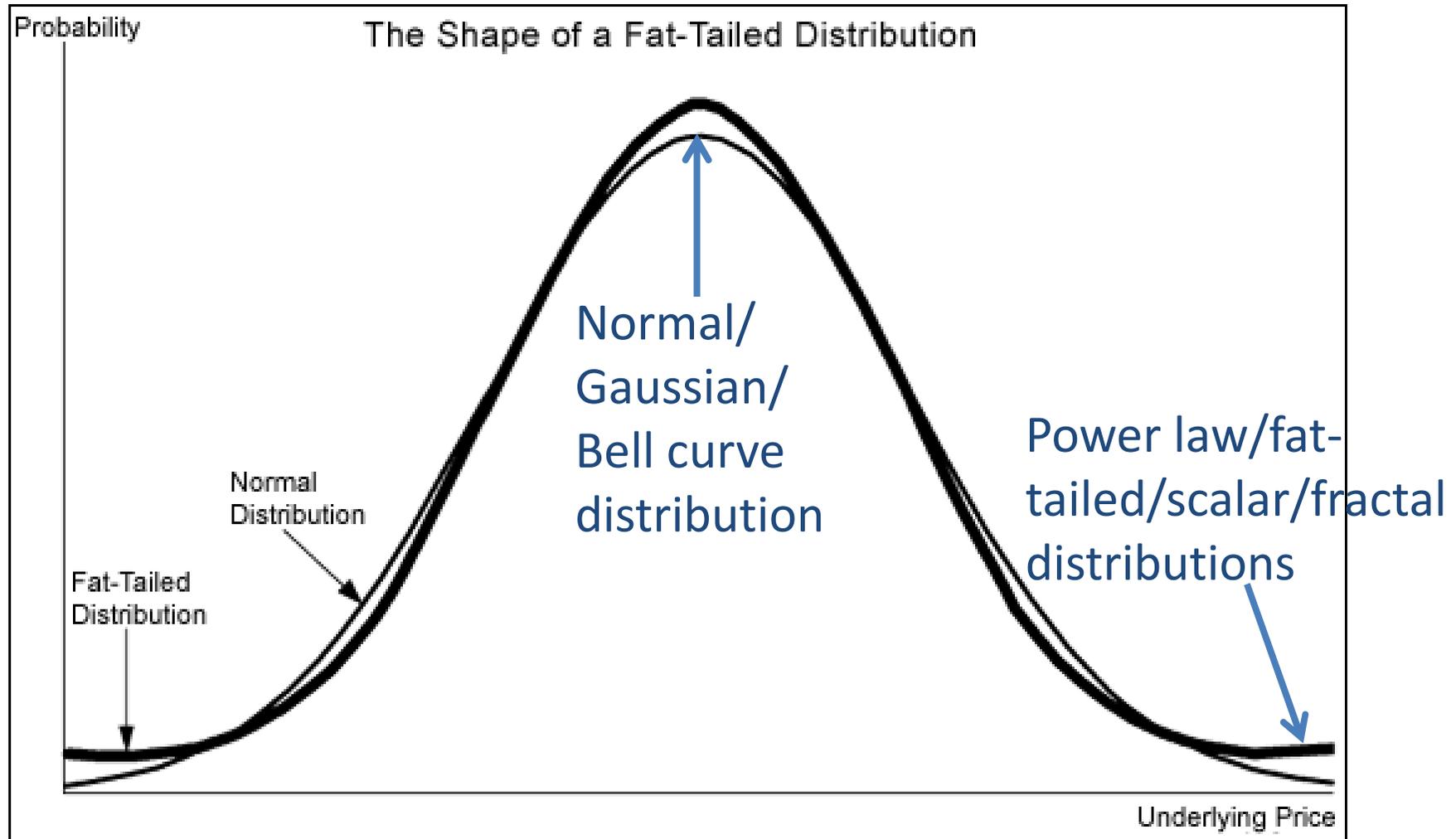


Virtually impossible
(~ 0% probability)



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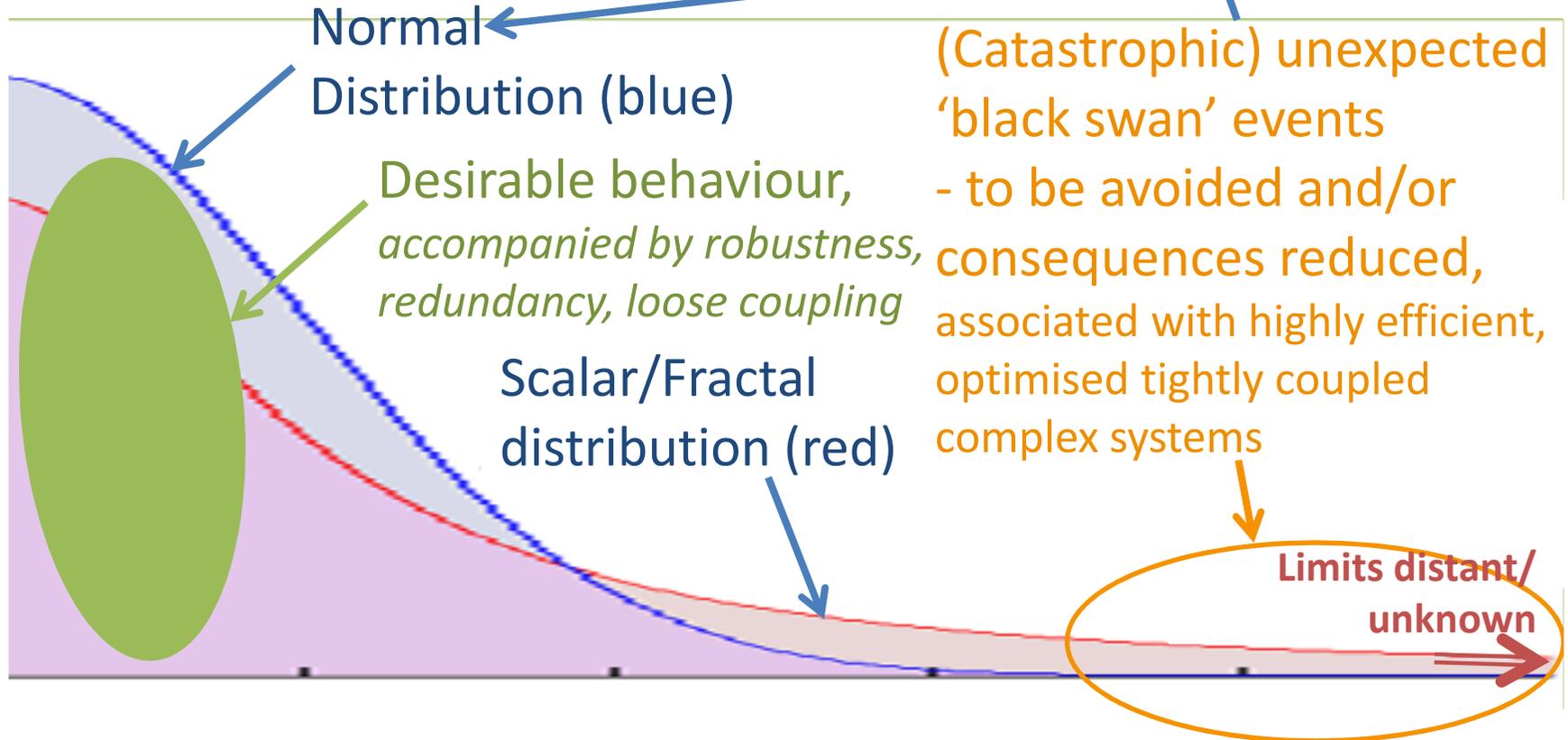
Models of Distribution





Normal versus Power law/Fractal Distributions

Highly surprising: as impossible according to this model

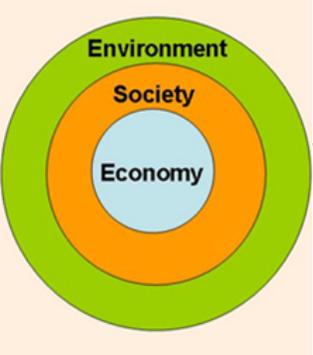


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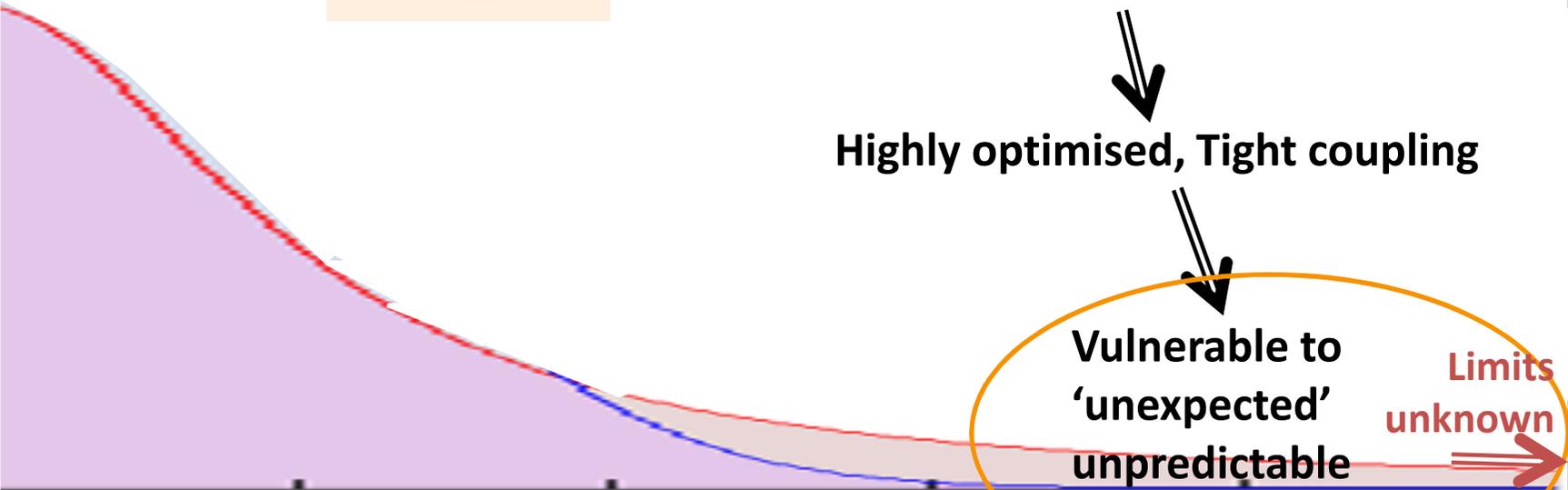
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Power law/Fractal/Scalar/Fat-tailed Distributions



Complex Systems:

e.g. Ecological, Social, Economic, Technological systems (with human input), Sustainability, Food Production, Water, Energy Generation and Distribution, etc., etc..



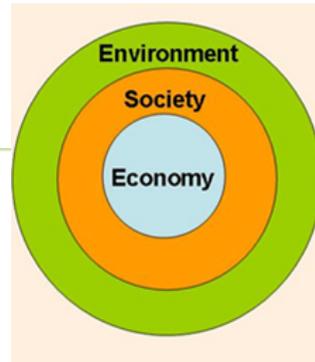
Highly optimised, Tight coupling

Vulnerable to 'unexpected' unpredictable Catastrophic Events
 Limits unknown

BE

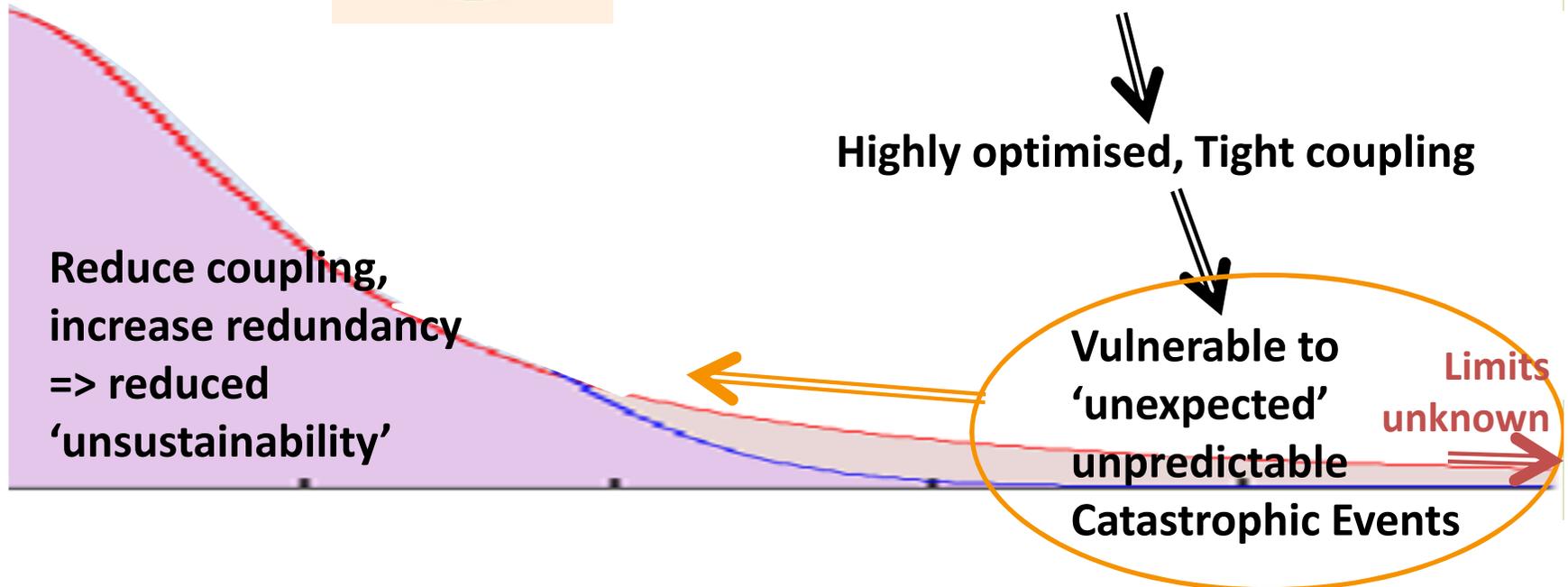


Power law/Fractal/Scalar/Fat-tailed Distributions



Complex Systems:

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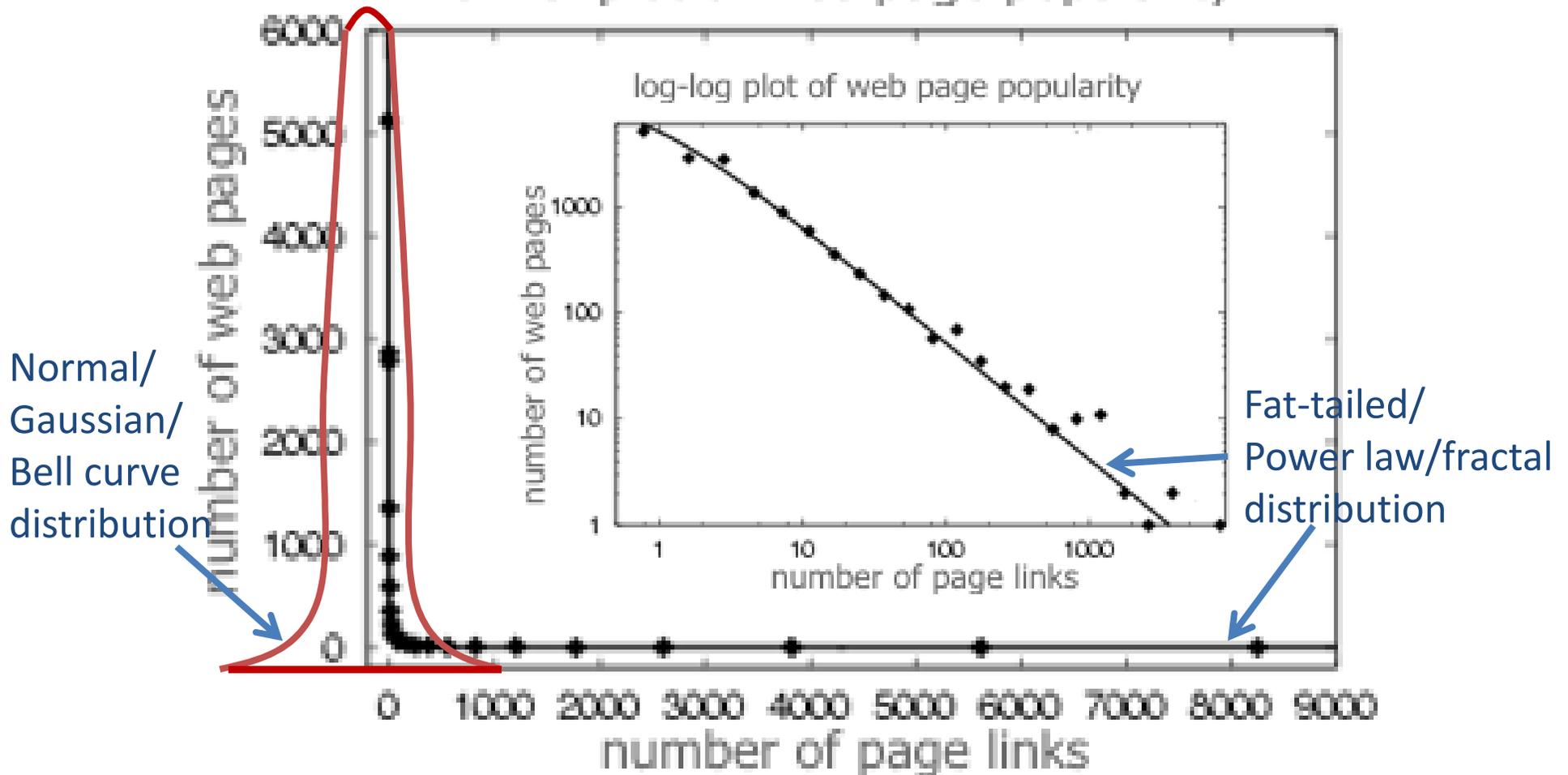


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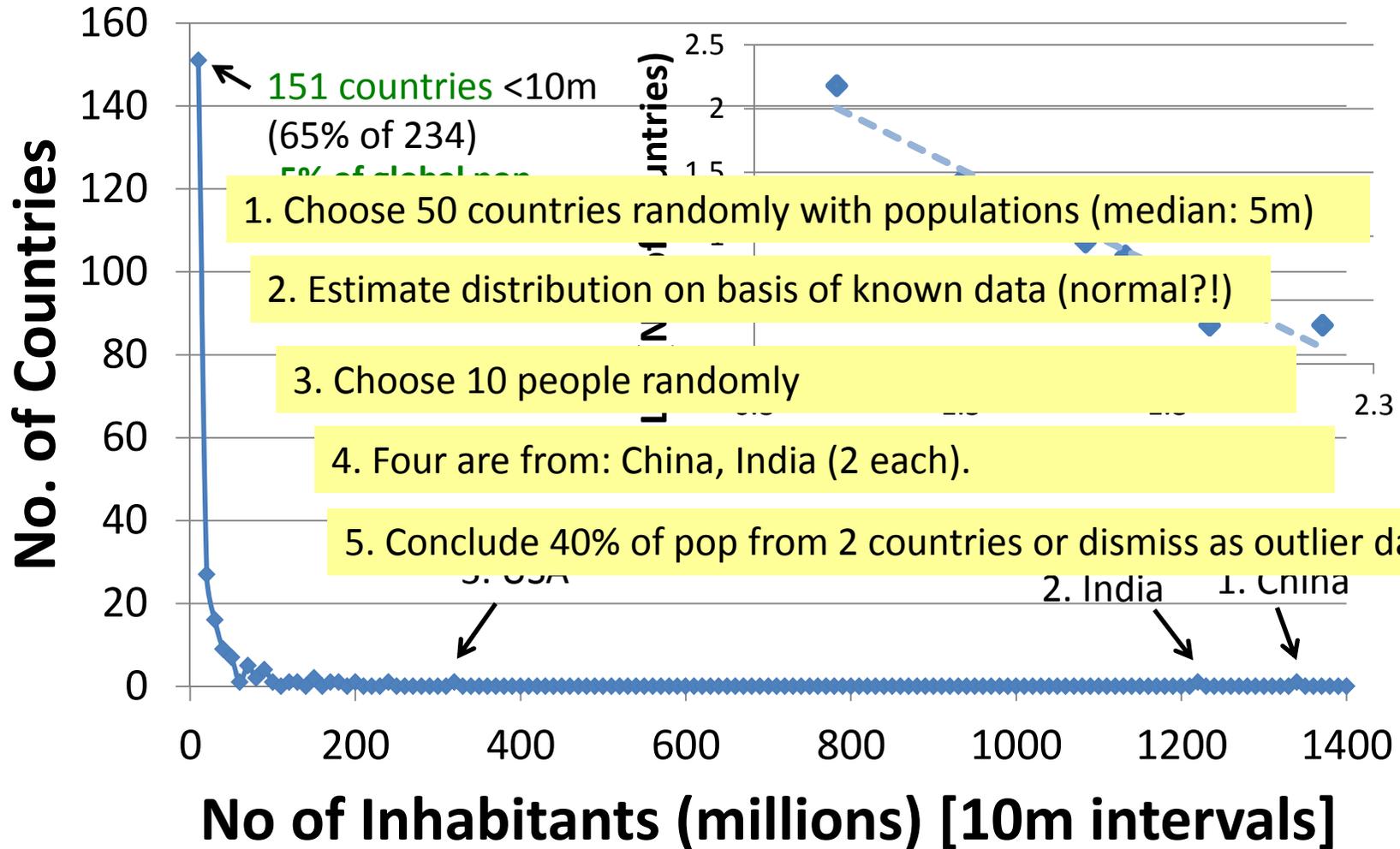
Power law/Fractal/Scalar/Fat-tailed Distributions

normal plot of web page popularity





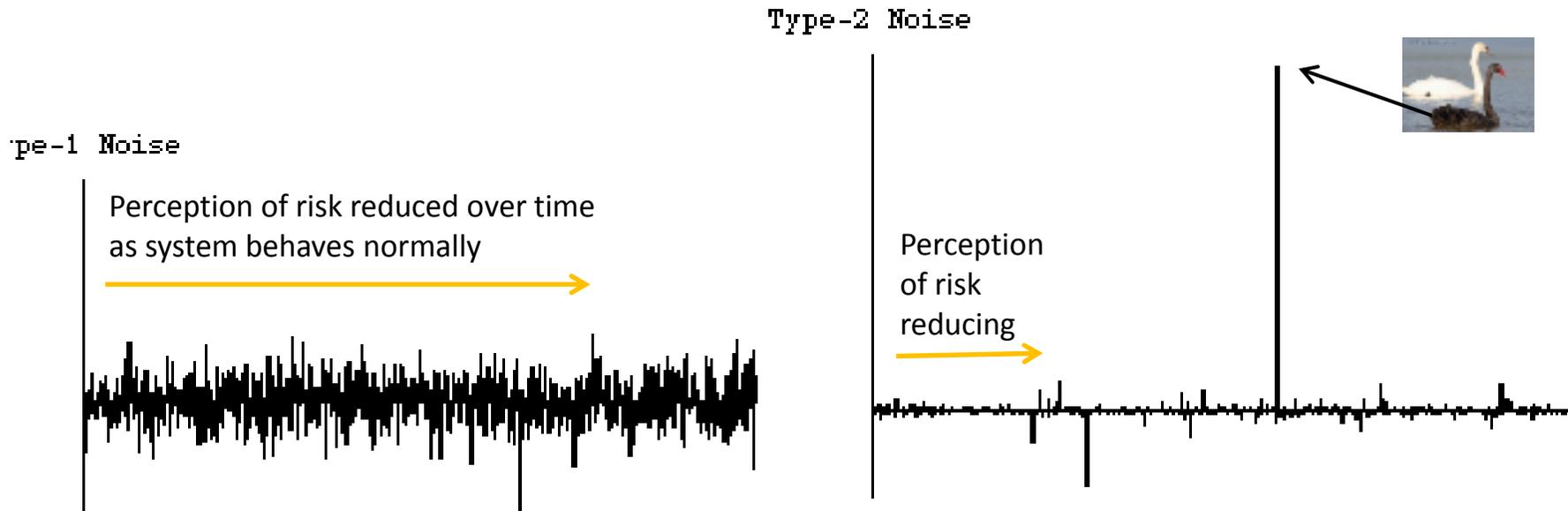
Power law/Fractal/Scalar/Fat-tailed Distributions



BE



Normal versus Power law/Scalar Distribution



Taleb: Type-2 (scalar) noise (with extreme spikes) necessitates more redundancy (or insurance). Policymakers and forecasters do not appreciate this for complex systems.

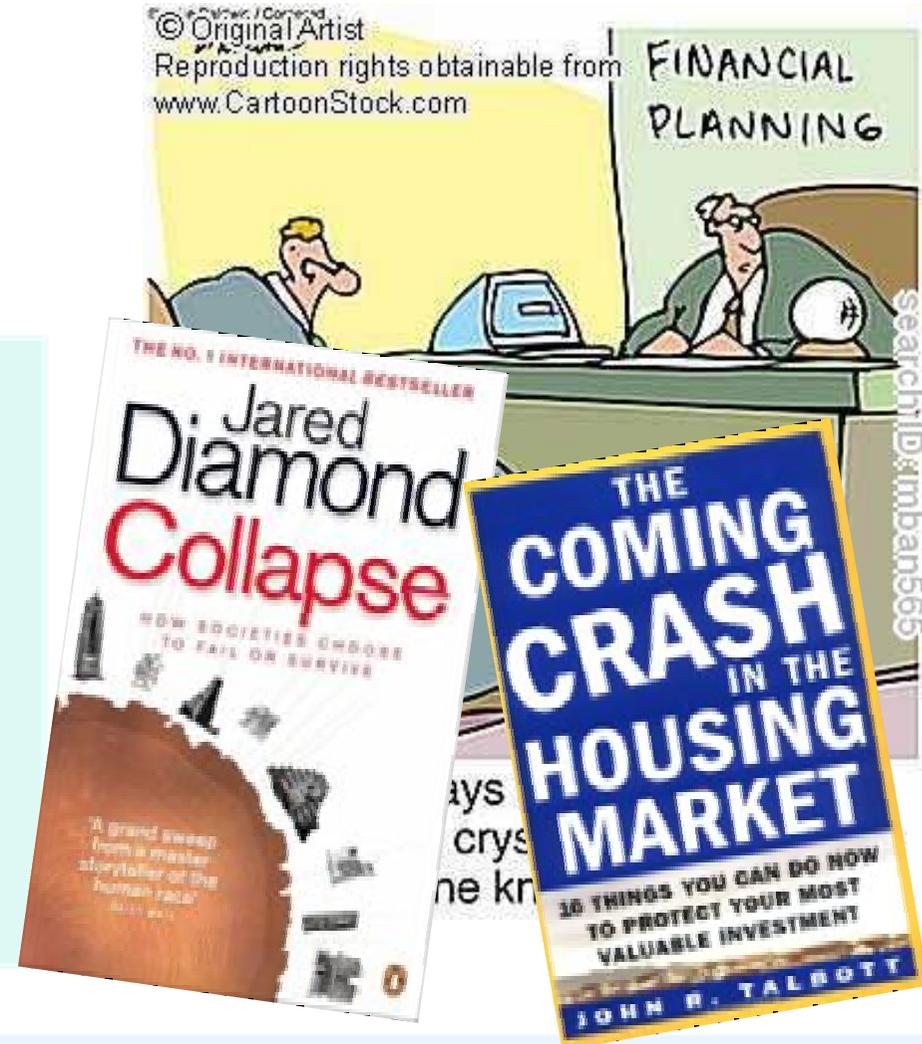
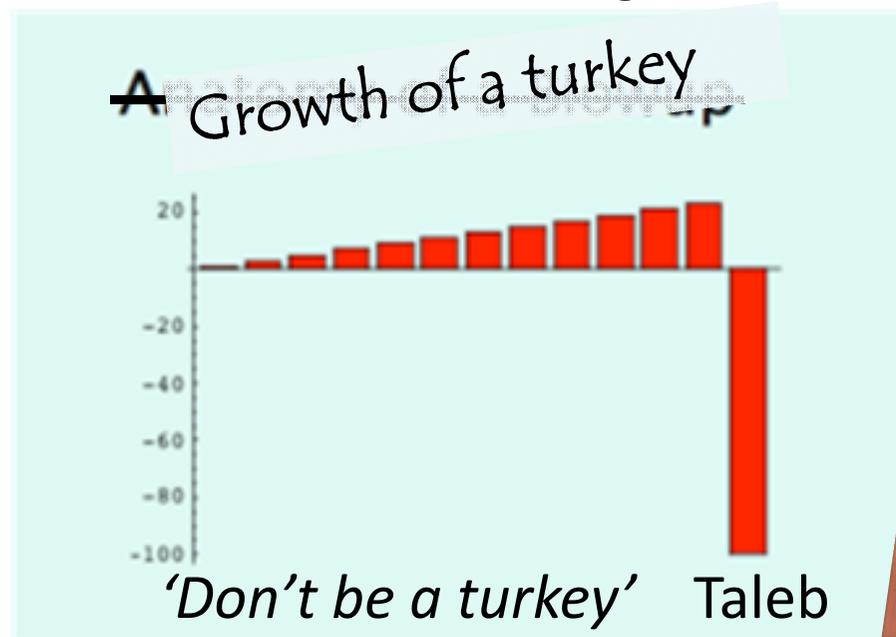
e.g. The German Commission on Process Safety “recommends adjusting **retrospective** data for water levels and rainfall by a “Climate Factor” of 1.2 for new installations with a lifetime until the year 2050. A **20% increase** of the severity of floods and heavy local rainfall until 2050 is **well in between most scenarios** of the scientific debate on climate change.”

C. Jocum, Chair, GCPS (2011)



Anatomy of a black swan

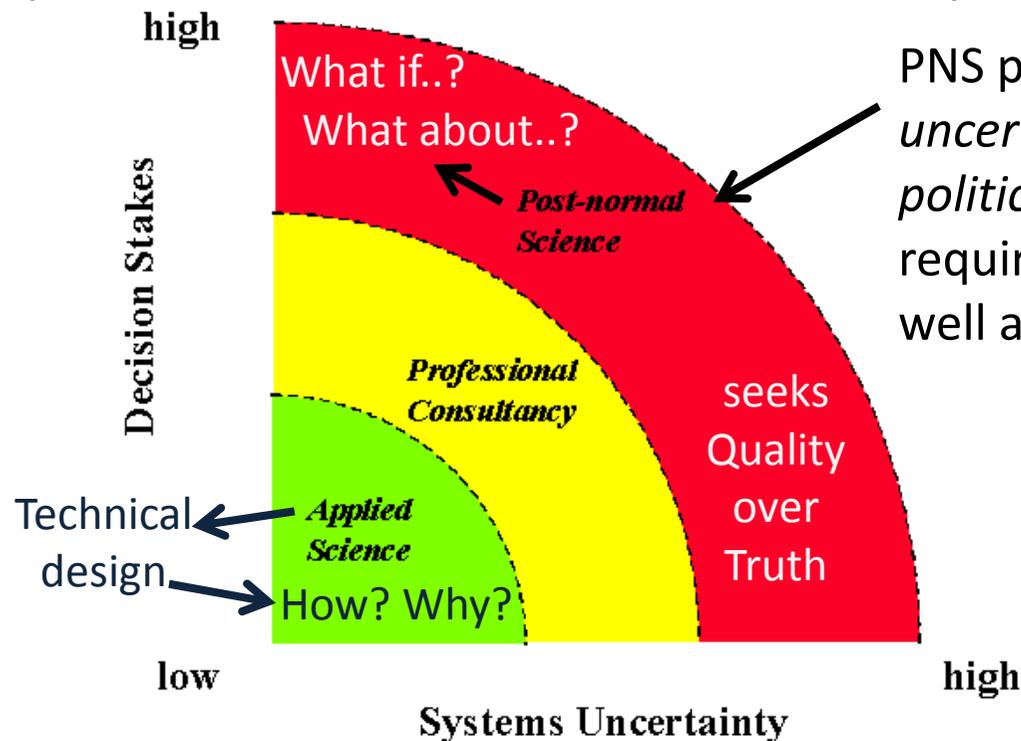
1. A **rare** and **unpredictable** event, **unexpected** by the observer ('a turkey').
2. Has **major impact**. Lead to almost all consequential historical events.
3. ..but **rationalised** in hindsight.





6. Dealing with uncertainty: Post Normal Science

PNS concept developed by Silvio Funtowicz and Jerome Ravetz in early 1990's to address (negative) **real world problems** where **facts** are **uncertain**, **values** are in **dispute**, **stakes** are **high** and **decisions urgent**. e.g. wicked problems, where problem definition is contested and consequences of options are unknown



PNS problem involves 'variability, uncertainty, complexity and influences of politics, power and privilege'* and thus requires 'extended peer community' as well as professional **expert** input

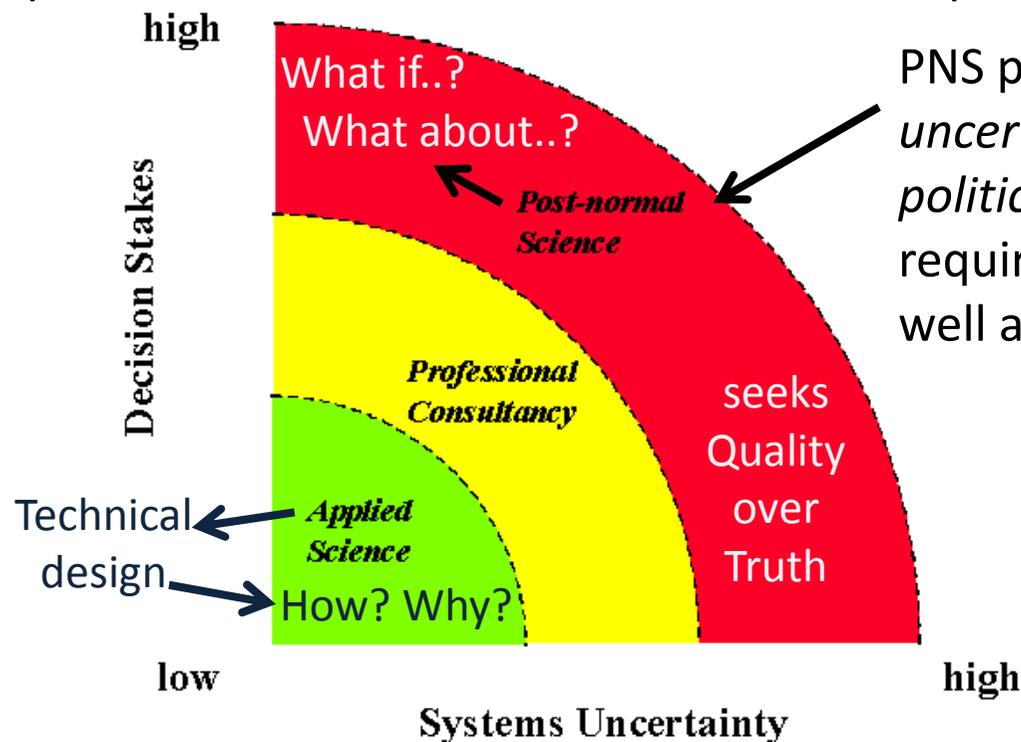
Non experts who can bring '**extended facts**' to issues; their own personal experience, surveys, knowledge to feedback and complement traditional science in an integrating social process

BE



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PNS problem involves 'variability, uncertainty, complexity and influences of politics, power and privilege'* and thus requires 'extended peer community' as well as professional expert input

"In general, the **real world** has so much variability and **uncertainty**, that it will be the more coarse, **rough-and-ready** aspects of the **scientific evidence** that are **relevant**."

Ravetz (2006)

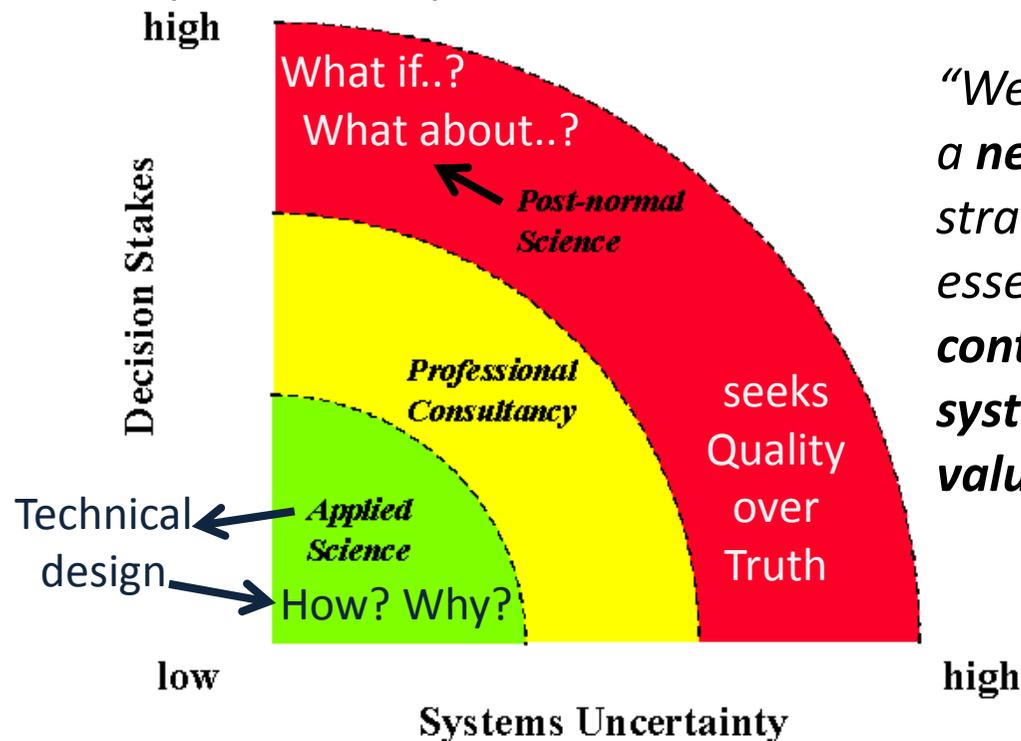
*Ravetz (2006), *Ecol. Complexity*, 3, 275.

BE



6. Dealing with uncertainty: Post Normal Science

PNS concept developed by Silvio Funtowicz and Jerome Ravetz in early 1990's to address (negative) **real world problems** where **system uncertainty** and/or **decision stakes** are **high**. e.g. wicked problems, where problem definition is contested and consequences of options are unknown



“We are now witnessing the emergence of a new approach to problem solving strategies in which the role of science, still essential, is now appreciated in its full context of the uncertainties of natural systems and the relevance of human values.”
Ravetz, 1999

*Ravetz (1999), *Futures*, 31, 647.



Normal Science and Mutual Misunderstandings

Traditionally scientists and engineers tended to presume that if the **public** had **more technical knowledge** of science then they would come around to **accepting** various **projects** and initiatives that arouse public **opposition**.

However, this is generally erroneous – the public is more concerned with issues of:

- Ethics/values
- Policies
- Risk
- Safety

*don't frack
with Leitrim* 



Since these are **normative** and **value laden** issues that science and engineering are **not capable of giving 'objective', absolute or definitive answers** to, and which scientists and engineers are generally less well informed about than technical issues, these **misunderstandings** have often led to mutual **misconceptions** and **distrust**, and a consequential poor image of science and engineering among the public.

BE

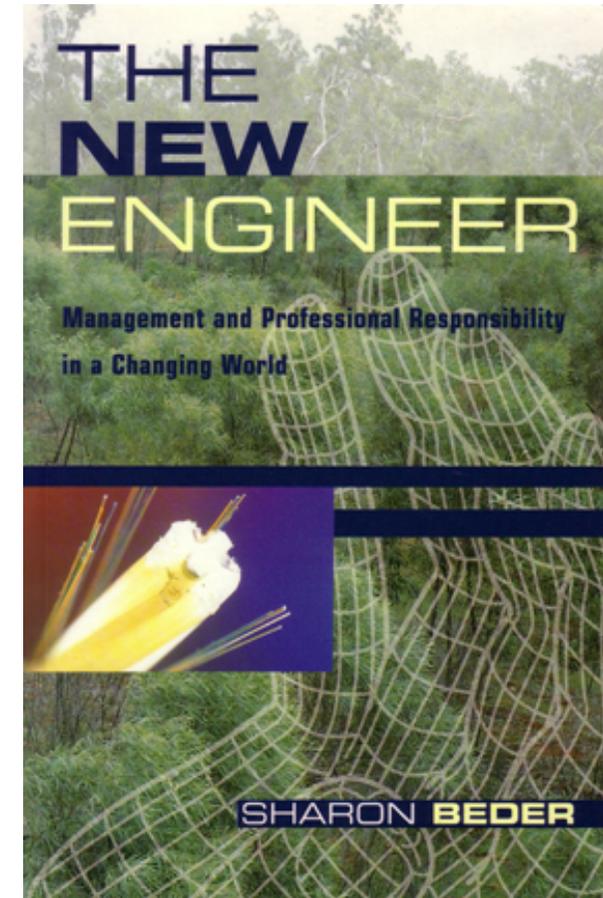


The New Engineer

*“A broader, more general approach is required ...there is also a need [for] an understanding of the **social context** within which [young engineers] will work, together with skills in **critical analysis** and **ethical judgement**, and an ability to **assess long-term consequences** of their work.*

*In this way the new graduates can **transform** the profession and take their place as the new engineers for the **21st century**”*

Sharon Beder, 1998



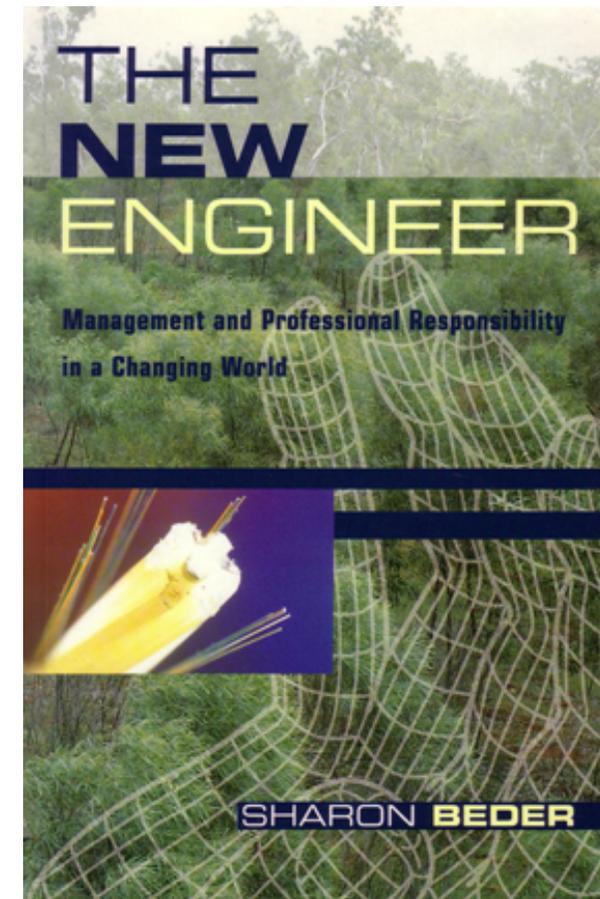
BE



The New Engineer

*“The current transformation to the **new engineer** is necessary to ensure that **future generations** will be served as well as past generations have been by the engineering profession.”*

Sharon Beder, 1998



BE



PE1006; Engineering/career take away points

- Most real life **engineering problems** are **complex**, messy and **wicked**, involving people and/or the natural environment. Such problems attract **different perspectives** and **object world** views from **different actors**.
- **Technical 'solutions'** alone are **not sufficient** to address wicked problems; **collaborative** approaches which recognise underlying **values** are required, including **ecological** and **societal**.
- **Simple answers** are **not sufficient** for **complex problems**. **'Complex thought'** is required. **'Simple thought'** only leads inevitably to **'unintended' consequences** and **more problems...**

BE



PE1006; Engineering/career take away points

- **Engineering** operates within (ecological, societal and economic) **context** and thus **cannot be value free**.
- Engineers have **micro** and **macroethical** responsibilities.
- **Uncertainty** is **inherent** in engineering and **risk** is a function of **perception**. It increases with **complexity** and **tight-coupling**.
- Recognition that **socio-economic** and **ecological** phenomena are **scalar/fractal** can help better understand risk and consequences.
- The **21st C** and its attendant problems invokes the services of the **New Engineer**.

BE



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PE1006; Engineering/career take away points

- Above all, **APPLY CRITICAL THINKING!**

Critically **examine received wisdom** and paradigms – science and society has always evolved through proposing new understandings.

Power does not infer wisdom; in fact it is more likely to resist changing paradigms.

Simple thinking and groupthink* can have **serious (often catastrophic) consequences**.

**“No-one gets sacked for being wrong - just for being wrong and different”.*



“ I have well-developed critical thinking skills, you dim-witted, under-achiever. ”

BE



...and ENJOY THE CHALLENGE on the road ahead!



BE



PE1006

Wind-down Reflection:

What is the role of the Engineer?

BE



PE1006

Wind-down reflection (2):

What are the **most important challenges** that engineers will face over the next 50 years? (i.e. over the course of your own career)