The Limits of Foresight in an Uncertain World

ASSC 2024 - Disruptive Technologies

Matthew Squair

Jacobs

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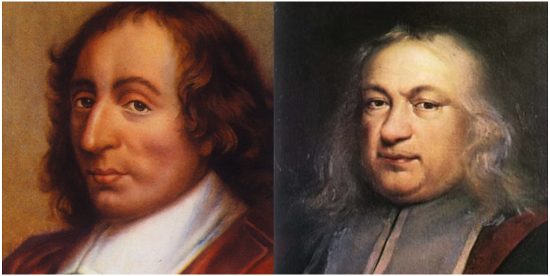
1. A short tour of classical risk

2. Risk, and it's limits

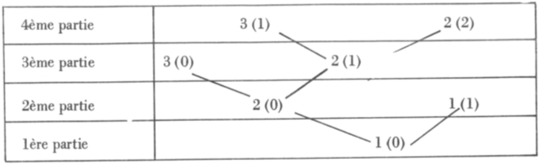
3. Dealing with risk differently

What is Risk?

We start with a conversation between two ~~gamblers~~ mathematicians about how to apportion points *fairly* for an interrupted game



Answer: Parallel worlds and expectation (amount x probability)



And then came de Moivre

Risk is the reverse of expectation (loss not gain)

Total risk = sum of individual risks (probability weighted mean)

This is the heart of classical risk

Pascalian logic (risk) is the dominant paradigm of risk, in the Kuhnian sense

To apply risk theory in the world

We need to make some assumptions...

- That we are certain about risk parameters
- That we can bound risk
- That we live in an ergodic world
- That we aren't ignorant of anything

All these assumptions are required to be able to quantify risk

YMMV as to how true these are leads to ad hoc 'fixes' for the theory:

- Risk proxies
- Qualitative risk matrices
- Probability neglect

Risk incorporates uncertainty

To return to Blaise Pascal's problem, we can easily determine a player's risk because the problem space is closed

If the real world were a game of cards, it's one of uncertain rules, only as you play the game can you start to infer the rules

There is inherent uncertainty about *both* severity and probability

Various sources aleatory (randomness), epistemic (knowledge) understood limitations, disagreements (of data and experts)

We often trade between the types, *sometimes implicitly* just to complicate matters

We may also be ignorant of risks we are taking

Worthwhile thinking about an uncertainty margin for quantitative risks

The world is not bounded - enough

To make risk work we must *assume* some bound on possible severity

When someone says, 'worst credible' that's the game they're playing...

If the distribution of extreme events is gaussian (normal) or exponential this is a fairly safe (low risk) assumption, if not?

The problem is on what basis do you judge the shape of the tail?

We know there are events in the real world that have heavy tail distributions

- Aircraft crashes
- Electrical power network outages
- Reactor accidents
- Software defect classes (important for robustness)

Even if the tail is truncated, extreme events will still dominate risk

Our systems behaviour may be heavy tailed

Highly Optimised Tolerance (HOT) is a plausible theory for heavy tails behaviour in biological and technological systems

Designing systems is an optimisation under constraints problem

- Results in a high tolerance for expected events
- But also a vulnerability to rare events or combinations of events

Results in heavy tail relationships (QF72 upset, AF447 disaster)

Note the performative nature of the optimisation model, in effect it dictates the sort of risks we will see with HOT systems

Rare events that are outside out robustness criteria then tend to have catastrophic consequences (literally designing for catastrophe here)

OK so resilience should 'fix' this but how do we specify it, measure it?

So what the hell is ergodic?

Means a system in which time and ensemble averages are the same

Fundamental to Pascal and Fermi's parallel worlds solution

Lets play a game

Say I ask 1000 people to play one round of Russian Roulette... the average survival rate is going to be $S=5/6$.

Would you play Russian roulette 10 times?

Most people say **NO!**

The reason. We live in a time series world as we play $S \to 0$

Of course when we use classical risk theory to argue the acceptability of extreme risks that's *exactly* what we're assuming... **And it's wrong**

How do we argue irreversible risks (catastrophes) are acceptable?

Borel's law (yet another french mathematician)

"Events with a sufficiently small probability never occur"

This is how we argue non-ergodic risks are acceptable

Why we see such risks expressed as likelihood *not* risk

Essentially we are fudging around the classical formulation of risk

Although we talk bravely about risk when it comes down to it, it's really about convincing people that "this is never going to happen"

Immensurability of risk has other malign effects (see seat belt laws, ABS)

Ignorance, surprises and new technology

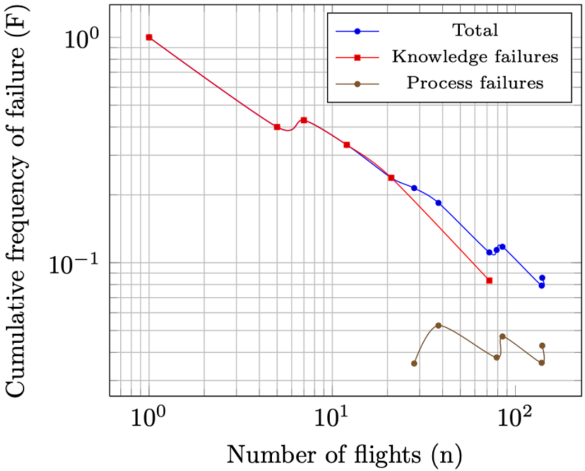


Figure 2: Knowledge and process failure rate for the RL-10 1962-2005 (Go 2008).

Uncertainty is a spectrum (so are risks)

Increasing uncertainty

Deterministic uncertainty → **Ontological uncertainty**

Region of ‘acceptable’ accident rates	Region of Knowledge accidents	Region of Unpleasant surprises
PARADIGM		
Is it Probable?	**Is it Plausible?**	**Is it Possible?**
CONTROLLING & MITIGATING		
Redundancy and design margins	Diversity, independence and robustness	Possibilistic design, mitigation or resilience
ANALYSING AND EXPRESSING		
Classical statistical techniques	Uncertainty analyses, Monte Carlo simulations, model building, service experience	Imagination, fundamental research, horizon scanning

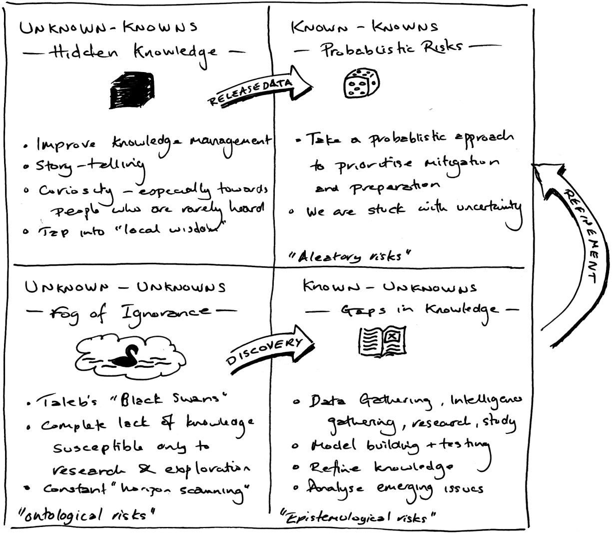
The Four quadrant model

Useful to refactor this spectrum into a four quadrant model

Secretary Rumsfeld's view

"...there are *known knowns*; there are things we know we know. We also know there are *known unknowns*; ...we know there are some things we do not know. But there are also *unknown unknowns*, the ones we don't know we don't know..."

A different model: The 4 quadrants of uncertainty & risk



Summing up

Classical risk theory is only one part of the spectrum (we know it pretty well)

For complex and novel technologies you'll need to deal with all types of uncertainty

The greater the consequences, and the smaller the required probability, the greater risk will be dominated by deeper uncertainties

Be prepared for heavy tail behaviour in your system, especially if you built it 'robust'(resilience is better)

Be prepared to be surprised (and measure it)