

Vulnerability of railway assets to black swans: Predicting the unpredictable



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Talking about black swans

- Creates a lot of enthusiasm
- Hard negative words from some researchers



Black Swan Events

Black Swan event as having the following three attributes:

- **Rarity**—It is an *outlier*, as it lies outside the realm of regular expectations, because nothing in the past can convincingly point to its possibility.
- **Extreme impact**—It carries an extreme impact.
- **Retrospective (though not prospective) predictability**—In spite of its outlier status, human nature makes us concoct explanations for its occurrence *after* the fact, making it explainable and predictable.



“Black Swan Event: An event or occurrence that deviates beyond what is normally expected of a situation and that would be extremely difficult to predict.”



The probability-based approach to treating the risk and uncertainties is **based on a background knowledge that could hide critical assumptions and therefore provide a misleading risk description**

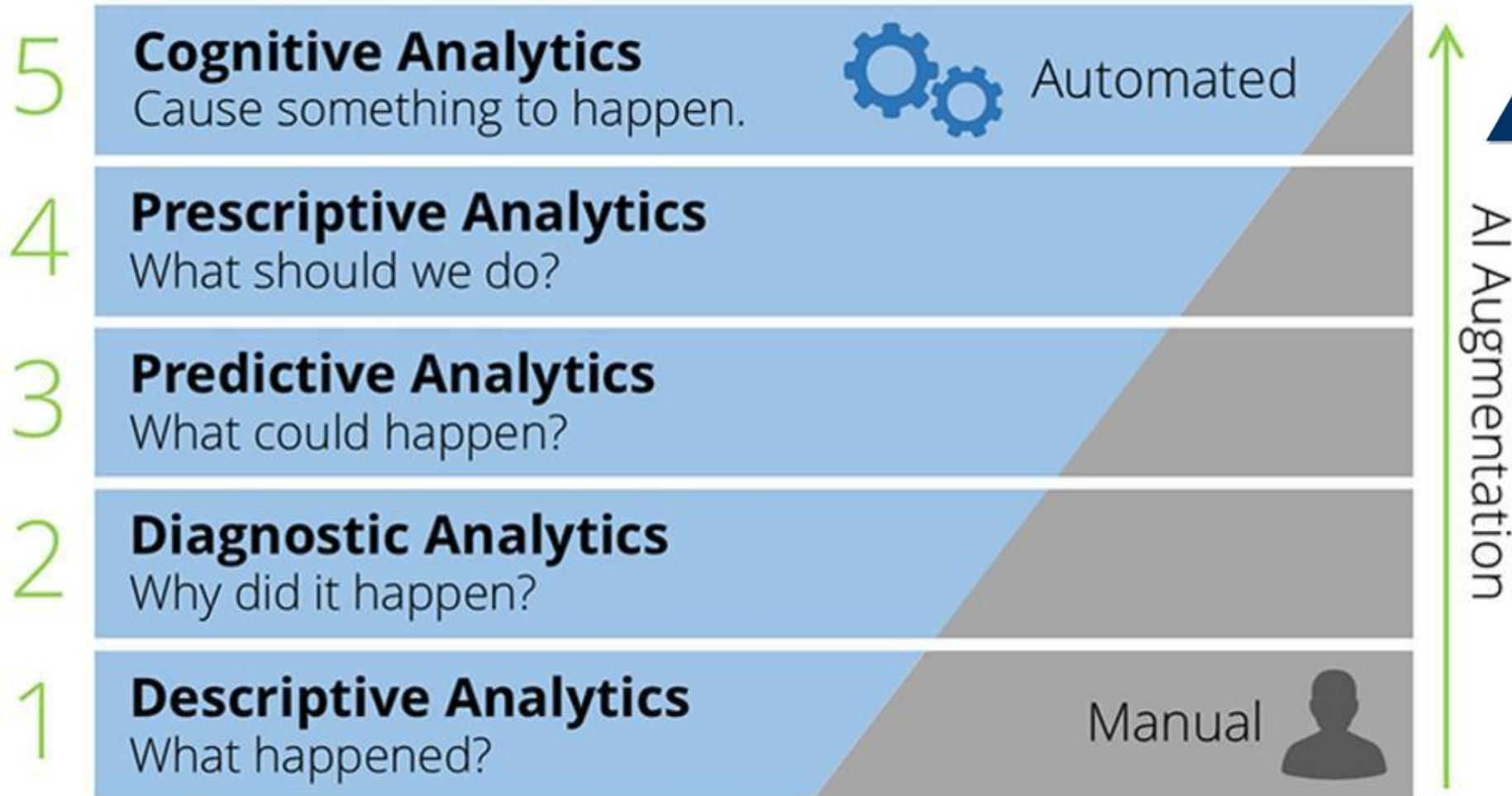


Depending on the assumptions made

we get completely different conclusions about the probability of a black swan occurring



Analytics and expectations also change



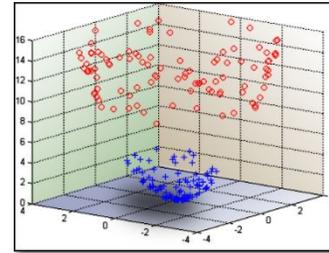
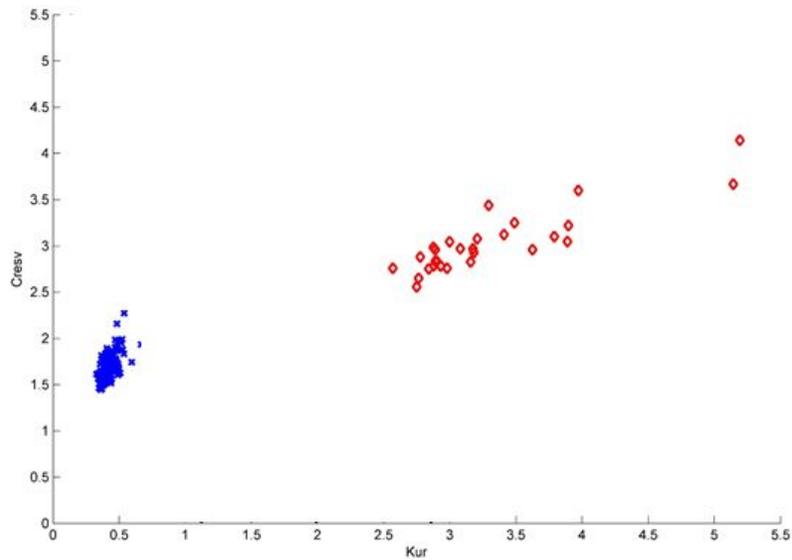
Types of data analytics

Descriptive
Analytics

Group historical
data according to
their similarity

Reports
Mapping

Descriptive analytics



Types of data analytics

Descriptive Analytics

Group historical data according to their similarity

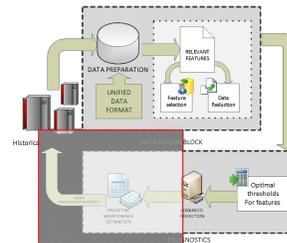
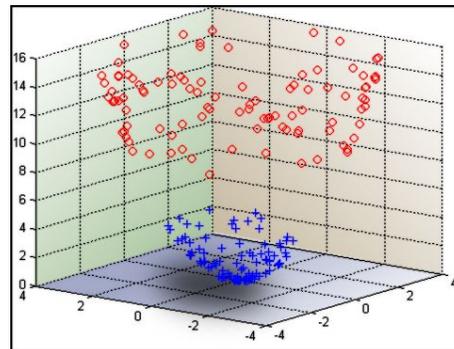
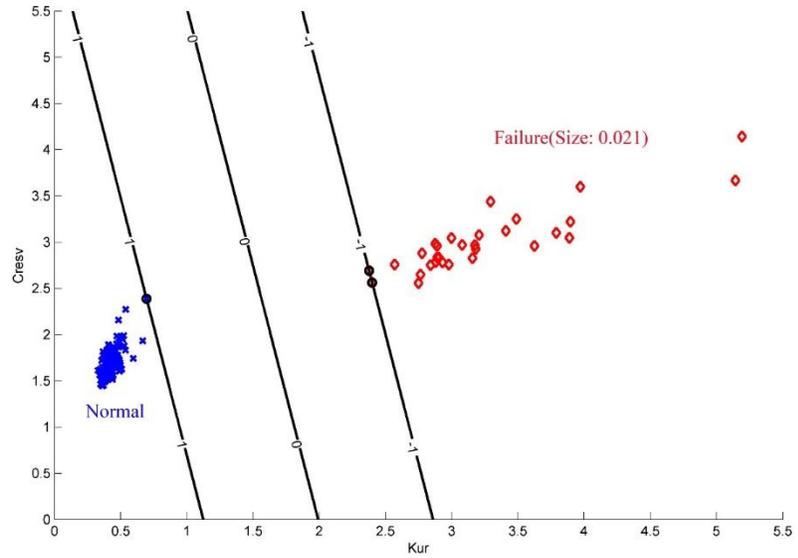
Reports
Mapping

Diagnostic Analytics

Determine cause of successes and failures

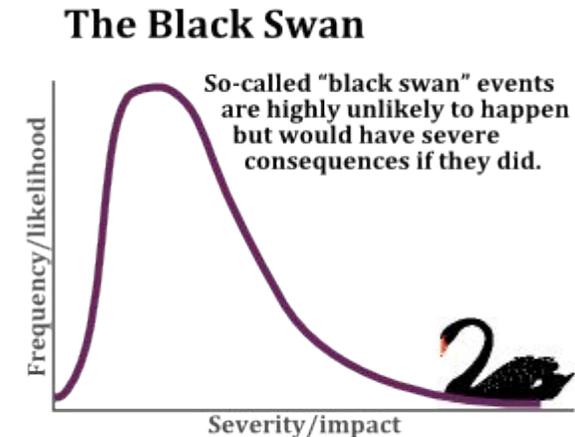
Statistical analysis
Queries
Data Mining

Diagnostic analytics



questions whether a black swan is

1. A surprising extreme event relative to the expected occurrence rate
2. An extreme event with a very low probability.
3. A surprising, extreme event in situations with large uncertainties.
4. An unknown unknown.

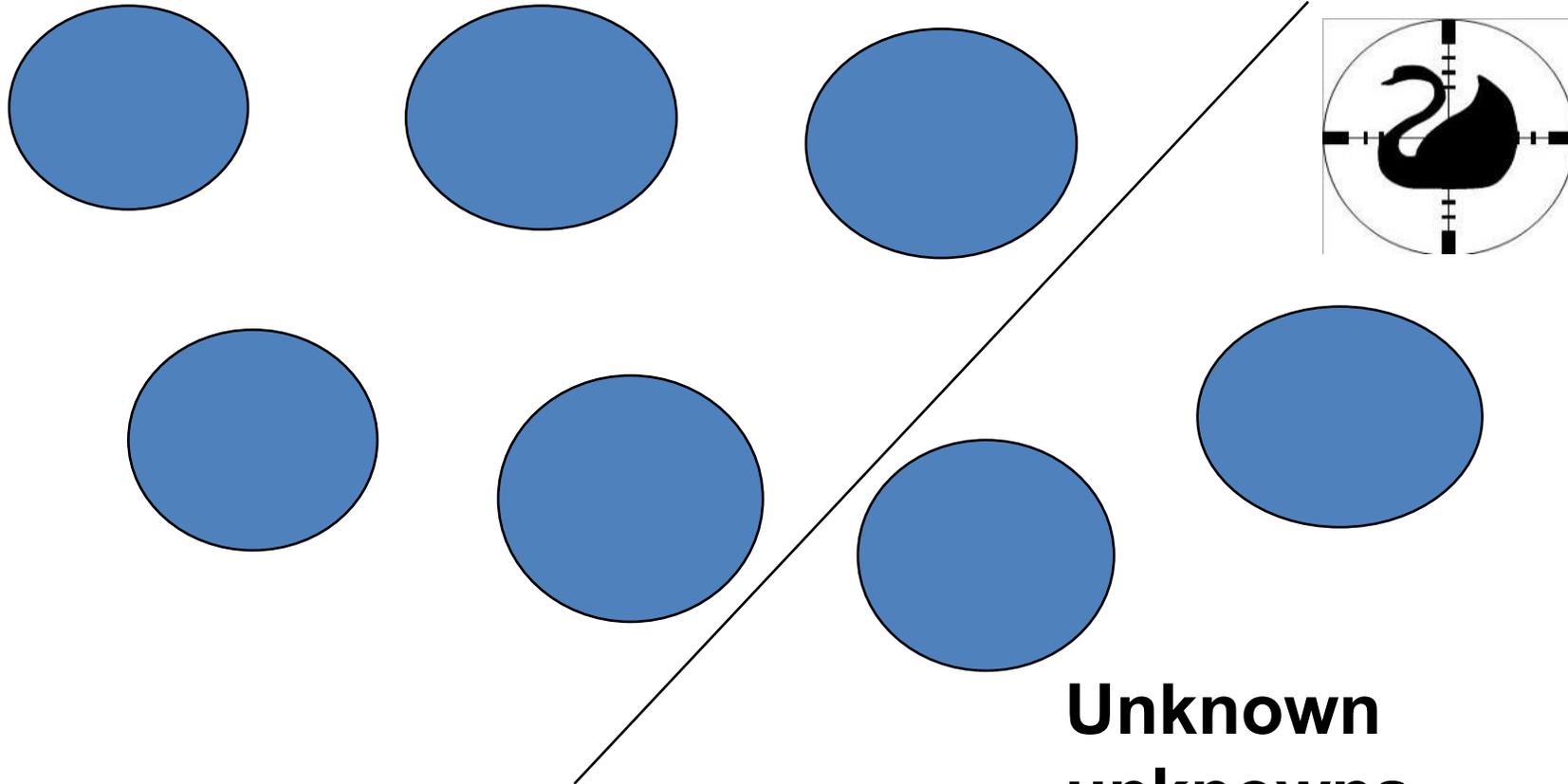


*Source: Chris Mandel,
Sedgwick Inc.*

Threats

Known

unknowns



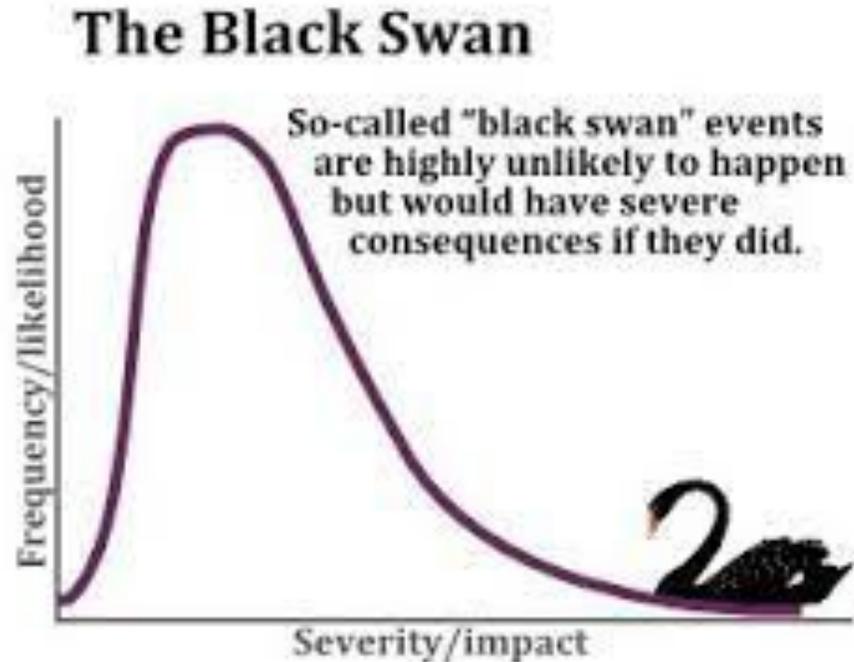
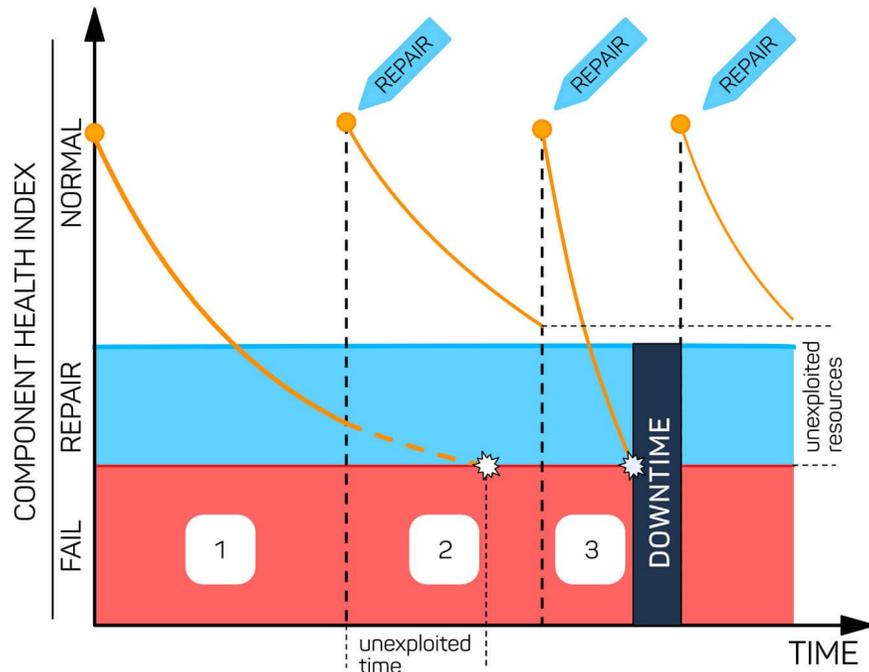
Unknown

unknowns,

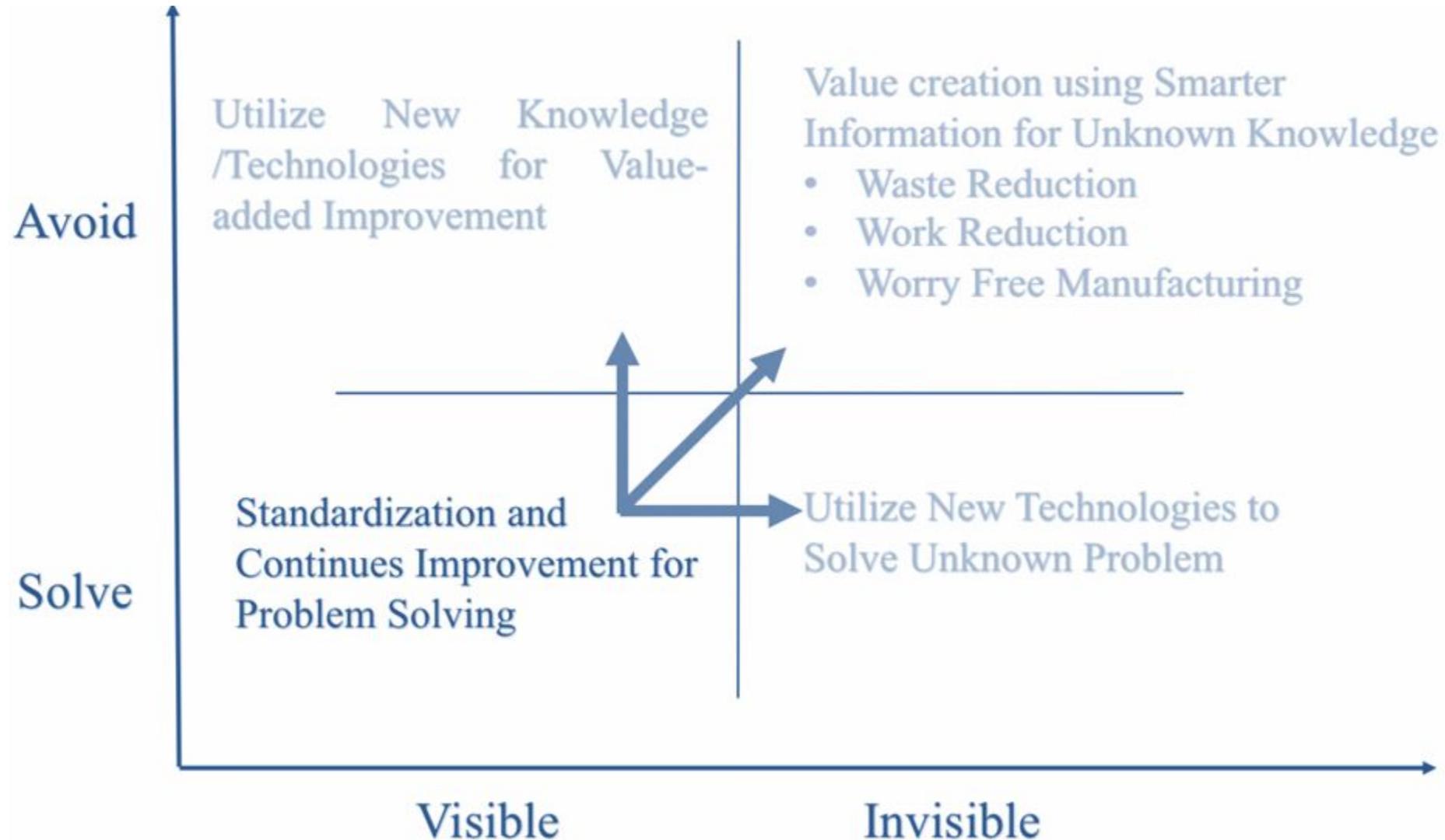
black swans

The Paradox of Increasing risk

- Technological progress has led to increasing efficiency.
- **In maintenance reducing vulnerability to small shocks may increase the severity of large ones.**



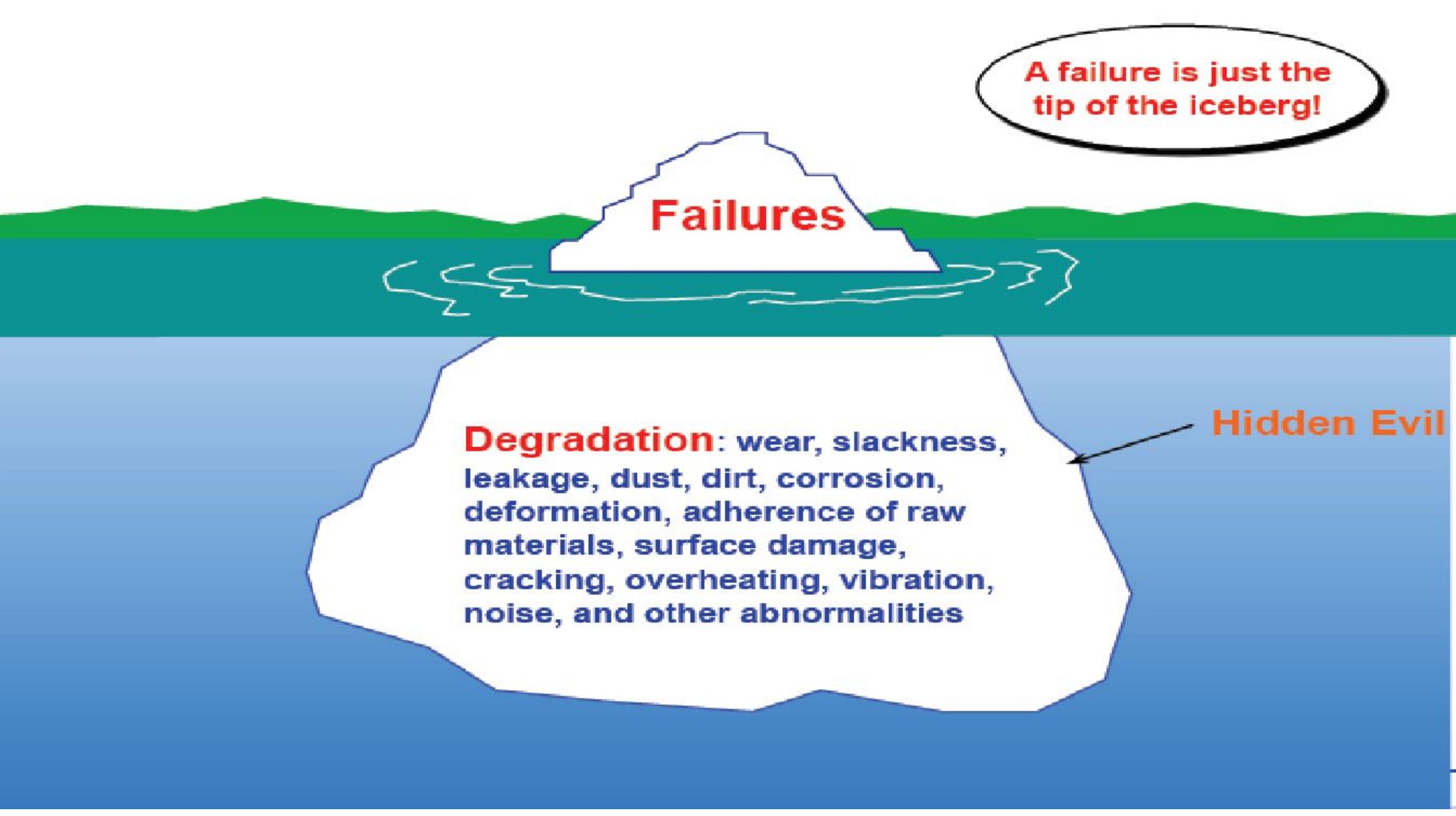
The Impact of Industrial AI: From solving visible problems to avoiding invisible ones



Some swans are more harmful than others

- A. Events that were completely unknown to the scientific environment (unknown unknowns)
- B. Events that were not on the list of known events from the perspective of those who carried out a risk analysis (or another stakeholder)
- C. Events on the list of known events in the risk analysis but found to represent a negligible risk



An illustration of an iceberg floating in a body of water. The tip of the iceberg is above the water line and is labeled 'Failures'. The much larger part of the iceberg is submerged below the water line and is labeled 'Hidden Evil'. A speech bubble above the tip of the iceberg contains the text 'A failure is just the tip of the iceberg!'. The water is depicted in shades of blue and green, with a green shoreline in the background.

A failure is just the tip of the iceberg!

Failures

Degradation: wear, slackness, leakage, dust, dirt, corrosion, deformation, adherence of raw materials, surface damage, cracking, overheating, vibration, noise, and other abnormalities

Hidden Evil

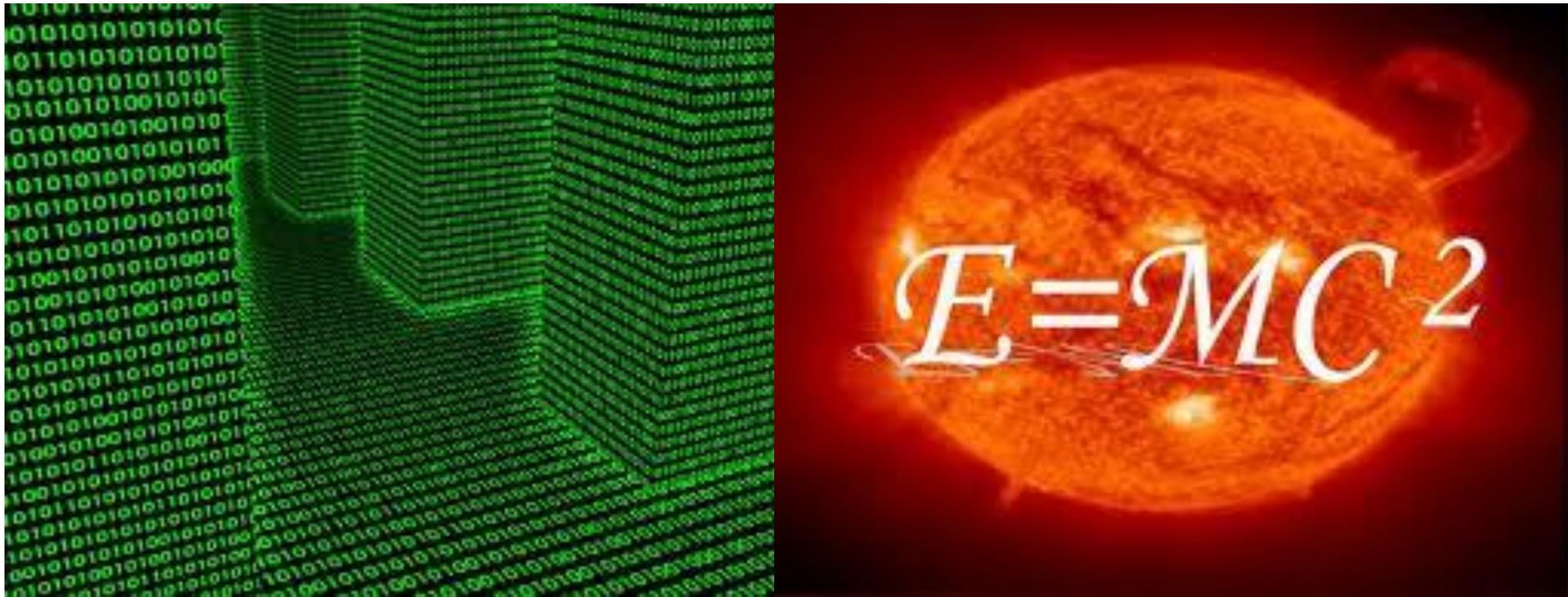
Black Swan Losses when all failure modes have not been registered

- Loss Distribution
 - Tail events are rare – very little data
 - Typically strong model assumptions

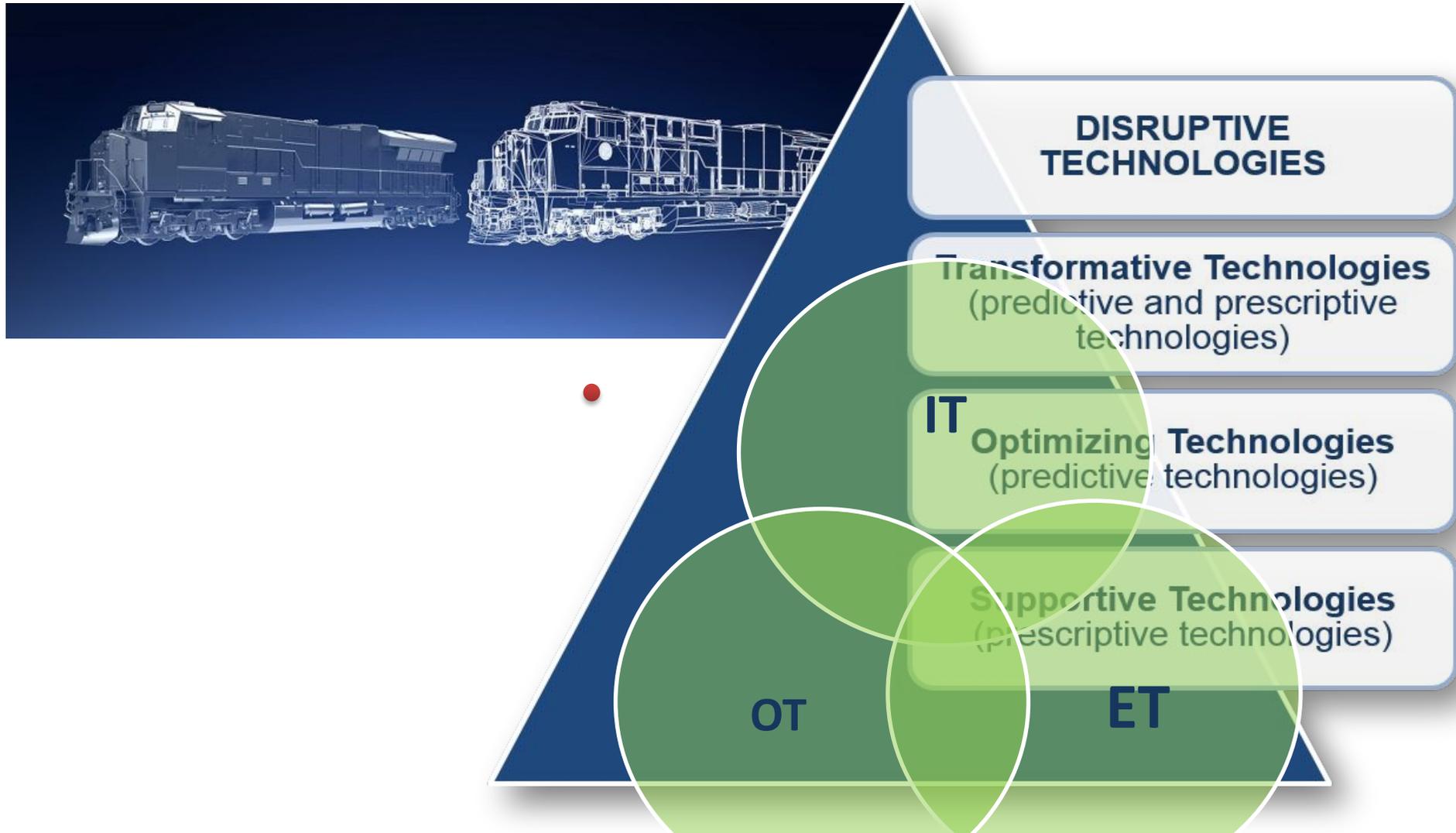


Data driven or model based?

Data-Based or Physics-Based
Models? – That is the question!



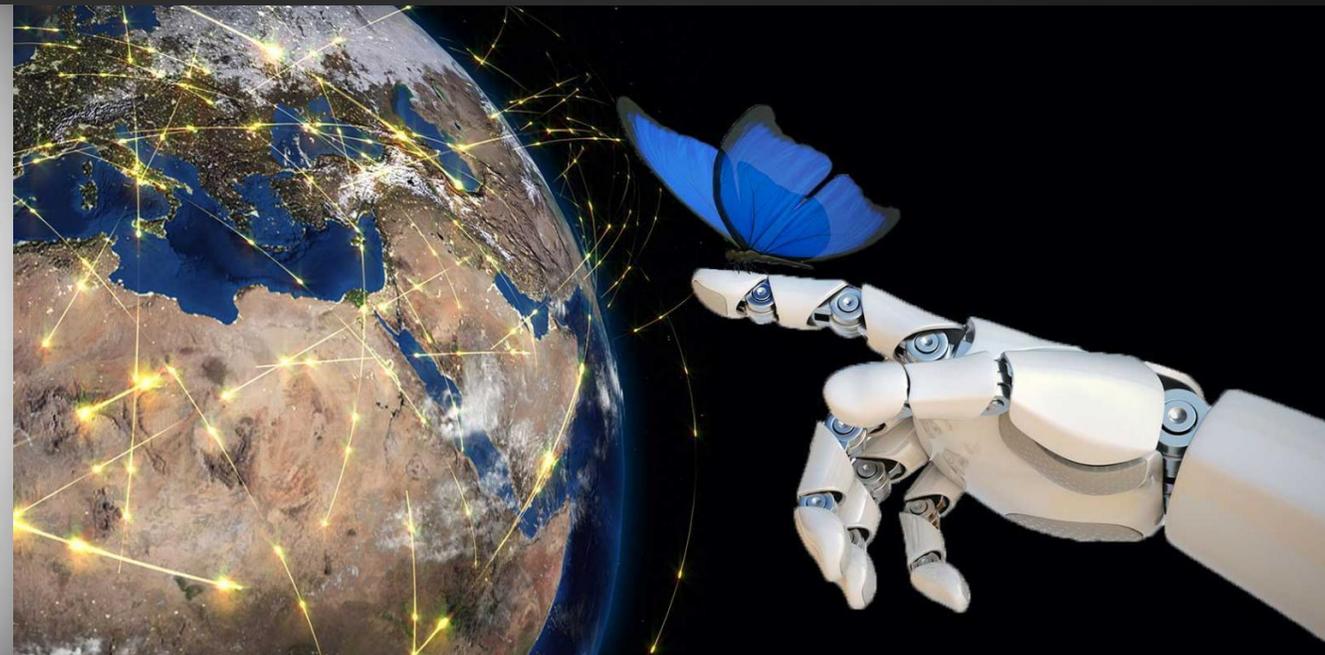
Digital twins including physics of the failures



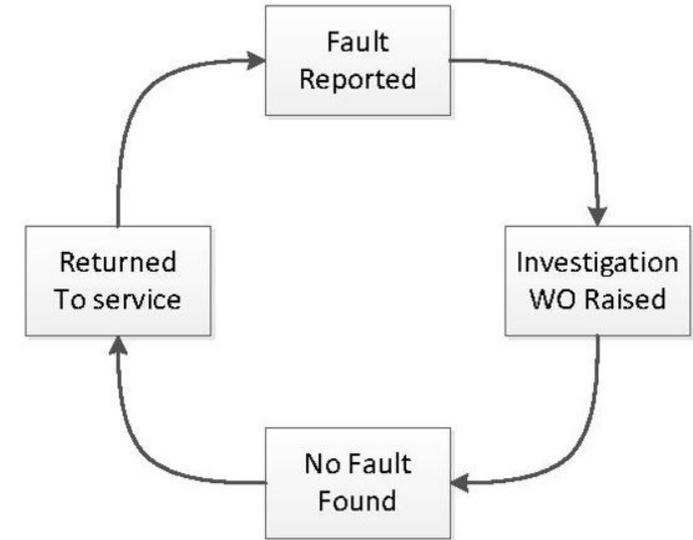
Can you predict and track the root cause of chaos?



THE DIGITAL BUTTERFLY EFFECT

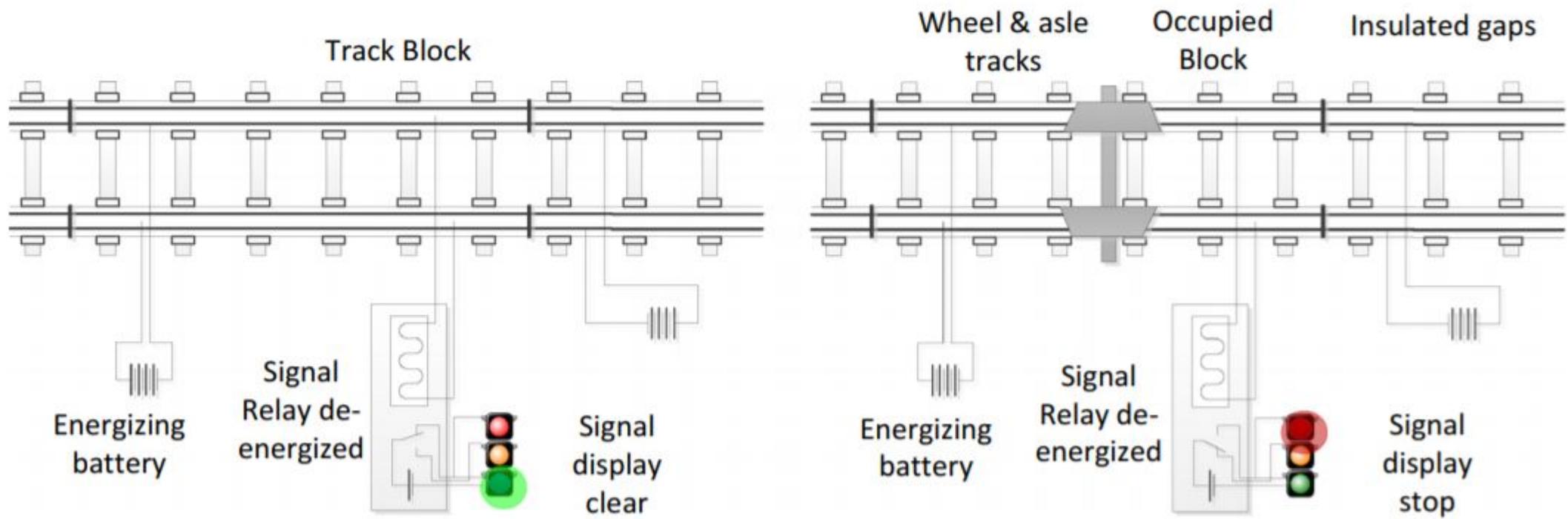
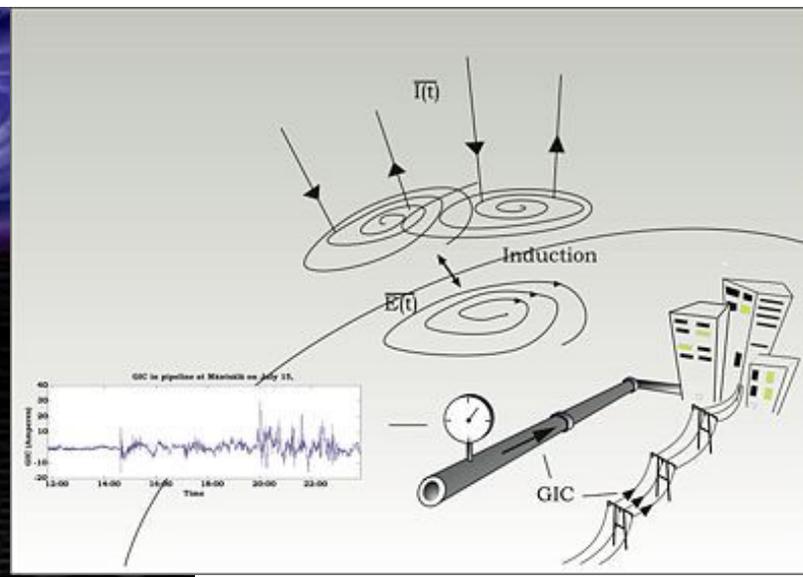
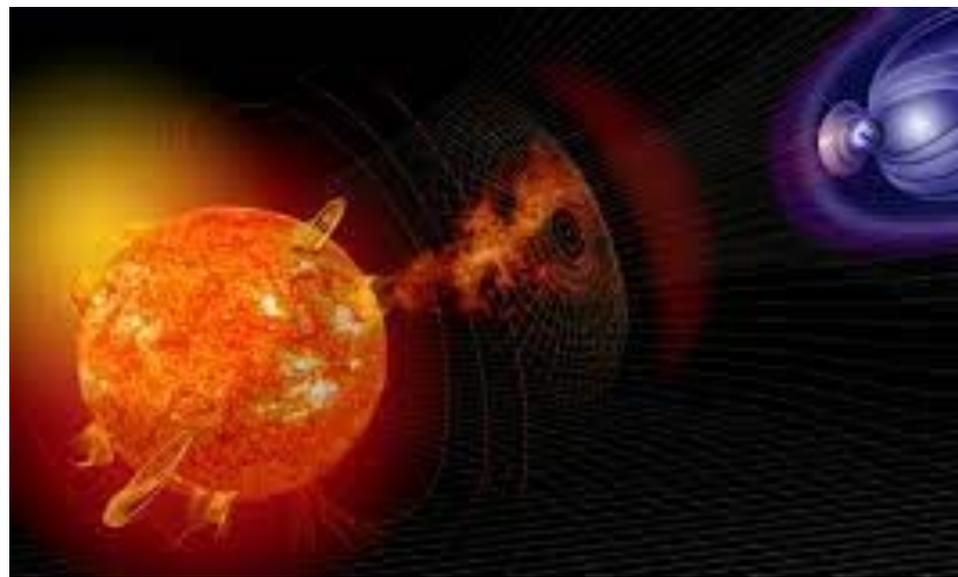


NFF Non Fault Found in railway signalling

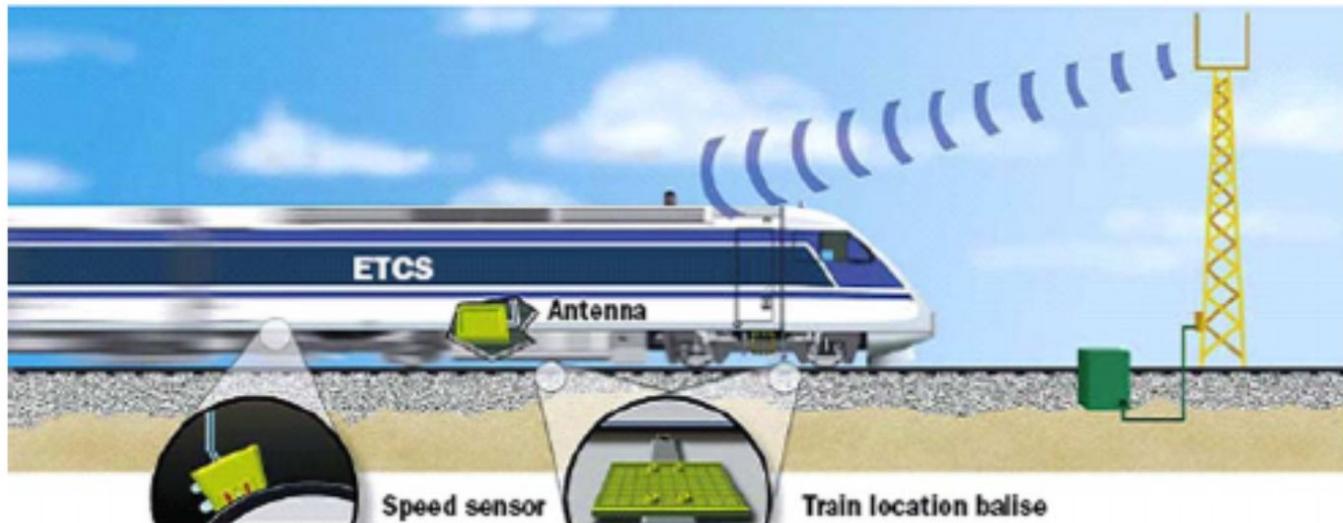


Corrective action	Electr.	External	Mech.	NFF	Non operative	Not defined
Adjust/Lubrication	21	0	11	2	12	58
Clean/Remove obst.	90	1	6	16	20	127
Control	16	7	1	402	7	169
No action	7	0	0	80	1	27
Not defined	5	1	3	5	2	12
Prov. repaired	13	0	9	0	27	14
Repair	54	4	48	1	171	65
Replacement	267	2	91	1	325	81
Restart	19	5	16	2	39	91
SW update	0	0	0	0	0	1

Ground currents and ghost trains

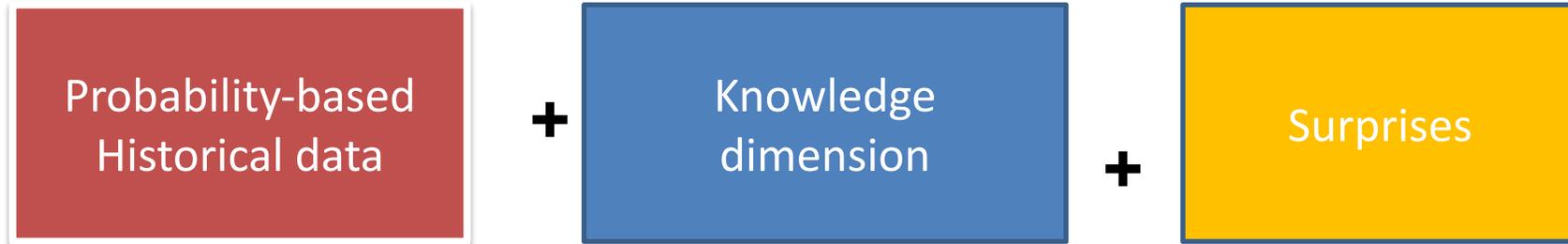


Railway sabotage or cyber attacks

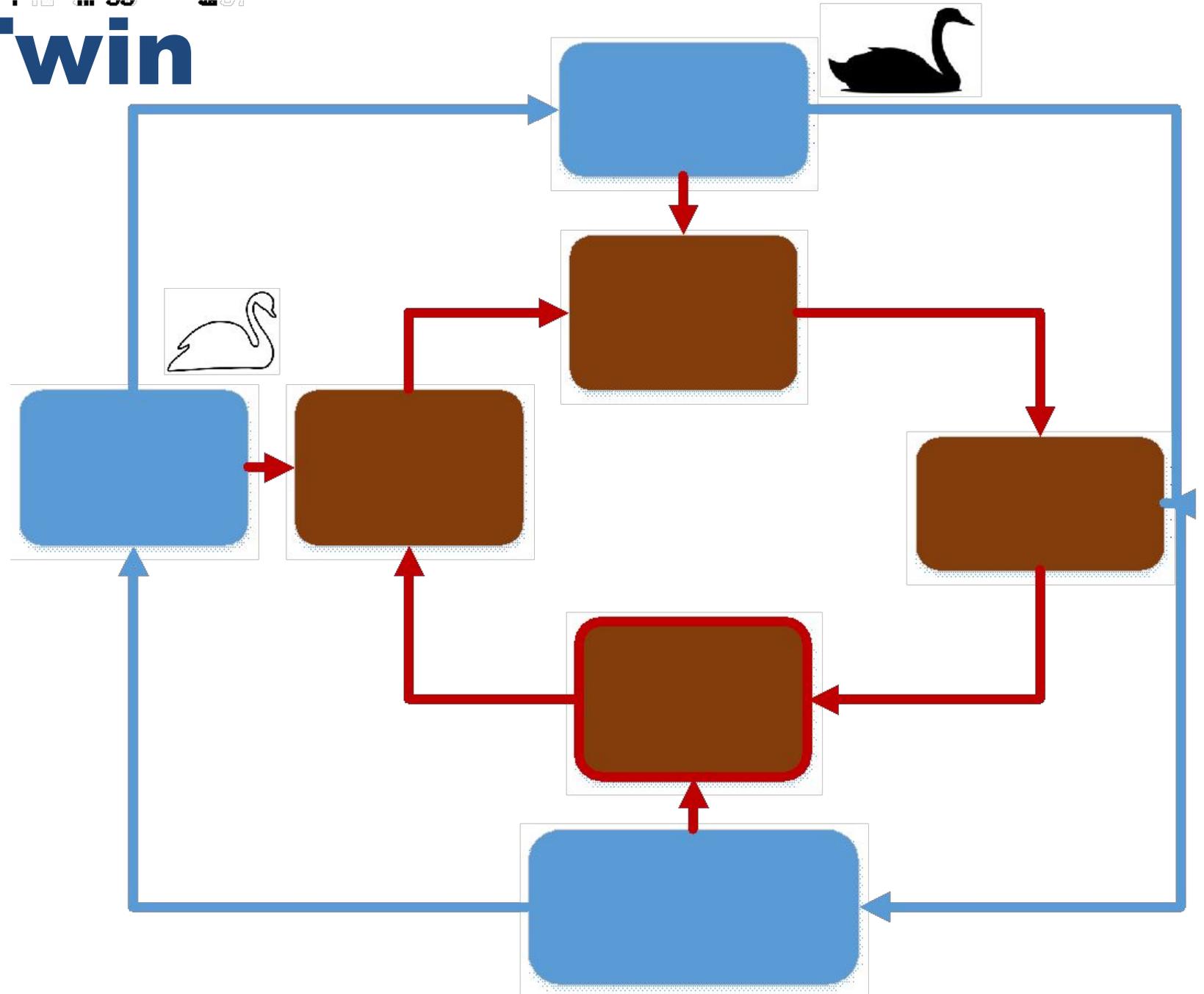


The cover of the ENISA report 'RAILWAY CYBERSECURITY: Security measures in the Railway Transport Sector'. It features the ENISA logo (a circle of stars) and the European Union flag in the top left and right corners. The title 'RAILWAY CYBERSECURITY' is prominently displayed in white on a blue background. Below the title, the subtitle 'Security measures in the Railway Transport Sector' is written in a smaller font. At the bottom, the date 'NOVEMBER 2020' is printed. The central graphic shows a blue train with red signal waves emanating from it.

All the knowledge together



Digital Twin



**Black
Swan
KD**

How to confront black swans

- Improved Risk Assessments
- Robustness
- Resilience
- Antifragility



In summary, are you sure you want to reduce risk?



Challenges in likelihood

- All probability statements are based on the assumptions of the models
- We normally do not admit that data are contaminated or that data sets may not reflect what we think they reflect
- Thus we almost certainly overestimate the confidence in our analysis



Conclusions

- Strictly speaking, probability of failure does not exist, but is necessary if we wish to remain self-consistent and conduct science (science is essentially Bayesian inference).
- Don't expect risk to decline.
- Avoid naive optimization at the expense of robustness maybe your systems is weaker and weaker
- Be sure if you are dealing with black swans or just your model is bad, your data are bad or your coding is bad





Thanks!!