

University of Piraeus

Decisions, Risks, Games

PART 2: RISKS



John A. Paravantis

Professor

Department of International and European Studies

March 2026

1. Preamble

1.1. Introductions

Please introduce yourself:

Who is your name?

Where do you come from?

What is your basic degree on?

What is your professional experience?

Did you have any other graduate educational experience?

What do you expect to gain from this course?

2. Risk overview and terminology [Started on Friday, March 13, 2026]

Think of some risk keywords that you have heard

3. Risk management process

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1. Preamble

These notes constitute the second part of a 3-part series:

1. Decisions
2. Risks
3. Games

1.1. Introductions

Instructor

- Dr. John A. Paravantis
 - Civil Engineering (Transportation, NTUA)
MSc Transportation & PhD Environmental Health ([Northwestern University](https://www.northwestern.edu), Chicago, IL, USA)
 - Professor (*Energy, Technology and Environment in Global Politics*)
Department of International and European Studies
University of Piraeus
 - <https://www.unipi.gr/en/people/paravantis-john/>
 - Relevant courses taught (since 2000)
 - Quantitative Methods, Decision Methods, Project Management, Operations Research, Simulation Methodology, Game Theory
 - Phone: +30 210 414-2771 & +30 697 3048824 (Viber, WhatsApp)
 - Emails: jparav@unipi.gr & paravantis@gmail.com
 - Would be happy to hold (virtual) office hours with you online (Google Meet)
-

Please introduce yourself:

What is your name?

Where do you come from?

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What do you expect to gain from this course?

2. Risk overview and terminology [Started on Friday, March 13, 2026]

Getting from fear to action

- Data ☒ Judgment ☒ Action

Risk terminology is notoriously circular and polysemic

Think of some risk keywords that you know of or have heard

Risk terms that will be considered and discussed (alphabetically)

- Avoidance
- Energy trilemma
- Mitigation
- Resilience
- Risk analysis
- Risk appetite
- Risk assessment
- Risk evaluation
- Risk identification
- Risk management
- Risk treatment
- Technological lock-in
- Threat
- Transfer
- Vulnerability
- Weakness

Google search

- *Risk analysis identification vulnerability weakness threat resilience assessment evaluation management treatment appetite mitigation transfer avoidance pdf*

3. Risk management process

Risk

- The measurable uncertainty ...
- ... surrounding a system's ability to maintain its intended function ...
- ... when faced with internal complexity or external pressure



Let's look at the formal components of the risk analysis, assessment, and management process

3.1. Risk analysis (step 1)

Step 1: **Risk analysis** ("How much")

- The technical process of understanding the nature and level of risk
 - Establish risk context
 - Frame risk
- Starts with **risk identification**
- Risk probabilities are calculated
- Risk consequences are assessed
 - Consequences = impacts
 - Adverse impacts ~ harm
 - These determine the severity of risk
- Raw data and logic are used

Risk analysis for energy projects typically lasts between 4 to 12 weeks

- The first 2 to 4 weeks of that involve stakeholder workshops to score and prioritize risks
 - Expert judgment is taken into account
-

3.2. Risk assessment (step 2)

Step 2: **Risk assessment** ("So what")

- Assess risk within the risk frame of the organization
 - The bridge between data and decision-making
 - A more formal definition (military): The process of identifying and analyzing the gap between strategic objectives (ends) and available resources (means)
 - Combines the technical analysis of Step 1 (risk analysis) with a value judgment on whether the risk is acceptable or tolerable
 - **Risk evaluation** is included ~ prioritizes the risk against your **risk appetite**
 - Colloquial: The “*comfort level that senior planners experience as they assess key variables*”
-

3.3. Risk management (step 3)

Step 3: Risk management (“Now what”)

- Responding to risk
 - Risk management strategy
 - The final, coordinated activity of directing and controlling an organization’s response to risk
 - Action: Implementing **risk treatment**
 - **Ignore** = Rarely and only for insignificant risk
 - **Mitigate** = Reduce the impact
 - **Transfer** = Move the risk (e.g. through insurance)
 - **Avoid** = Stop the risky activity
 - Risk management is not a one-time event; it includes
 - Constant communication with stakeholders
 - Monitoring to ensure the situation has not changed
 - Oftentimes considered a separate step
-

EXAMPLE: Offshore wind farm

Project overview

- The *North Reach Offshore Wind Project* is a hypothetical €1.8 billion renewable energy venture, involving the installation of 60 high-capacity turbines in the North Sea

- Construction and turbine erection are scheduled to begin in late September and run through November to meet the *Commercial Operation Date* (COD) required by the government contract
- However, historical maritime data indicates that weather patterns in the North Sea become increasingly volatile during these fall months
- The project has chartered a specialized Jack-up vessel at a day rate of €220,000
 - The vessel cannot safely operate if wind speeds exceed 12 m/s or wave heights surpass 2.5 m
 - A standard fall gale could stall operations for 10 to 14 consecutive days



Senior planners must now determine if the €1.8 billion investment

- Can withstand the financial drag of potential weather delays
- Or if the project should be re-baselined
 - Even if it means missing the initial energy delivery deadline

Risk management process

1. **Risk analysis** (*How much?*)

- Risk identification
 - High wind speeds, especially dangerous during turbine installation
- Calculation of risk **probabilities** (**likelihood**)
 - Meteorological data from the last 20 years suggests a 15% chance of weather downtime during the period in question

- Assessment of risk **consequences (impacts)**
 - If a storm hits while a turbine is half-installed, the harm includes
 - Potential structural damage to the blade
 - Daily loss of €220,000 for the specialized installation vessel sitting idle
- The severity of this risk is determined to be high
 - The combination of a 15% probability and multi-million-euro consequences exceeds standard nuisance thresholds

2. **Risk assessment** (*So what?*)

- Senior leadership at the energy company has to decide if this project is still worth it within their specific **risk appetite**, considering
 - The 15% probability
 - The financial data
- The leadership team looks at the data and asks
 - Is a €2 million potential weather delay acceptable for a project that will generate €500 million in revenue?
 - €2 million potential weather delay?
 - The installation vessel costs €220,000 per day
 - The meteorological data says a typical autumn gale lasts 9 days
 - Doing the math: $9 \times 220,000 = 1,980,000$
 - The above information translates to a potential impact of roughly €2 million in idle-time costs alone
 - Not including delayed labor or late-delivery penalties
 - €500 million in revenue?
 - This is the projected Gross Revenue the wind farm is expected to yield in its first few years of operation
 - This could be a significant portion of its Net Present Value (NPV)
 - You cannot judge a risk in a vacuum

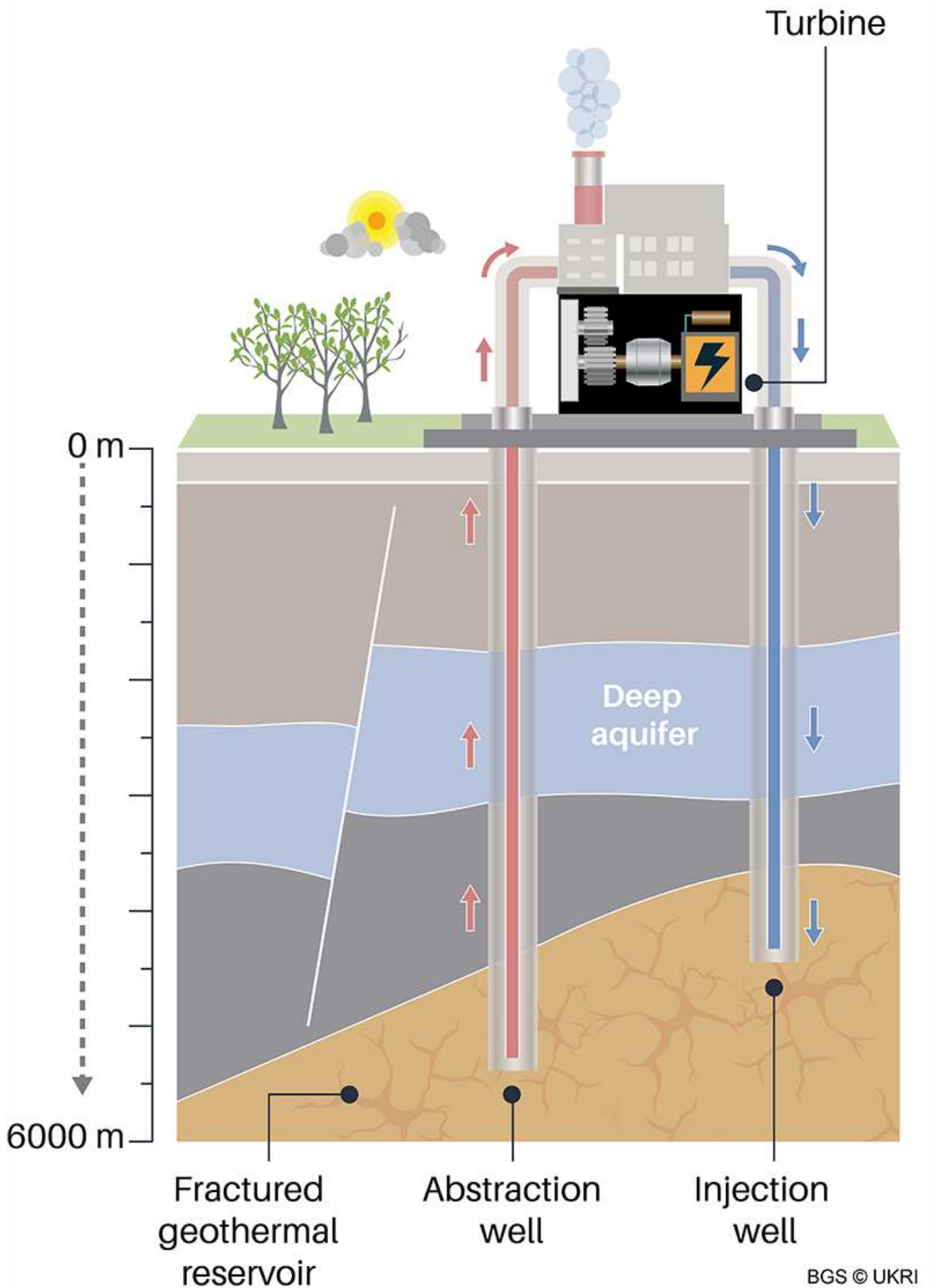
- A €2 million risk is catastrophic for a €5 million project
 - The same risk would be negligible (only 0.4%) for a €500 million revenue stream
 - The objectives (finishing the wind farm by next year) are weighed against the resources (limited budget for vessel rentals)
 - If the company is backed by a conservative pension fund (**risk averse**), their comfort level with a €2 million delay might be low
 - If they are a venture-backed tech firm (**risk prone**), they might accept it as a standard cost of doing business
 - This risk is prioritized with others (e.g. supply chain delays for copper cables) to decide which one needs the most executive attention
3. **Risk management** (*Now what?*)
- With the risk assessed as tolerable but needing action, the company decides to implement a measured response (**risk treatment**)
 - Here are the basic options of their risk management strategy
 - **Mitigation**
 - The project manager schedules the installation for August instead of October
 - This reduces the probability of a storm from 15% to 2%
 - Even though it costs more to book the boat earlier
 - **Transfer**
 - The company takes out an insurance policy specifically covering delay-in-startup (DSU) due to bad weather
 - **Avoidance**
 - The company decides not to build in a specific hurricane-prone zone at all

EXAMPLE: Deep geothermal project

Geothermal projects have a completely different risk profile than wind

- Wind projects ~ Weather risk (above ground)

- Geothermal projects ~ Resource risk" (below ground)



Project overview

- Scope
 - A €120 million deep geothermal plant designed to provide carbon-neutral heating to 15,000 households
- Financial objective
 - Projected to generate €12 million in annual heat sales
 - 25-year operational lifespan
- Timeline
 - The critical Phase 1 (Exploratory Drilling) is scheduled for a 6-month window starting in April
- Technical requirement
 - The project requires hitting a target reservoir at 3,500 meters
 - Flow rate of at least 60 liters per second (l/s) at 120°C

Risk management process

1. Risk analysis (*How much?*)

- Risk identification
 - Dry hole Risk (subsurface resource failure)
- Risk **probabilities (likelihood)**
 - Geological surveys and seismic data indicate a 20% probability that the reservoir flow rate will be below the required 60 l/s
- Risk **consequences (impacts)**
 - Cost ~ A failed well represents a €15 million loss in drilling costs that cannot be recovered
 - Harm ~ If the flow is insufficient, the well cannot support the heat exchangers
- Severity
 - Critical ~ While the probability is moderate (20%), the €15 million impact could bankrupt the project before it starts

2. Risk assessment (*So what?*)

- Leadership must decide if a €15 million potential loss is tolerable for a project aiming for €300 million in total lifetime revenue (€12M × 25 years)
 - Is the 20% chance of losing €15M acceptable to secure a long-term green energy asset?

- The objective (decarbonizing the city) is weighed against the means (the project's cash reserves)
- Comfort level
 - A municipal government might have a high comfort level due to climate mandates
 - A private bank might see the 20% failure rate as too risky without external guarantees

3. Risk management (Now what?)

- **Mitigation**
 - Perform additional 3D seismic imaging (costing €500k)
 - This will reduce the dry hole probability from 20% down to 10%
- **Transfer**
 - Enroll in a *Government Geothermal Guarantee Scheme*,
 - The state reimburses 80% of drilling costs if the well fails to meet the 60 l/s threshold
- **Avoidance**
 - Relocate the drill site 2 km away to a proven volcanic fault line
 - Even if land permits are more expensive there

4. Nature and components of risk

Refining the definition of risk

- Risk = The possibility that something detrimental will occur
 - The realization that things can go wrong despite meticulous planning
- Risk ~ Potential for loss, damage, or other negative impacts (e.g. political, physical, or economic)
- Risk does not exist in a vacuum — it results from the alignment of internal weaknesses with external threats
 - **Vulnerabilities** = Internal **weaknesses** + External **threats**

Slippery and polysemic terminology

1. **Weakness** ~ internal

2. **Vulnerability** = Internal weakness + External **threat**
 3. **Risk** ~ Exploitation of vulnerability
-

4.1. Weaknesses

(1) **Weakness** = An internal flaw, error, or omission in the design, implementation, or operation of a system

- Weaknesses exist in a latent state (whether or not they are ever discovered or exploited)
 - Weaknesses are internal and structural
 - In a strategic context, weaknesses are
 - Flaws in the ways (concepts)
 - Deficiencies in means (resources)
-

Think about some examples of weaknesses in energy systems

Examples of weaknesses in energy systems

- Single points of failure, e.g. relying on a single major pipeline or a single large power plant for an entire region
 - Consider the 2026 conflict in Iran and the threats made by both the US and Iran to target civilian infrastructure
 - Aging infrastructure, e.g. using outdated transformers or power lines that are prone to mechanical failure
 - Low fuel diversity, e.g. over-reliance on a single energy source (e.g. natural gas) without backup alternatives
 - Geographical concentration, e.g. locating most generation assets in a single area prone to natural disasters
 - Cybersecurity gaps, e.g. running industrial control systems on legacy software that lacks modern encryption
 - Limited storage, e.g. an inability to store surplus energy, making the system brittle during peak demand
-

4.2. Vulnerabilities

(2) **Vulnerability** = A **weakness** that can be exploited by an external threat to cause harm

- A weakness only becomes a vulnerability when a threat exists that has the capability and intent to target it
- As long as a vulnerability is not exploited, it does not become a risk
- Example
 - An outdated encryption (weakness) becomes a vulnerability only if there is a hacker (threat) with the knowledge and tools to break that specific protocol

Think about some examples of vulnerabilities in energy systems

Examples of vulnerabilities in energy systems

- **WEAKNESS:** Subsurface pipelines located in a conflict zone
+
THREAT: Hostile actors in the area, proficient in ground sabotage
=
VULNERABILITY: Exposed physical infrastructure that is easily accessible to hostile actors
- **WEAKNESS:** Industrial control software connected to the public internet
+
THREAT: Remote hackers
=
VULNERABILITY: A digital entry point that allows unauthorized outside access to the power grid
- **WEAKNESS:** A national grid relying on a single mountain pass for transmission
+
THREAT: Severe localized weather or a physical blockade
=
VULNERABILITY: A geographic **choke point** that can be severed by a single event
- **WEAKNESS:** Use of unencrypted satellite signals for data
+
THREAT: Electronic warfare units
=
VULNERABILITY: Communications that can be intercepted or spoofed by an adversary
- **WEAKNESS:** Zero on-site fuel reserves (Just-in-Time supply)
+

THREAT: A maritime blockade or transport strike

=

VULNERABILITY: A system that lacks the buffer to survive even a short-term disruption in supply

- **WEAKNESS:** Power stations built in low-lying coastal areas

+

THREAT: Rising sea levels or storm surges

=

VULNERABILITY: Infrastructure that is physically unprotected from predictable environmental shifts

4.3. Risks

(3) **Risk** = The probability and impact of a **vulnerability** being exploited

- Risk ~ The result of a threat acting upon a vulnerability
 - Risk = Likelihood × Impact
 - Likelihood ~ How much should we worry?
 - Impact ~ What is the potential loss
-

Risk is double-edged

- Risk is usually viewed as a negative concept
- But risk also presents an opportunity for improvement
 - It exposes flaws (vulnerabilities) in a system
 - Once these flaws are addressed, long-term **resilience** is built

Ancient Chinese
symbol for risk:

担險

↑ ↑
Danger Opportunity

Central task of a strategist

- Eliminating risk is the wrong target
 - Asking the right question: Is the potential reward worth the potential risk?
-

4.4. Hazards and threats

Risks arises from specific hazards or threats, e.g. threats to mission success, military operations, national security

- A hazard is a loaded gun sitting on the table
- The threat is a person walking into the room who wants to take the gun and pull the trigger



Hazard = Anything that has the potential to cause harm or injury, e.g. a wet floor on which someone may slip and suffer an injury

- A condition or factor that can potentially cause harm or a dangerous situation, e.g. bad weather, difficult terrain, vulnerable equipment (that may be threatened by cyber attacks)
- Inherent properties or conditions that can cause harm, e.g. toxic chemicals, unstable structures
- Hazards exist regardless of external triggers, and are static or passive in nature

Threat = Potential danger stemming from an event or adversarial action that could negatively impact the success of a mission or strategic goal, e.g. political instability, environmental hazards, enemy forces

- Threats ~ Potential causes of unwanted incidents, e.g. cyber attacks
 - The frequency of occurrence of a threat cannot be altered
- Threats are dynamic or active in nature and exploit vulnerabilities



Examples of hazards and threats

- **Hazard**: A wet floor in a kitchen;
Threat: Someone running through that kitchen without looking
- **Hazard**: A loose stair rail;
Threat: A child climbing it recklessly
- **Hazard**: A parked car with the keys inside;
Threat: A stranger trying to steal it
- **Hazard**: Living close to in-laws;
Threat: In-laws showing up unannounced daily
- **Hazard**: Introducing automation or AI in high-risk industries;
Threat: Employee resistance due to fear of job loss or distrust in system reliability
- **Hazard**: A player with poor defensive footwork;
Threat: An opposing guard who exploits it with quick crossovers and drives
- **Hazard**: Open or poorly monitored borders;
Threat: Smugglers or extremist groups exploiting gaps to move people or weapons

The risk chain ~ A sequence of events leading to a negative outcome:

1. **Weakness** (internal flaw)

- *Our gate has a broken latch* (A static fact about the system)
 - 2. **Hazard & threat** (external trigger)
 - Hazard ~ *A heavy wind blows the gate open* (accidental/natural)
 - Threat ~ *A burglar sees the gate* (intentional/human)
 - 3. **Vulnerability** (exposure)
 - *The gate is now swinging open, leaving the house unprotected* (flaw + trigger)
 - 4. **Risk** (calculation)
 - *There is a 20% chance of a 5000 euro theft this month*
-

5. Likelihood and impact

- Likelihood
 - Probability of a hazard causing harm or injury
- Accident
 - An unplanned or uncontrolled event
 - Has led to, or could have caused harm or injury
 - A lighter or near accident may be called an incident
- Impact
 - The severity of the outcome if the hazard is realized
 - Impacts can be
 - Low/minor i.e. cuts & bruises
 - High/major i.e. multiple injury or fatality
- Control measures
 - Something that has been implemented or installed to remove or reduce the likelihood of a hazard causing an accident

Let us now review key terms and concepts useful in risk analysis in reference to a strategic conflict setting

Careful how you read a threat leading to a hazard

- April 17 to 19, 2011
 - Major cyber attack on Sony

- Compromised personal details from 77 million accounts and prevented users of PlayStation 3 and PlayStation Portable consoles
- Made clear that cyber vulnerability constitutes an important concern for energy security!

Hackers mine PlayStation 3

Sony has shut down its gaming network after suspected data theft

"Believed" obtained from registered users
Between April 17 and April 19

- ▣ Name
- ▣ Address
- ▣ Email address
- ▣ Birthdate
- ▣ PlayStation password and login

"Possibly" also lost

- ▣ PlayStation profile data
 - ▶ Purchase history
 - ▶ Billing address

"Cannot rule out"

- ▣ Possible theft of credit card data

Source: Sony

<https://phys.org/news/2011-04-sony-reveal-playstation-hack-probe.html>

- August 15, 2012
 - Cyber attack (Shamoon virus) on 30,000 computers of Aramco, the Saudi Arabian oil company
 - Aramco supplied 10% of the global demand for oil
 - Biggest computer hack in history
 - Alerted the world to the terrifying possibility of a cyber Pearl Harbor

No IT payment systems, no Gas



<https://en.wikipedia.org/wiki/Shamoon>

More risk terms

- **Incident**
 - Specific event that causes or could have caused an undesirable outcome
 - Equipment failure
 - Skirmish
 - Incidents are often minor or localized but can escalate
- **Accident**
 - Unplanned event leading to unintended consequences
 - Injury
 - Loss
 - Operational failure
 - Accidents are usually not deliberate actions by opposing forces
 - Can have serious impacts in military settings
- **Likelihood (Probability)**
 - Probability or chance that a specific event, threat, or risk will occur

- Key factor in risk assessments
 - Helping prioritize which risks need the most attention
- **Impact (Consequence)**
 - Potential effect or result of a risk materializing
 - Political destabilization
 - Mission failure
 - Loss of life
 - Loss of equipment
 - Loss of territory
- **Vulnerability**
 - Weakness or gap in
 - Defense
 - Systems
 - Strategies
 - Can be exploited by adversaries
 - Increase the likelihood of a risk materializing (becoming a reality)
- **Mitigation**
 - Actions or strategies designed to reduce the severity or likelihood of a risk
 - Fortifying defenses
 - Pursuing diplomacy
 - Enhancing intelligence operations
- **Severity**
 - A measure of how serious the consequences of a risk event will be if it occurs
 - Higher severity risks could involve
 - Loss of life
 - Key strategic failures
 - Significant military setbacks
- **Risk tolerance** (also referred to as **risk appetite**)
 - Level of risk that a nation, organization, or military force is willing to accept in pursuit of its goals

- How much loss or disruption is deemed acceptable for an operation
 - In a given strategic context, it reflects the balance between
 - Risk-taking
 - Caution
 - Risk prone vs risk averse
 - We will discuss these concepts in the context of Game Theory
-

- **Contingency planning**

- Preparing alternative courses of action to
 - Manage risks
 - Deal with unexpected events
- Ensures flexibility in response to evolving threats or incidents

- **Criticality**

- Importance of following in achieving strategic goals
 - Resource
 - Asset
 - Mission objective
- High-criticality elements
 - Are essential
 - Need risk mitigation or protection

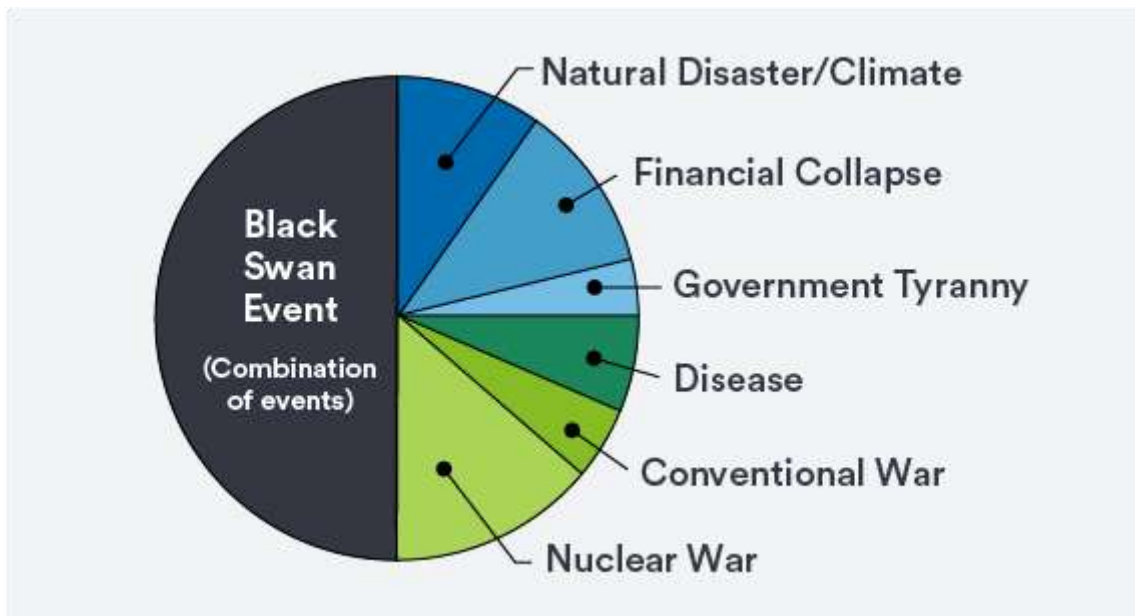


(Fullerton, 2018)

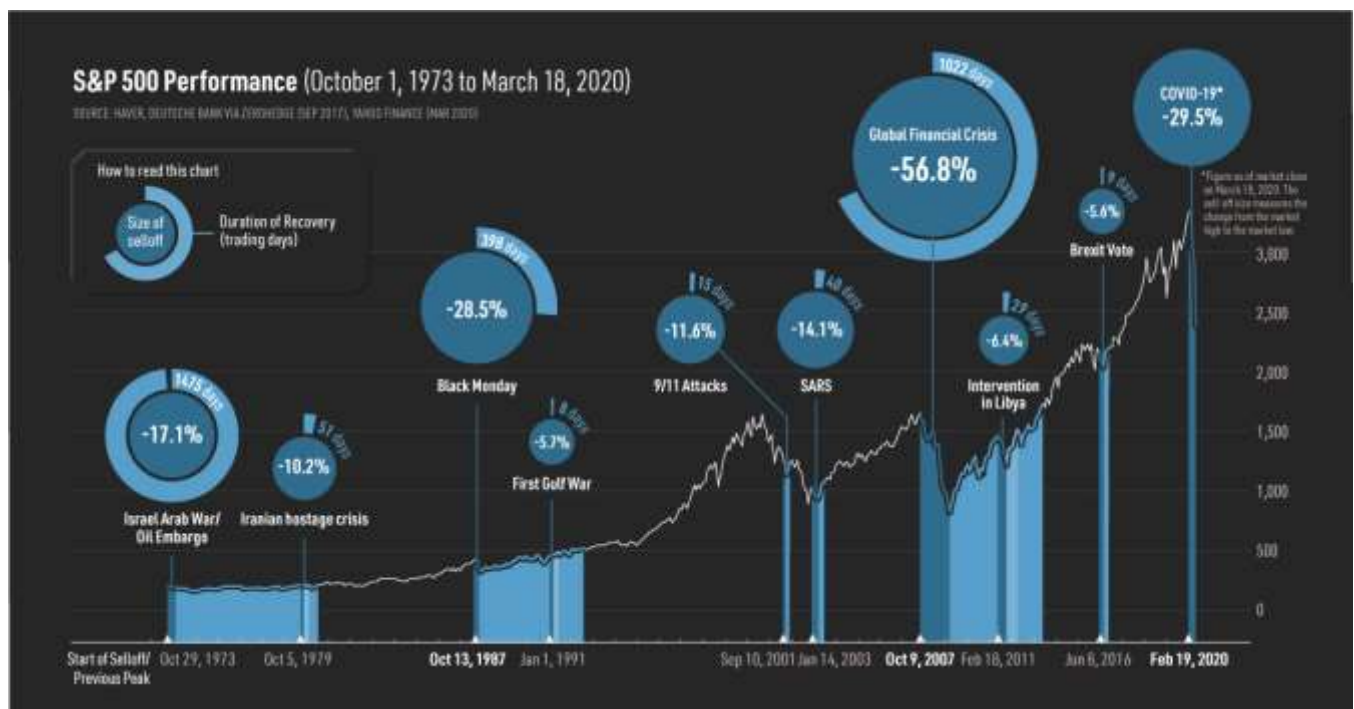
- **Resilience**

- Ability to recover and adapt after a disruptive event
 - Military defeat

- Equipment failure
 - Political unrest
 - Planning for how to maintain operations under stress
- **Intelligence**
 - Information gathering and analysis to understand
 - Threats
 - Risks
 - Strategic landscape
 - In conflict situations, intelligence reduces uncertainty and informs risk analysis
- **Scenario analysis**
 - A method used to evaluate different possible outcomes
 - By analyzing various hypothetical situations
 - In a conflict situation, it helps understand the risks associated with different strategies
- **Risk matrix**
 - Tool used to visually assess and prioritize risks based on their
 - Likelihood
 - Impact
 - Helps in decision-making by categorizing risks from low to high
- **Black Swan event**
 - An event that
 - Is highly improbable
 - Is unpredictable
 - Has massive impact
 - Conflict scenarios
 - Unexpected alliances
 - Revolutions
 - Terrorist attacks
 - Technological breakthroughs
 - Environmental disasters
 - Earthquake



<https://www.protolabs.com/resources/blog/preparing-for-the-next-black-swan-event/>



<https://advisor.visualcapitalist.com/black-swan-events/>

- **Collateral damage**
 - Unintended harm, damage, or loss caused by military operations
 - Typically affecting civilians or non-military targets
 - Reducing collateral damage is often a key consideration in risk analysis

6. Technological risk

High-tech systems are often

- Interactively complex
- Tightly coupled

In these systems

- Small, seemingly trivial failures can interact in unexpected ways
- As a result, serious accident may occur
 - These accidents are catastrophic in that they cannot be stopped in time

Unlike natural disasters, technological risks are often invisible, e.g.

- Radiation
- Chemical runoff

Technological risks are truly global

- They usually have long-term, global consequences that ignore national borders, e.g. Chernobyl
-

TECHNOLOGICAL RISK

What are the real dangers, if any, of toxic chemicals, the greenhouse effect, microwave radiation, nuclear power, air travel, automobile travel, carcinogens of all kinds, and other threats to our peace of mind?

H.W. LEWIS

Winner of the Science Writing Award of the
American Institute of Physics

The special case of risk related to

- Science
- Technology

Technological risk is a major issue related

- Politics
- Society

Technological risk causes uneasiness about scientific process

Risk and benefits go together

- Miracles of modern chemistry ✘ Chemical contamination
- Clean electricity from nuclear power plants ✘ Nuclear accidents
- Vaccines against disease ✘ Harm (probabilistically rare) but widely publicized
 - Parents refuse to immunize children
- Fluoridation of drinking water fights tooth decay ✘ Fear of chemicals



We are both

- Beholden to technology
- Suspicious of associated risks
 - Especially when they are unfamiliar

Risk = price we pay for benefits

- Hard to estimate
 - Even for experts

Most of us would agree that

- There is no point in exposing ourselves to a risk for which we get nothing in return
- We should accept great risks if the stakes are high (enough)

There are trivial risks that scare us

- High level nuclear wastes in geologic storage
- They may leak in 1000s of years

Then again there are real risks that don't bother us

- Accidental electrocutions
 - Most of the world uses domestic distribution
 - Voltage higher than 110 V ❌ economic gains
- Lighting accidents (fatal)
- Smoking
 - Even some doctors smoke
 - More prevalent among
 - Less educated
 - Blue collar workers

TABLE 1 *Average annual risk of death as a consequence of an activity*

Activity associated with death	Risk of death per person-year
Voluntary	
Motorcycling	2000.0×10^{-5}
Smoking (20 cigarettes per day)	500.0×10^{-5}
Car racing	120.0×10^{-5}
Scuba diving	60.0×10^{-5}
Surgical anaesthesia	50.0×10^{-5}
Car driving	17.0×10^{-5}
Pregnancy	9.8×10^{-5}
Drinking (one bottle of wine per day)	7.5×10^{-5}
Rock climbing	4.0×10^{-5}

Difficulties related to risk ...

... assessment

... management

Importance of ...

... public understanding of the issue

Threats to life

Morbidity (sickness)

Mortality (death)

Important risk issues

Value of (human) life

Regulation of risk

Specific risk examples

Toxic chemicals

Chemical carcinogenesis

Transportation

Highway safety

Air transportation

Radiation

Ionizing

Non-ionizing

More specific risk examples

Energy and turbines

Nuclear winter

Global politics

Nuclear war

Nuclear winter

Dr. Strangelove

Risk depends on ...

... (geopolitical and economic) location

Visible in developed nations

... time

Became important in last 40+ years

Necessary background for appreciation of risk

Likelihood of rare events

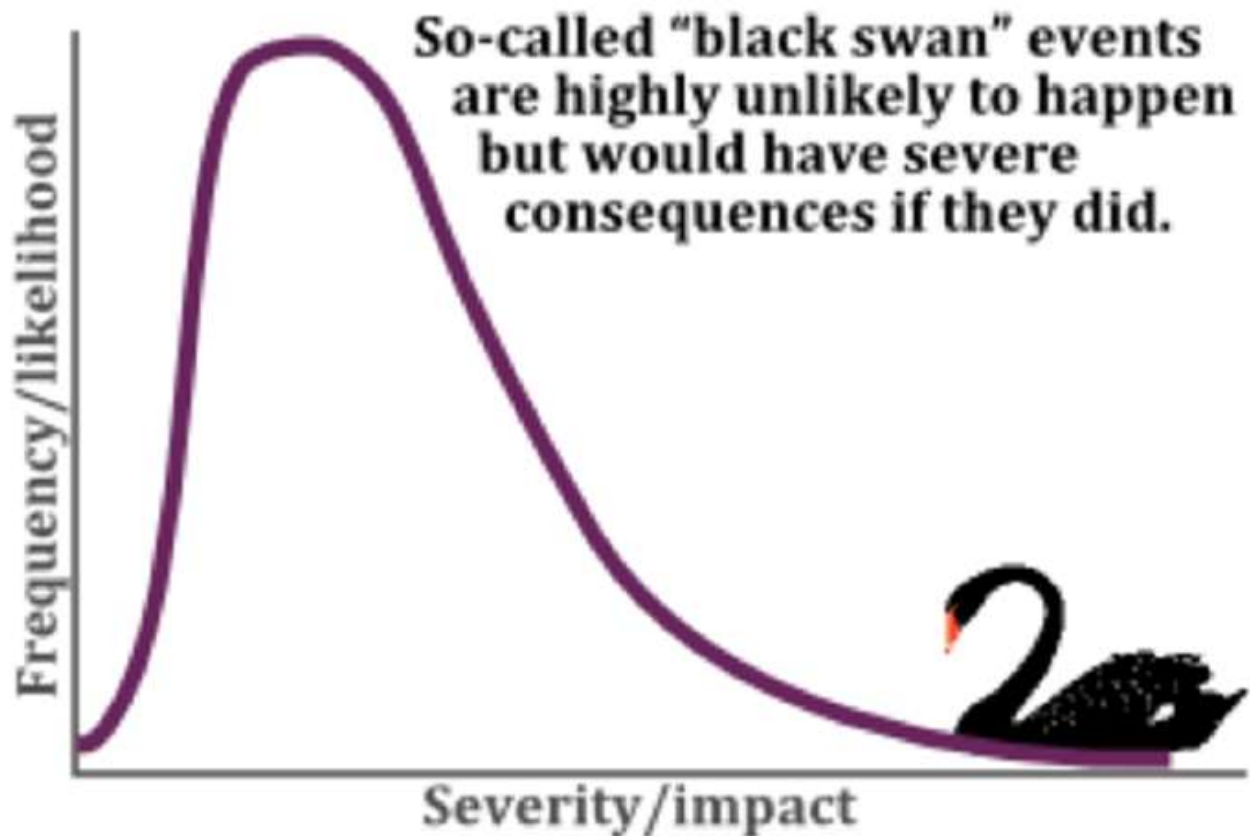
Black swan events

Minimal knowledge of ...

... statistics

... probability

The Black Swan



What is a 'Black Swan' event?

- A 'Black Swan' is an event which cannot be foreseen, but when it occurs changes the whole understanding of the market.
- The theory is outlined in Nicholas Taleb's book 'The Black Swan' published in 2010.
- It is so-called as, prior to discovering black swans in Australia, Europeans believed that all swans were white.
- In fact, a lack of knowledge and experience showed that their understanding of nature was fundamentally mistaken.
- 'All observed swans are white – hence all swans are white'
- By assuming some event is 'impossible', people and companies become complacent and this leads to lack of preparedness.



A look into the future

Obvious risks may not be serious

Nuclear accidents

Toxic chemicals in the air

Less obvious risks represent more severe dangers

Global climate change

Tipping point

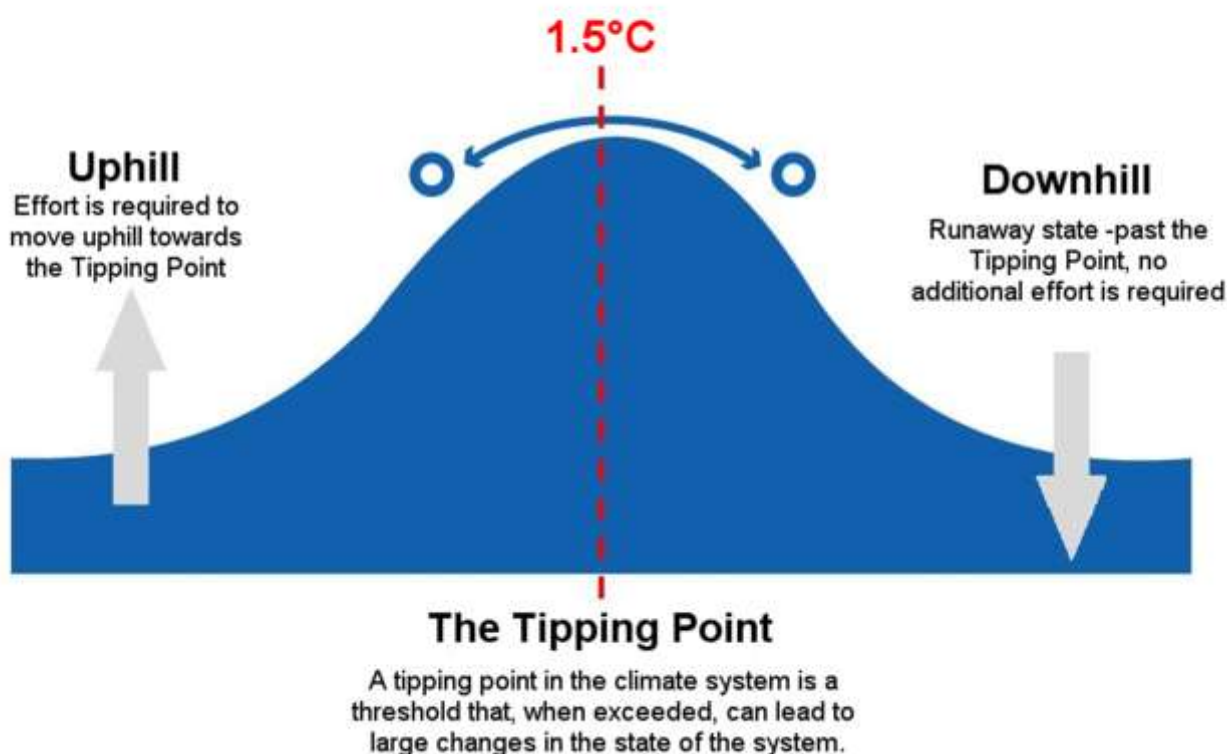
Overpopulation

Time scale for solving?

Pandemics

Asteroids

Tipping Point Effect



CLIMATE TIPPING POINTS

The world has already crossed nine 'tipping points' that will lead to catastrophic climate change, scientists have warned.

■ TIPPING POINTS
➔ CONNECTIVITY

1

Amazon rainforest
Frequent droughts

2

Arctic sea ice
Massive losses

3

Atlantic circulation
A slowdown since 1950s

4

Boreal forest
Increase in fires

5

Coral reef
Mass die-offs

6

Greenland ice sheet
Ice loss accelerating

7

Permafrost
Melting

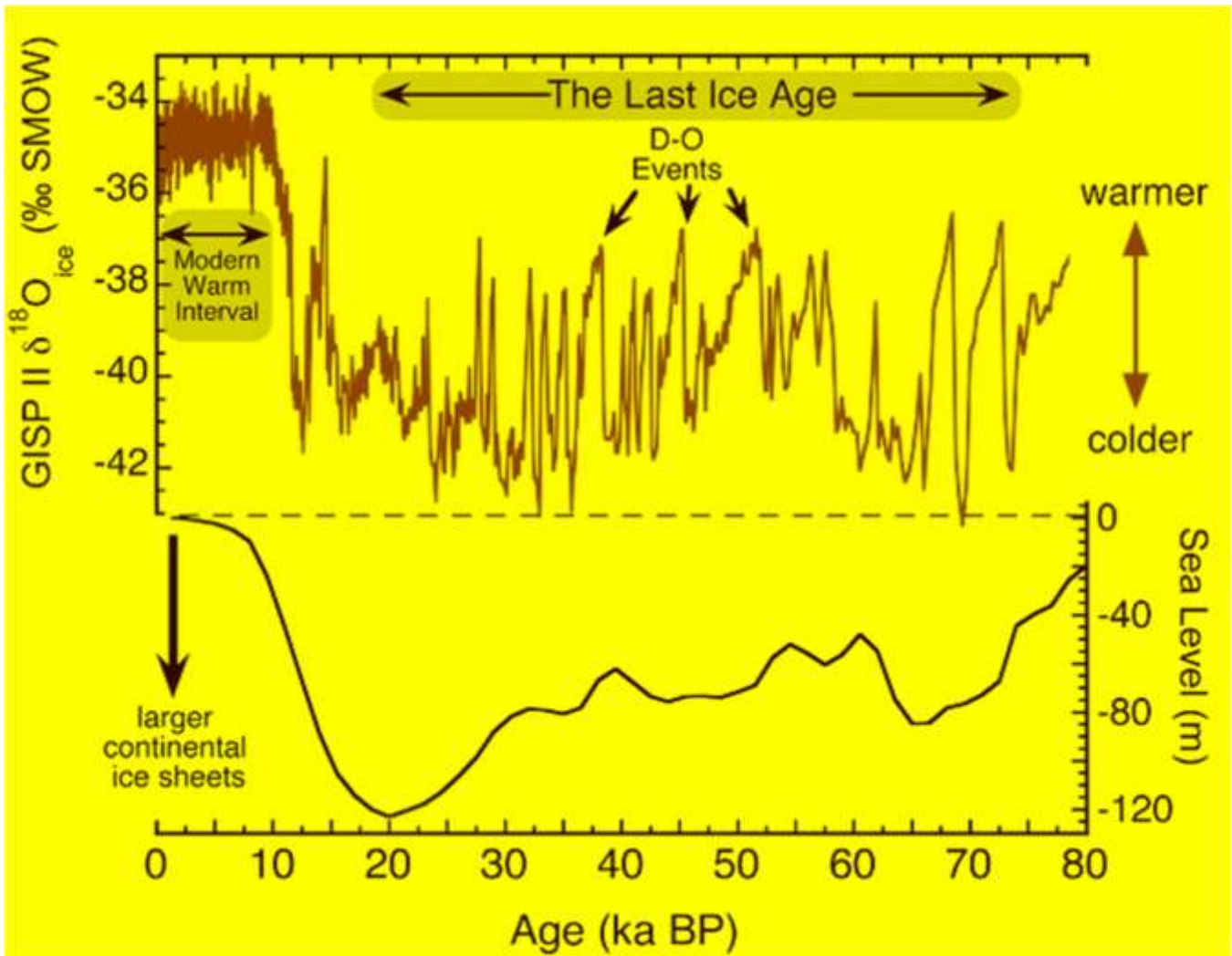
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West Antarctic ice sheet
Ice loss accelerating

9

Wilkes Basin
East Antarctica ice loss accelerating

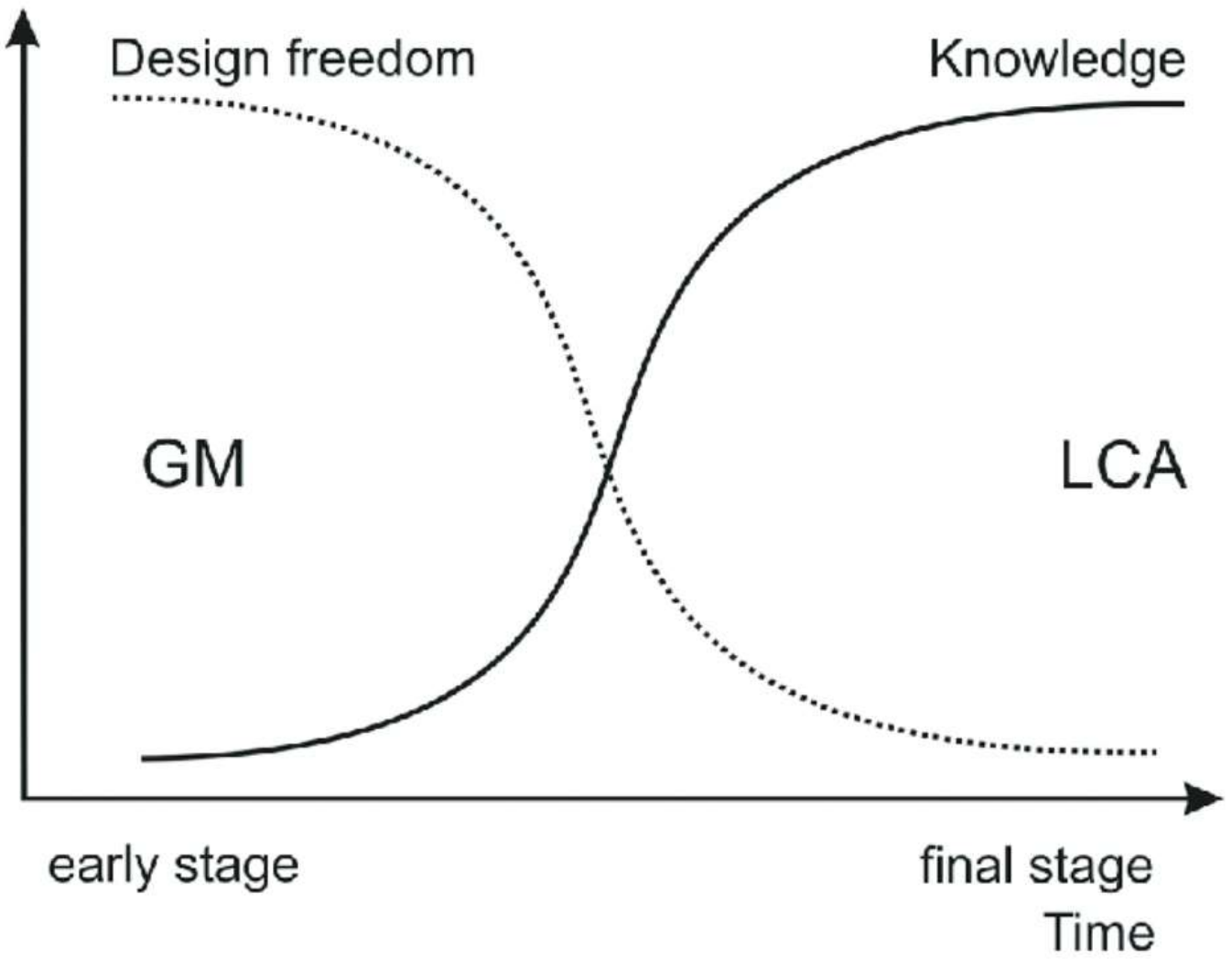




6.1. Collingridge dilemma

The **Collingridge dilemma** paradox

- During the early stages of a technology, its risks are hard to predict
- By the time the risks are clear, the technology is so deeply locked-in to the economy that it is too expensive or difficult to change
- This results in a methodological quandary



GM: Green Metrics; LCA: Life Cycle Assessment

The Social Control of Technology

David Collingridge

Frances Pinter (Publishers) Ltd., London
St. Martin's Press, New York

822074

Preface

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6.2. Risk in energy projects

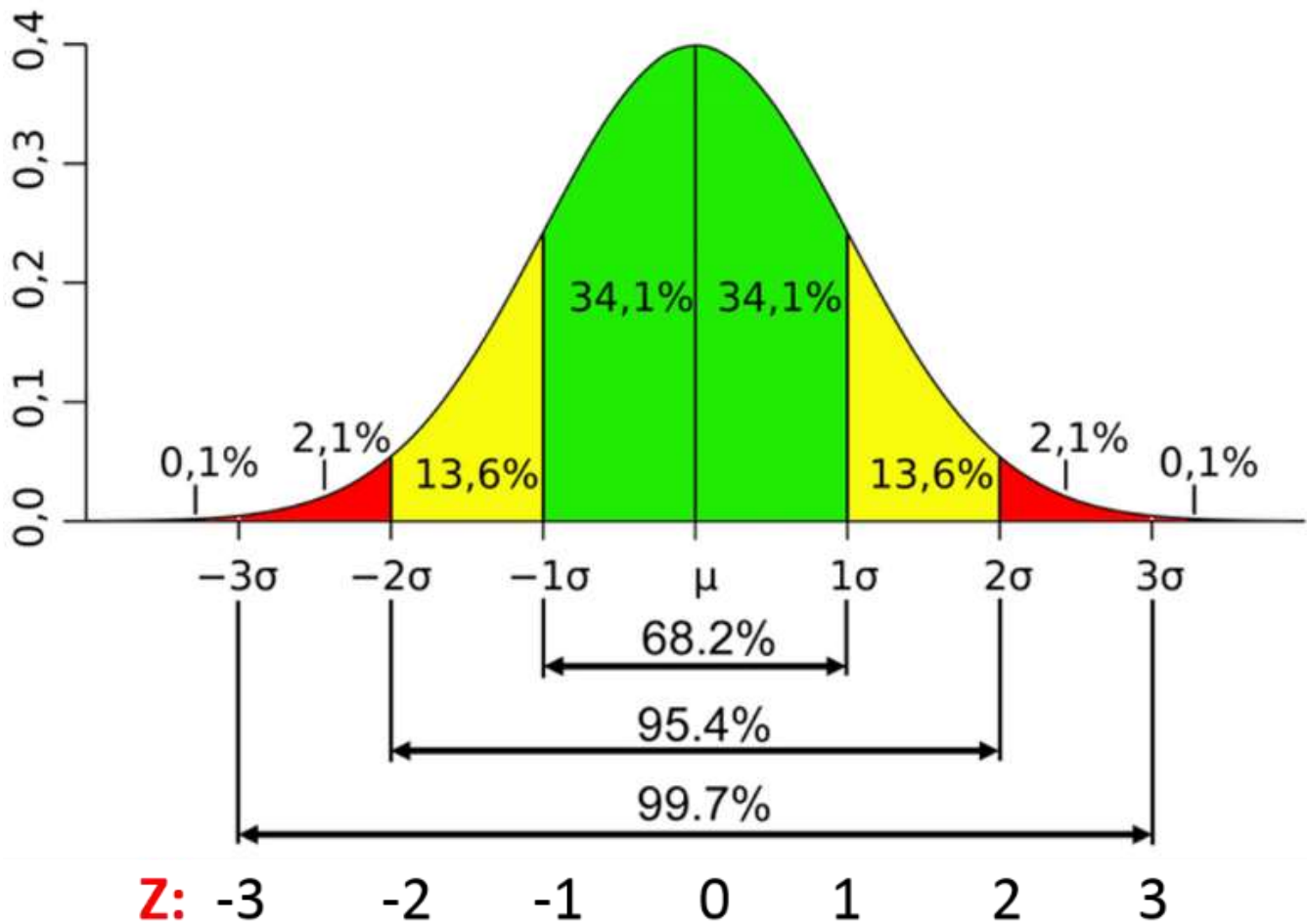
Energy projects represent some of the highest-stakes technological risks due to their

- Scale
- Longevity
- Environmental footprint

Types and sources of risks in energy projects

- Complexity and scale, e.g. nuclear vs. hydro
 - Large-scale energy projects are prone to tail risks ~ events that have a low probability but catastrophic consequences

- Tail risk = Potential for rare, extreme financial losses that fall far outside the expected, normal distribution of returns (often >3 standard deviations)

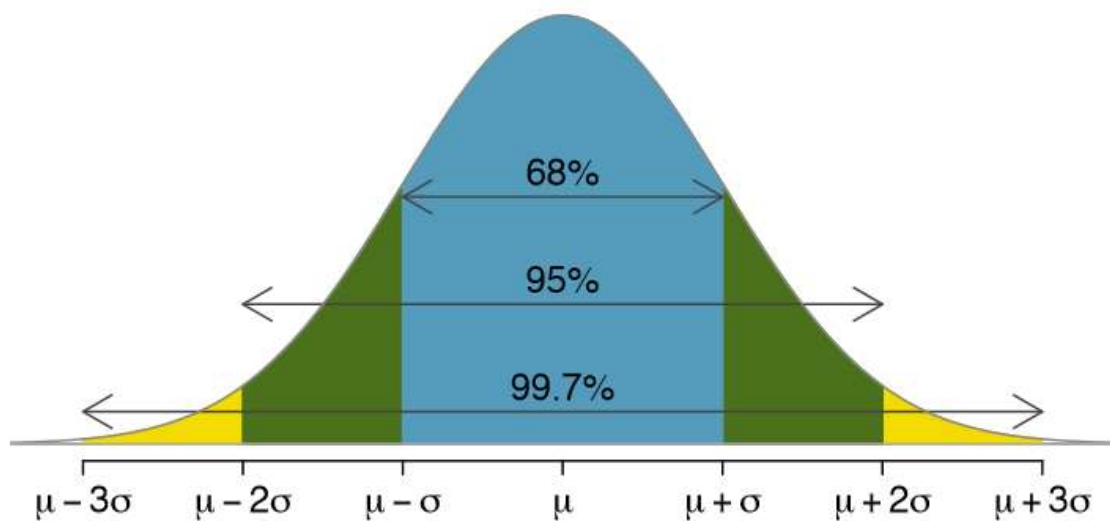


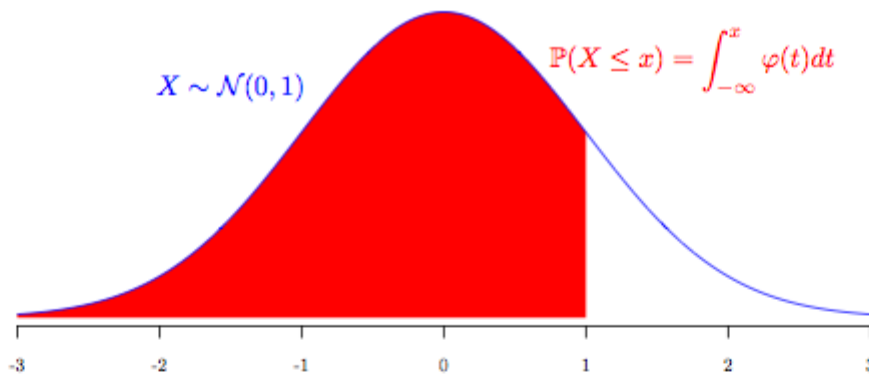
- Example: A dam failure or a nuclear meltdown is a **black swan** event that can motivate a nation to redefine its energy policy overnight
- Systemic path dependency
 - Energy infrastructure (e.g. grid or gas pipelines) requires massive upfront capital
 - The risk here is **technological lock-in**, e.g.
 - A nation stays committed to an outdated, risky, or dirty energy source because the cost of transitioning the entire infrastructure is seen as too high
- **Energy trilemma**
 - Risk in energy projects is often a balancing act between three competing goals
 - Energy security
 - Energy equity (affordability, access to all)

- Environmental sustainability (acceptable environmental impacts)
 - The problem is that mitigating risks in one area (e.g. building coal power plants for security) often increases risk in another (e.g. climate change)
- Supply chain and geopolitical vulnerability
 - For green energy technologies (e.g. wind, solar, batteries), the risk shifts from the operation to the supply chain
 - Dependency on critical minerals from volatile regions creates a geopolitical risk that can stall national energy transitions
 - Russia ~ Major supplier of high-grade nickel and palladium (used in hydrogen tech and catalytic converters); sanctions and geopolitical isolation create massive price shocks and supply choke points for the West
 - Greenland ~ Politically stable, though with complex diplomatic and environmental status; contains 25 of the 34 minerals classified as critical raw materials by the European Commission, e.g.
 - Neodymium and dysprosium, southern Greenland, essential for the high-strength permanent magnets used in wind turbines and electric vehicle (EV) motors
 - Widespread natural graphite deposits, the primary material for EV battery anodes; major strategic counterweight to China's dominance of the world's graphite processing
 - Citronen Fjord project (Northern Greenland), one of the world's largest undeveloped zinc-lead resources; zinc is vital for galvanizing steel for renewable energy infrastructure
 - Nickel and copper, found in western and central Greenland; critical for the wiring, motors, and stainless steel housing of clean energy tech
 - China ~ Dominant supplier, but often characterized more by geopolitical competition than internal volatility
 - Indonesia ~ World's largest nickel producer, has implemented export bans on raw ore to force foreign companies to build refineries domestically (Resource Nationalism) disrupting global markets

- Chile, Argentina, Bolivia (The Lithium Triangle) ~ Not volatile in a conflict sense, but facing political and regulatory volatility with shifting government policies on the nationalization of resources, and water-rights disputes with indigenous communities
 - Democratic Republic of the Congo (DRC) ~ The DRC produces over 70% of the world's cobalt, essential for electric vehicle batteries; however, the region faces chronic political instability, human rights concerns, and armed conflict, making the supply chain extremely fragile
- Cyber risks
 - Modern energy projects are increasingly digitalized (smart grids)
 - This introduces a new layer of risk, where a software vulnerability can lead to a physical failure of the energy supply

6.2.1. Standard normal distribution





	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990

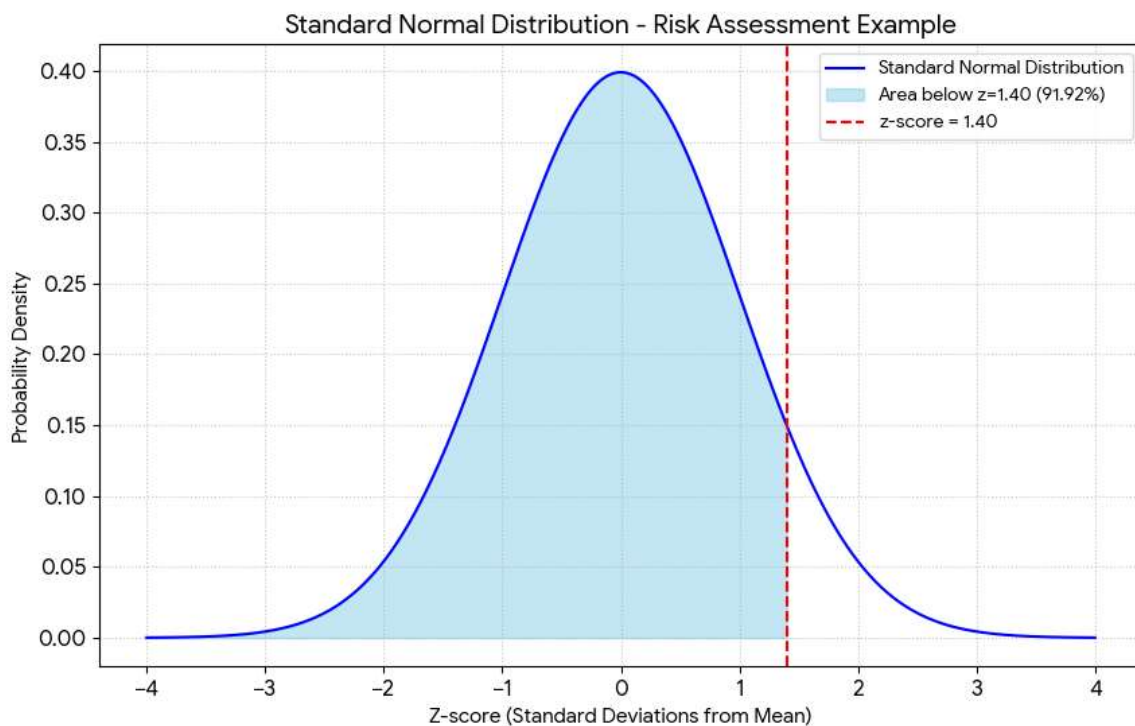
Energy projects rarely finish on budget — let us examine a hypothetical example

- We have a dataset of similar regional projects with the following statistics
 - Mean cost overrun (μ): 15%

- Standard deviation (σ): 5%
- Our new hydrogen plant is projected to have a 22% cost overrun (X)
- What tells us how many standard deviations our specific project sits away from the average is the z-score

$$z = \frac{X - \mu}{\sigma} = \frac{22 - 15}{5} = 1.4$$

- Using a standard normal distribution table (like the one shown before), we find the area below $z=1.4$
 - Area Below = 0.9192 (or 91.92%)
 - Area Above (Tail Risk) = $1 - 0.9192 = 0.0808$ (or 8.08%)



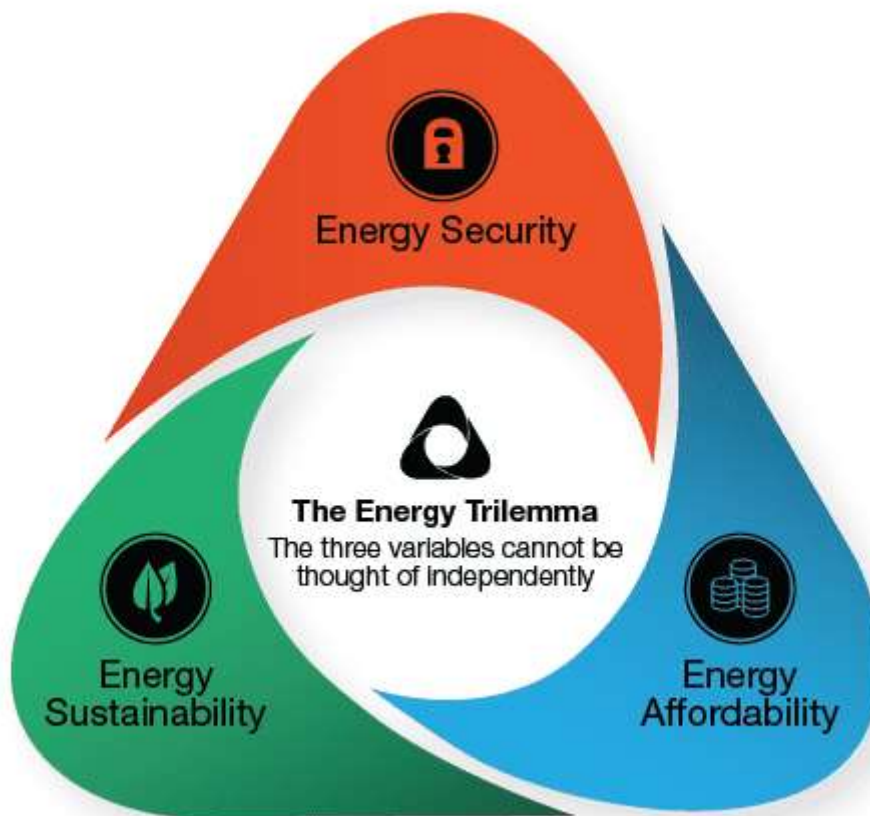
Recapping and conclusions

- Statistical fact ~ Approximately 92% of similar energy projects have a cost overrun smaller than ours
- Assessment ~ Our project is in the top 8% of the most expensive (thus risky) projects compared to historical data
- Decision ~ Is a 22% overrun acceptable?
 - Let us assume that our risk appetite only allows for projects within one standard deviation (≤ 1)
 - In that case, this project would be flagged as high risk and would require risk treatment

6.3. Risk appetite [Reached here Friday, March 20, 2026]

Some perspectives on risk appetite and energy projects

- Energy projects often face trade-offs related to the energy trilemma
 - Energy security (reliability)
 - Energy equity (affordability/access)
 - Environmental sustainability (decarbonization)



- Risk appetite is typically
 - Lower for proven technologies e.g. combined-cycle gas turbines
 - Higher for first-of-a-kind (FOAK) deployments, e.g. carbon capture or small modular reactors
- A low appetite for technological failure can lead to technological lock-in
 - A firm stays with old, inefficient systems to avoid the uncertainty of new ones
- In energy, most organizations have a zero-tolerance or near-zero risk appetite for safety and environmental compliance
 - This is a non-negotiable boundary
 - Avoidance (\neq ignore; = mitigate to zero value) is the only acceptable strategy

- Large-scale energy projects (e.g. offshore wind farms) involve massive upfront costs, so a firm's risk appetite is often dictated by its balance sheet strength
 - Smaller firms may have a lower appetite for delay risks because a six-month setback could lead to bankruptcy
 - An organization may show
 - A high risk appetite by selling power on the spot market (variable prices)
 - A low appetite by securing long-term Power Purchase Agreements (PPAs), which transfer the price risk to the buyer
 - For international energy projects (e.g. pipelines crossing multiple borders), risk appetite usually involves deciding whether to operate in geophysically stable but politically volatile regions
 - This is often managed through transfer via [political risk insurance](#)
 - Political risk insurance protects businesses from financial losses due to political events, e.g.
 - Expropriation
 - Political violence
 - Policies may be in effect for up to 15 years
 - Insurance policies can cover a wide range of risks, including
 - Sovereign debt defaults
 - Changes in government policies
 - Common buyers of political risk insurance include
 - Banks
 - Exporters
 - Infrastructure developers
 - Multinational corporations
 - Even “[AI can now be thought of as a new form of insider risk](#)”
-

EXAMPLE: The Titan submersible implosion (June 2023)



<https://www.bbc.com/news/world-us-canada-66014565>

- Stockton Rush's (CEO of OceanGate) controversial interview remark that reflected his disregard for conventional safety regulations
 - *"At some point, safety is just pure waste. I mean, if you just want to be safe, don't get out of bed. Don't get in your car. Don't do anything"*
 - This statement was made before the Titan submersible accident
 - Highlighted his belief that over-regulation and traditional safety measures stifled innovation and exploration
 - This attitude has since been heavily criticized
 - In light of the tragic accident that occurred during an expedition to explore the Titanic wreck



<https://www.1news.co.nz/2024/09/20/titans-goal-was-to-make-dreams-come-true-mission-specialist/>

- Jay Bloom (prospective customer of OceanGate <https://edition.cnn.com/videos/us/2023/06/23/submersible-titan-father-son-turned-down-seats-efof-bts-vpx.cnn> and <https://www.businessinsider.com/titanic-sub-stockton-rush-flew-experimental-plane-visit-reluctant-passengers-2023-6>)
 - Bloom said that Rush came to visit him after he and his son expressed concerns about the trip
 - After he questioned why Rush was landing at North Las Vegas Airport rather than one of the city's other airports, Rush said
 - He was *“coming in on a two-seater experimental plane that he built”*
 - *“And I started to think about it: He's coming in on a two-seater experimental plane to pitch me to go on a five-seater experimental sub that he built down to the ocean floor to see the Titanic”*
 - Bloom said he understood that Rush had *“a different risk appetite than I do. I'm a pilot, I have my helicopter pilot's license, I wouldn't get into an experimental aircraft”*
 - Bloom's son said *“I just didn't think it could survive going that low into the ocean”*
 - His father agreed with his concerns
 - When they tried to ask Stockton questions *“he kind of brushed it off a little bit”*

- Their seats went to another father and son, Shahzada and Suleman Dawood, who died on board when the submersible imploded
- Rush obviously had an adventurous nature and willingness to embrace significant personal and operational risks
 - These later became a subject of concern regarding OceanGate's safety practices with the Titan submersible

Let us formalize all the above into the steps we discussed previously

1. **Risk analysis** (*How much*)

- Innovation ~ OceanGate utilized a carbon fiber hull instead of the industry-standard titanium or steel for deep-sea exploration
- Probability ~ Experts in the Marine Technology Society warned that the experimental nature of the hull had a high probability of cyclic fatigue (i.e. weakening over multiple dives)
- Impact ~ Total hull failure at 3,800 m, involving near-instantaneous implosion with 100% fatality rate

2. **Risk assessment** (*So what*)

- Risk appetite: CEO Stockton Rush famously stated
 - Safety is just pure waste
 - I've broken some rules to make this
- This signals an extreme risk appetite
 - The potential reward (lowering costs and disrupting the industry) was judged to be worth the potential risk (catastrophic failure)
- Evaluation gap
 - OceanGate refused classification through third-party evaluation by organizations like the American Bureau of Shipping
 - They performed their own internal assessment but skipped the external audit
 - The external audit could test whether the So What judgment was sane

3. **Risk management** (*Now what*)

- Treatment choice: Acceptance (hard to believe)
 - OceanGate did not mitigate the risk through standard testing (like acoustic monitoring that could stop a dive)

- They accepted the risk and moved forward
 - Result: A “normal” or “system” accident (per sociologist Charles Perrow, a pivotal figure in the theory of why and how things fail)
 - “[Charles Perrow] *introduced the concept of normal accidents, which he also refers to as system accidents. These are near-inevitable catastrophic failures in highly complex and tightly coupled systems. In these complex systems, despite efforts to prevent them, component failures arise and can interact unpredictably with other components, particularly if components are dependent upon each other. Perrow also argues that many measures intended to bolster system resilience can inadvertently increase its complexity, leading to new potential failure states.*” (<https://psychsafety.com/normal-accidents/>)
 - The complex interaction of the carbon fiber hull and titanium end-caps under immense pressure led to a failure that was tightly coupled
 - Once the crack started, there was zero time for an emergency response
-

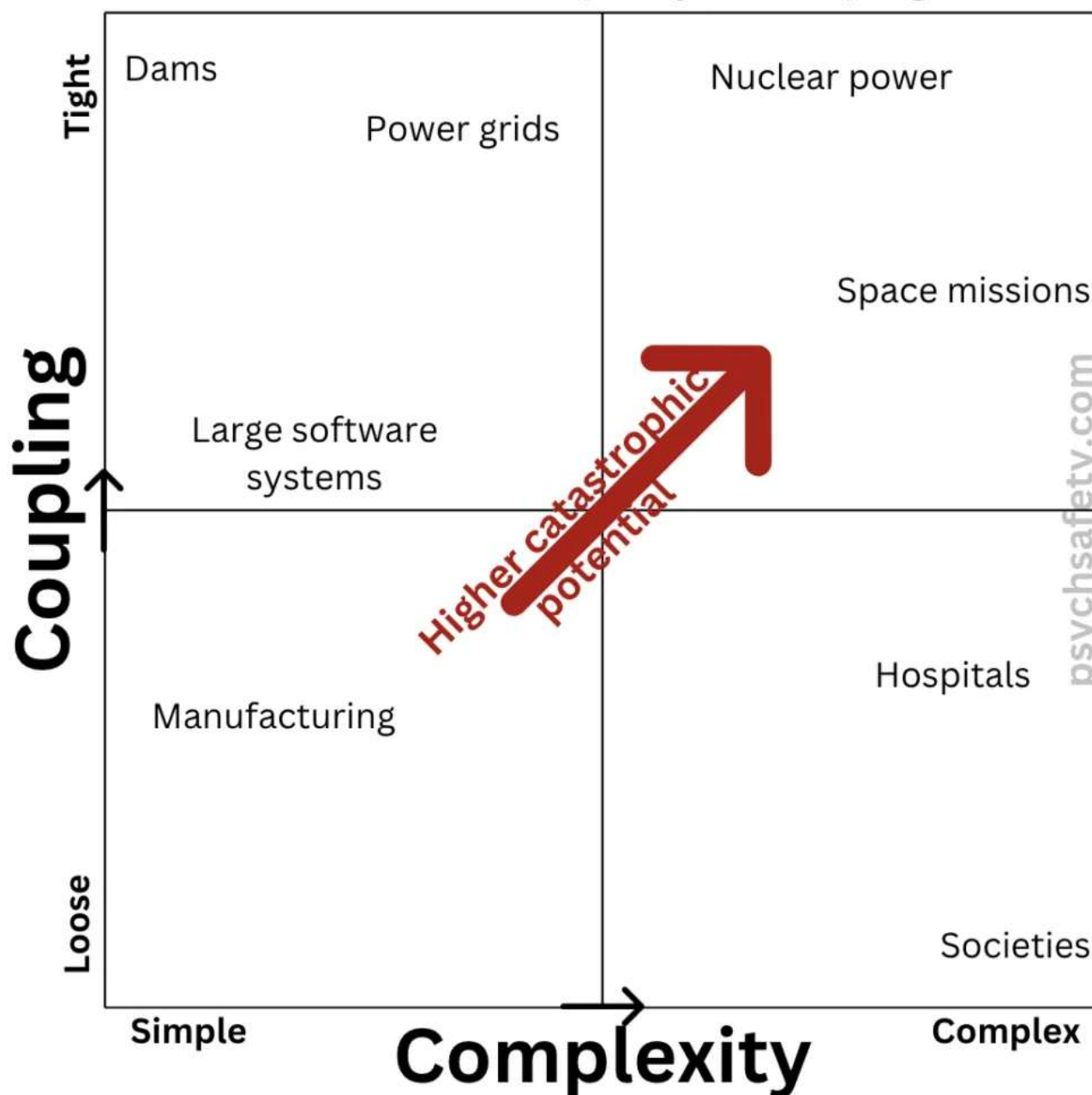
6.4. Normal or system accidents

Perrow outlined three conditions that make any system more prone to suffering a “Normal Accident”

1. Highly complex system (spiderweb effect) ~ Having lots of components with unpredictable interactions increases the likelihood of failures
2. Tightly coupled system (domino effect) ~ If elements within the system are closely connected and dependant, a failure in one part has a “*prompt and major*” impact on others
3. System with catastrophic potential ~ When the stakes are high, a failure can lead to severe consequences

These characteristics are shared by energy systems

Normal Accidents: Complexity and Coupling

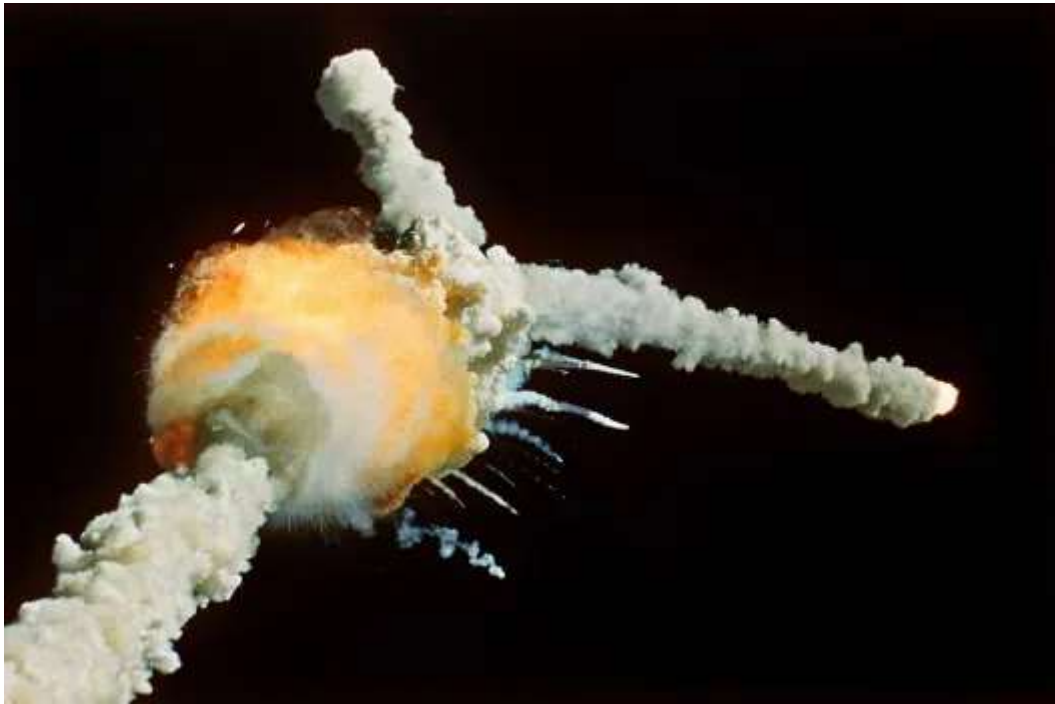


Recapping and provides examples

Complexity + Coupling	Result	Example
Complex + Tight	Catastrophic risk	Nuclear power, Space shuttle, Titan submersible
Complex + Loose	Manageable chaos	A university research lab, The legal system
Simple + Tight	Mechanical	Toaster,

	failure	Dam
Simple + Loose	Mistakes can be fixed before turning into disaster	Home solar setup

EXAMPLE: Challenger disaster (1986)



<https://youtu.be/Hueh49QX-nw>

False sense of security

- NASA had designed the shuttle without an escape system for the middle phase of flight because they assessed the probability of a total vehicle breakup as so low that the weight of an escape system was not worth it
- They managed for the likely (minor malfunctions), but left the crew completely vulnerable to the consequence of the unlikely (total loss of vehicle)

Examples of hazards in technological projects ~ inherent conditions existing within a project

- Operational wear, e.g. high maintenance needs in biomass or biogas systems
- Physical infrastructure risks, e.g. equipment failures (gear trains, bearings in wind turbines), component breakdowns in solar systems

- Resource uncertainty, e.g. wind variability (affecting wind turbines), seasonal rainfall (affecting hydropower), geothermal drilling failures
- Technology immaturity: Prototypical risks in tidal/wave power or concentrating solar power
 - Imagine putting a giant propeller or a flipper at the bottom of the ocean to catch the moving water

Hazard: The ocean is a very “grumpy” place — it has salt that eats metal, giant waves that smash structures, and sand that clumps gears; if we haven’t built many such machines yet, we don't know exactly how to keep them from breaking when a big storm hits
 - Imagine using many shiny mirrors to bounce sunlight onto one single spot (like using a magnifying glass to light up a piece of paper); this makes that spot hotter than a kitchen oven

Hazard: Because it gets very hot, the pipes holding the heat can melt or crack; since this is a newer prototypical (experimental) way to make power, scientists are still trying to find out which metals can handle that much heat for years without turning into soup
 - Prototypical risk ~ *“We think this works, but we haven’t done it enough to be 100% sure”*

Examples of threats in technological projects ~ external triggers that exploit vulnerabilities in the project environment

- Regulatory changes: Policy shifts that eliminate subsidies or feed-in tariffs, threatening project viability
- Financial market instability: High borrowing costs (especially in developing countries) making projects unaffordable
- Cyber attacks: Threats to grid infrastructure and critical systems in utility-scale projects
- Climate impacts: Physical damage to infrastructure or reduced resource availability due to climate change
- Carbon financing uncertainties (Dagoumas)

In geopolitics

- A hazard is often a structural vulnerability, e.g. geography, dependency, weak institutions;

- A threat is an actor or event that exploits it, e.g. state, non-state, or systemic (like economic collapse or climate migration)

Geopolitical risk examples

- **Hazard**: Military bases located very close to civilian neighborhoods;
Threat: An airstrike that misses its target and hits a nearby apartment building
- **Hazard**: An electrical grid that relies on old, unpatched computer software;
Threat: A state-sponsored hacking group launching a virus to shut down the power
- **Hazard**: The world's extreme dependence on oil from the Persian Gulf;
Threat: A total blockade of the sea lanes that causes gas prices to double in a very short amount of time

EXAMPLE: Abu Dhabi, Dubai, and their tourism industry

United Arab Emirates (UAE)

- UAE is a federal semi-constitutional monarchy composed of seven emirates: Abu Dhabi, Dubai, Sharjah, Ajman, Umm Al Quwain, Ras Al Khaimah, and Fujairah
- The federation was founded on December 2, 1971, by six emirates; Ras Al Khaimah joined the following year (1972)
- Abu Dhabi is the capital and largest emirate (holding about 87% of the land)
- Dubai is the most populous and serves as the country's primary global commercial and tourism hub
- Their governance is a unique blend of federal and local systems
- The Federal Supreme Council is the highest constitutional authority, made up of the individual rulers of the seven emirates
- The Council elects a President (traditionally the Ruler of Abu Dhabi) and a Vice President (traditionally the Ruler of Dubai) from its members every five years
- While the federal government manages foreign policy, defense, and national security, each individual Emirate retains significant control over its own internal affairs, including its economy, judicial system, and natural resources (like oil)



UNITED ARAB EMIRATES

- ⊙ National Capital
- ⊙ Emirate Capital
- Town, Village
- - - Int'l boundary
- - - Emirate boundary
- Main Road
- Secondary Road
- ✈ Int'l Airport
- Sabkha (Salt flat)



0 50 100 km
25 50 mi

OUR LEGACY



The Zayed Future Energy Prize is an annual award, established by the United Arab Emirates government to recognise and award excellence in renewable energy and sustainability.

Launched in 2008 and managed by Masdar, the Prize honours the legacy of the late founding father of the UAE, Sheikh Zayed bin Sultan al Nahyan, who championed environmental stewardship and sustainability as an integral part of UAE history and heritage.

In six years, the Zayed Future Energy Prize has rewarded 30 winners across the globe - recognising people, companies, organisations and high schools working to advance a more sustainable future.

















Hazard = a condition or situation that has the potential for harm but is passive or dormant ~ an inherent vulnerability

- Geographic proximity
 - High-end tourist and financial hub
 - Situated in a volatile region
 - Physical location near potentially bad actors or geopolitical flashpoints
- Tourism industry vulnerability
 - Dubai's economy is uniquely exposed because, compared to its neighbors, it lacks vast oil reserves
 - Its wealth is built on the Dubai Dream
 - Western confidence
 - Luxury tourism (\$30 bn/year)
 - Expatriate labor (90% of the population)
- Passive nature of the hazard
 - For decades, this hazard has existed without incident
 - The proximity to Iran did not change — the potential for disaster was always baked in to the city's blueprint

A threat is the active expression of a hazard — a specific actor with the intent and capability to cause harm ~ dynamic escalation

- Catalyst
 - The transition from hazard to threat occurred when the US and Israel launched strikes on Iran
 - A regional tension (hazard) was metamorphosized into an active military campaign (threat)
- Targeting the Dream
 - The threat became dynamic when Iranian projectiles began hitting specific symbols of Dubai's stability, such as the Fairmont Hotel on the Palm Jumeirah and the Dubai Airport.
- Nature of the threat
 - Active and dynamic
 - Unlike the static hazard of geography, the threat involves shifting tactics designed to erode the psychological sense of safety required by tourism
 - Missile strikes
 - Drone attacks
 - Cyber attacks on data centers

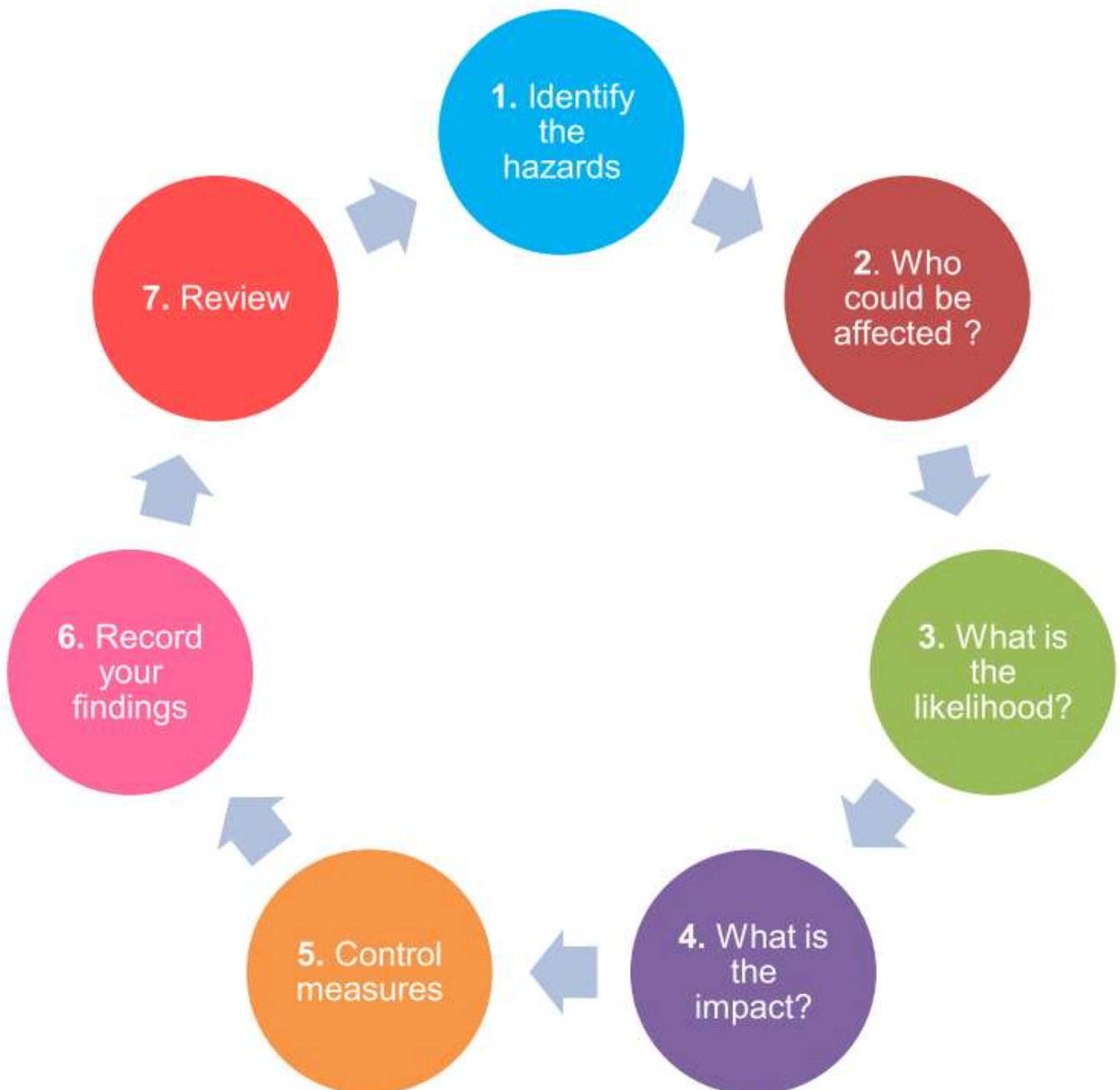
6.5. Risk assessment

Basic questions in risk assessment (Fullerton, 2018)

- What is the likelihood something bad will happen?
- How bad will it be if it does?

Mission-based risk management

- Is what we are doing (or proposing to do) supporting and/or helping us achieve our mission?



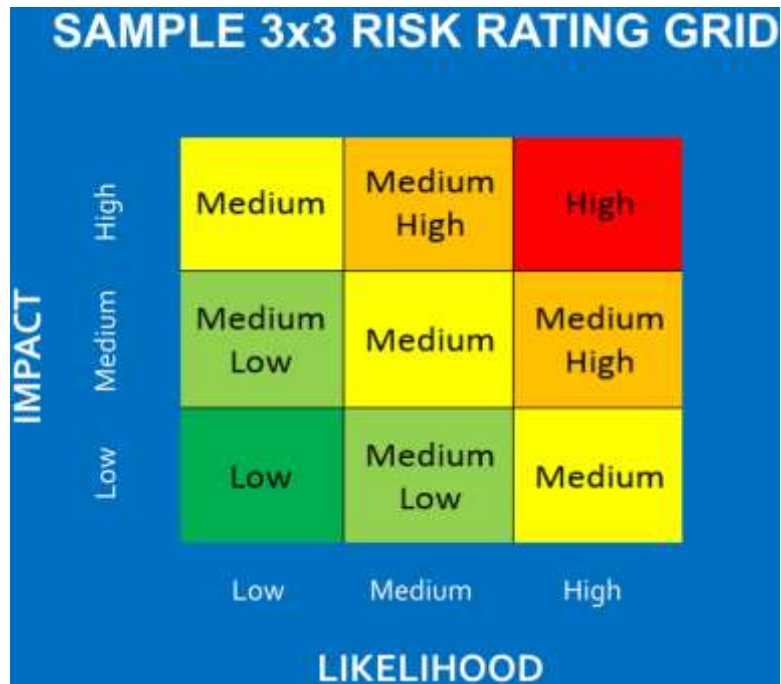
<https://www.edwindoran.com/wp-content/uploads/2023/04/Step-by-step-guide-to-risk-assessment.pdf>

Steps in risk assessment

1. Identify the hazards
2. Who could be affected?
3. Assess the likelihood
4. Determine who will be affected
5. Evaluate the impact
6. Develop control measures

Impact vs likelihood tables

- Usually in either 3x3 or 5x5 format



Rating risk

(Fullerton, 2018)

Consequences

Score	1	2	3	4	5
Description	Insignificant	Minor	Moderate	Major	Catastrophic
Example	Minor injury, no first aid required	Harmful injury (first aid required, under 3 days recovery time)	Serious injury, medical assistance required. Injury must be reported.	Major injury, urgent medical assistance required.	Fatality

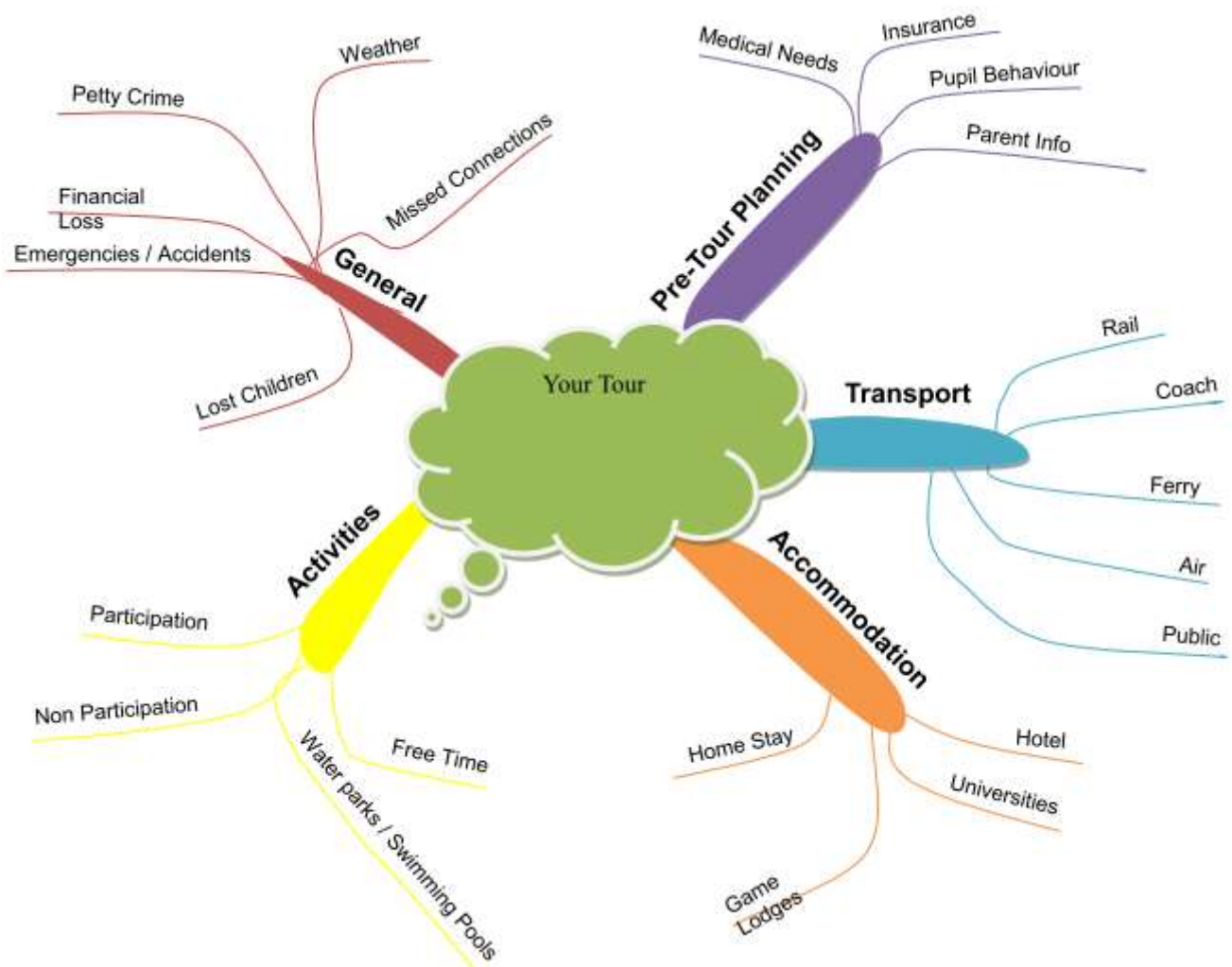
Likelihood

1	2	3	4	5
Rare	Unlikely	Possible	Likely	Almost Certain

Consequences/ Impact	Catastrophic	5	5	10	15	20	25
	Major	4	4	8	12	16	20
	Moderate	3	3	6	9	12	15
	Minor	2	2	4	6	8	10
	Insignificant	1	1	2	3	4	5
		1	2	3	4	5	
		Rare	Unlikely	Possible	Likely	Almost Certain	
Likelihood/ Probability							

Risk assessment guidelines version 2
August 2016

Risk mind maps may also be used



<https://www.edwindoran.com/wp-content/uploads/2023/04/Step-by-step-guide-to-risk-assessment.pdf>

After rating risk

- **Avoid** the risk
 - The activity is too risky
 - There are no reasonable ways to reduce risk to an acceptable level

- **Transfer** the risk
 - The level of risk to our organization is too high
 - Therefore, we will transfer the risk to another party
- **Reduce** the risk
 - The level of risk is at a higher level than we are comfortable accepting
 - Action is required to reduce the level of risk (either likelihood or impact)
- **Accept** the risk
 - The level of risk is low enough

6.5.1. Risk analysis of a petroleum refinery tour

Please carry out a risk analysis of a petroleum refinery tour



<https://www.najah.edu/en/academic/academic-news/2023/05/18/an-najah-facilitates-educational-visit-to-jordan-petroleum-refinery-for-chemical-engineering-professors-and-students/>

For reference, Let us take a look at a risk analysis of an education visit (of graduate students) to a petroleum refinery

Index	Hazard	Likelihood (1-5)	Impact (1-5)	Risk rating
-------	--------	---------------------	-----------------	----------------

1	Student photos/videos creating confidentiality issues/GDPR violations	4	3	12
2	Worker accident	2.5	3.5	8.75
3	Health effects on students, e.g. noxious odors and fumes	3	2.5	7.5
4	Student accident onsite	2	3.5	7
5	Access of a student to a restricted area	2.5	2.5	6.25
6	COVID-19 dispersion (catching and giving it)	4	1.5	6
7	Infrastructure accident: Explosion	0.5	5	2.5
8	Infrastructure accident: Fire	0.5	5	2.5
9	Infrastructure accident: Leakage	0.5	5	2.5
10	Terrorist activity from external sources	0.5	4.5	2.25
11	Terrorism or illicit activity from student body	0.5	4.5	2.25
12	Extreme weather causing accident (e.g. lighting, windy)	0.5	4	2
13	Earthquake	0.5	4	2
14	Traffic accident of the bus	0.5	3	1.5
15	Protestors not allowing entrance to refinery	0.5	2	1
16	Student tripping from/to bus	0.5	1.5	0.75
17	Bus malfunctioning	0.5	1	0.5

7. Strategic risk

Strategic context for risk

- Risk = Probability × Impact (standard formula)
- Risk = Threat × Vulnerability × Consequence (national security context)
- Risk ~ The tilt of the strategic stool when ends (objectives), ways (concepts), and means (resources) are out of balance

Strategy triad by Arthur F. Lykke Jr. (retired Army colonel and professor at the US Army War College)



1. **Ends** (strategic objectives)

- Specific goals to be accomplished
- These must be clearly defined strategic outcomes that support the overall mission

2. **Ways** (strategic concepts) ~ methods

- How the strategic goals will be accomplished
- These detail how resources will be employed to achieve the objectives

3. **Means** (resources)

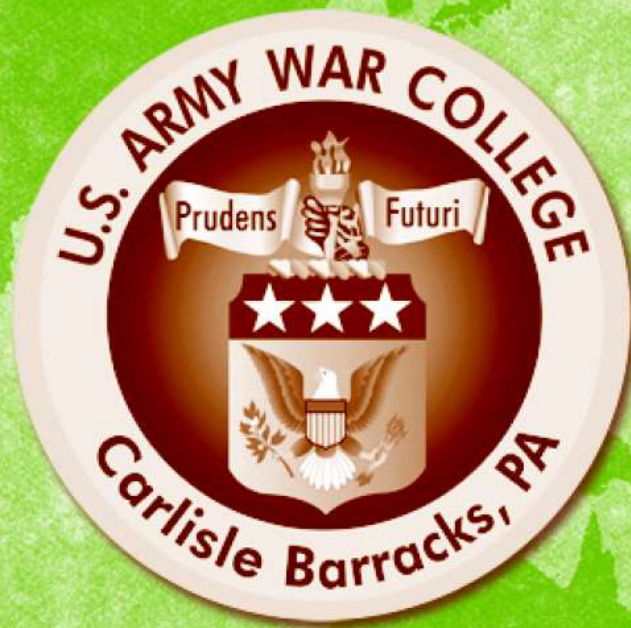
- What resources will be used to execute the methods and achieve the ends
 - These include
 - Tangible resources. e.g. money, personnel, equipment
 - Intangible assets, e.g. data, time, reputation
-

In an army context, risk assessment is often the very last thing a staff officer does before handing a plan to a General

- “*Sir, here is the plan (the means and the ends)*”
 - a. “*My analysis shows a 20% chance of failure (how much)*”
 - b. “*My assessment is that this risk is moderate but acceptable (so what)*”
 - c. “*We must manage it by keeping a reserve force ready (now what)*”

U.S. Army War College Guide to National Security Issues

Volume I: Theory of War and Strategy



2012

Edited by J. Boone Bartholomees, Jr.

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John Collins on Risk

- *“Discrepancies between ends, which we have identified as interests and objectives, and means—available resources—create risk, which can rarely be quantified”*

- “Ends-means mismatch”

B. H. Liddell Hart

- “Strategy depends on success ... on a sound calculation and coordination of the ends and the means ... An excess may be as harmful as a deficiency”

Strategic risk

- The probability of failure in achieving a strategic objective at an **acceptable cost**.

Art Lykke’s model

1. **Ends** = objectives
2. **Ways** = concepts, options of courses of action for achieving them
3. **Means** = resources

Means = resources, e.g.

- Personnel
- Money (“treasure”)
- Equipment
- Political will
- Time

Three-legged stool (strategy)



If the three legs of the stool (ends, ways, means) are not of equal length, the stool (and the strategy) is unbalanced

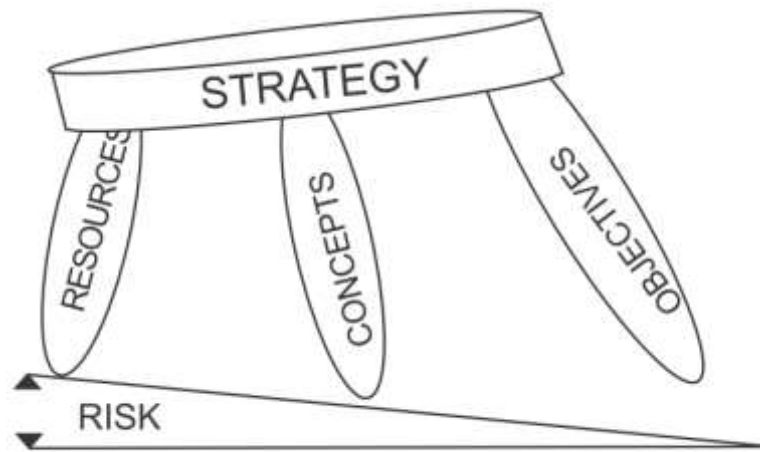


Figure 3-3. The Lykke Model.

This conceptual model applies to all strategy aspects

- National security (grand) strategy
- Defense
- Military or theater strategies
- Business strategy
- Personal strategy

Example situation

1. Identify, accurately and adequately
 - Objectives to be achieved (ends)
 - Resources to be provided (means)
2. Courses of action (ways) to achieve them are not in balance
3. Result ❌ Risk of failure to achieve the strategic objective

Risk = degree of lopsidedness (i.e. imbalance)

Strategy is a dynamic process

- All three elements are variable and subject to change over time and circumstance

Decision theory helps formulate effective strategies

- Constant quest to ensure balance among the variables

7.1. Strategic risk assessment

War and conflict = relationship between thinking adversaries

- Ambiguity, uncertainty, risk
- Thus the use of game theory

Clausewitz on **uncertainty**

- “Chance”
- “Luck”
- “Uncertainty”
- “Probabilities”

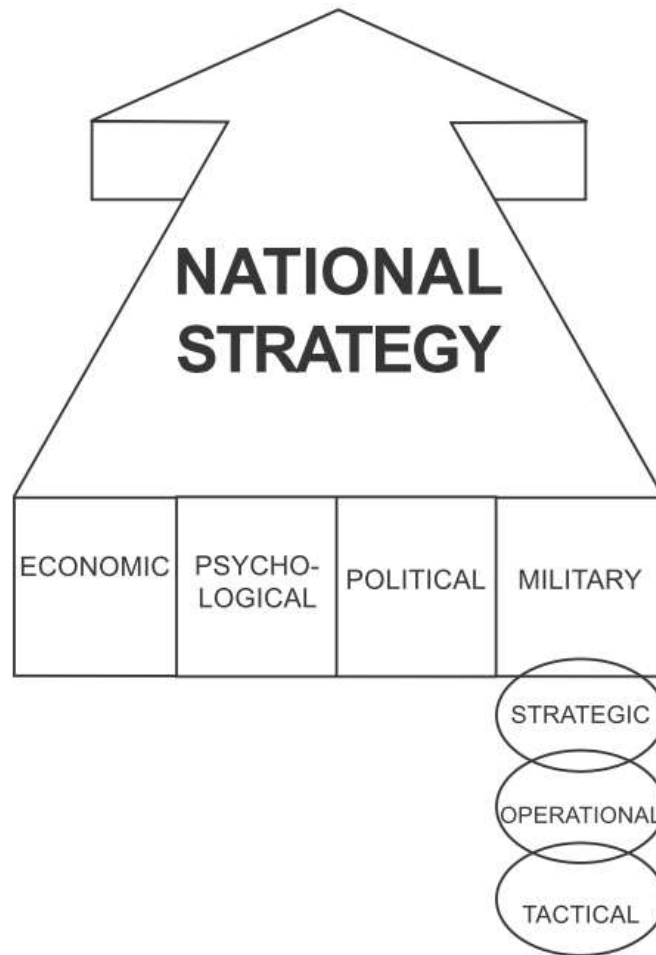
Clausewitz on **war**

- “Duel on a larger scale”
- “Pair of wrestlers”
- “Commerce”
- “Collision of living forces”
- “Game of chance”
- “Animate object that reacts”



Figure 1-4. The Continuum of War.

The horizontal and vertical plane of strategy



Natural Determinants

- Geography
- Population
- Natural Resources

Social Determinants

- Economic
- Military
- Political
- Socio-Psychological

Actor Structures

- Individual
- Leadership
- Groups
- Organizations
- Institutions
- Interagency/Bureaucracy
- Movements
- States
- International Business Organizations
- Private Organizations
- International Governmental Organizations
- Society/Culture

Dimensions of Strategy²⁵

- People
- Society
- Culture
- Politics
- Ethics
- Economics and Logistics
- Organization
- Administration
- Information and Intelligence
- Strategic Theory and Doctrine
- Technology
- Operations
- Command
- Geography
- Friction/chance/uncertainty
- Adversary
- Time

Strategy definition by Andre Beufre

- *“Art of the dialectic of two opposing wills using force to solve their dispute”*

As we climb up the strategic ladder

- Moral factors gain primacy over material ones
- Ambiguity and uncertainty increase

Clausewitz

- *“At this point, then, intellectual activity leaves the field of the exact sciences of logic and mathematics. It then becomes an art in the broadest meaning of the term—the faculty of using judgment to detect the most important and decisive elements in the vast array of facts and situations.”*

Why is strategic risk assessment difficult?

- Strategic risk assessment is difficult because it has to do with strategy
- Strategy is difficult because it has to do with war
- War is difficult because it is the most complex of human undertakings
- On top of that, war is filled with unknowns
- The strategic student is adrift in a strategic sea of uncertainty

The effective strategist

- Strives for the *“closest approximation of the truth”*
- Is aware of the fact that complete knowledge is impossible

Clausewitz spoke of

- “... first, an intellect that, even in the darkest hour, retains some glimmerings of the inner light which leads to truth;”
- “... second, the courage to follow this faint light wherever it may lead.”

Von Moltke the Elder

- “... to discover the situation, such as it is, in spite of its being surrounded by the fog of the unknown;”
- “ ... then to appreciate soundly what is seen, to guess what is not seen, to take a decision quickly, finally to act with vigor , without hesitation”

What can help find the closest approximation to the truth?

- Intellect and courage cannot be easily taught
- Theoretical uncertainties are inherent in war, conflict, strategy, and policy
- Education in strategic studies
- Continuous historical study
- Experience
 - Through exercise
 - Actual experience

(Grand) strategy is

- Guessing what is not seen
- Guessing well

Essence of the challenge of strategic risk assessment

- Relating ends to ways and means
 - The ends are usually abstract
 - The ways and means are usually well defined
- Translate “*obtuse, politically couched*” objectives into specific actions

Managing risk helps achieve clarity in political objectives

- Especially given the multiplying crises regionally and globally

Potential pitfall for the grand strategist

- The tail wagging the dog
 - The means can in fact “*deflect the direction of ends*”
 - Michael Howard: “... the strategy adopted is always more likely to be dictated rather by the availability of means than by the nature of the ends”

But how do we measure the degree of risk in a strategic endeavor?

Criteria for assessing a particular issue as a vital interest

1. Value factors
2. Cost/Risk factors

Value Factors

Proximity of the danger

Nature of the threat

Economic stake

Sentimental attachment

Type of government and human rights

Effect on the balance of power

National prestige at stake

Support of allies

These factors can be

- Rated high, medium, low
- Assigned numerical scores
- Weighted or prioritized

Scores can be summed up

Such a method lacks a scientific basis but

- “... provides for systematic analysis of specific foreign policy issues; it should therefore lead to better judgments about levels of interest ... and, one would hope, to wiser policies than would otherwise be the case.”

7.3. Calculating risk

Admiral J.C. Wylie's mathematical approach

- Intended to ridicule early whiz kids
 - More when we analyze the Cuban Missile Crisis

Symbols used by Admiral Wylie

- C_f : cost of attempt that fails
- C_n : cost if not attempted
- C_s : cost of attempt that succeeds
- P : profit if successful
- S : probability of success

Wylie defines risk R (an index of sorts) as the ratio of potential profit (P) divided by the cost of a failed attempt (C_f)

$$\text{Risk} = P/C_f$$

If this ratio is

- Greater than 1, the strategy is encouraged
- Less than 1, the strategy is discouraged

Furthermore

- $P \times S$ = Profit if successful \times the probability of success
 - Represents the potential benefits
- $C_f \times (1 - S)$ = Cost of failure \times the probability of failure
 - Represents the potential costs

Therefore, we may write the following determining equations

If $P \times S < C_f \times (1 - S)$ then no go

If $P \times S > C_f \times (1 - S)$ then go

In addition, the cost of a failed attempt over the cost of a successful attempt must be less than the probability of success divided by the probability of failure

$$C_f/C_s < S/(1 - S)$$

Wylie only wanted to intrigue and inspire the readers

- *“To ensure success in its use, there is only one condition that must be met: the factors involved must never be expressed in arithmetic quantities. That would blunt the fine edge of judgment and obscure the true balance of intangibles.”*

Other useful admonitions by Wylie

- *“... plan for a complete spectrum of strategies in order to have a ‘reserve’ of strategies for the inevitable changes that will occur.”*

- *“... the player who plans for only one strategy runs a great risk simply because his opponent soon detects the single strategy—and counters it ... “*
 - *“... planning for certitude is the greatest of all military mistakes ...”*
 - Reserve of strategies = conceptual hedging for uncertainty (with its inherent risk)
-

7.4. Managing risk

Risk assessment

- Constant effort to identify and correct imbalances among key variables
- Risk variables are in constant flux
- Recognizing when variables change is an important strategic ability
- Other variables must be adjusted to account for changes (the “delta”)

Risk management options for the strategist

1. Modify ends
 2. Modify means
 3. Modify ways
 4. Reassess risk
-

(1) Modifying **ends**

- When
 - The price of achieving a particular objective is too high
 - The ability to affect the center of gravity is limited
- What
 - Reduce the overall objective to more realistic terms
- Historical examples
 - Forego a cross-channel attack in 1942 in favor of North Africa
 - Accept a lesser objective than the unification of the Korean peninsula after the Chinese invasion
 - Attempt to ensure that Afghanistan does not become a sanctuary for terrorists
 - Rather than establishing a viable and self-sustaining democracy

(2) Modifying **means**

- Reallocate or increase resources
 - Resources include unpredictable and changeable elements
 - Such as public support of a particular policy or strategy
- Examples
 - Failing to adequately modify means by calling up reservists and generating sufficient public support in Vietnam
 - Early failure to recognize the nature of the insurgency in Iran resulting in insufficient counterinsurgency forces
- *“Failure to provide adequate resources ... risks a longer conflict, greater casualties, higher overall costs, and ultimately, a critical loss of political support. Any of these risks, in turn, are likely to result in mission failure.”*

(3) Modifying **ways**

- Multiple ways to achieve the desired end state
- Using political, military, economic, information national power in different combinations
- Kosovo example
 - Initially Milosevic endured extended bombing but showed no intention of withdrawing
 - Then came a combination of both threats and actions
 - Deployment of Task Force Hawk
 - Planning for possible ground options by the Allied Command Europe Rapid Reaction Corps (ARRC)
 - Expanded targeting
 - In the end, Milosevic decided to withdraw forces
- Afghanistan example
 - Target Al Qaeda in its sanctuaries
 - Conduct a classic counterinsurgency campaign

(4) Reassessing the risk

- Over time
 - Additional information becomes available

- Gaps of knowledge are filled
 - Some assumptions may prove to be invalid
 - The 100% solution will always be elusive due to “*ephemeral factors*”
 - The process is dynamic
 - Both material and psychological data must be synthesized
 - One man’s risk is another man’s certitude
-

7.4.1. Strategic patterns

Five patterns

1. Ends moderate, means large
 - Strategy of direct threat
 - Example: nuclear deterrence
 2. Ends moderate, means limited
 - Pattern of indirect pressure
 - Useful when freedom of action is limited
 - Emphasizes political, diplomatic, economic elements of power
 - Deemphasizes direct military action
 - Example: US and Soviet Union avoiding direct confrontation
 3. Ends important, ways limited, means limited
 - Low freedom of action
 - Combination of direct threat and indirect pressure
 - Appropriate to nations strong defensively but with limited resources
 4. Ends important, ways unlimited, means inadequate
 - High freedom of action
 - Strategy of protracted war but at a low level of military intensity
 - Example: Mao Tse-Tung’s theory of protracted struggle
 5. Ends important, means unlimited
 - Violent conflict aiming at military victory
 - Example: Napoleonic era
 - Principle theorist: Clausewith
-

Example of how to balance the strategic equation by Collins

1. Eliminate waste = modifying ways and/or means
 2. Compress objectives = modifying ends
 3. Adjust strategy = modifying ways
 4. Augment assets = modifying means
 5. Reduce ends and increase means = modifying ends and means
 6. Bluff = adversary misinterprets your ends, ways, means
 - Game theory
 7. Give up on the objective = the ultimate modification of ends
-

7.4.2. Risk and readiness

McNamara's era

- Introduction of systems analysis to defense planning

What systems analysis brings to strategy

- Help to guess well

Strategic risk is closely related to readiness

8. Psychology of risk

Cognitive bias (Fullerton, 2018)

- Recency/primacy effect
 - People tend to remember best the information they hear first (and last)
- Zero risk bias
 - People tend to favor reducing a small risk to zero over a greater reduction in a larger risk
- Confirmation bias
 - Tendency to listen/give weight to only that information which supports our existing position/beliefs
- Ostrich effect
 - Tendency to avoid or ignore negative information
- Availability heuristic
 - Tendency to overestimate the importance of the information that is available to us

Dread factors

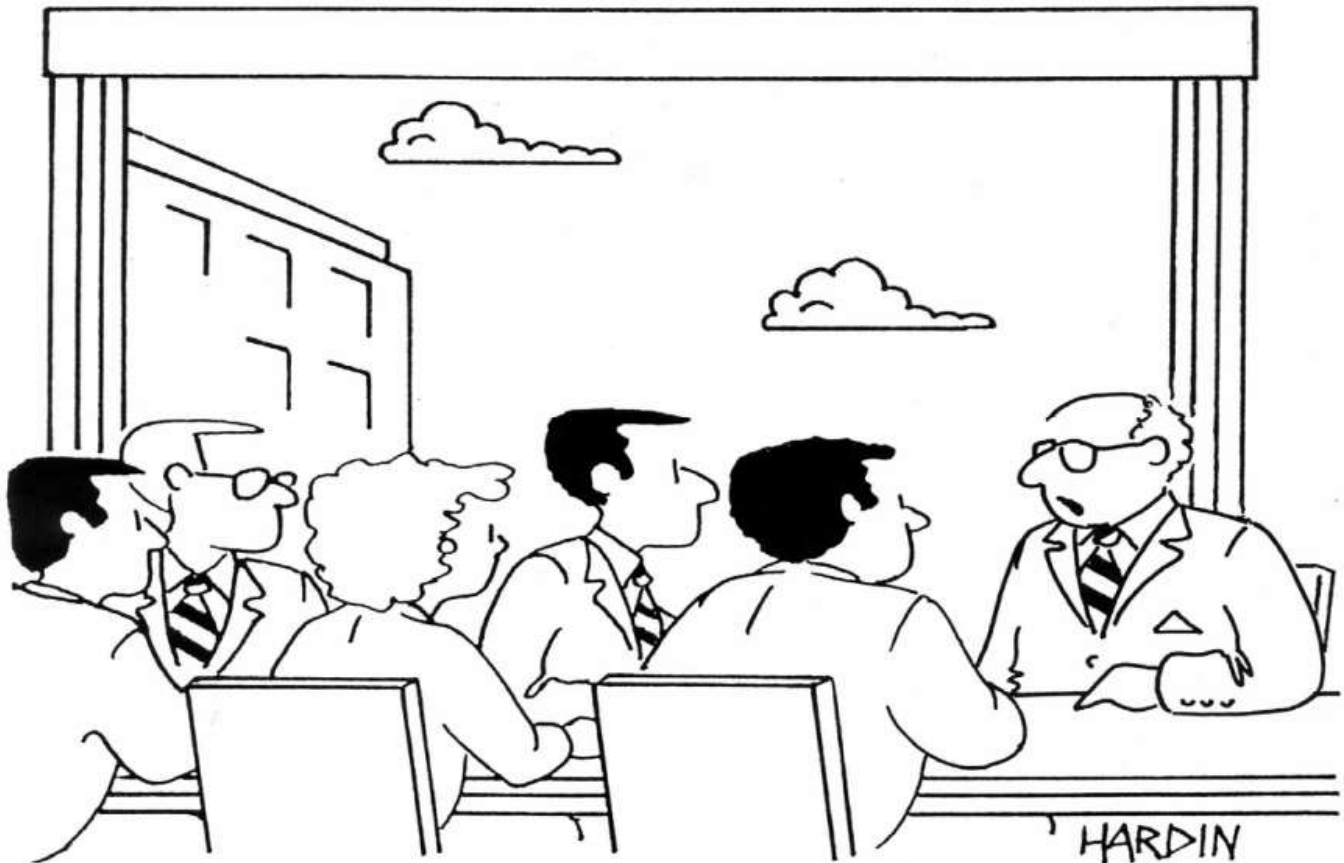
1. Scale
2. Immediacy
3. Imaginability
4. Personal control
5. Lack of choice
6. Unfairness
7. Children involved
8. Lack of familiarity
9. Untrustworthy origin
10. Media coverage

*“People who don’t take risks make about two BIG mistakes a year.
People who do take risks make about two BIG mistakes a year.”*

Peter Drucker



<https://strategiesforinfluence.com/peter-drucker-coaching-tips/>



"We've considered every potential risk except the risks of avoiding all risks."

(Fullerton, 2018)

9. Closing remarks on risk

Assessing and managing strategic risk is an inherently inexact process

- Combine material and moral inputs
 - Defying empirical resolution
- Weigh these inputs
 - Identify possible outcomes
 - Plan for uncertainty

True mark of strategic genius

- Account for potential changes
 - Recognize actual change in a timely manner
- Adjust strategic variables

Colin Gray

- *“In historical practice, uncertainty, chance and risk assuredly attend war and warfare, but they are simply conditions under which strategically educated leaders must labor.”*

The essential elements of strategic risk are unchanged through the ages

- Proper balancing of ends, ways, and means to achieve the desired strategic outcome

Risk = “*guessing well*” through

- Study
- Exercise
- Experience

Recommended reading (for all three parts)

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