Is the sky falling?
Or is everything going swimmingly well?
Probably neither!

Observations and recommendations about uncertainties from a risk analyst's perspective

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Is the sky falling?

- Seldom for mankind -although the great plague of the Middle Ages almost did it; a large meteorite could do it; the shrinking sun will do it … in a few billion years
- Always for individuals … sooner or later
- Meanwhile, what do we do and when about possible or real threats, given that we have imperfect knowledge, and limited resources?
- The "precautionary principle" may not be prudent!

Bad news, individual decisions and public policies

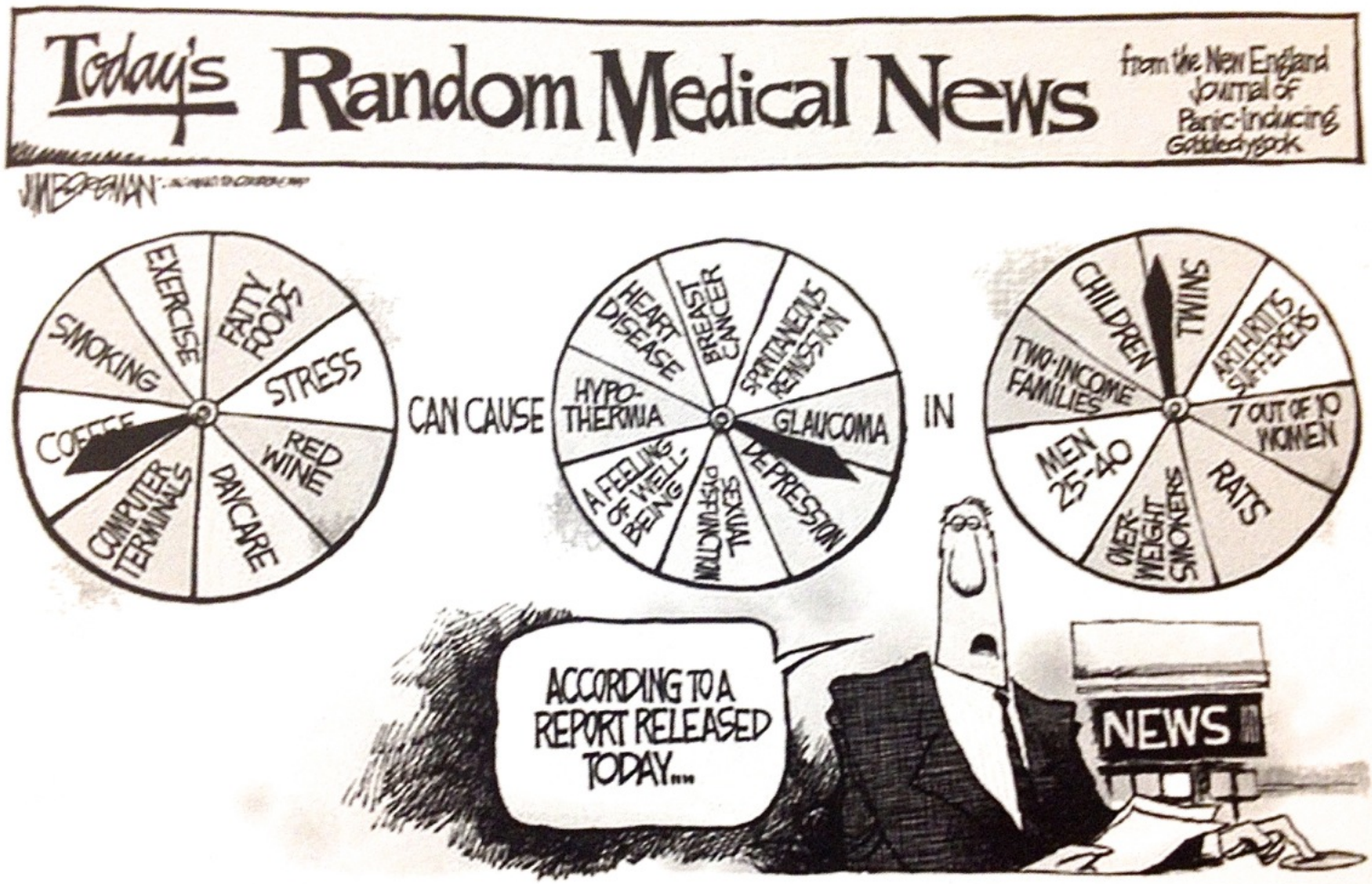
- Negative news/views sell and attract attention
- Temptation to emphasize the catastrophic aspects of risks, sometimes with over-reaction or wrong focus
  - Ebola is a nasty threat but hysteria is probably not the response (understanding transmission paths is)
  - Nuclear power plants present unquestionable risks but they have to be compared with those of alternative energy sources (German experience?)
- Some motivations for bad news without qualification: scare individuals? stimulate (criticize) policy makers?

Was the sky falling?

- Edison (19th century): The "War of Currents". Predictions that AC was going to kill animals in the fields (and much more).
- Electro-magnetic fields. After lengthy debates, in 1996, the WHO finally concluded that "evidence does not confirm the existence of any health consequences from exposure to low levels of electromagnetic fields"
- President Carter (1977): Unless we make drastic cuts in oil consumption, "within 10 years we would not be able to import enough oil, from any country, at any acceptable price."
- Population bomb: Paul Ehrlich in 1968 predicted mass starvation and major societal upheavals
- In most cases, no consideration of alternative hypotheses

And from the New England Journal of Panic-Inducing Gobbledygook

Source: Jim Borgman in Kim Thompson's *Risk in Perspective*



But no news can be bad news! Ex: costs of warning delays

- The risks of cigarette smoking took a long time to be exposed… but not the uncertainties about it
- The brewing of extremist Islamist movements (now ISIS) was known for a long time
- Some defects in airplanes (A320 software) and cars were discovered way before they were addressed
- Near misses (e.g. on BP offshore platform) are sometimes ignored. The reasoning: we did nothing because nothing had "exploded"

A "PROVOCATIVE" THOUGHT?

"Provocative", definite, unqualified statements are generally wrong…

The worst (or the best) is not always certain!

A logical, rational approach is needed to provide a balance…

and it does not have to be "thinking slow"!

Risk analysis as an alternative to the "stuff-happens" philosophy

- To try to provide the best, even if incomplete, information available to describe uncertainties, set priorities, and support decisions under constraints. *Uncertainty is not a reason for inaction!*

- But the best decisions under uncertainty do not "avoid risk, avoid harm" [as stated recently about climate change!] in medicine, diplomacy, politics, etc. They are courses of action that represent the best balance given our options (resources), our knowledge, our preferences and our rate of discount

Qualify or quantify the risk?

- Words ("possible", "likely") are interpreted differently by different people. Ex.: the "very likely" scenario that ended up with a 65% chance of happening…
- "Heat matrices" do not include correlations and dependencies (Two "Low" risks resulting in a "High")
- "Alternative hypotheses" provide no comparison base without a probability.
- *If presented adequately*, quantification does not imply a "hard number" or a "false sense of certainty". Intervals seen as more credible than single figures.

The power of words…

Source: SKCD.com

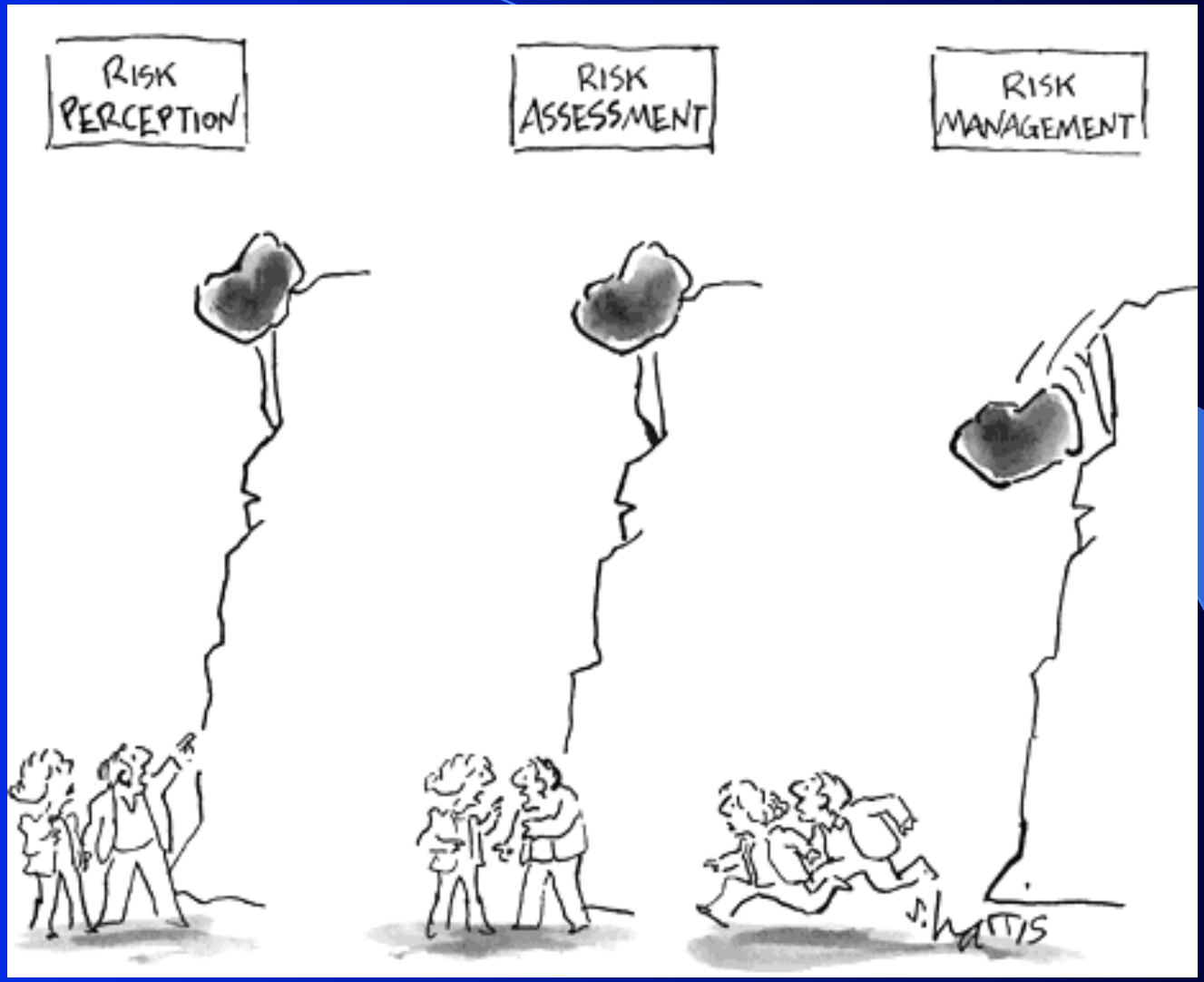
More seriously: a "Heat map" from the FAA on airplane safety

Severity / Likelihood	No safety effect	Minor	Major	Hazardous	Catastrophic
Frequent	Minor loss of separation				
Probable	AND ??				
Remote		Minor Reduction of op. capability	Serious injury to passengers		
Extremely remote					Mid-air collision
Extremely improbable					

Quantification is not always necessary!
From common sense to complex analysis

- Six levels of uncertainty description (MEP, 1996)
  - None needed (fencing a small pond to protect little kids)
  - Worst case or maximum loss (bets in a state lottery)
  - Quasi-worst case ("plausible upper bound"): floods/dams
  - "Best estimate": most likely hypotheses and parameter values; the result is often 0. Most likely: nothing happens
  - *Probability & distribution of losses (risk curve CCDF)* ←
  - Uncertainty about probabilities: families of risk curves Much more complex. Helton: nuclear plant components
- Choose the level that is best fitted to the case

That's one way…

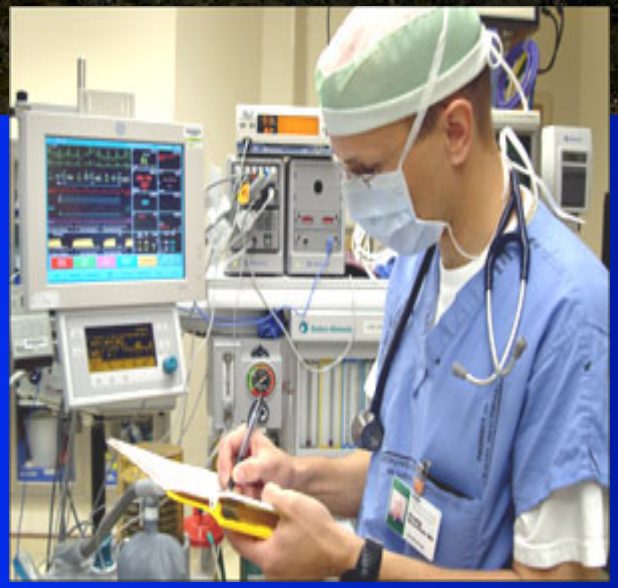


Source: Harris in Kim Thompson's *Risk in Perspective*

'[Be careful! All you can tell me is be careful?"]
One can do better…

Source: Sidney Harris in Kim Thompson's *Risk in Perspective*

What I studied: from space to earth to sea



What follows: a few observations and recommendations to analysts -when the sky may or may not be falling

- A vast spectrum of "analysts" (medical doctors to intelligence analysts, systems engineers and operators, political advisors, etc.)
- Objective: support decisions
  - Whether a risk requires immediate attention compared to other hazards
  - Set priorities among options within limited resources

1. Recognize and communicate uncertainties in spite of…

- Instinct to jump to conclusions
- Pressures to "make the call" and pretend certainty (to look confident? reassure? motivate?)
- Fear that revealing uncertainties is going to make people doubt "the truth" (climate change?)
- But: there uncertainties are unavoidable when making decisions in new or poorly known situations

2. Don't present the most likely hypothesis as if you were sure of it!

- It is tempting to present news/information (good or bad) as certain (the start of the 2003 Iraq war)
- The danger of wanting to communicate a message for which one will be liked, and to rely on "group think" for support
- Medical saying: when one hears "sounds of hoofs", it is more likely to be a horse than a zebra. But consider high-consequences zebras!

Ex: Communicating uncertainties or not L'Aquila vs Napa earthquakes

L'Aquila, Italy, April 6 '09: the sky *was* falling

- A 6.3 magnitude earthquake killed 306 people.
- Pre-shocks for the previous 3 months. Officials declared them "normal" and told people to stay home in spite of similar sequences of tremors (in 1349, 1461 and 1703)
- No notion of risk and uncertainty in communications to the public => scientists and officials sentenced to jail (they are appealing)

Napa Valley, August 24, 2014.

- Magnitude 6 earthquake. Experts (e.g., USGS) left the choice to the public; warned that the probability of a large one in the area could either
  - Increase if this was a pre-shock ["5 to 10 % chance of something bigger than a magnitude 6 earthquake in the next week"]
  - Decrease if there was actually a release of stress in the fault from EQ and 80 small aftershocks (3-4 M).
  - The sky did not fall (yet!); but they told the truth: they did not know one way or the other and they said so.

3. Simplify the risk messages
Don't get into unnecessary details

- Avoid large numbers of complex scenarios
- Future events: adding more details makes a scenario look more likely (having a flu AND someone else in your family having one is less likely than simply your having a flu)
- Past events: Adding more details in description seems to make it impossible to have "predicted it" or assessed the risk ("the black swan" illusion)

Ex: Browns Ferry NPP fire in 1975
(retrospective)

- March 22, 1975: a fire started when a worker, using a candle to search for air leaks accidentally set a temporary cable seal on fire.
- Such a specific scenario would not be included in a risk assessment as a separate initiating event
- But fire risks and uncertainties in NPP's (oil refineries or Coast Guard cutters) are indeed computed, by aggregating probabilities of starting mechanisms, sites, propagation, and effectiveness of intervention

Ex: The "one in a million" story of the paraglider (also retrospective) How to create a "black swan?"

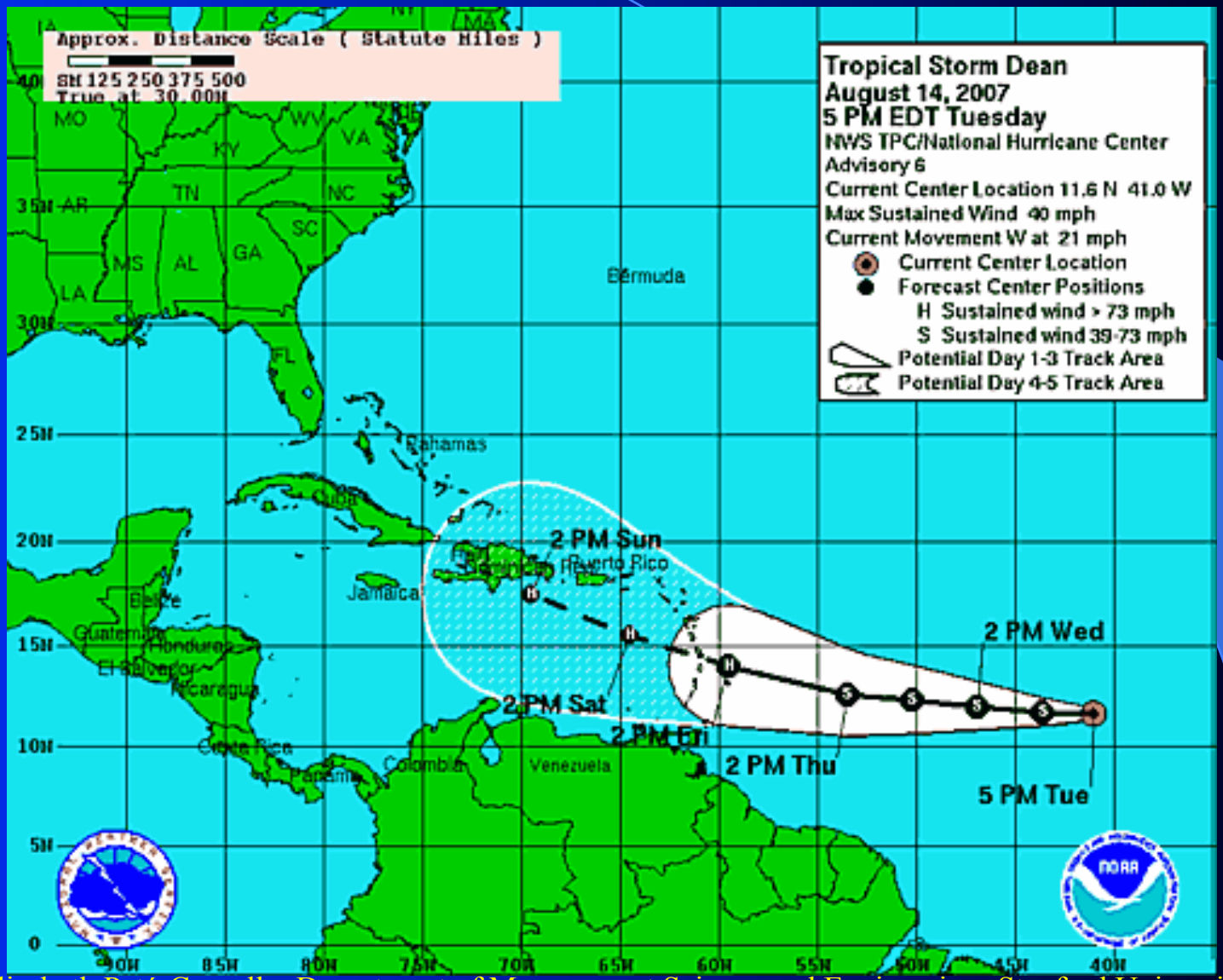
- A paraglider got entangled in his line (got out of it)
- Based on an extremely detailed story of the scenario, claimed that the risk could not be assessed ("would be one in a trillion!") make it specific enough and it is 0!

  [Zero probability of a single point in a continuum]
- In reality the risk of a rope accident seems to be about 4/10,000 when uncertainties are aggregated (sufficient for risk management)

4. Don't "predict" when you are not certain of what is ahead

- "Predictions" have an aura of certainty
- "I predict" often means "I bet". "I had predicted" often means "I won my bet". Uncertainties?
- Dangers of prediction without notion of uncertainty (hurricanes) inducing possibly dangerous actions
- Problem of linear or exponential extrapolations, ignoring uncertainties in changes of trends (ex: population growth)

Hurricane cones rather than predictions: Ex: Tropical storm Dean in 2007



5. Evidence means much more than statistics!

- Why we use Bayesian probability (priors & updating)
  - When statistics are insufficient
  - When they have limited relevance because things have changed (Ex: financial correlations)
  - When we know more than statistics represent (Ex: risks to a specific patient)
- Decomposition of the problem,

  Logical aggregation and updating of information. Probability of a scenario {A and B and C}: p(A) x p(B given A) x … etc.
- Sources of information in engineering risk analysis
  - *In situ* statistics, test data (not always as will work *in situ*),
  - Surrogate data, physical/engineering models, expert opinions

A joke about evidence-based medicine based on statistics

when there is no uncertainty about a basic mechanism

- Ref: Smith and Pell, 2003 Profs at Cambridge.

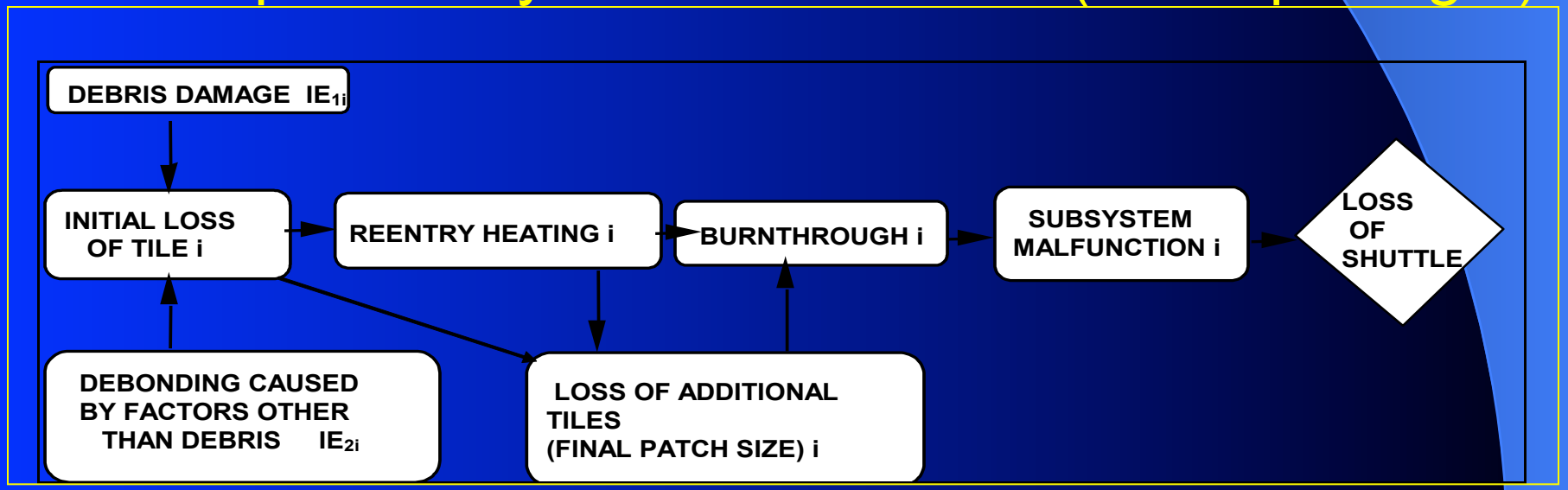
  "Parachute use to prevent death and major trauma related to gravitational challenge"

- Their point: No randomized study has yet shown the usefulness of parachutes in jumping from planes. Should we ignore what we know about the effects of a free fall on the human body?

- Proposal for a (joke) double-blind study that they called "a call to broken arms…"

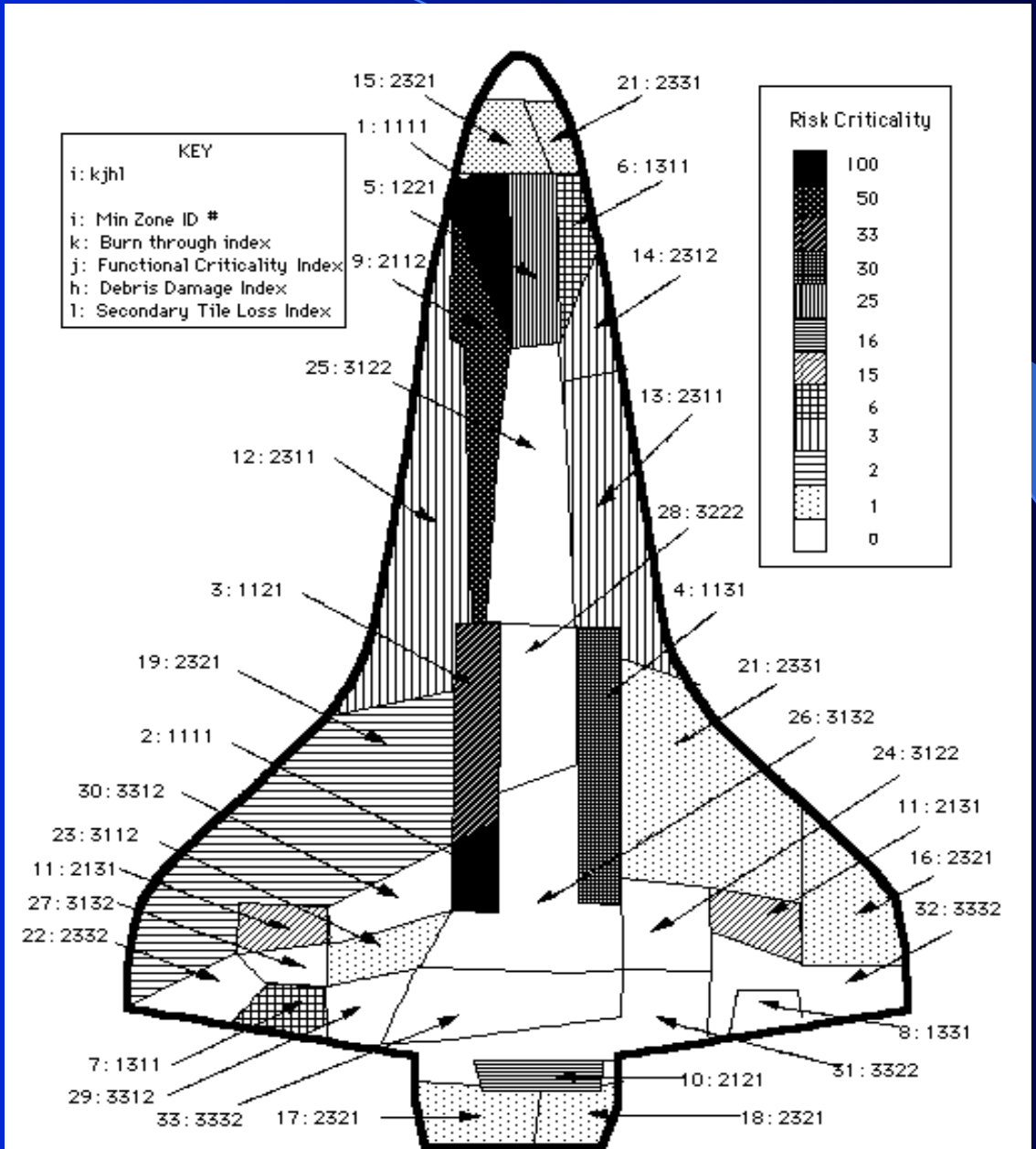
No joke! The tiles of the space shuttle

- 1986: 33 flights. 2 tiles had debonded in flight => Low (and variable) estimate by Boeing of the contribution of the tiles to mission failure based on that sample
- Instead, we used systems analysis and Bayesian probability (1990). More stable result p(F):10^{-3} =10% of overall probability of mission failure (1/100 per flight)



The result: a risk map of orbiter and the tiles

Source: Paté-Cornell and Fischbeck, 1990



6. We often need expert opinion and we are well aware of limitations!

- Decomposing the problem into parts and areas of expertise (trust your doctors and ask questions!)
- Making sure that each expert understands the whole problem (issue of over-specialization)
- "Notional" assessments have little value. Ex.: space project. Engineers thought global chances of a space success = "90%". PRA showed much less (needed: launch, guidance and navigation, and oper. success)
- Known biases (Kahneman and Tversky)

Managing groups of experts

- Risk of artificial consensus (group think)

  Tendency to focus on most likely/popular hypothesis

- But also: disagreements that need resolution
  - Understand why they disagree (experience base, different hypotheses, egos, wish to influence policies, media influence, etc.)
  - Aggregation: means of probabilities? Delphi method?
  - Better still: get them together to exchange hypotheses, probabilities and reasoning

Ex: The anesthesia patient study

- Objective: find ways to increase patient safety.
- We had a statistical "reality checks" at both ends of the model (initiating events, and overall accident rate)
- Experts to provide other data (best source: nurses)
  - Initiating events: starting and unfolding of accidents
  - Assessment of reaction times given different situations (anesthetist competence and alertness)
  - Result: reduction of error rate and reaction time with a number of possible management measures
  - An effective one: better supervision of residents

7. Don't forget prior information

- Danger of roaring headlines and of letting the message of a new event overwhelm "base rates" and what was known before (engineers vs artists among students, ignoring the base rates)
- Classic example of medical test: rare disease ($p=10^{-3}$) test: 5% chance of false positive; 2% of false negative Positive result=> p(D)~2%. If Priors = 1/100, post.=20%
- Interpretation of signal of attack:
  - Prior probability (high tensions? apparent calm? Possibility of surprise attack?)
  - Reliability of sensors or sources and their dependencies

Ex: Strong reaction to the Chelyabinsk asteroid

- 15 February 2013; 20m size; blew up above Northern Russia. Attracted enormous attention (funding?)
- Question: what is the risk? We found p(at least 1 person killed in 100 years)~ 3×10^{-4}
- Next: what to do (and at what cost) to deflect bolides: gravity traction, kinetic impact, nuclear device?
- High costs, low probability in inhabited area, high uncertainties; but it may deserve some attention given possible magnitude in spite of long lead times…

All I am saying is now is the time to develop a technology to deflect asteroids

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8. More information does not mean less uncertainty

- One hypothesis may be attributed a low probability, and everyone may agree
- Surprise: another possibility shows to be quite possible as well (probabilities?) with increased uncertainty; but information (even with more uncertainty) may be critical to better decision
- Corollary: feeding more data in a computer model may not decrease uncertainty! (depending on the quality of the model and the data)

Examples

- Uncertainties in global climate change models:
  - Ex: the role of the oceans (more scientific research leading to more uncertainty). Ex: Science Oct. 2014 on the conveyor belts of the oceans
- Intelligence situations
  - The goal is not to reduce uncertainty *per se* but to present the best state of information at a given time. Ex: what weapons are out there or being developed
  - Yet, one wants to prevent the "fog of war" from going digital (a huge flow of info and more unstructured uncertainty may not help)

9. Don't truncate the evidence base to obscure uncertainties

- It is sometimes in the interest of the opposing parties (e.g., in a court of law) to focus on the evidence that supports their position (eliminating what is unclear)

- But it can be disastrous to ignore some of the evidence that does not fit immediate interests

Ex.: Fukushima-Daiichi
The tsunami design criterion

- There was evidence of large subduction plate earthquakes off the coast of Sanriku since 869 AD
- That evidence was ignored when choosing the tsunami design criterion (5.7 m based on a recent event caused by an earthquake in Chile) because the relevant, unquestionable data were “too old”. Ts>8m were “unlikely”

A partial history of subduction-plate earthquakes and tsunamis along the Sanriku and Sendai coasts.

Year	Magnitude	Interval in years
869	8.6	
1611	8.1	742
1793	8.2	182
1896	8.5	103
1933	8.1	37
1960	8.5	27

And it does not look stationary ("non-ergodic") [Epstein]

Result: P(Ts>8m in 30 yrs)~15% if stationary, 23% if not

10. Don't assume independence without checking it

- It is common to assume independence of events, therefore that the probability of a scenario is simply the product of the probabilities of its components (redundancies; intelligence sources)
- This can lead to serious underestimation of the chances of "perfect storms" (rare conjunctions)
- Or overestimations of risks, due to correlations of apocalyptic predictions (same media sources)

11. Effective warning systems are key to risk management

- Need enough lead time considering trade offs between false positives and false negatives
- Importance of precursors and near-misses (Macondo)
- Of monitoring the dynamics of attackers (drug gang)
- Need for organizational filters (several sets of eyes may be needed). But they may fail (IC, 2001). What matters: what was known at decision time, and how to improve the system
- Information content of "no signal" (Pearl Harbor)

12. "Black swans" and "perfect storms" as poor excuses for bad risk management

- "Black swans": could not be imagined before the fact
  But events that are predictable: financial bubbles, or traders mistakes: wrong incentives; lack of monitoring
- "Perfect storms": conjunctions of events so "unlikely" they can be ignored…except if events are dependent and not so rare… Ex: sequences of operator errors (Japanese train conductor under schedule pressures)
- Both are often excuses after the fact

In conclusion: value intuition but check its logic

- Uncertainties are uncomfortable. Fear is a powerful motivation
- Some situations deserve reflection and analysis to avoid both hysteria and negligence
- Communication of uncertainties is key to an unbiased exchange between an analyst and a decision maker
- Quantification helps with dependencies & complexities
- One can think fast and well! (consider alternatives!)