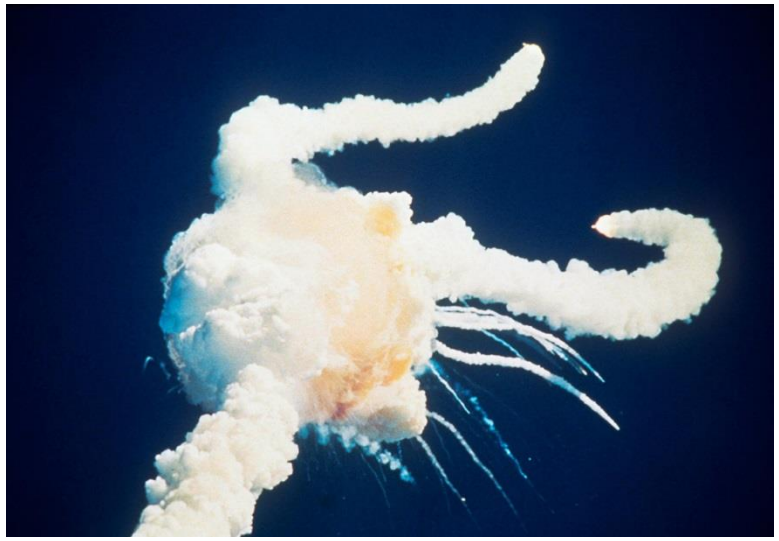
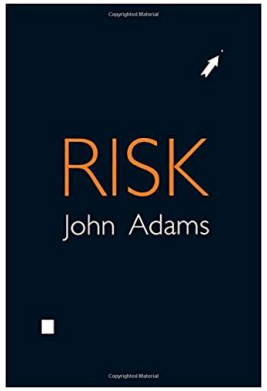
Risk Awareness:

A New Framework for Risk Management in Flight Test



Presented at the Society of Experimental Test Pilots 62nd Annual Symposium, Anaheim CA, 26-29 Sep 2018 · Col Douglas "Beaker" Wickert · Air Force Test & Evaluation, Headquarters USAF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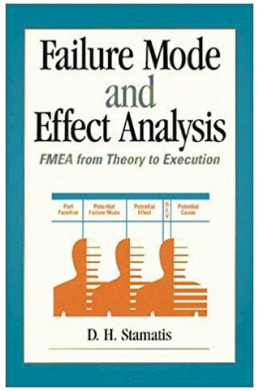
John Adams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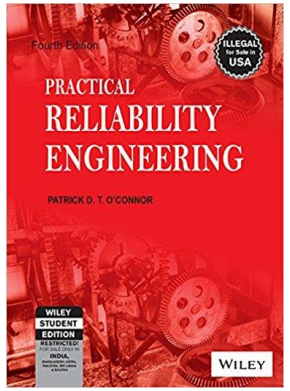
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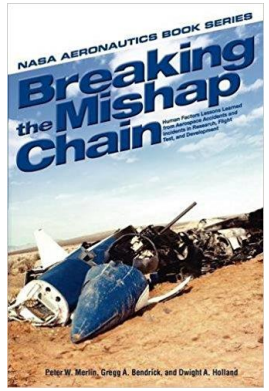
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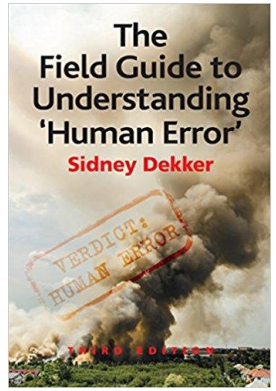
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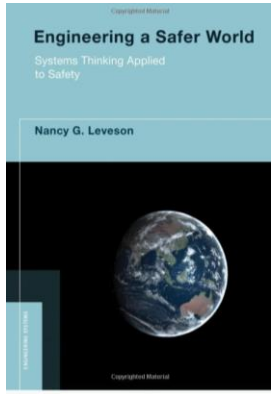
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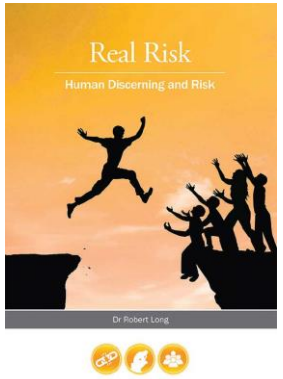
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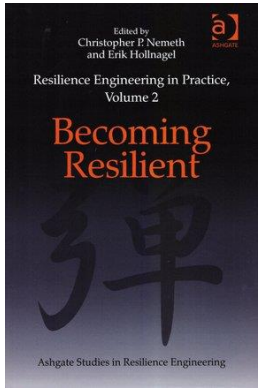
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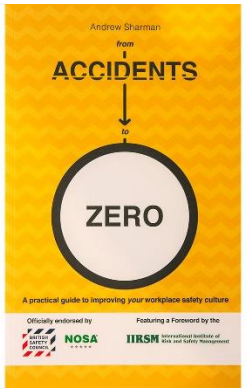
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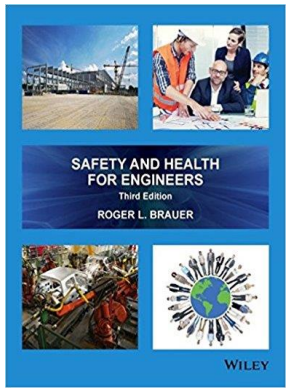
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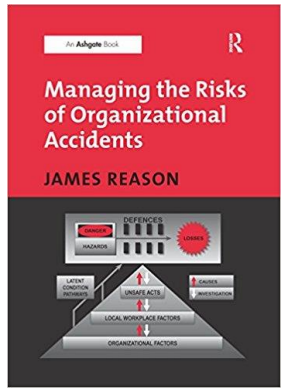
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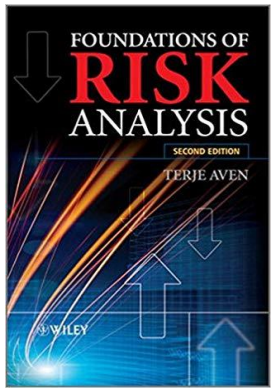
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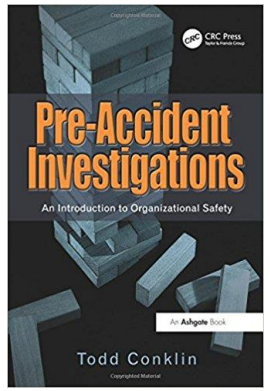
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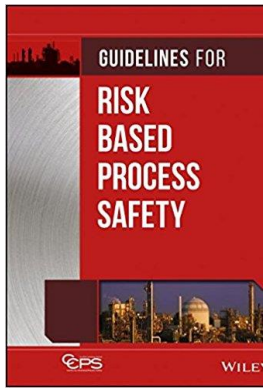
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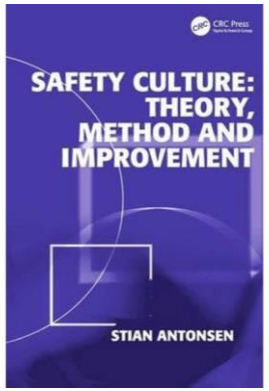
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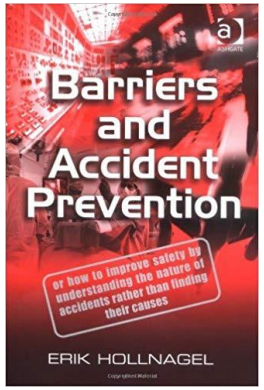
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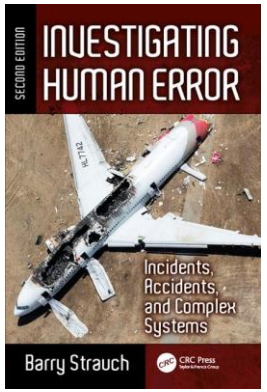
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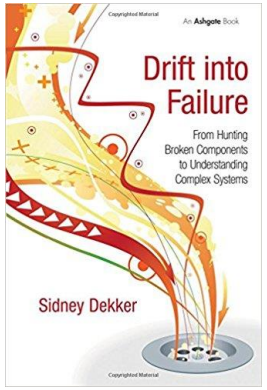
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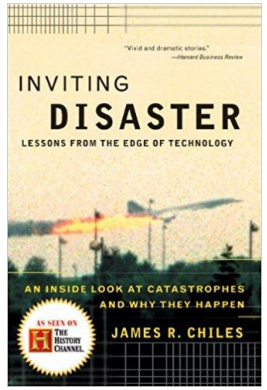
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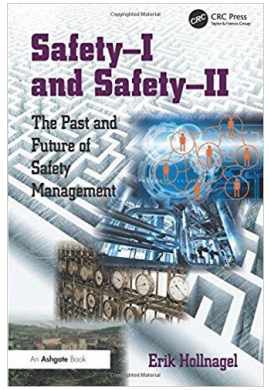
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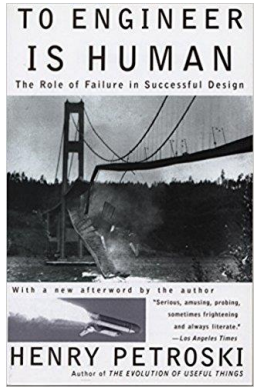
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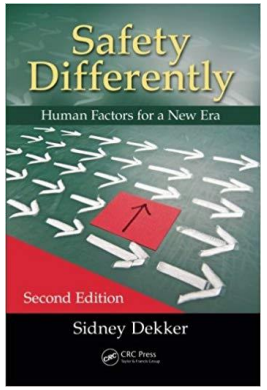
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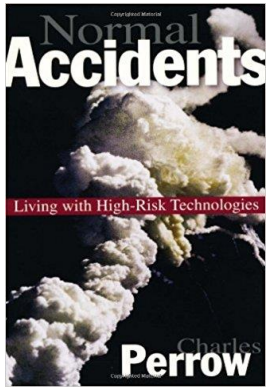
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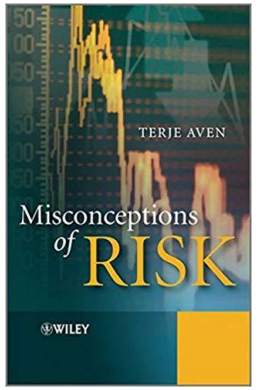
Charles Perrow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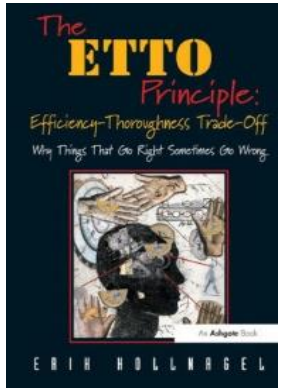
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Risk Awareness

The perception of the elements of uncertainty and the potential, projected outcomes resulting from uncertainty

Situational Awareness

The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future[1]

[1]Endsley, M. R., "Design and evaluation for situation awareness enhancement," *Proceedings of the Human Factors Society 32nd Annual Meeting*, Santa Monica, CA, 1988.

What Risk Awareness Is Not…

Spanish prostitutes ordered to wear reflective vests for their own safety

Prostitutes working on the street outside a town northern Spain have been ordered to wear reflective vests to make them visible to passing traffic and reduce the risk of accidents.

Prostitutes wearing high visibility vests in Els Alamus Photo: REX

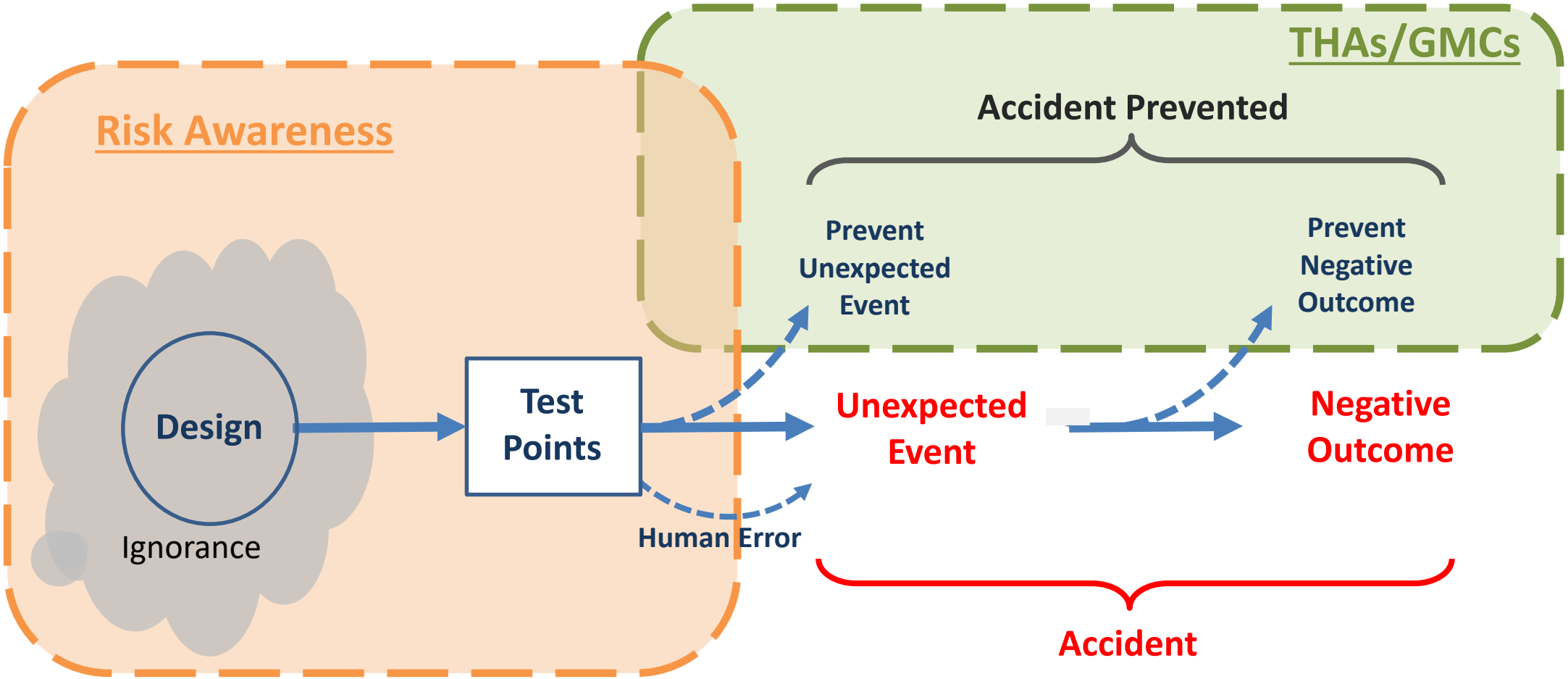
By Fiona Govan in Madrid
6:57PM BST 25 Oct 2010

Women touting for customers on a rural highway outside Els Alamus near Lleida in Catalonia have been told to don the yellow fluorescent bibs or pay fines of 40 euros (£36) under road traffic laws.

reasons: for not wearing the reflective jacket and for creating danger on the public highway."

The move follows recent legislation introduced by Els Alamus town hall to ban prostitutes from offering sex

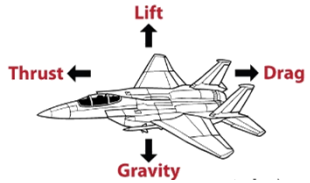
Accident & Risk Management



Accident: *a sudden, unexpected event that results in an unwanted, negative outcome*

Domains of Uncertainty

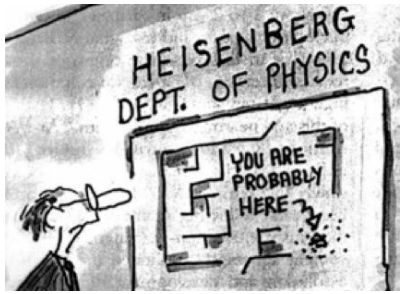
Deterministic



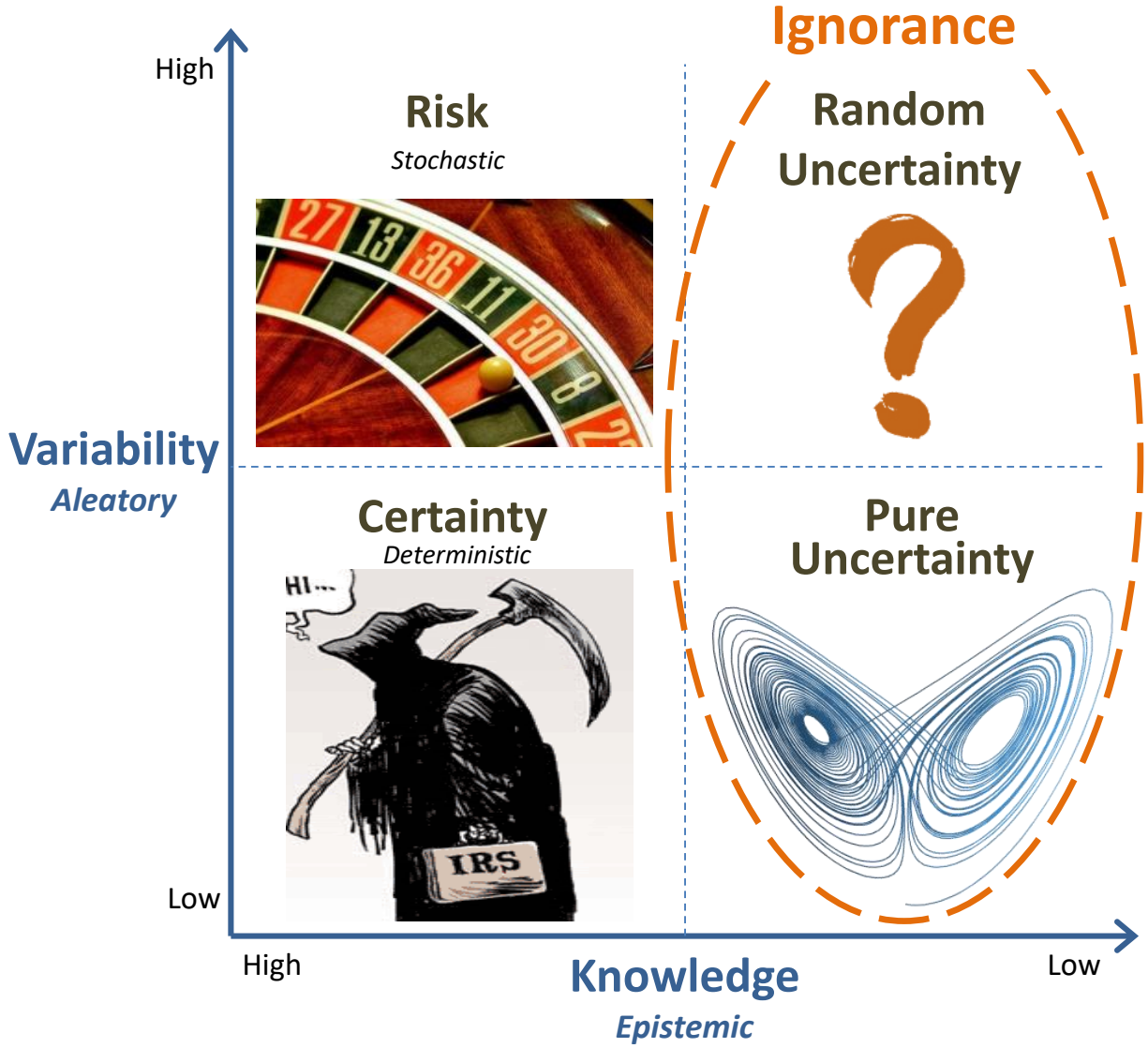
Stochastic

Ambiguous Scenarios

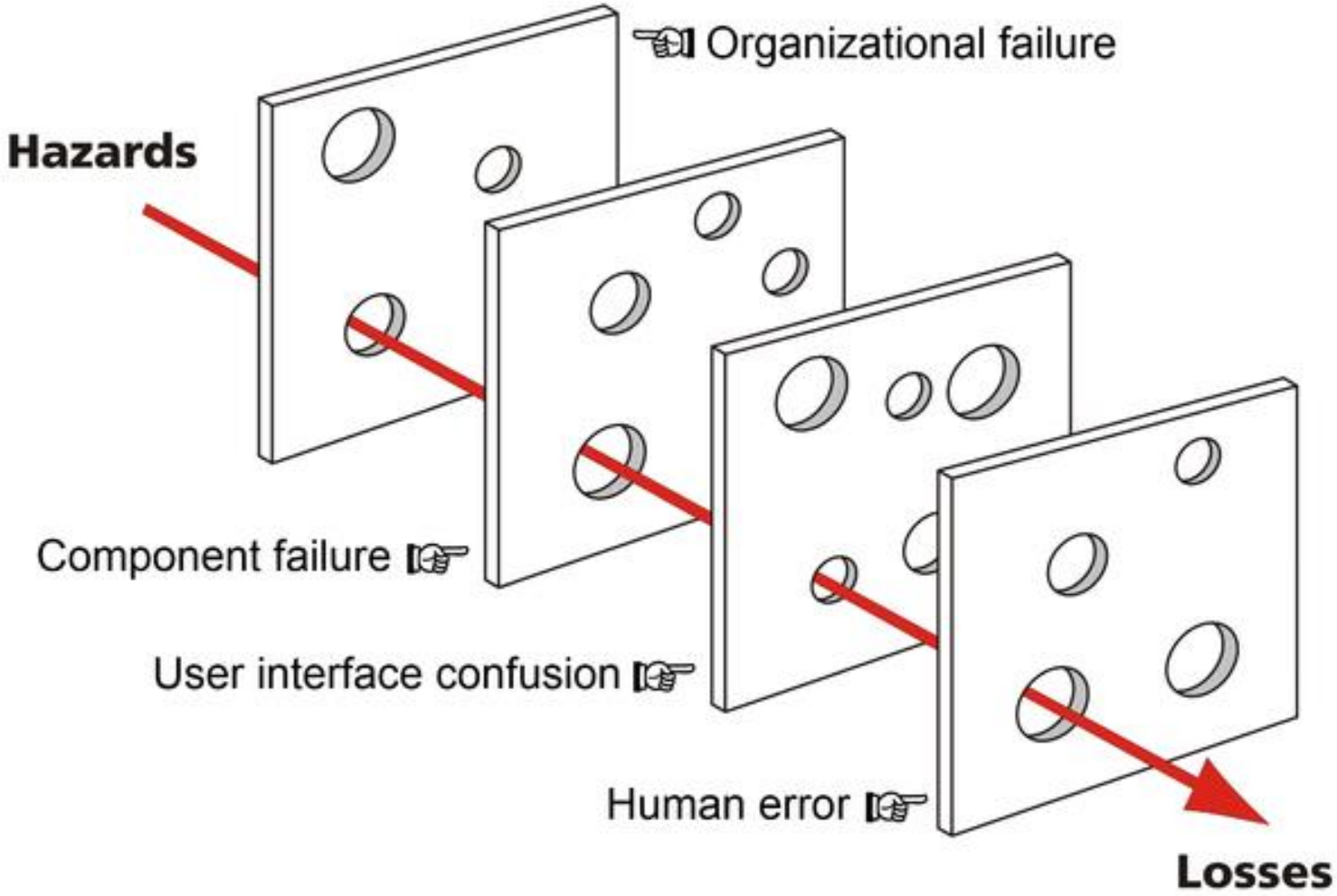
Known Unknowns



Unknown Unknowns



Swiss Cheese Model



James Reason, 1997

Accident Models

Domino Model

Heinrich (1931)

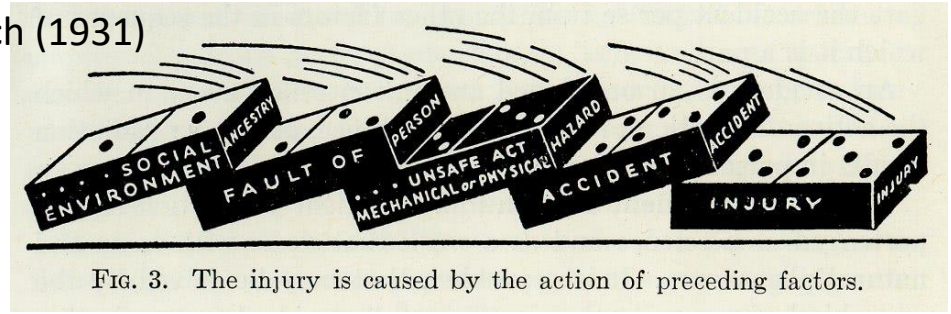
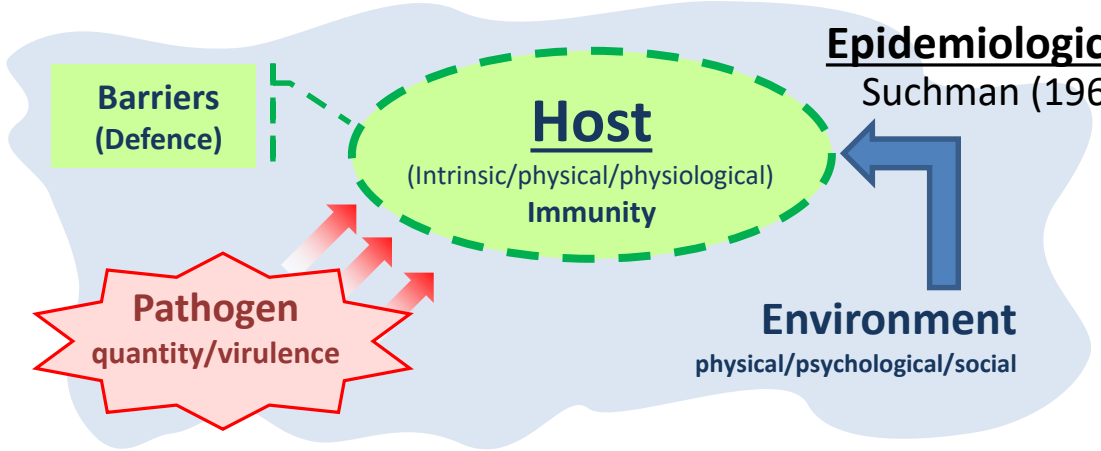


Fig. 3. The injury is caused by the action of preceding factors.

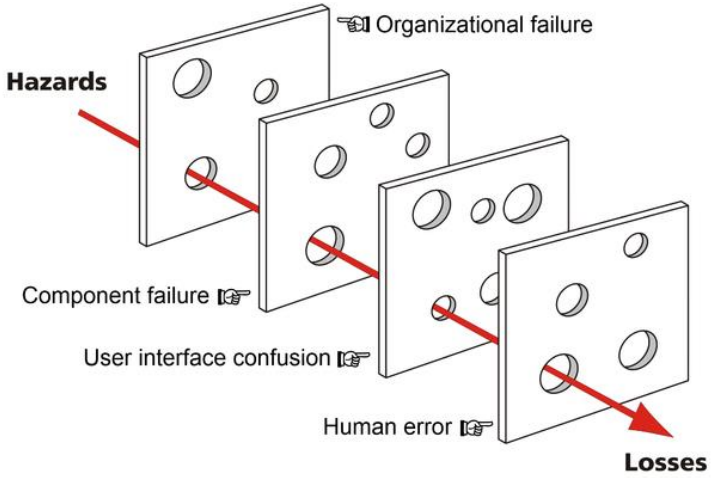
Epidemiological

Suchman (1961)

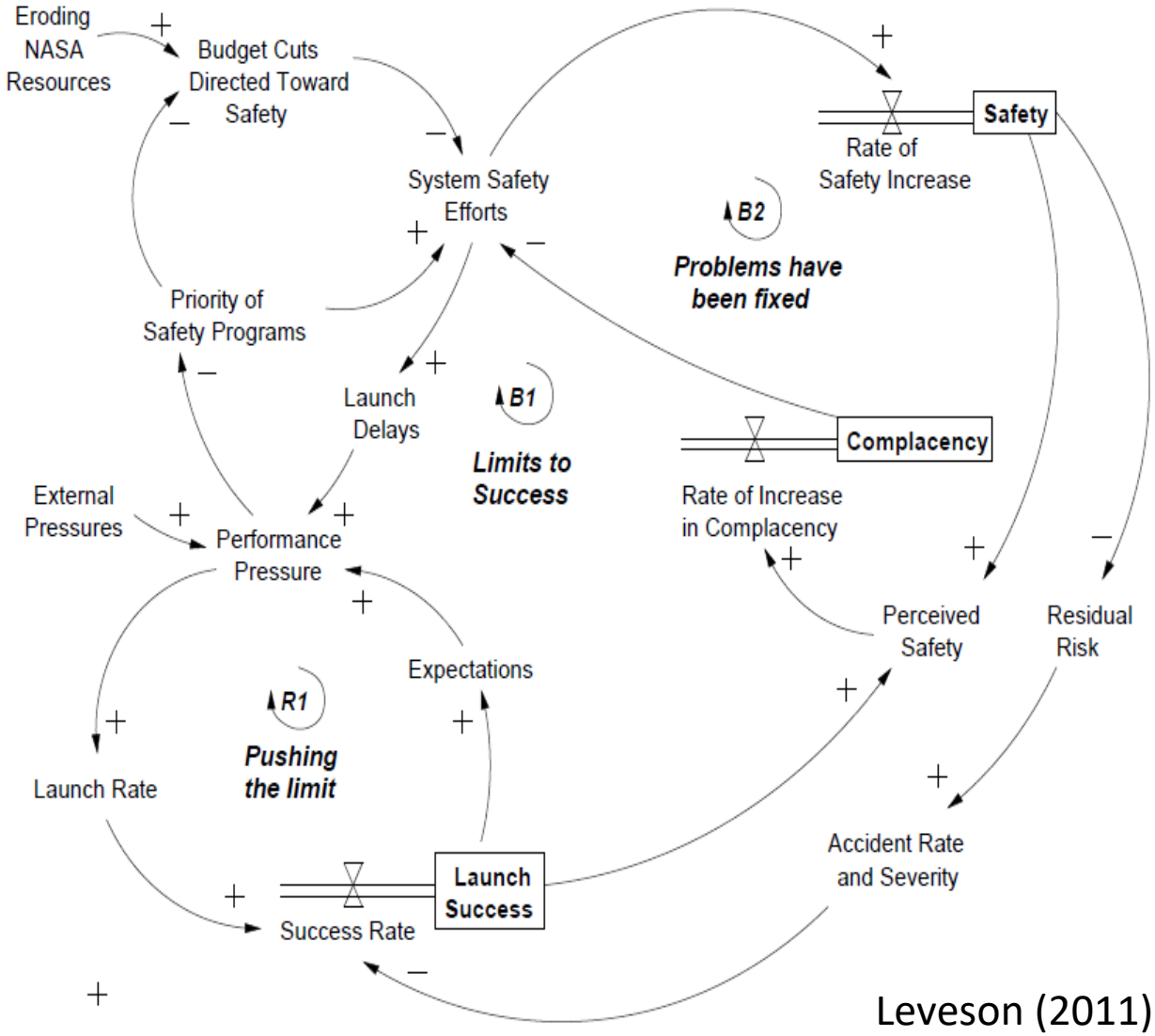


Swiss Cheese

Reason (1997)



Systemic Model

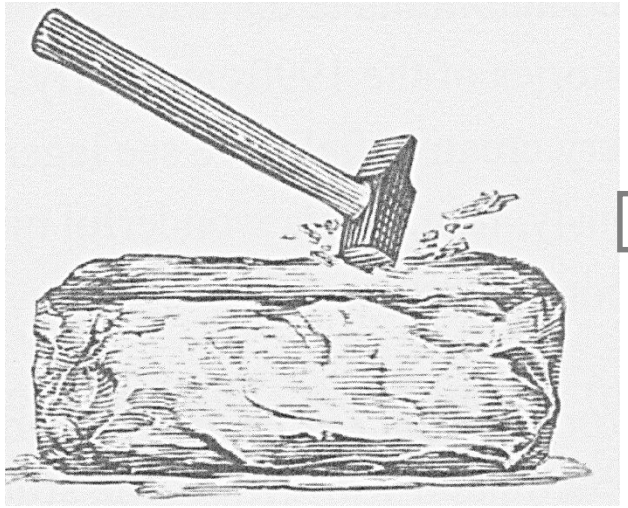


Leveson (2011)

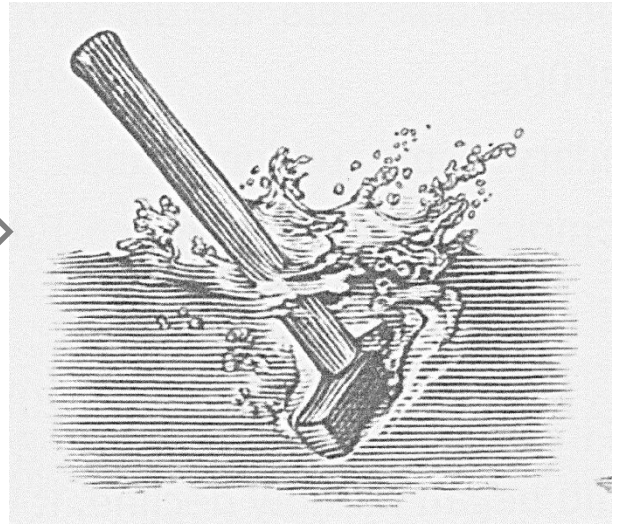
Complexity & Emergence

Phase Change

Intermolecular Forces Dominate



Increase Temperature



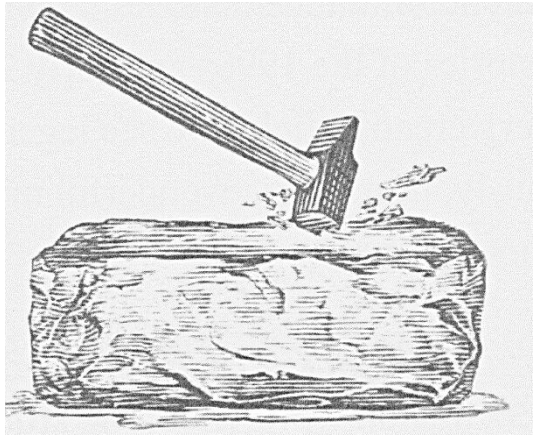
Entropy Dominates

Understanding Dominates

Decrease Knowledge

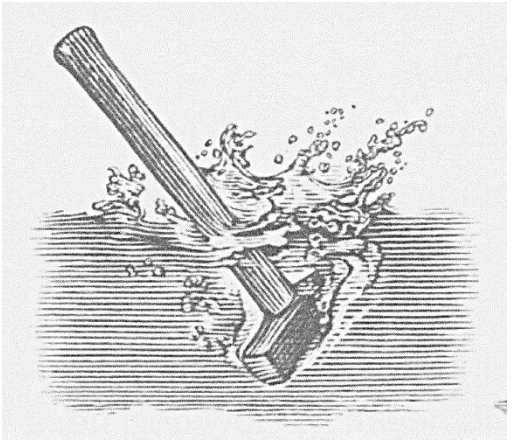
Uncertainty Dominates

Intermolecular Forces Dominate



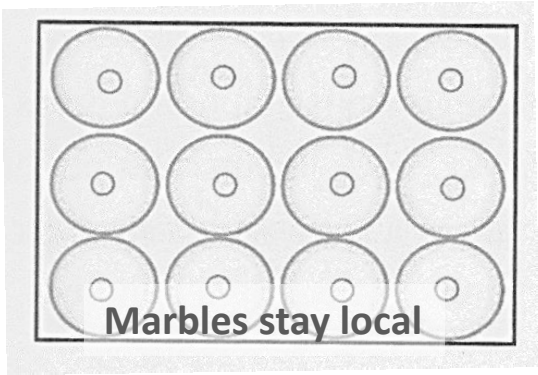
Phase Change

Increase Temperature

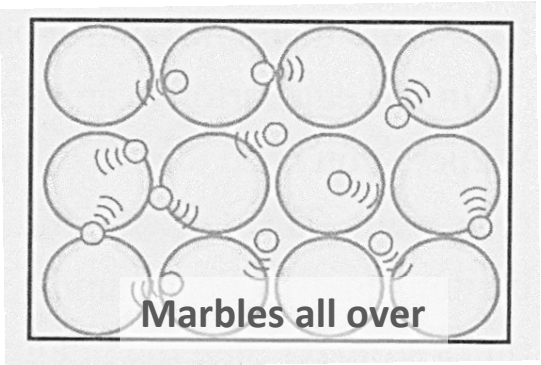


Entropy Dominates

Local Stability Dominates



Increase Shaking



KE dominates

Understanding Dominates

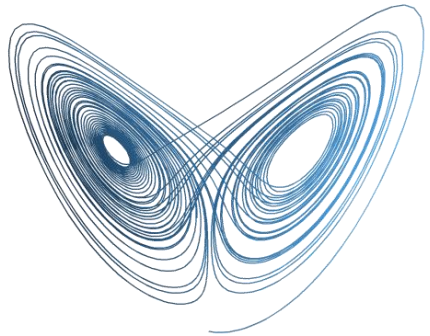
Decrease Knowledge

Uncertainty Dominates

Certainty

Risk

Uncertainty



Deterministic → **Stochastic** → **Ambiguous Scenarios** → **Recognized Ignorance** → **Ignorance**

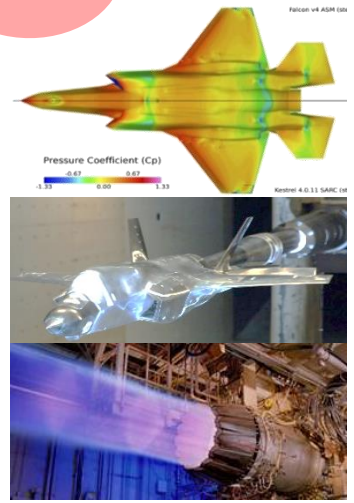
- Irreducible
- Reducible

Probability of Mishap Occurring During the Test	Mishap Severity Category			
	Catastrophic–I	Critical–II	Marginal–III	Minor–IV
Frequent (A)				
Probable (B)	HIGH			
Occasional (C)		MEDIUM		
Remote (D)			LOW	
Improbable (E)				NEGLIGIBLE

Safety Review Board

- What is unknown?
- What tests where not done?
- Where are the gaps in knowledge?
- What model surprises thus far?
- Confidence intervals of “knowns”?
- What does test inform?
- Is there sufficient schedule to learn?

Reduce Reducible Ignorance



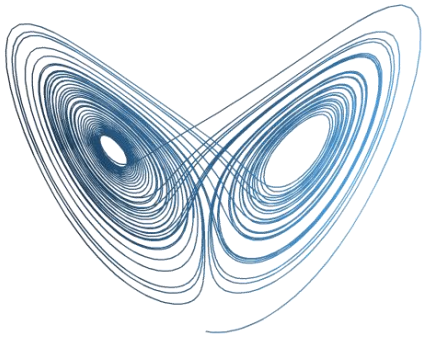
Zero-risk illusion

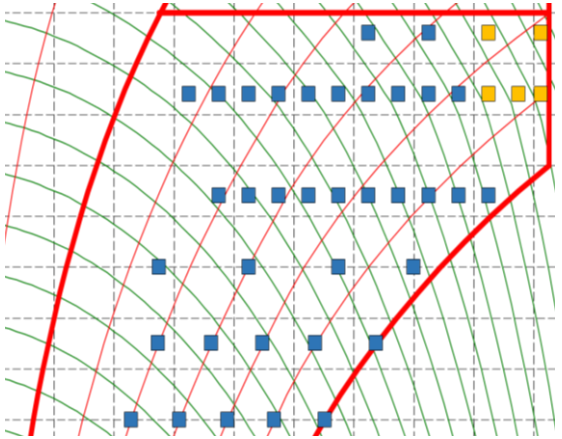
Turkey illusion

Certainty

Risk

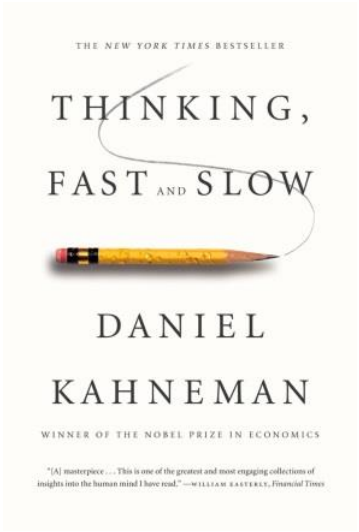
Uncertainty





Slow Thinking Preferred

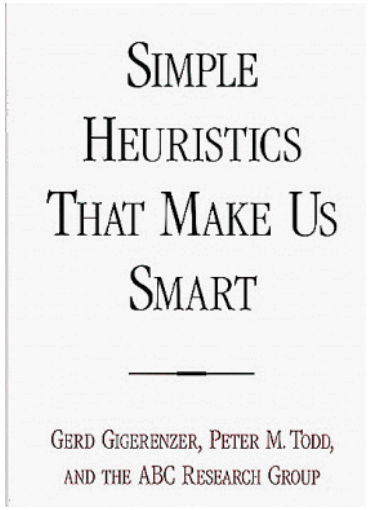
Heuristics Preferred



Cognitive biases:

- Anchoring
- Availability
- Confirmation
- Framing
- Escalation

- Intuition
- Simple
- Rules of thumb
- Reliably better decisions

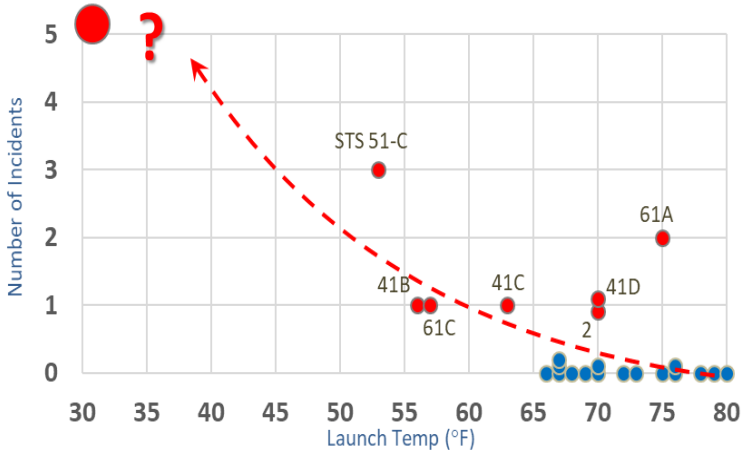


Heuristics for Flight Test

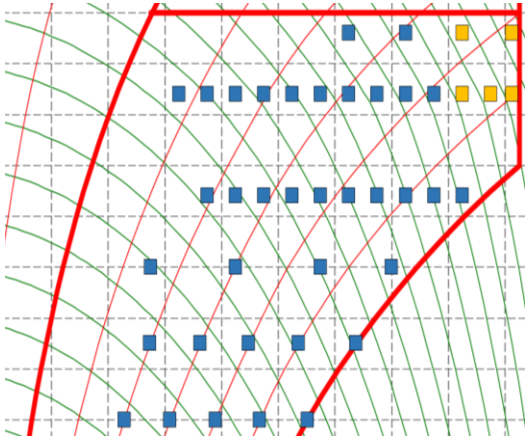
Keep it Simple

Slower is Faster

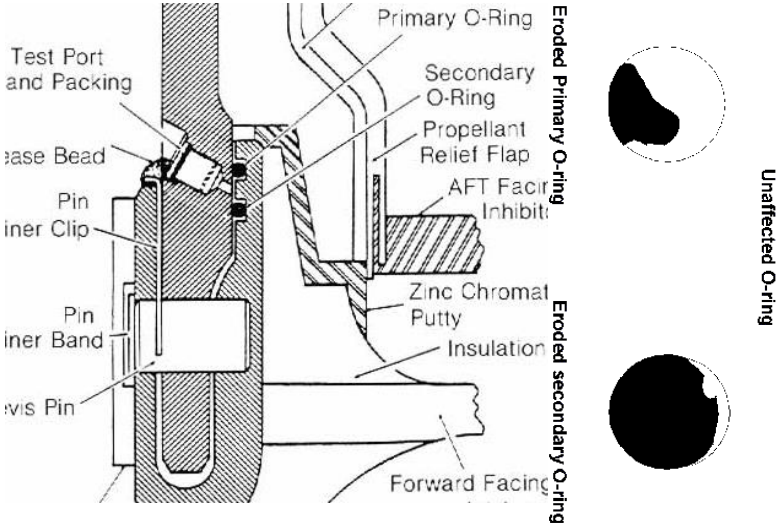
Seek contrary data



Don't be a Turkey

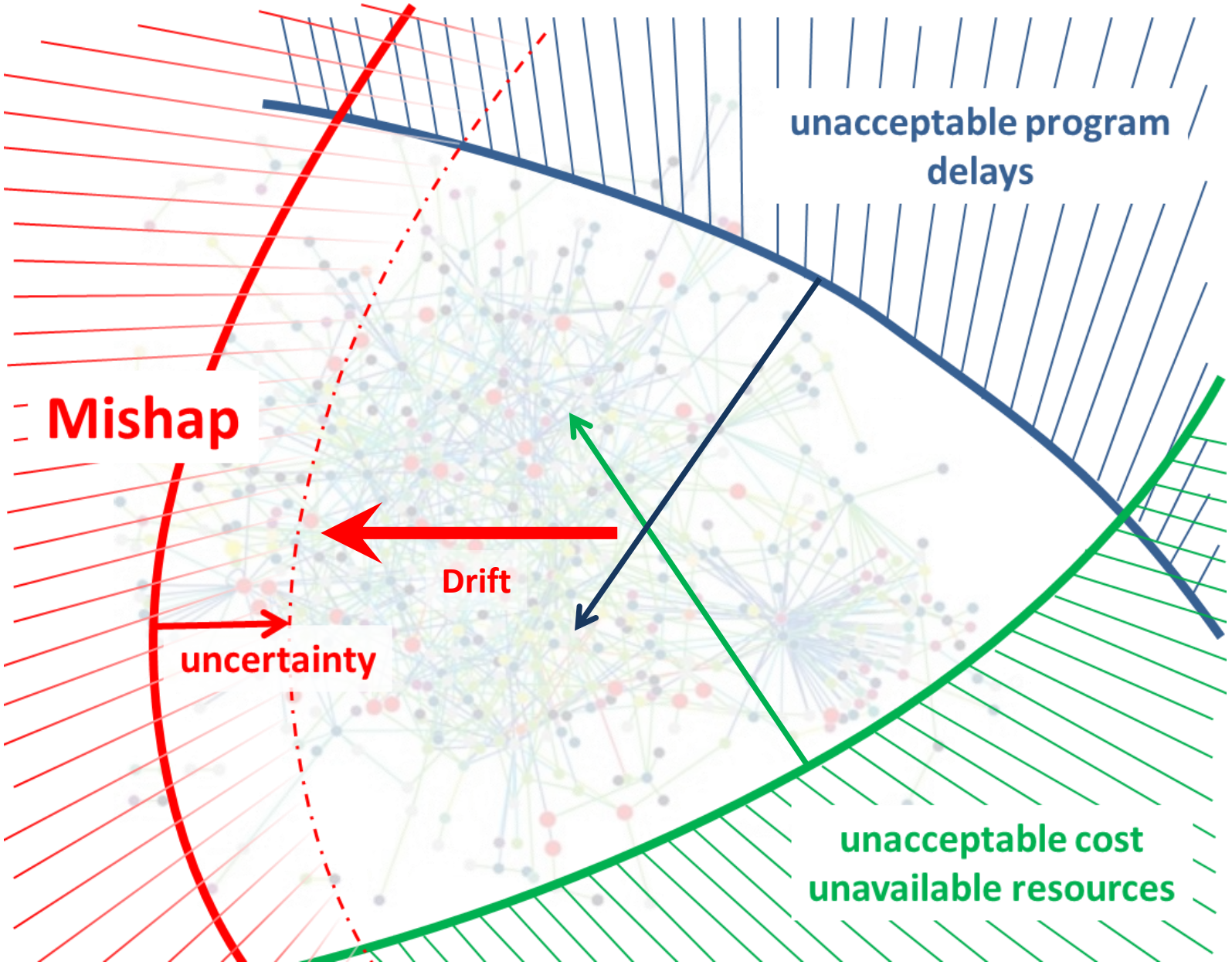


Understand unexpected deviations before continuing



*** Surprises are Warnings ***

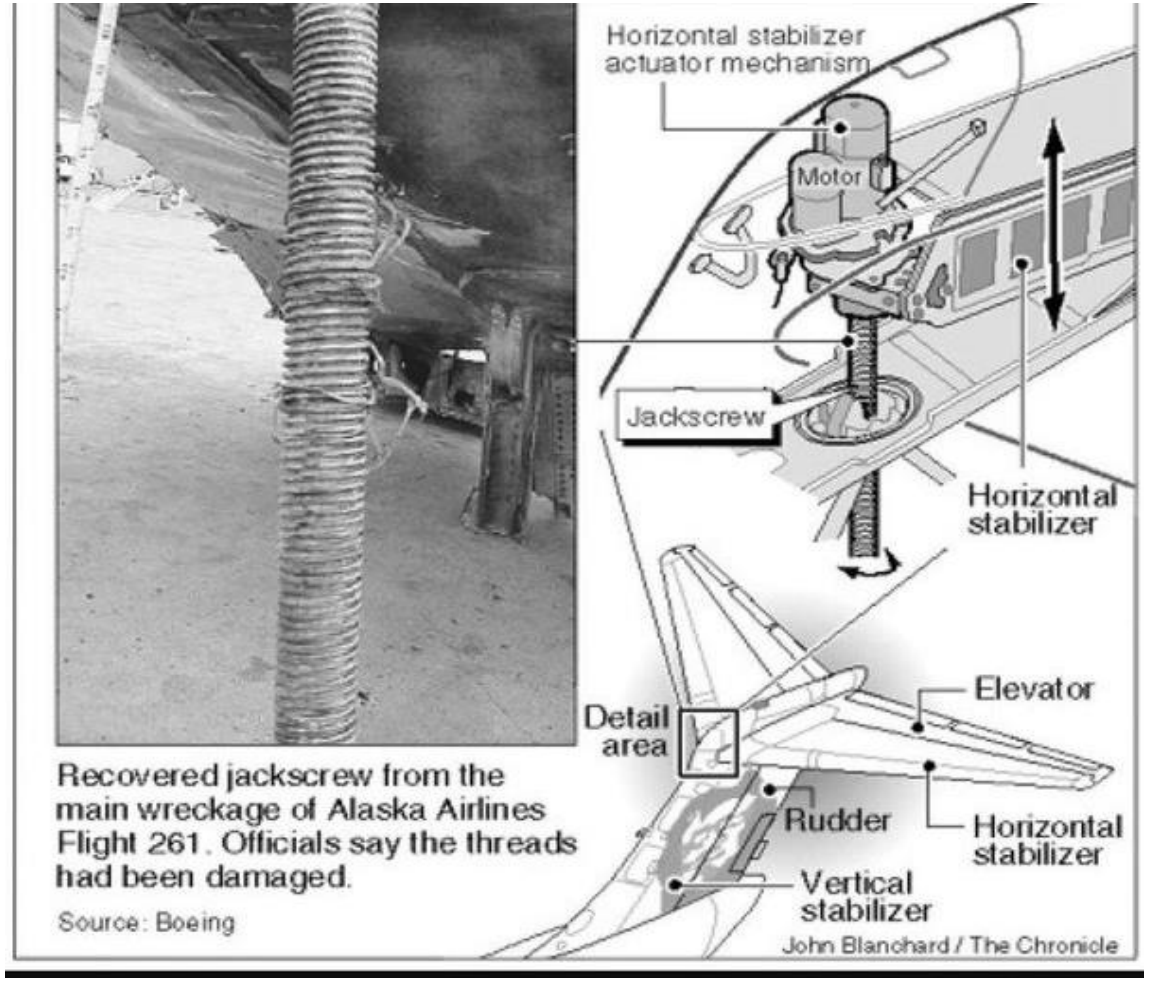
Program Gradients & Drift



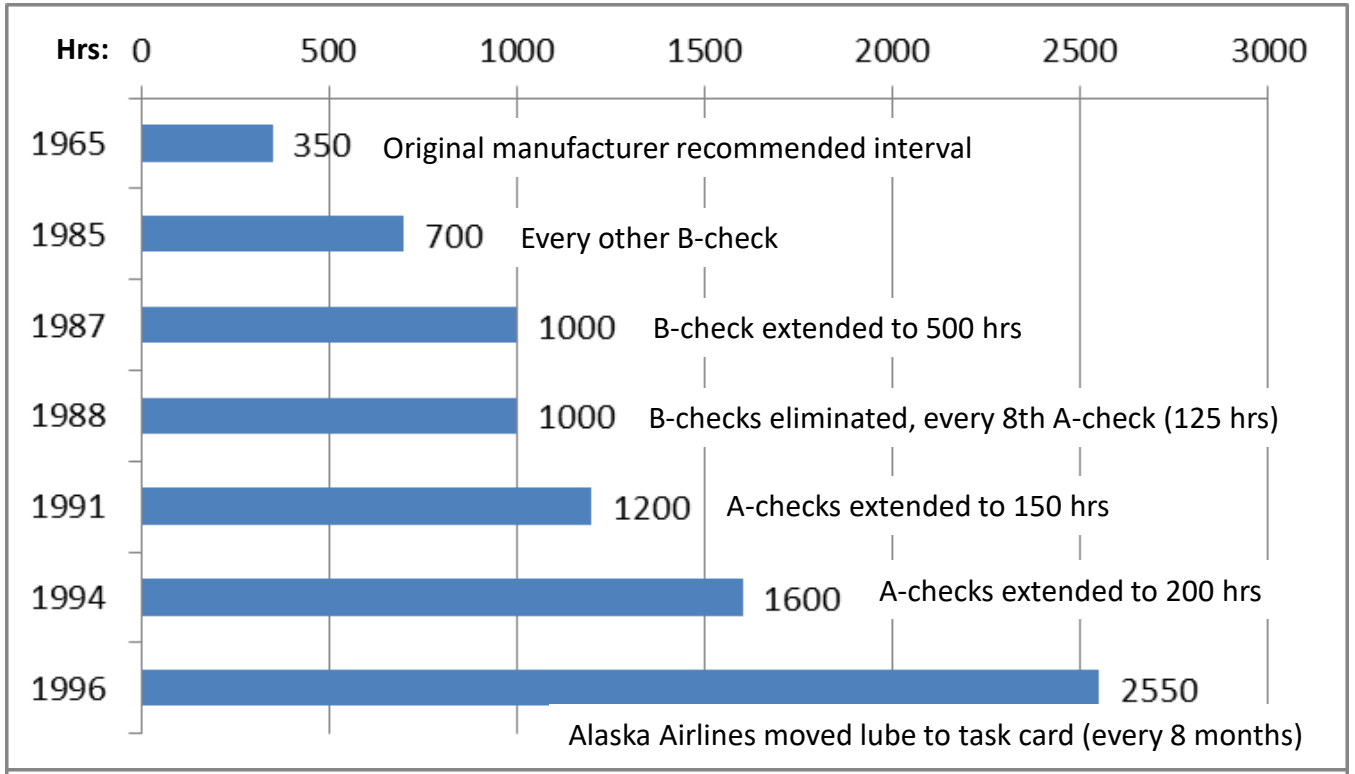
Alaska Airlines Flight 261

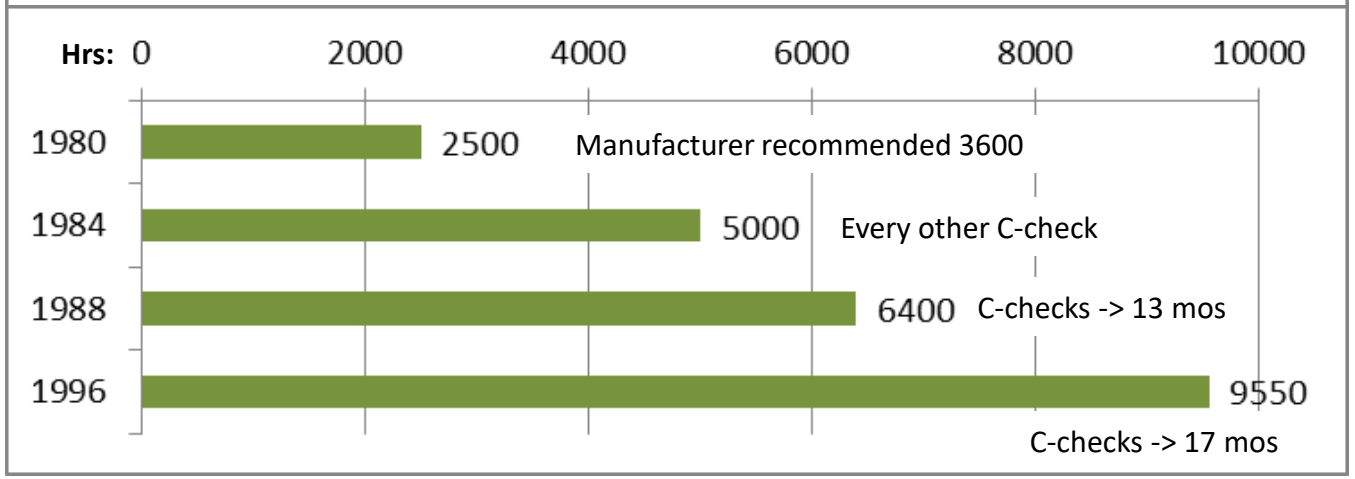
- 31 Jan 2000
- McDonnel Douglas MD-83
- 88 killed
- NTSB Findings
  - Horizontal stabilizer trim jackscrew failure
  - Excessive wear due to inadequate lubrication
  - Extended lubrication intervals
  - Extended end-play check intervals
- DC-9 design (certified 1965) (MD-80/90, 717)
  - 95 million flight hrs / 2300 aircraft

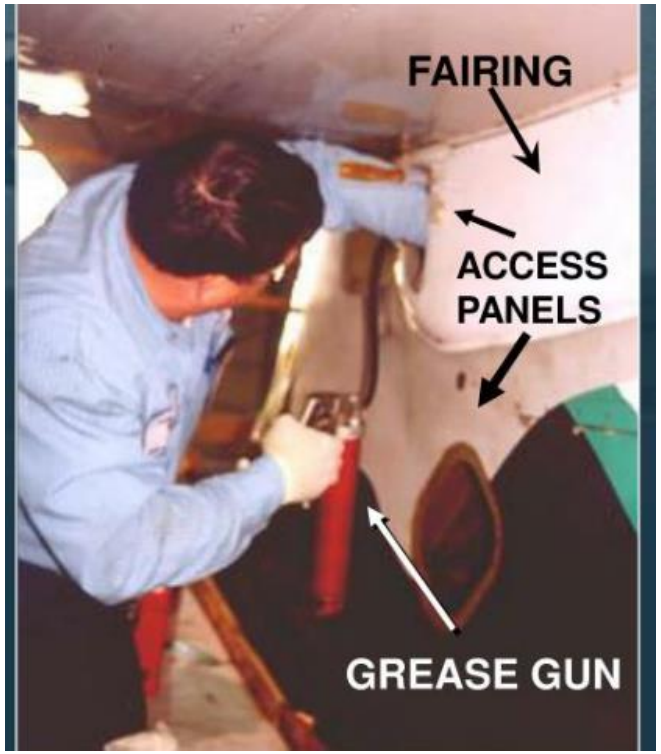
MARK NOWLIN / THE SEATTLE TIMES



Alaska 261 - Extension of Lubrication Interval

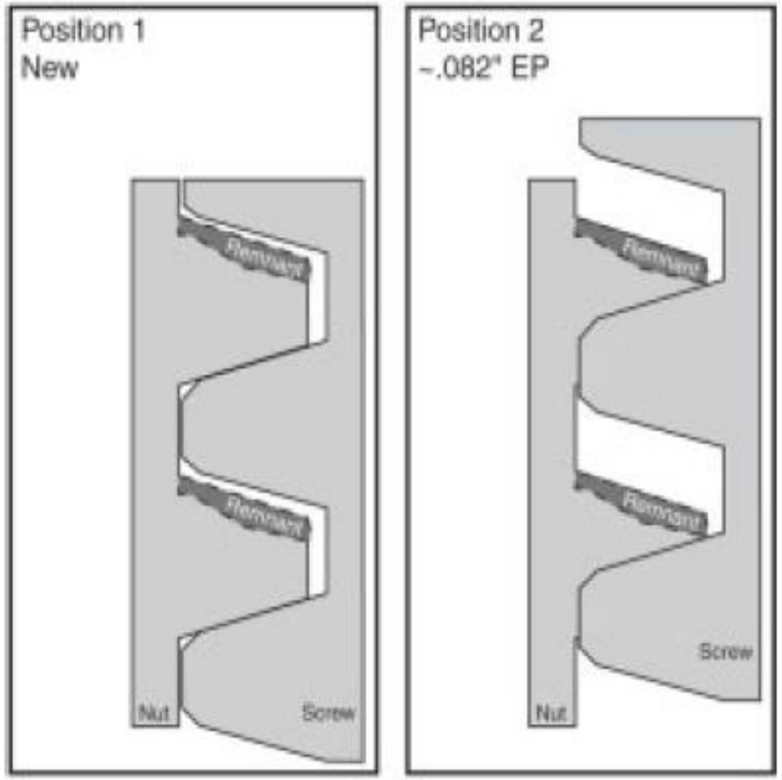




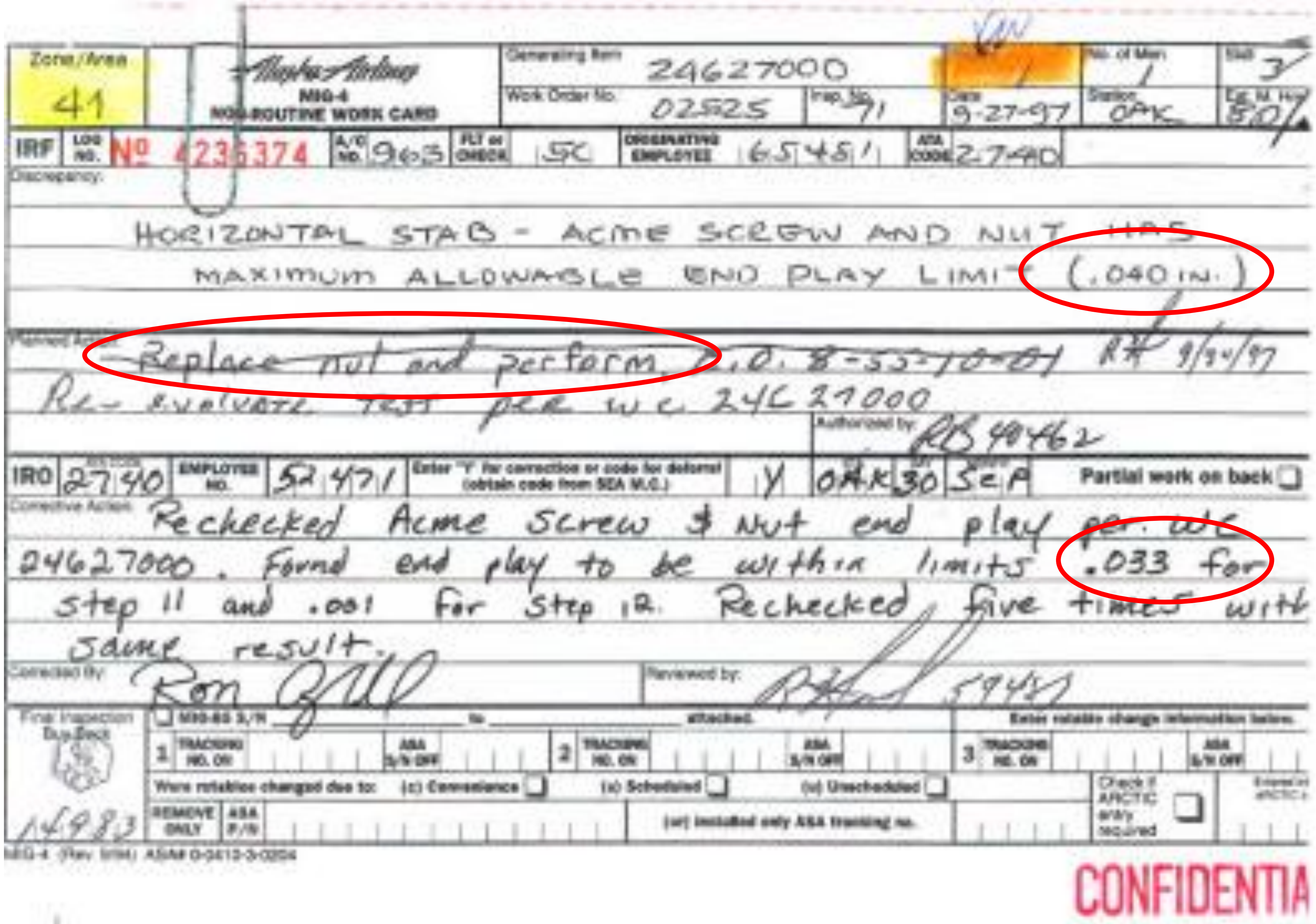


Alaska 261 - End-play Check Work Card

Figures showing the four positions of the screw threads versus the nut threads



AOL max allowable: 0.040 in


Zone/Area 41
Alaska Airlines
MIG-4
NON-ROUTINE WORK CARD
Generating Item 24627000
Work Order No. 02525
Insp. No. 71
Date 9-27-97
No. of Men 1
Station OAK
Skill 3
IRF LOG NO. Nº 4235374
A/C NO. 963
FLT or CHECK 5C
ORIGINATING EMPLOYEE 65481
ATA CODE 2740
Discrepancy:
HORIZONTAL STAB - ACME SCREW AND NUT HAS MAXIMUM ALLOWABLE END PLAY LIMIT (.040 IN.)
Planned Action:
~~Replace nut and perform E.O. 8-55-10-01~~ RK 9/30/97
Re-evaluate test per W.C. 24C 27000
Authorized by: RB 40462
IRO 2740
EMPLOYEE NO. 52471
Enter "Y" for correction or code for deferral (obtain code from SEA M.C.) Y
OAK 30 SEP
Partial work on back
Corrective Action:
Rechecked Acme screw & nut end play per. WC 24627000. Found end play to be within limits .033 for step 11 and .001 for step 12. Rechecked five times with same result.
Corrected by: Ron Gill
Reviewed by: 59481
Final Inspection Buy-Back
MIG-85 S/N to attached.
Enter rotable change information below.
1 TRACKING NO. ON | ASA S/N OFF
2 TRACKING NO. ON | ASA S/N OFF
3 TRACKING NO. ON | ASA S/N OFF
Were rotables changed due to: (c) Convenience (s) Scheduled (u) Unscheduled
Check if ARCTIC entry required
REMOVE ONLY | ASA P/N
(or) Installed only ASA tracking no.
14983
MIG-4 (Rev. 9/94) ASAM 0-0413-3-0204
CONFIDENTIA

Risk Awareness

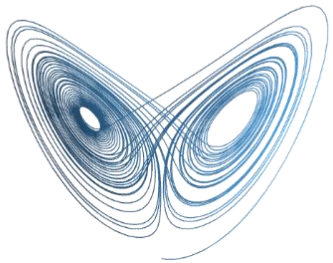
Perception of the elements of uncertainty and the potential, projected outcomes resulting from uncertainty

1) Identify & characterize the nature of the unknowns

Slow Thinking

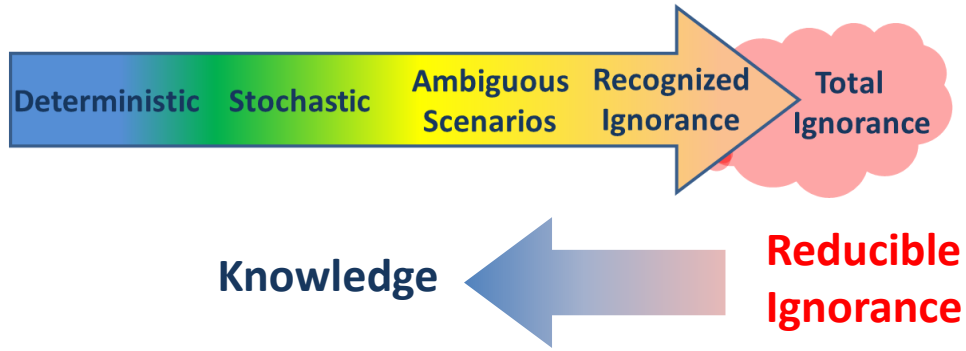
Risk

Uncertainty

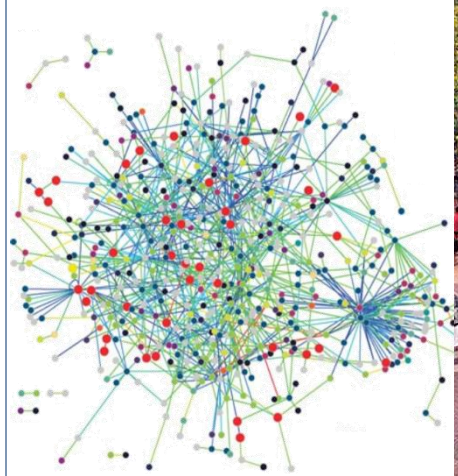


Heuristics

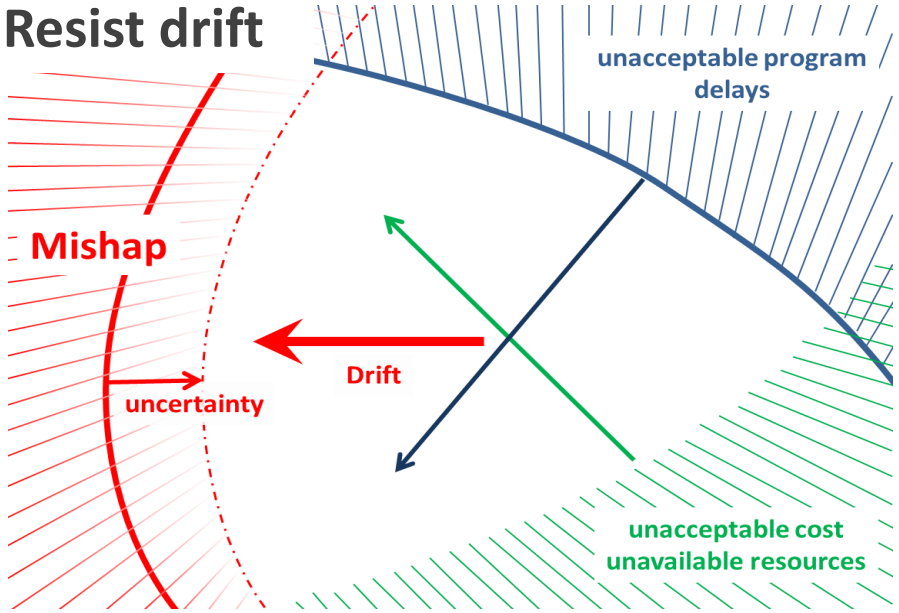
2) Reduce the reducible ignorance



3) Democratize safety decision making

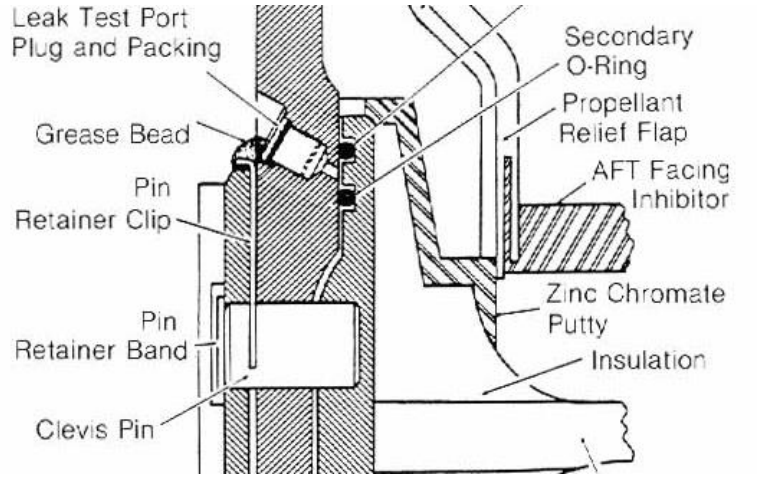


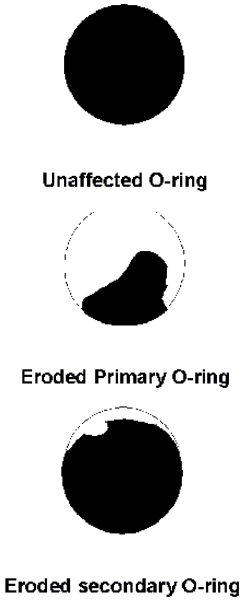
4) Resist drift



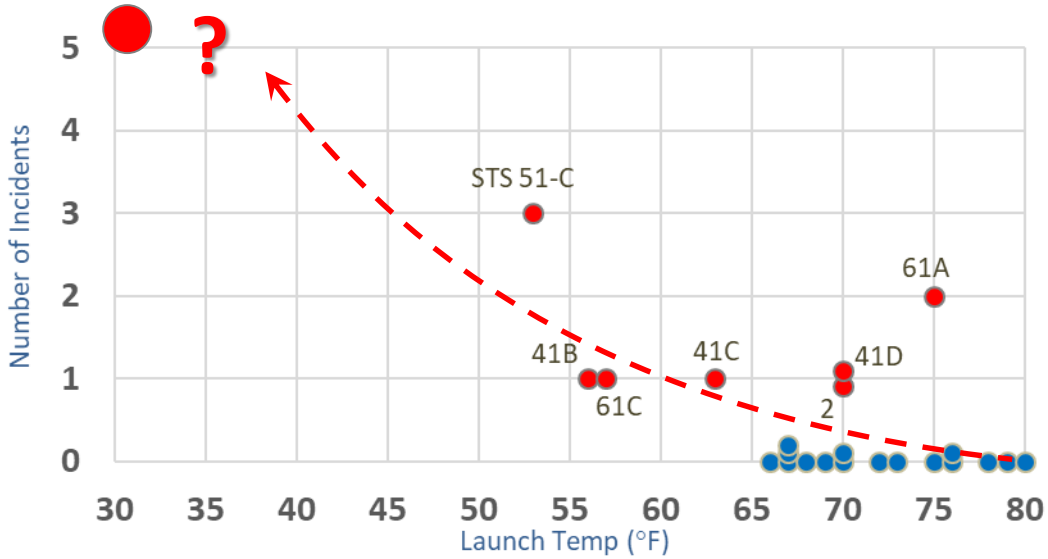
Risk Awareness: STS-51 (*Challenger*, 28 Jan 1986)

1) Identify & characterize the nature of the unknowns



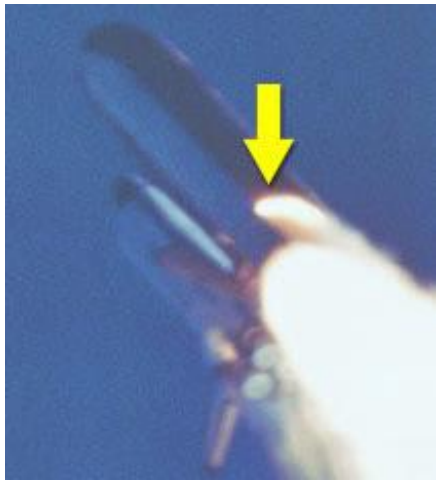


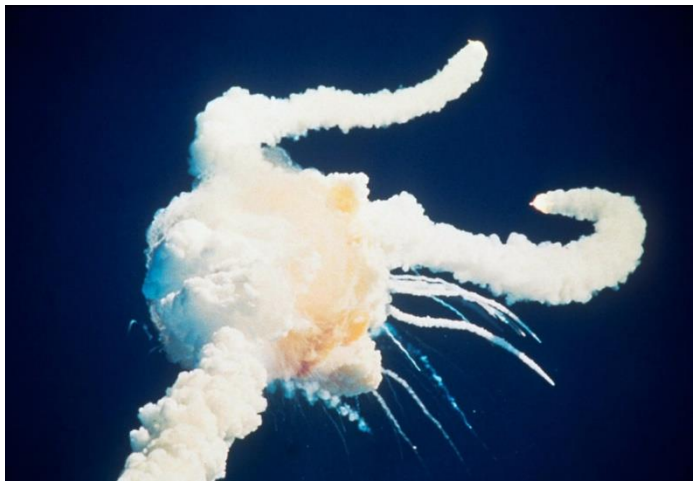
2) Reduce the reducible ignorance



3) Democratize safety decision making

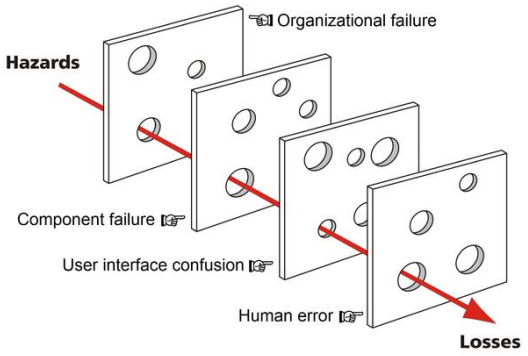
4) Resist drift



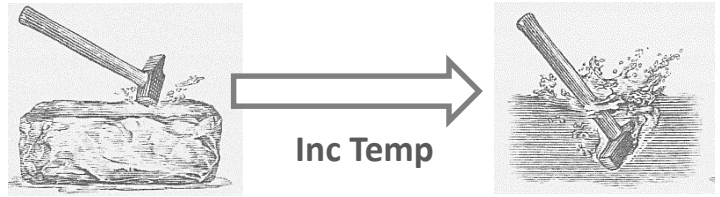


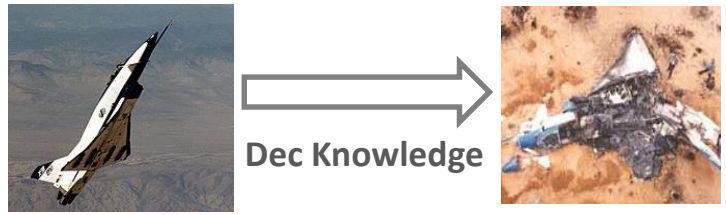
Key Takeaways & Lessons Learned

1. Flight test needs an updated accident model



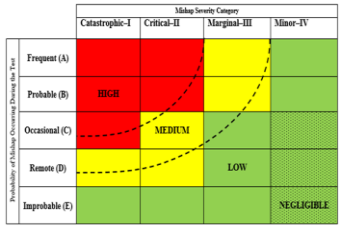
2. Knowledge is a Control Parameter

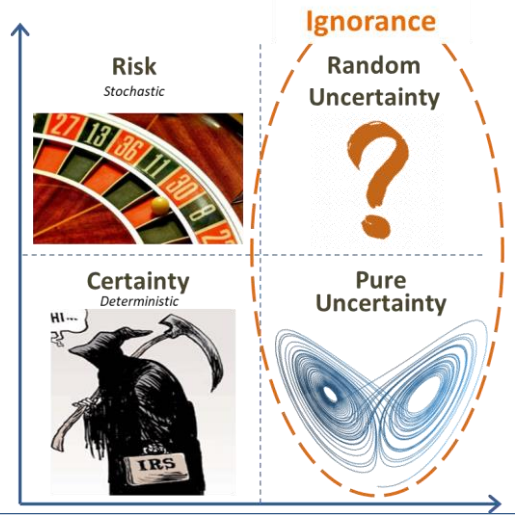




3. Different cognitive tools are appropriate for different types of uncertaintv

Slow Thinking



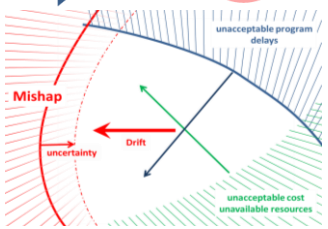


Heuristics

4. Risk Awareness:

Perception of uncertainty and the potential, projected outcomes from uncertainty

1) Characterize the unknowns
2) Reduce reducible ignorance
3) Democratized safety culture
4) Resist Drift

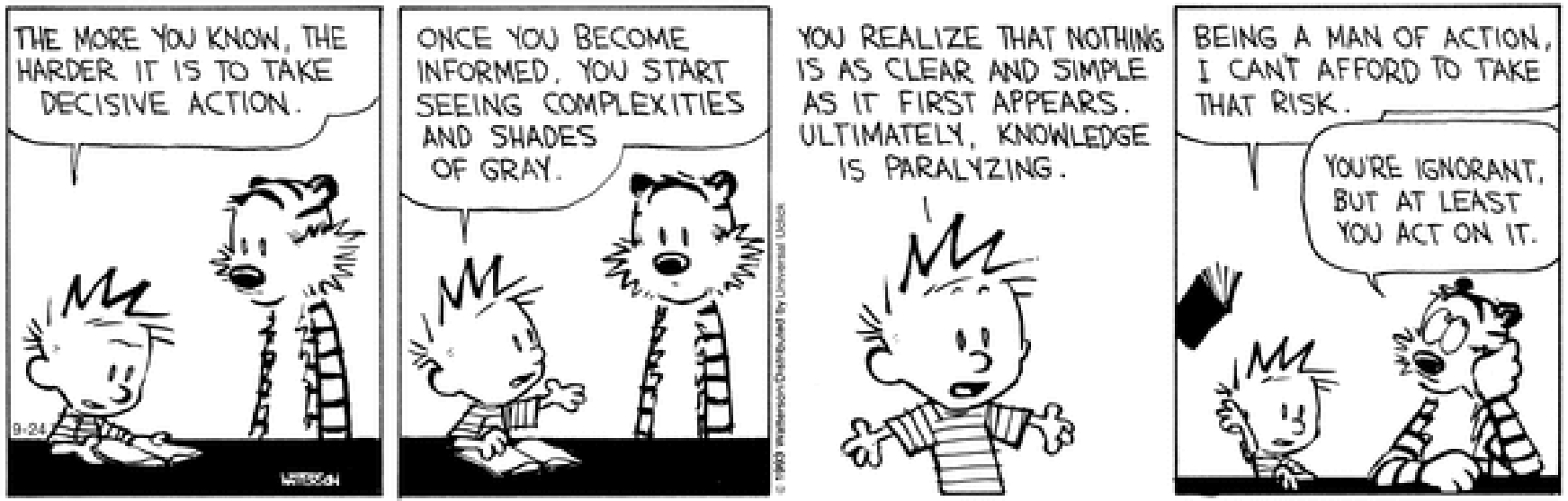


Questions…

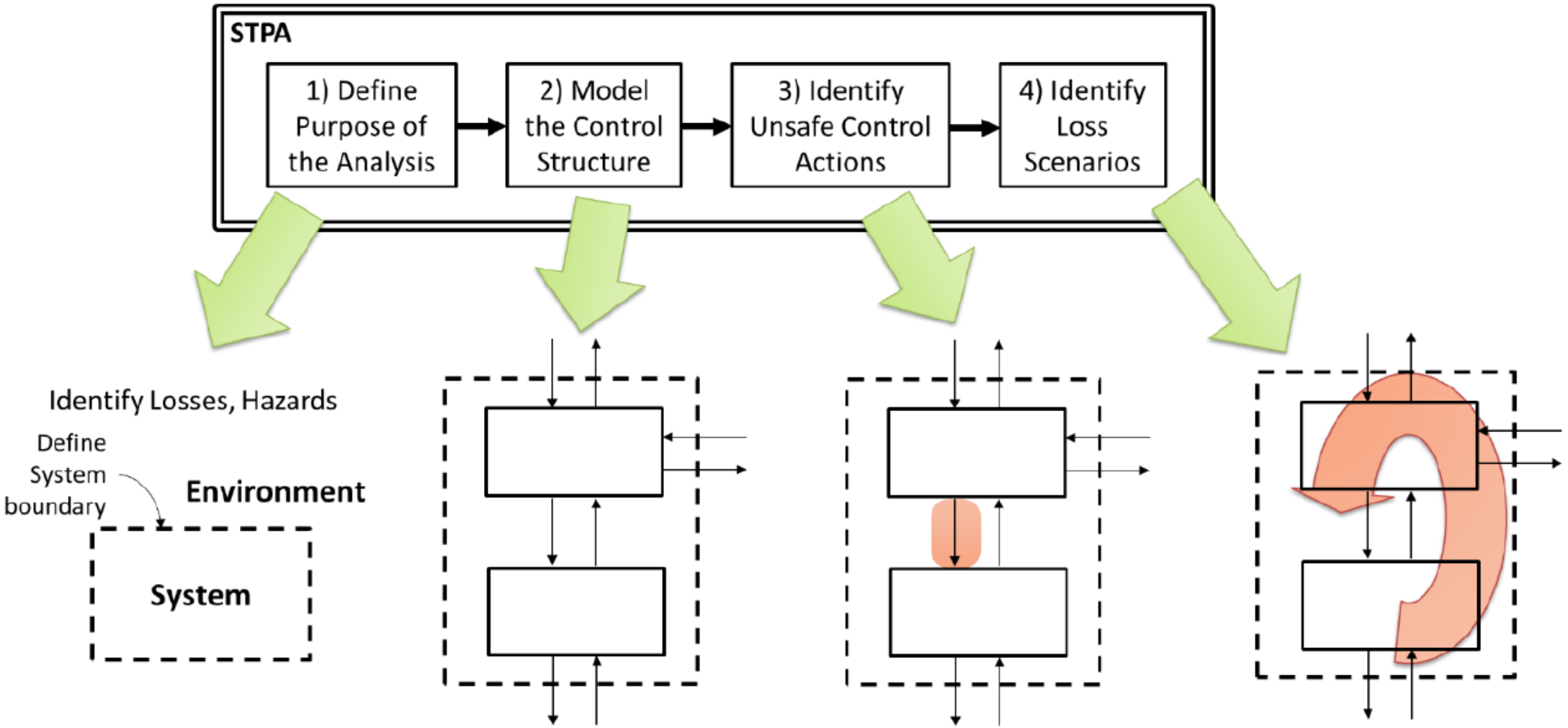
Risk Awareness
Flight Test
Uncertainty
Safety
System
Knowledge
Risk Awareness
Domain
Result
Accident
Risk Management
Control
Drift
Aware
Mishap
Framework
Design
Failure
Model
Phase
Make
Pressure
Prevent
Nature
Schedule
Understand
Time
Different
Heuristic
Reducible
Ignorance
Cognitive
Use
Plan
Wide
Node
Launch
Complex
Organically
More
Unknown
Probability
Challenge
Biases
Effect
Explain
Potential
Operates
Tool
Water
State
High
Ignore
Interact
Shuttle
Program
Practice
Example
Known
Year
Change
Two
Over
Between
Parameter
Engine
Occur
Event
Primary
Interval
Emerge
Organizational
Limit
Safe
One
Due
Force
First
Crew
Loss
Theory
Review
Aircraft
Bias

Backup Slides

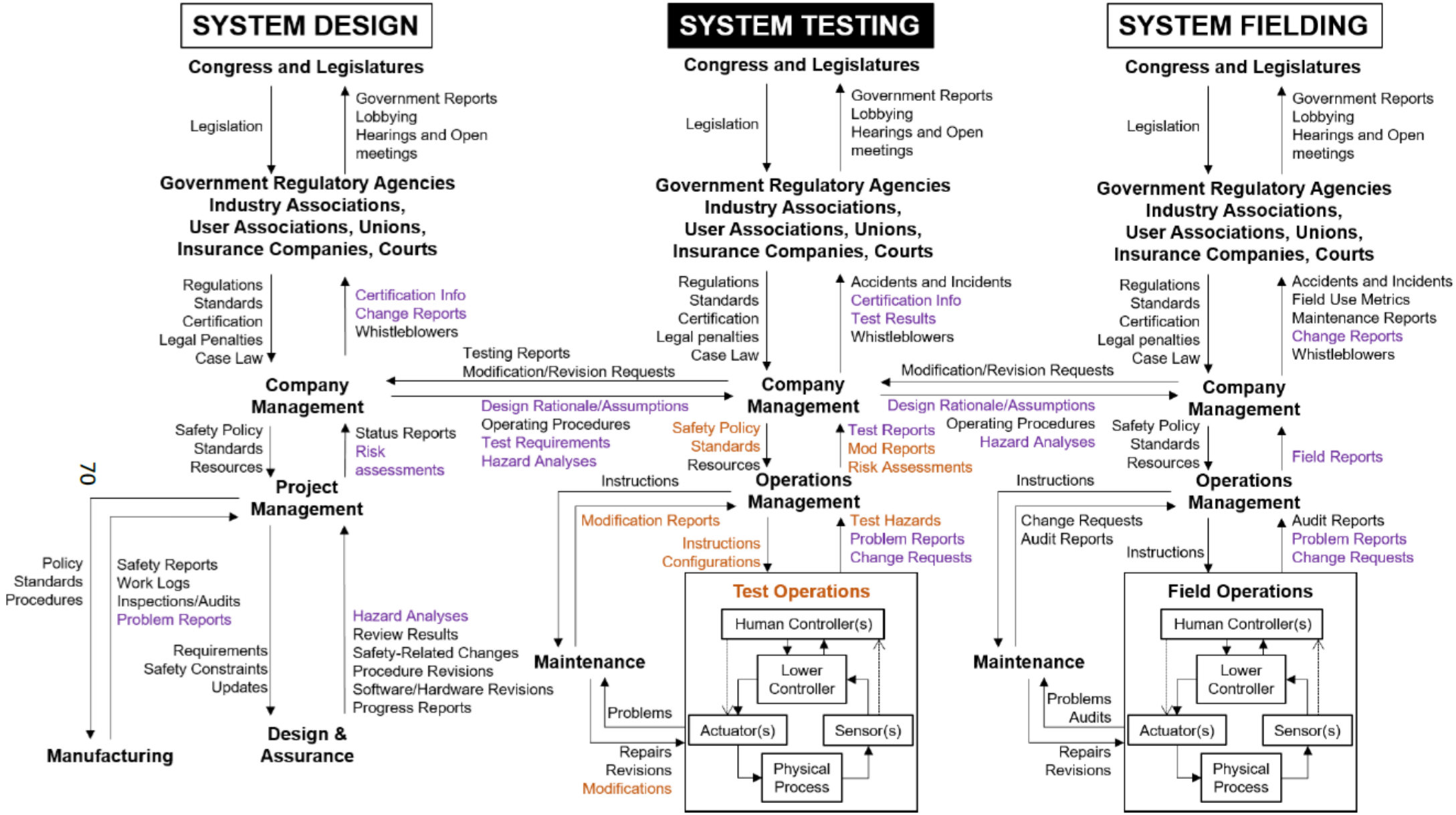
Risk, Uncertainty & Decision Making



Systems Theoretic Process Analysis (STPA)



Leveson, N.G., and Johnson, J.P., *STPA Handbook* (2018)


SYSTEM DESIGN
Congress and Legislatures
Legislation
Government Reports
Lobbying
Hearings and Open meetings
Government Regulatory Agencies
Industry Associations,
User Associations, Unions,
Insurance Companies, Courts
Regulations
Standards
Certification
Legal Penalties
Case Law
Certification Info
Change Reports
Whistleblowers
Company Management
Testing Reports
Modification/Revision Requests
Design Rationale/Assumptions
Operating Procedures
Test Requirements
Hazard Analyses
Safety Policy
Standards
Resources
Status Reports
Risk assessments
Project Management
70
Policy
Standards
Procedures
Safety Reports
Work Logs
Inspections/Audits
Problem Reports
Requirements
Safety Constraints
Updates
Hazard Analyses
Review Results
Safety-Related Changes
Procedure Revisions
Software/Hardware Revisions
Progress Reports
Manufacturing
Design & Assurance
SYSTEM TESTING
Congress and Legislatures
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Standards
Resources
Test Reports
Mod Reports
Risk Assessments
Operations Management
Instructions
Modification Reports
Instructions
Configurations
Test Hazards
Problem Reports
Change Requests
Test Operations
Human Controller(s)
Lower Controller
Actuator(s)
Sensor(s)
Physical Process
Maintenance
Problems
Repairs
Revisions
Modifications
SYSTEM FIELDING
Congress and Legislatures
Legislation
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Maintenance Reports
Change Reports
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Design Rationale/Assumptions
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Safety Policy
Standards
Resources
Field Reports
Operations Management
Instructions
Change Requests
Audit Reports
Instructions
Audit Reports
Problem Reports
Change Requests
Field Operations
Human Controller(s)
Lower Controller
Actuator(s)
Sensor(s)
Physical Process
Maintenance
Problems
Audits
Repairs
Revisions

Montes (2016)

Safety Cultures – Human Error Models

Person Approach

System Approach

	Healthcare	Aviation
Frequency	~200,000 preventable deaths (USA) (3 airlines crash everyday)	Avg 1 death per 3 million departures (worldwide)
Norms	Checklists rare, unaccounted “tools”	Checklists, Shadowed Tools
Cause of Errors	Forgetfulness, Inattention, Negligence, Carelessness, Recklessness	Errors are consequence, not causes “Upstream” systemic factors
Safety Measures	Fear, threat of litigation, disciplinary measures, retraining, shaming	Layer of defences, barriers & safeguards
Openness	Error admissions rare	Readily admit to mistakes
Culture	Who is at fault?	Why did defences fail?

Goldman Sachs Asset Management

"We were seeing things that were 25σ moves, several days in a row"

Financial Times, 13 Aug 2007

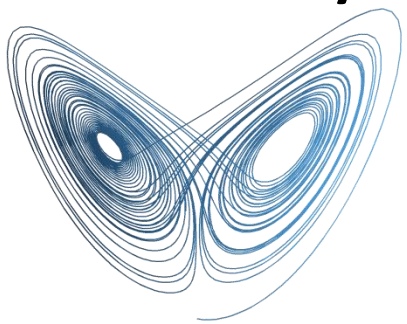
Zero-risk illusion

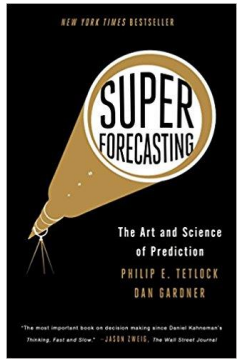
Turkey illusion

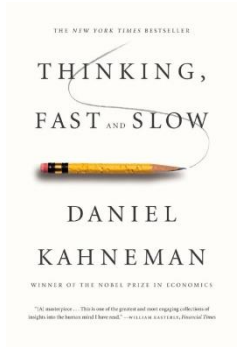
Certainty

Risk

Uncertainty



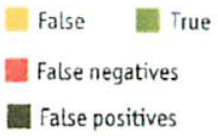




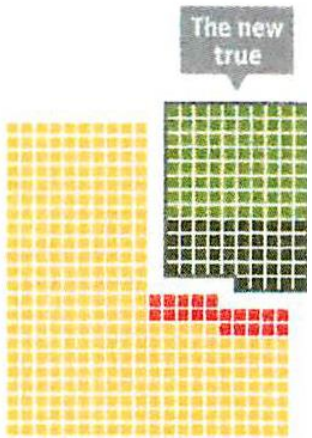
1000 trials

$\alpha = 5\%$

$\beta = 20\%$



125 'true' results
- 80 true positives
- 45 false positives



System 1
Fast Thinking

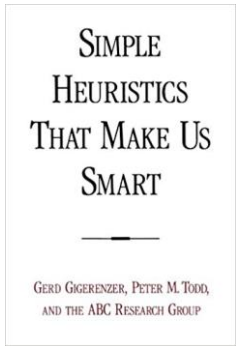
Cognitive biases:

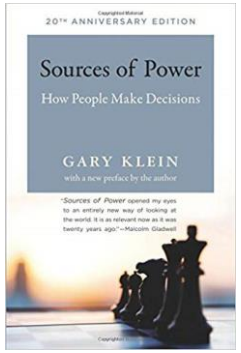
- Anchoring
- Availability
- Confirmation
- Framing
- Escalation

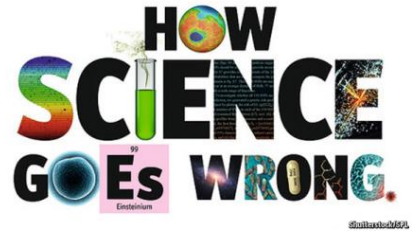
System 2 – Slow Thinking

Heuristics

- Intuition
- Simple
- Rules of thumb
- Reliably better decisions







John Ioannidis (2005, Stanford)

"Most published research findings are probably false."

$\alpha = 5\%$ (Type 1 error)

$\beta = 20\%$ (Type 2 error)

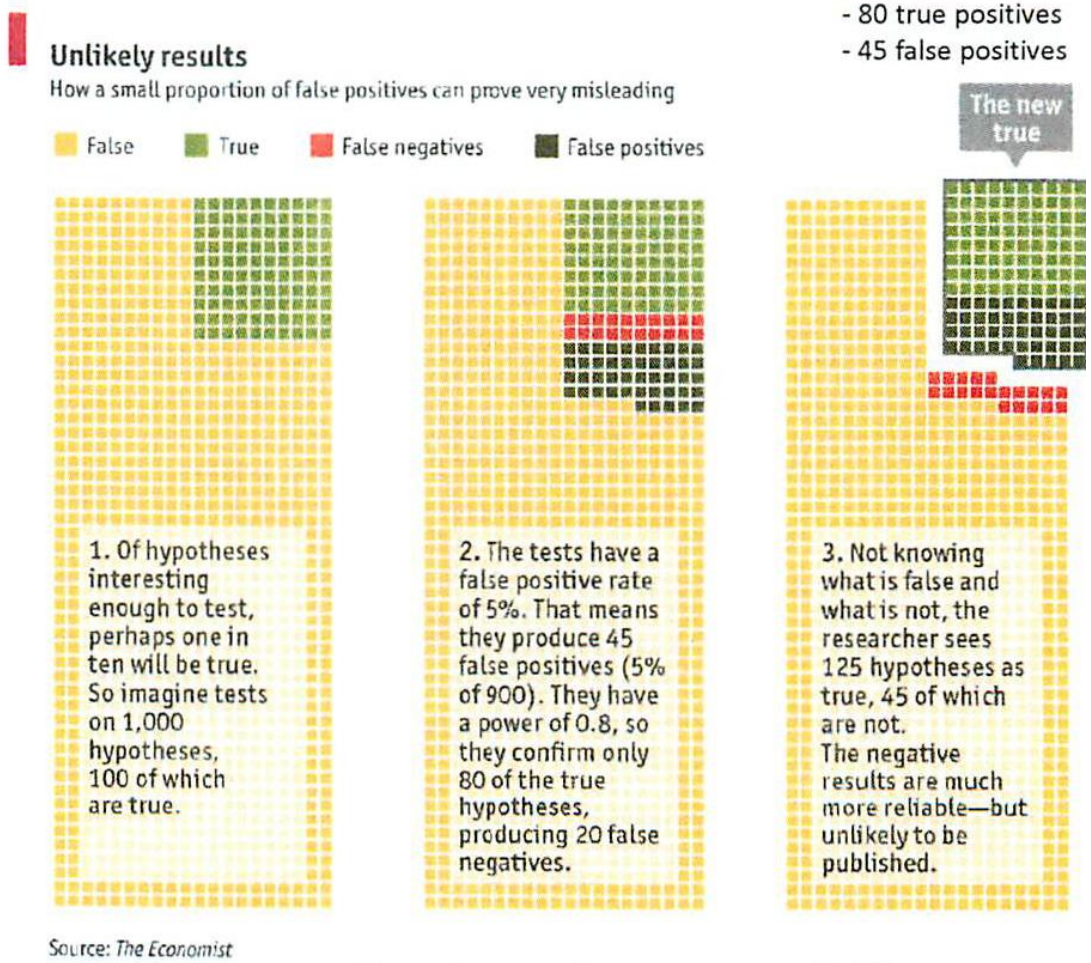
Power of the test = 80%

Statistical power is often < 40%

40 true positives

45 false positive

125 'true' results
- 80 true positives
- 45 false positives

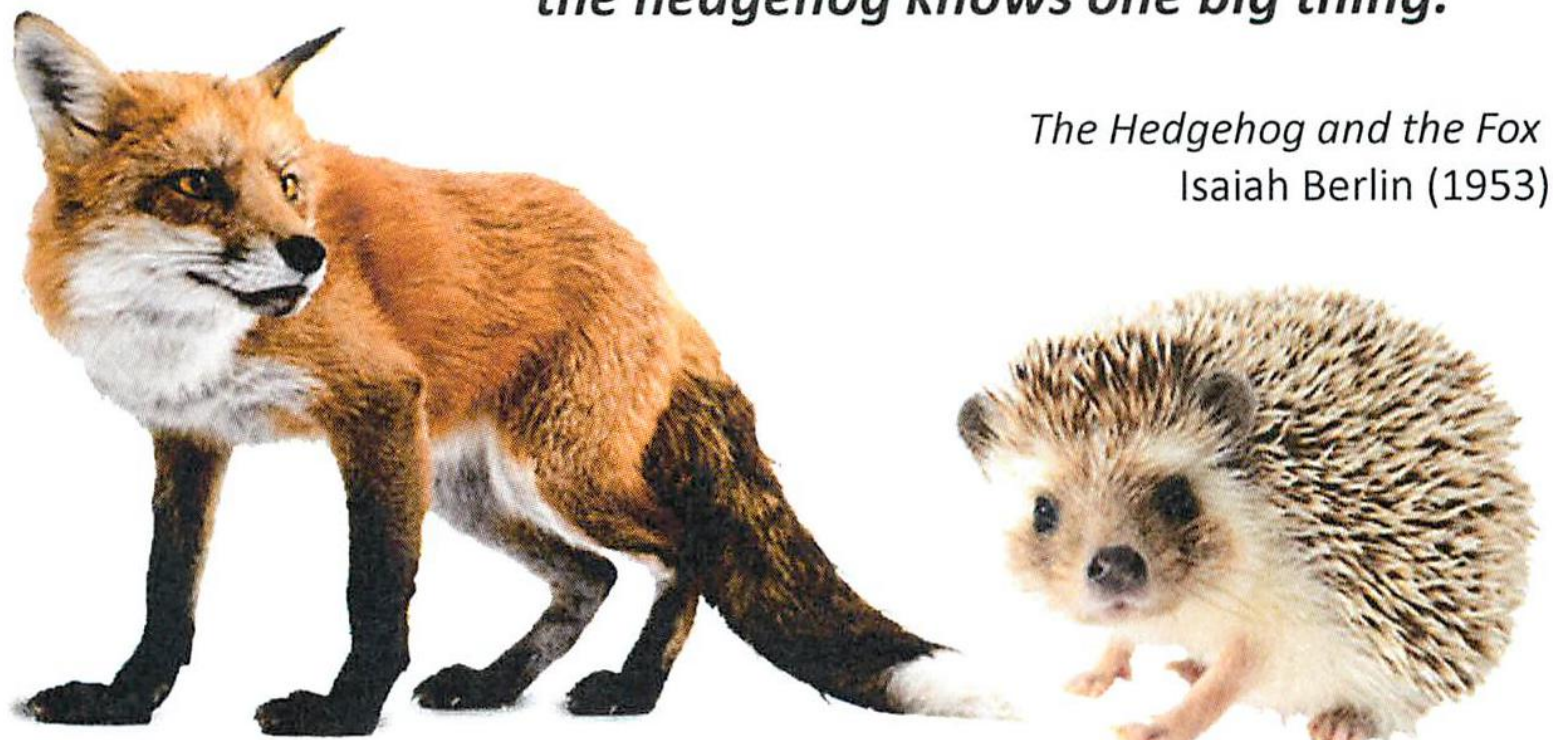


Source: *The Economist*

Negative results are more reliable (trustworthy), but less likely to be published.

"The fox knows many things...
the hedgehog knows one big thing."

The Hedgehog and the Fox
Isaiah Berlin (1953)

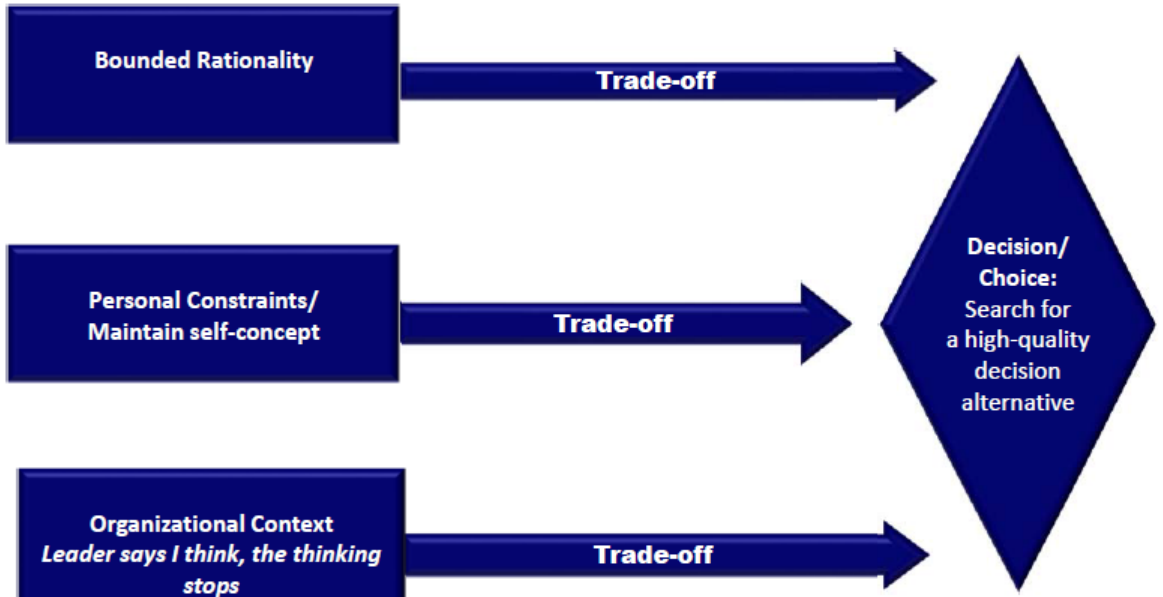


Rational Decision Model

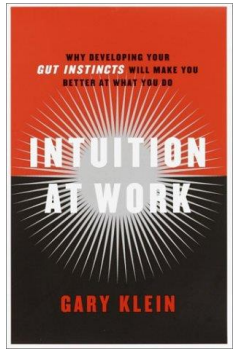
- Steps in the rational decision model
  - Clearly identify problem
  - Clearly identify criteria for successful solution
  - Identify options
  - Evaluate options in light of criteria for success
  - Select outcome that maximizes criteria

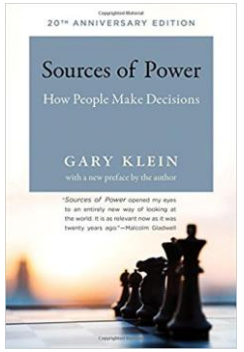
- Problems with the model
  - Probabilities and all alternatives are not known
  - Values (preferences) may be unclear or in conflict
  - Perceived rationality may become a "rationalization"

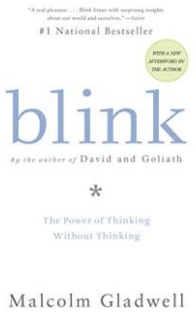
The Realities of Decision Making

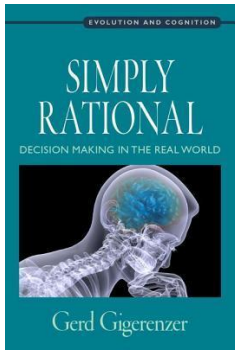


Sources: Adapted from Irving L. Janis, *Crucial Decisions* (New York: Free Press, 1989); and A. L. George, *Presidential Decision Making in Foreign Policy: The Effective Use of Information and Advice* (Boulder, Colo.: Westview Press, 1980).









Confirmation Bias

Suppose each of the cards below has a number on one side and a letter on the other, and someone tells you: "If a card has a vowel on one side, then it has an even number on the other side." Which of the cards would you need to turn over in order to decide whether the person is lying?

- Most people select either E or "E and 4"
- Very few give correct answer of "E and 7" (less than 10%)

Confirming Evidence

- To test a hypothesis, you need to collect both confirming and falsifying evidence
- Everyday we make hypotheses and seek only confirming evidence
  - Assumptions about subordinate competence (Pygmalion effect)
  - Leadership first impressions
  - Decision is made, then we seek out support

Tools for Decision Making under Uncertainty

- Start with a concise problem statement:
  - *"What are we trying to solve"*
  - Question assumptions and be wary of anchors
- Awareness/self-awareness of cognitive biases
- Ask: *"Is this a risk problem or an uncertainty problem?"*
- Seek outside inputs/perspectives (without anchoring)
- Diversity of opinion is necessary, but not sufficient: Need a process!
  - *"We're going to 2-5 min and everyone is going to say what they need to know"*
  - Ask: *"What do you need?" "What do you know?"*
- Beware of problems/solutions mindsets and psychology of advocacy (strive to persuade)
- Inquiry first, then advocacy
- Leader Traps:

"Fix it!" "Bring me solutions, not problems…" "How come I didn't know about this earlier?"

	Advocacy	Inquiry
Concept of decision making	Contest	Collaborative problem solving
Purpose of discussion	Persuasion & lobbying	Testing & evaluation
Participants' role	Spokesperson	Critical thinkers
Patterns of behavior	Strive to persuade Defend your position Downplay contrary evidence	Balanced arguments Open to alternatives Accept/process contrary evidence
Minority views	Discouraged /dismissed	Cultivated / valued
Outcome	Winners / losers	Collective ownership

Adapted from Garvin, D.A., & Roberto, M.A. (2001). What you don't know about Making decisions. *Harvard Business Review, September issue.*