Aviation safety and risk
A historical perspective

John Stoop

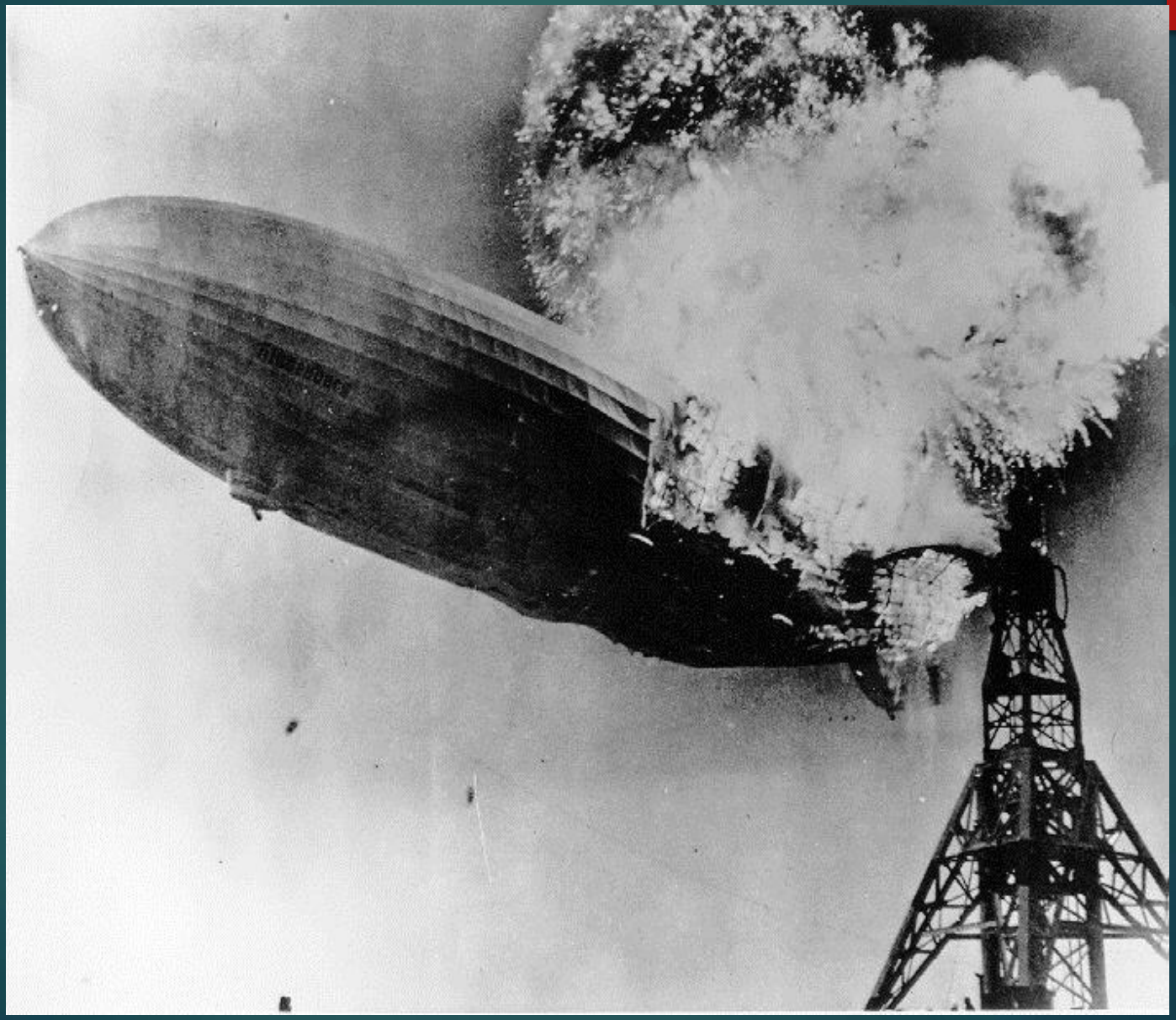
Aviation, a special case?

- High tech and cutting edge performance: hostile operating environment, high level playing field
- Public confidence: A Citizens' Right and Society's Duty
- Business continuity: Zero Defect and First Time Right:
- Beyond the 10*-7 likelyhood: low probability, major consequences
- Anticipating a systems leap in performance: +50% performance, -50% impact while maintain safety performance

A new role for safety investigations?

- If we start killing our passengers, we are on the wrong track: restoring public faith after accidents
- Identifying system and knowledge deficiencies

Hindenburg



De Havilland Comet

Aloha Airways

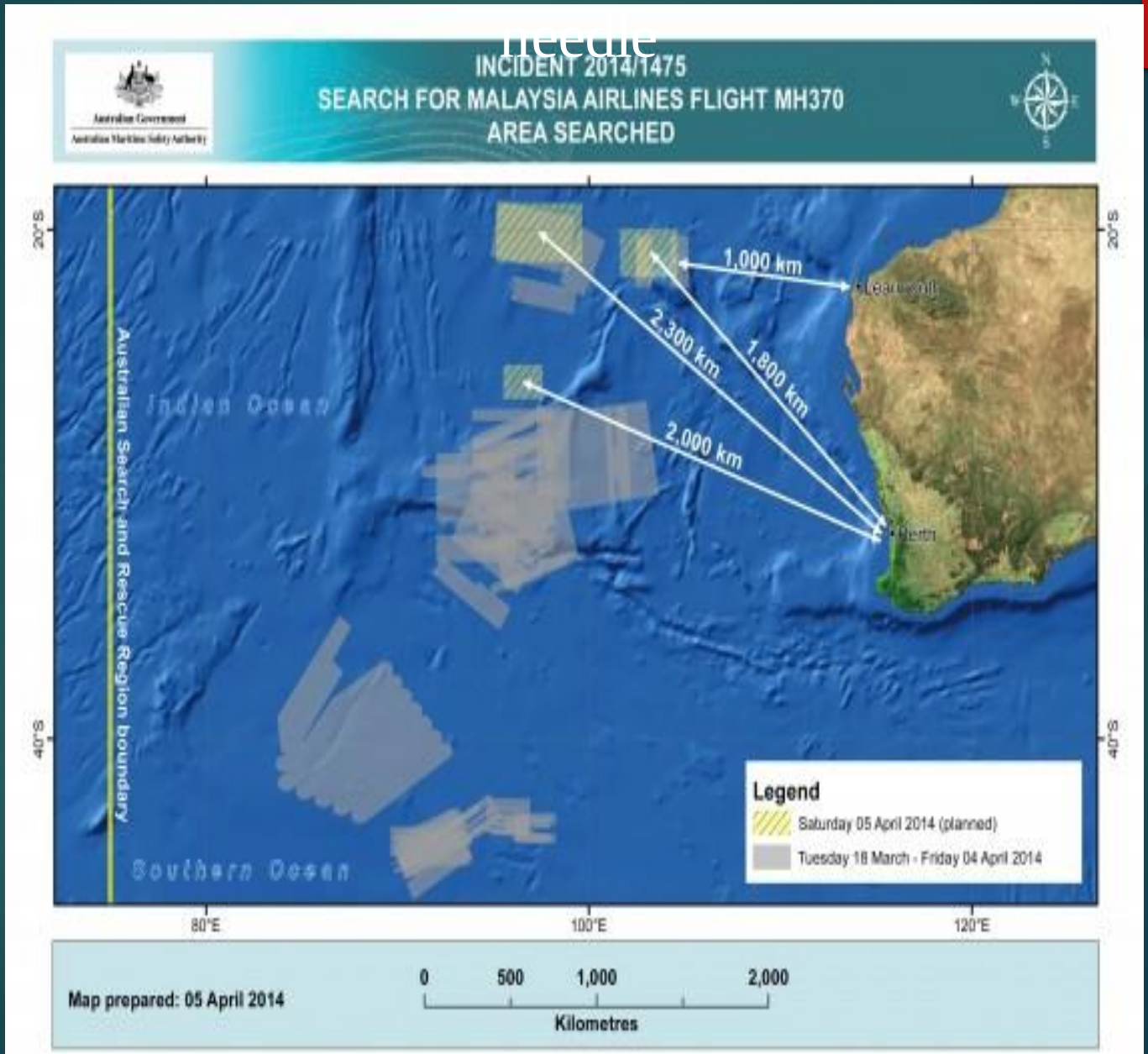
Tenerife

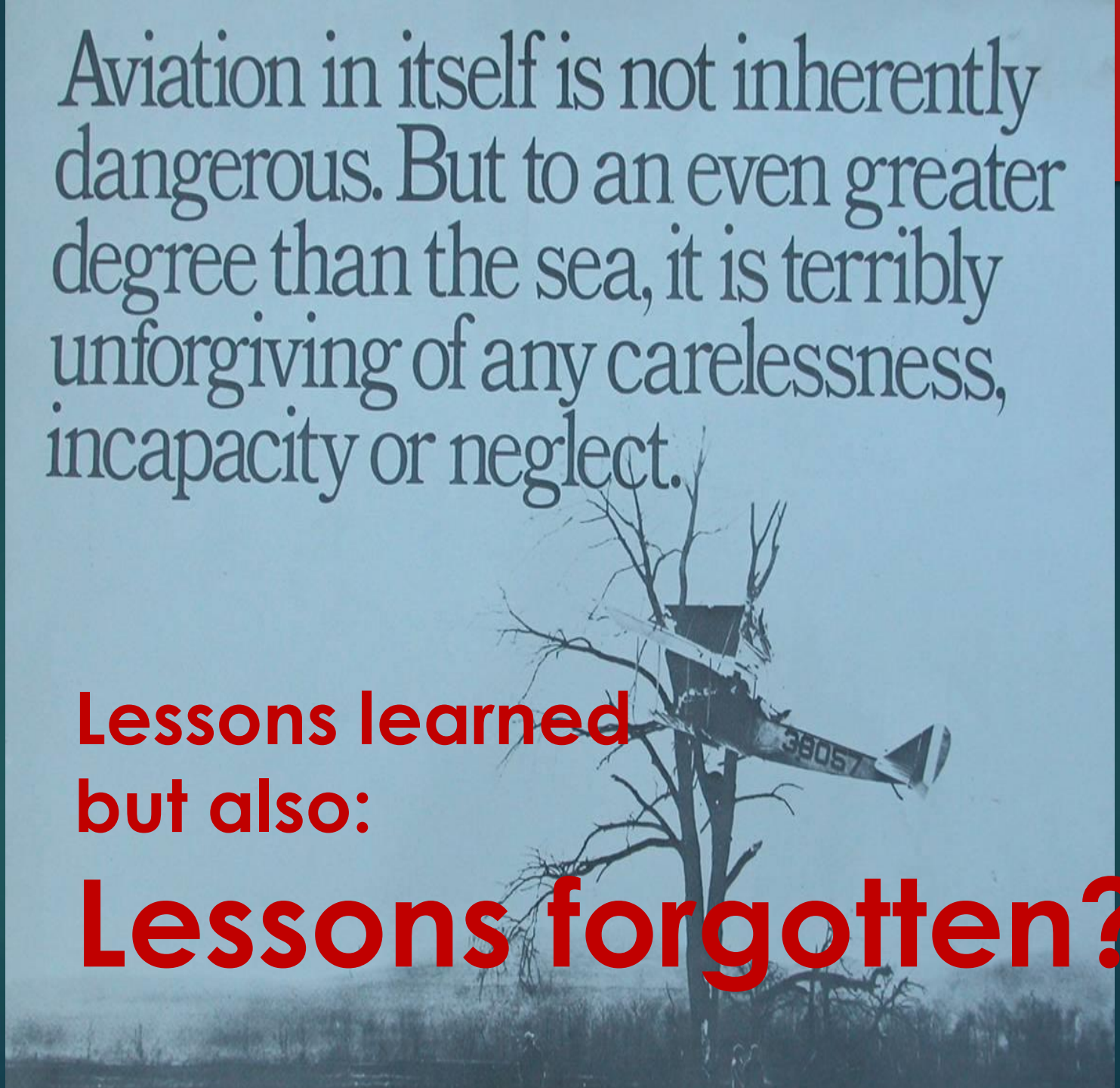
TWA 800

Bijlmermeer crash

Concorde

Finding the haystack before the needle




Aviation in itself is not inherently dangerous. But to an even greater degree than the sea, it is terribly unforgiving of any carelessness, incapacity or neglect.
Lessons learned
but also:
Lessons forgotten?

History of safety assessment

Expanding the scope

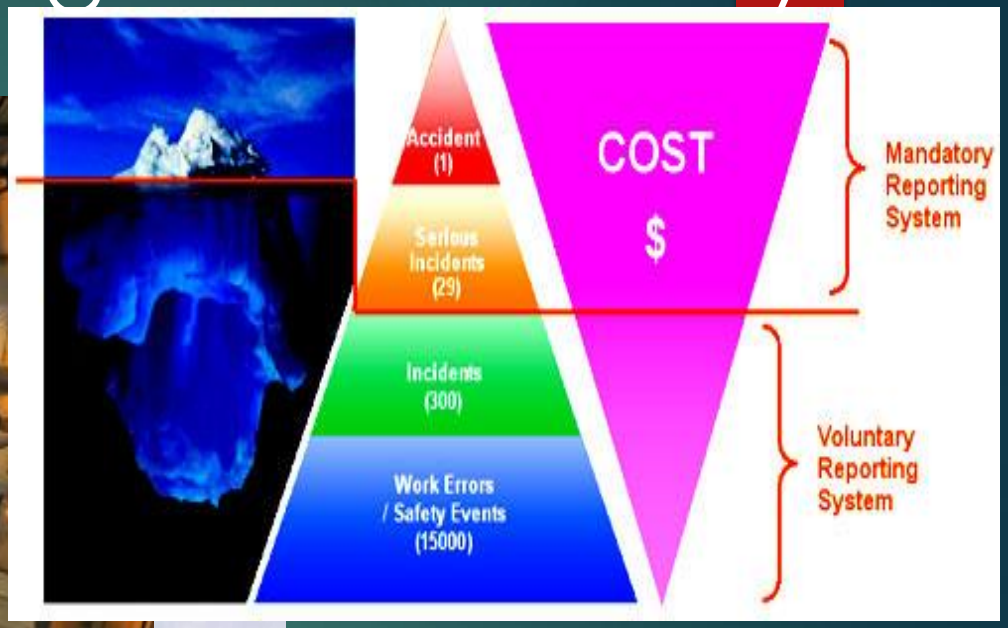
- Technical failures (1850): transport, rail, aviation, shipping
- Probability of failure (1950): process industry, statistical likelyhood
- Human factors (1970): space, medical, risk management
- Systemic learning (1990): life cycle approach, business continuity
- Governance and control (2000): resilience, security

Debates and focus

- A shift from technical via managerial to policy and governance
- Integral or integrated: intermodal or international?
- One Size Fits All: transport, process, nuclear?
- New entrants, rescue and emergency, victims

Modelling aviation safety

London Melbourne race
DC-2 1934

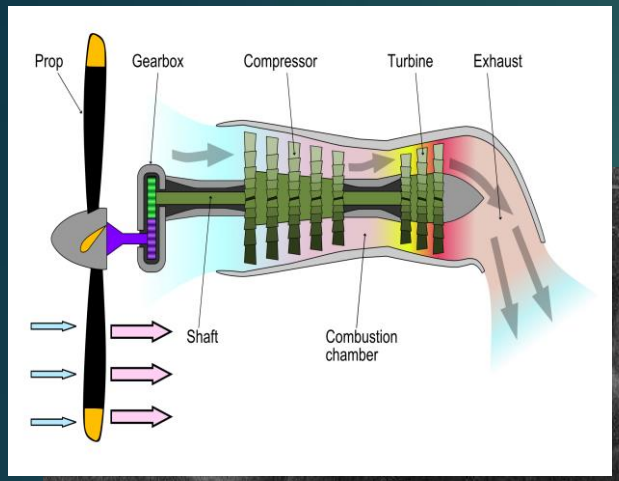


1932

Luchthaven gebouw Schiphol 1928

In 1930:
Heinrich's Iceberg

Domino Stones
1928



The turboprop age

Aviation in 1960: jet engines

Risk = frequency * cor
Risk = Human error

Lockheed Electra

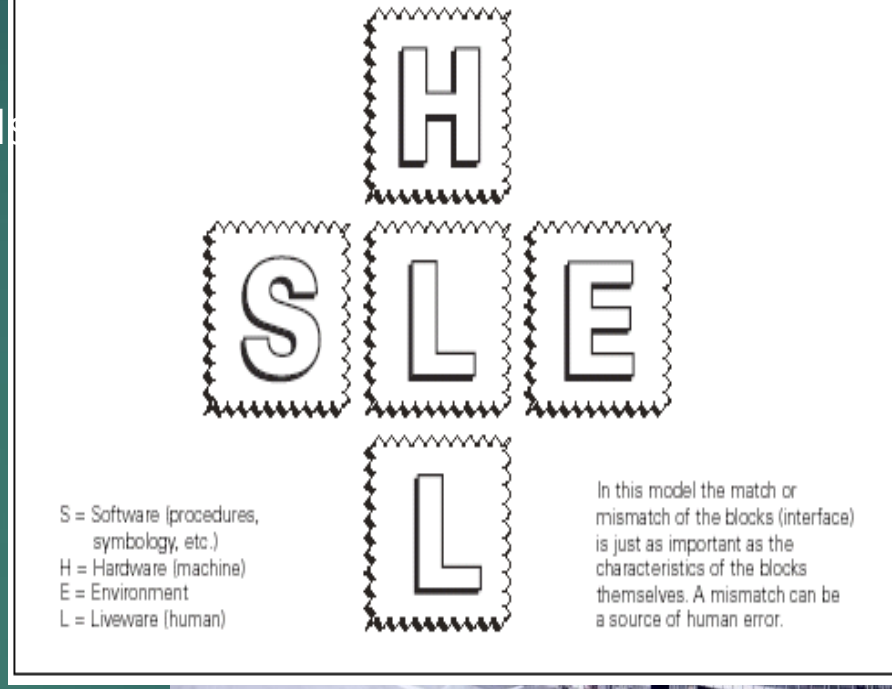
First flight
DC 8
30 may
1958

Aviation in 1970: hyjackings

Edwards 1972: SHELL m

English Channel

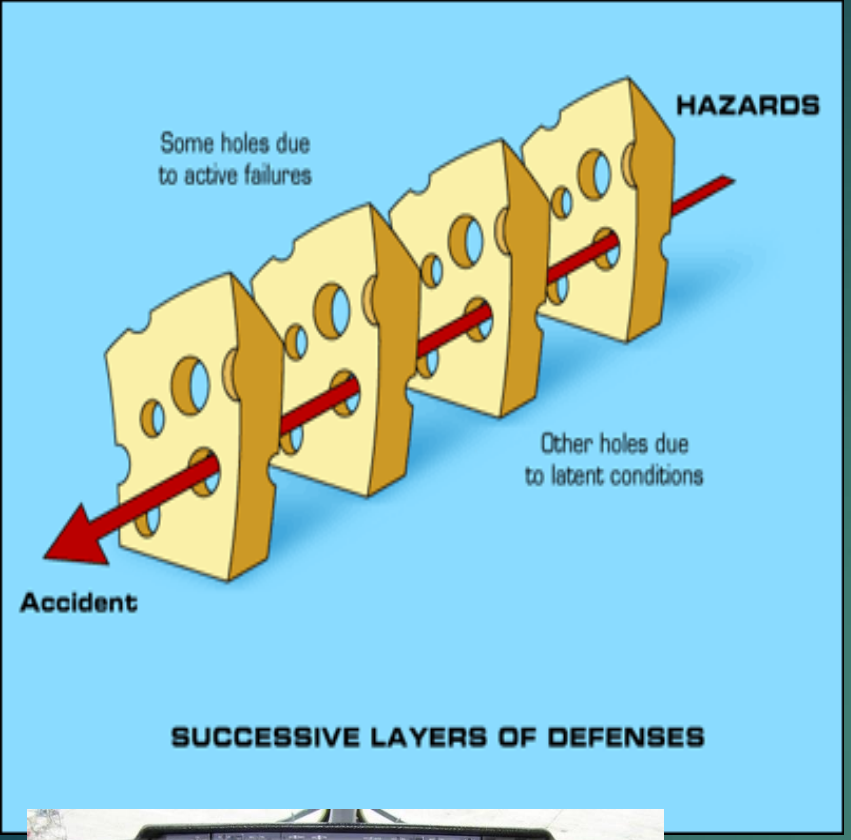
Brussels



Dawson Fields

Aviation in 1990

Swiss Cheese model



MD 11

Glass cockpits

Safety is integrated in the aviation system

Safety institutions

- Sectorial arrangements: ICAO Annex 13
- International legislation: EU Directives 94/56/EC and 2003/42/EC
- Certification and regulations: FAR/JAR
- National legislation and regulations
- ISASI
- FSF
- IATA
- IFALPA

ICAO Annex 13

The purposes of Annex 13 are threefold:

- standardise accident/incident reporting procedures
- establish procedures that ensure participation of experts in the investigation
- ensure rapid dissemination of important safety and airworthiness information

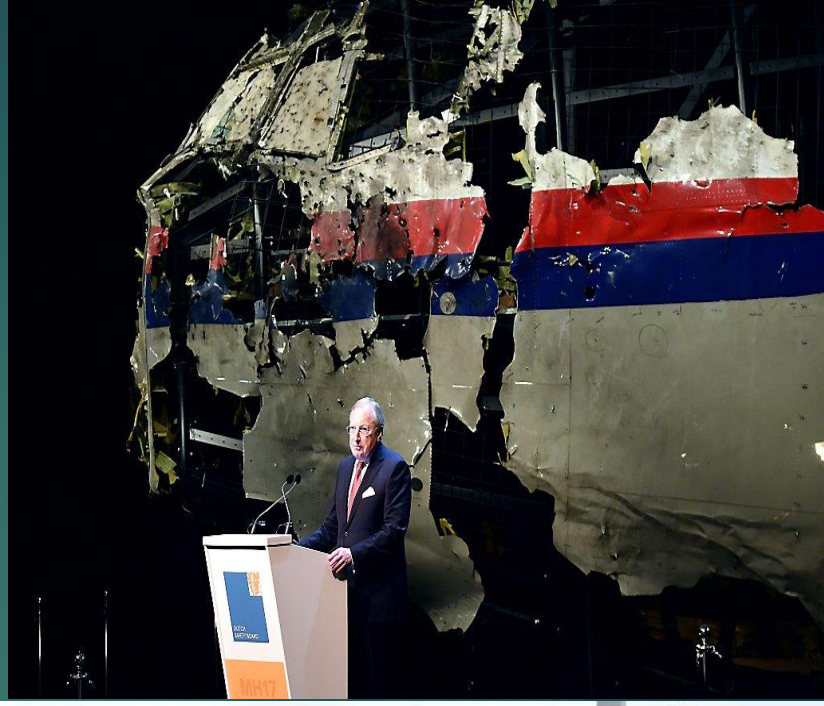
Stock prise

New indicators
Impact at
different recurs

Flight control problems

Financial and image control prob

Perception
Interpretation
Framing



Bigger and larger, towards conceptual limits

and beyond

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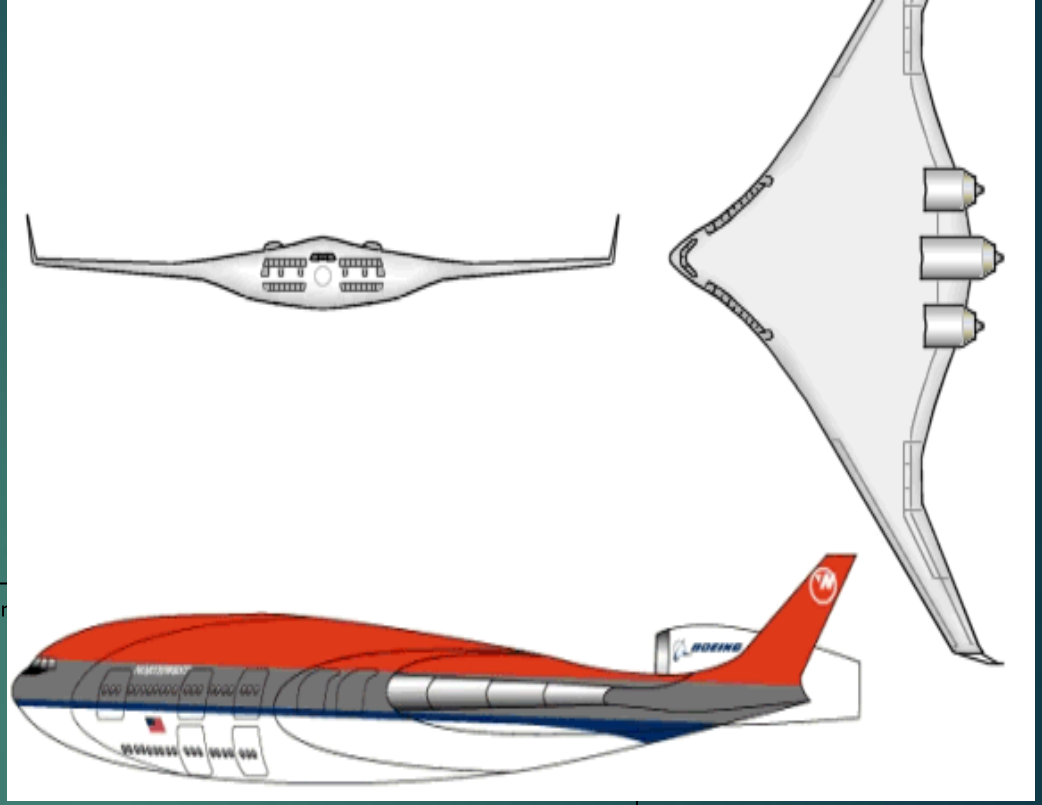
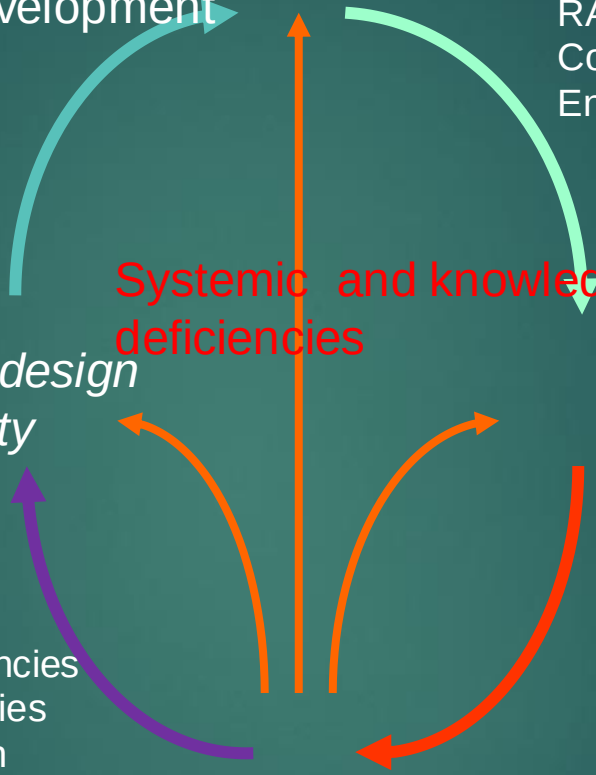


The ultimate flying experience

Closing the life cycle



From reliable towards available

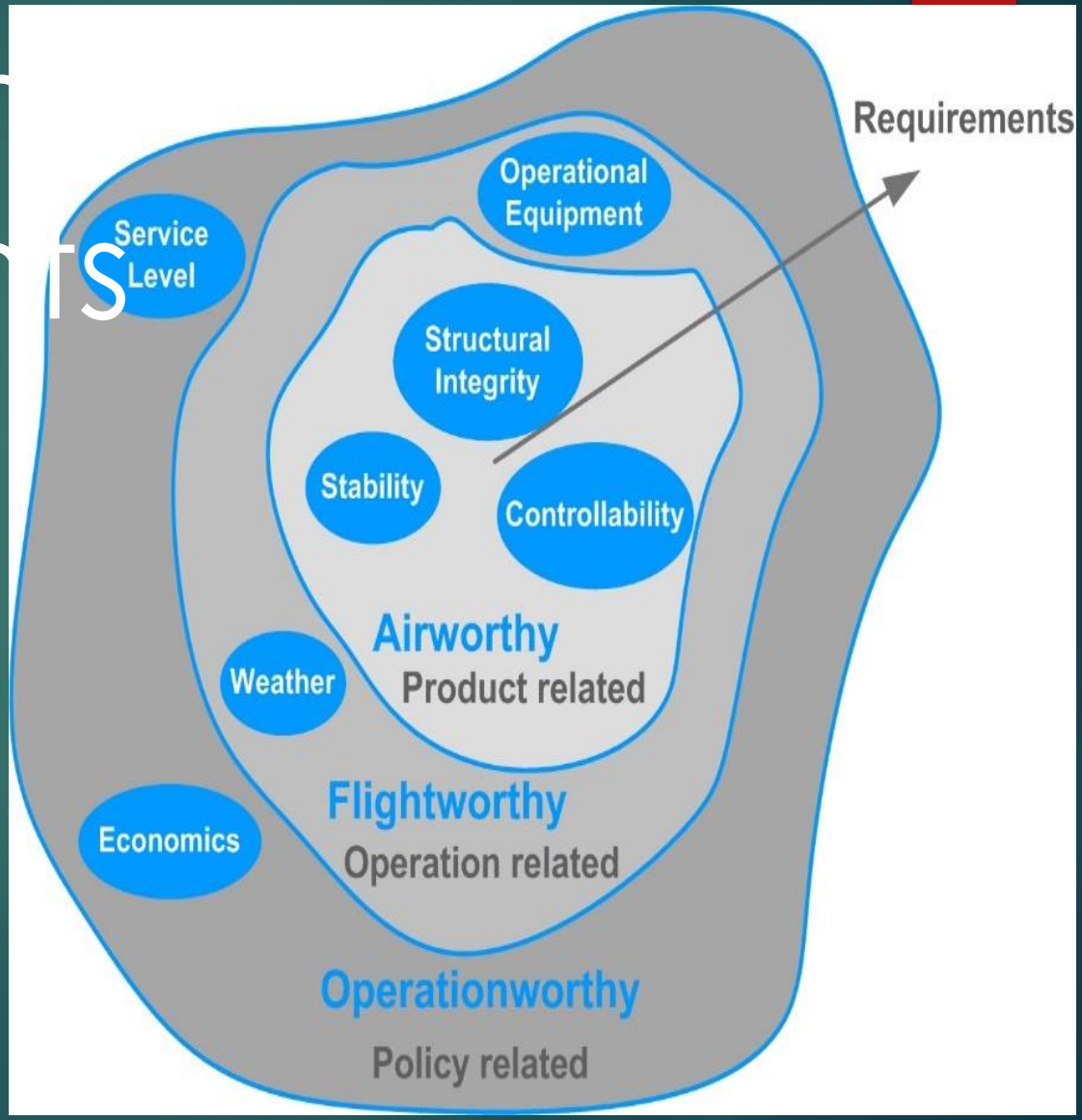
Transport specific demands

- 7/24 available
- Open access
- Time and space independent
- Public transport function
- Immediate demand supply synchronization

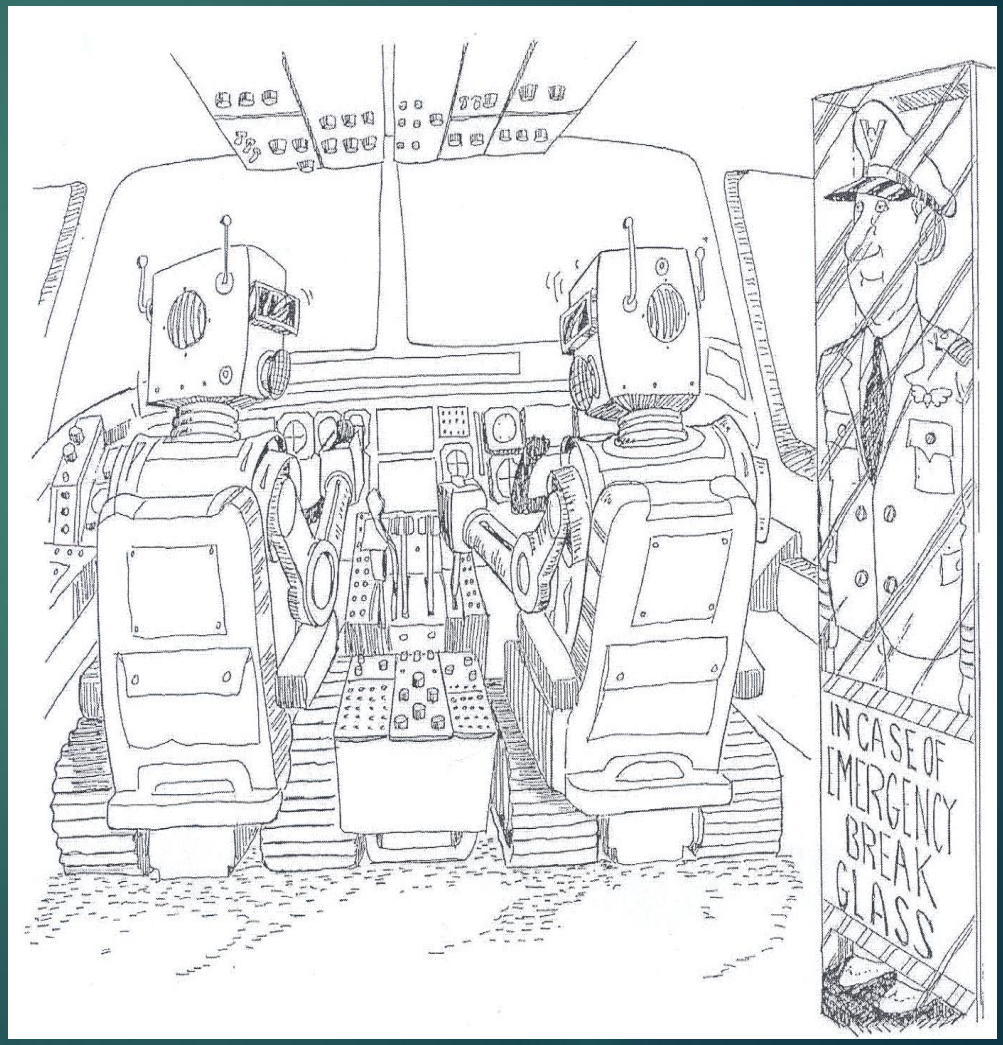
Available= reliable + safety

Conflicting interests: safety, economy and environment

Expandin constraints



Do the usual suspects suffice: Who is to blame?

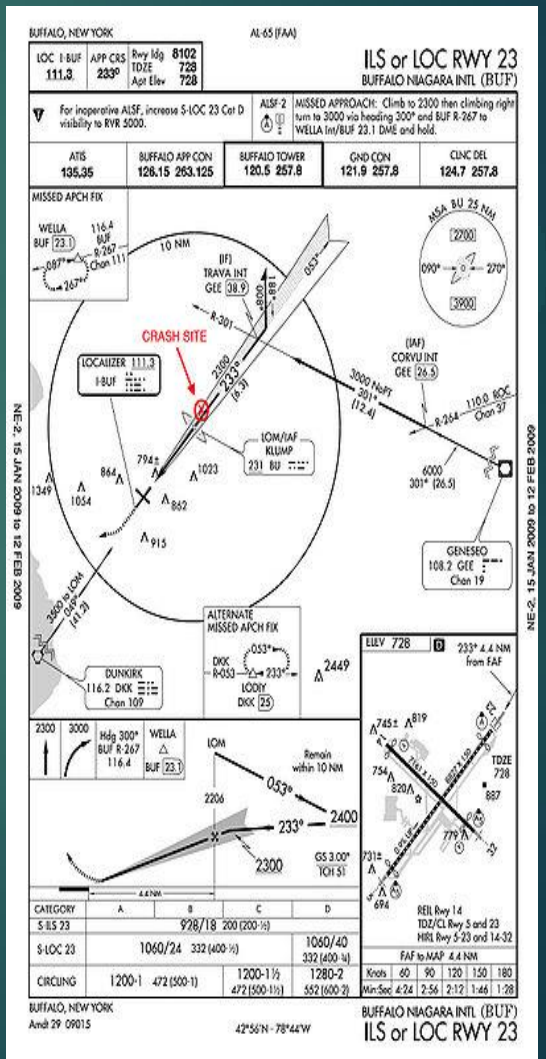


Pilots: heros or slaves?

Pilots RyanAir:
Fuel policy is life threatening
Deep rooted culture of fear

Colgan Air:
Fatigue and work cycles

Air India:
15% wage reduction



Flight Safety Information

April 21, 2014

Air China pilots warn flight safety under threat by unequal pay and lack of rest

Tensions in the cockpit partly fueled by 'highly' pay for


Hero or Villain?

But also opiniating issues

‘public perceptions’

‘framing the debate’

TWA 800

Lockerbie

Swissair 111

Mockups, a common reconstru


DUTCH
SAFETY BOARD


DUTCH
SAFETY BOARD
Final repor

Aviation since the millenium: a comprehensive and specific framework

Core notions and concepts:

- International institutional frameworks: ICAO, EASA, FSF, ISASI, ITSA
- Accident and incident investigation methodology: empirical evidence
- Precautionary measures: Good Airmanship, Standard Operating Procedures
- Safety Management Systems: operators, airports, governance oversight
- Victim and family assistance: legally based, organised by the flight numbers
- R & D Networks and programs: Horizon 2050

Engineering Design Methodology:

- Knowledge Based Engineering
- Value Engineering
- Multidisciplinary Design Optimization
- Technologically innovative and disruptive concepts

Conclusiones

Nothing left but

- Residual risks: LOC-I, CFIT, RE?
- Maintaining present levels: SMS, safety oversight?
- Fighting complacency: training, proficiency, recovery?

Or new notions?

- Higher order systems drivers: business models, Minsky
- Intuition, emotion and empathy: Slovic and Kahneman
- Innovation: 5th generation aircraft, composites, new configurations, new business models

And a new context?

Modern safety and risk assessment

Precautionar principle

- First control then comprehend
- From oversight to insight

The New View

- Human performance makes systems safe
- Investigative also from a user's perspective

Requires a specific methodology

- no metaphors but modelling
- Human performance in their socio-technical environment

uncertainty

Knowledge

Certain → Uncertain

Values

Agreement ↓ Contested

Problem: *Performance* Solution: *Quantification/calculation* ***Conventional Engineering*** ***Best practices***	Problem: *Information* Solution: *Analysis/techological innovation* ***Scientific Research and Development***
Problem: *Disagreement* Solution: *Coercion/discussion* ***Managing/mediation*** ***forensic sciences***	Problem:*Knowledge and consent* Solution: *Precaution/Crisis handling* ***Architecture*** ***System Integration***

Rol van de ingenieur-ontwerper: prospectie en preventie

- Garanderen zorg en borg in vroege fasen systeemontwerp en – ontwikkeling
- Reduceren onzekerheden
- Integreren maatschappelijke waarden in discussie en afwegingen

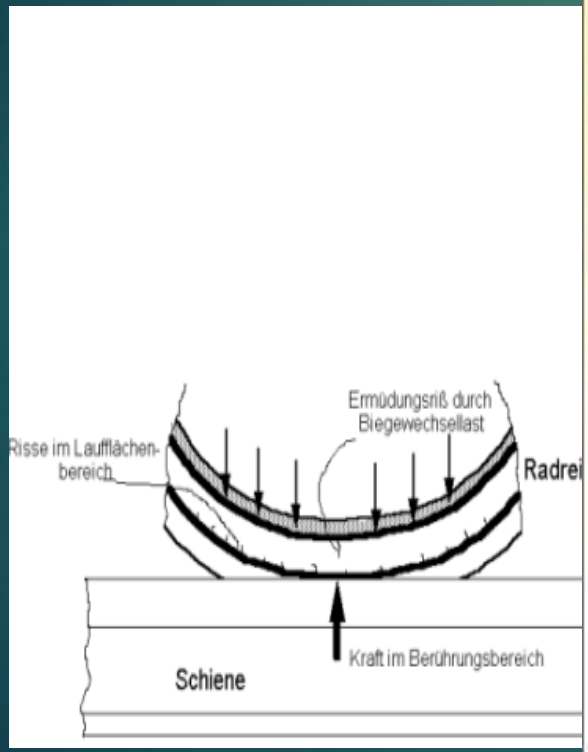
- Variation selection en voorkeursoplossingen (Vincenti: optimaliseren prestaties, reduceren onzekerheden, identificeren eigenschappen)
- Rol van innovatie: principes, aannames, vereenvoudigingen, design trade-offs

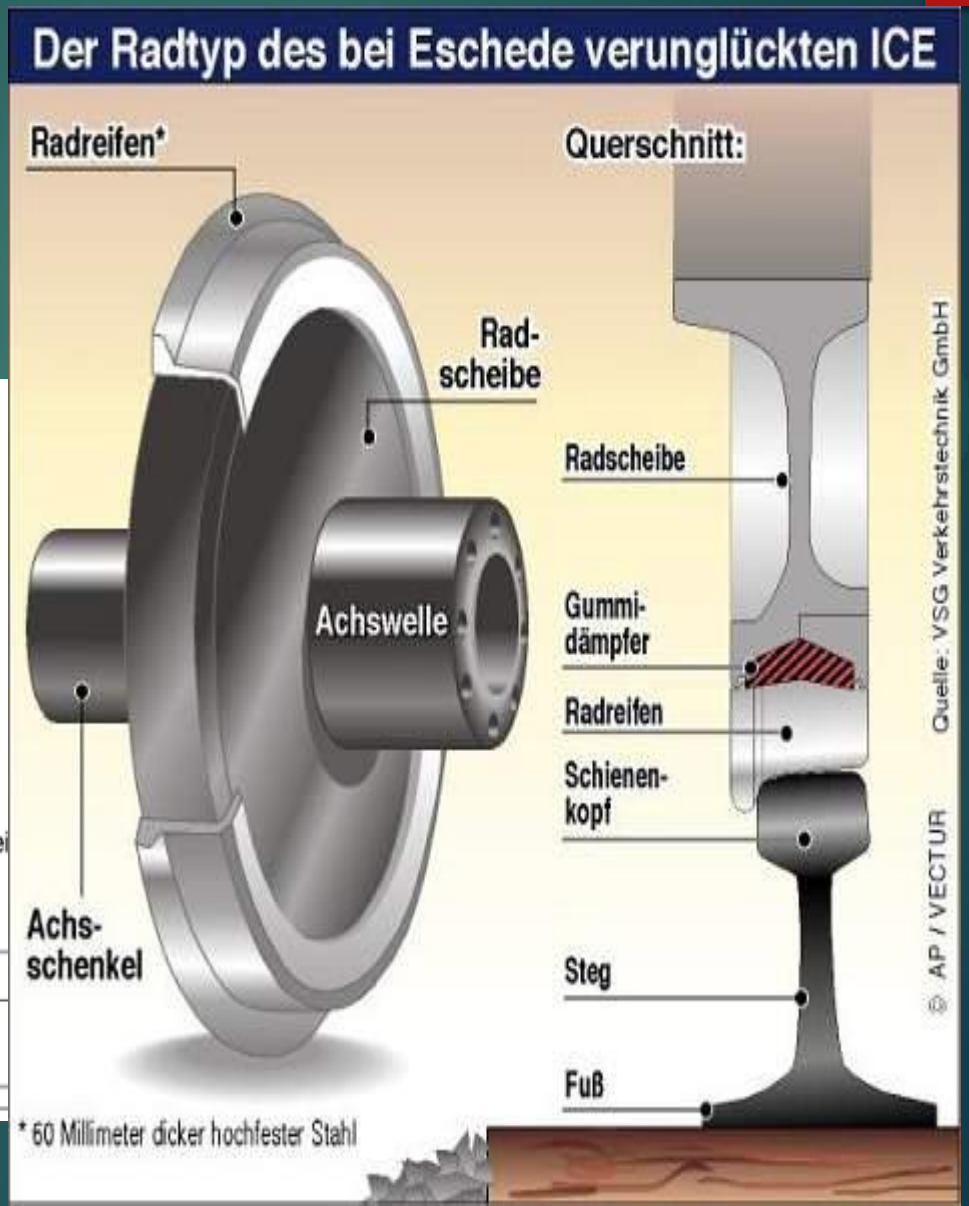
- Ethiek en professioneel oordeel: prestatie indicatoren, maatschappelijke waarden

Questions?

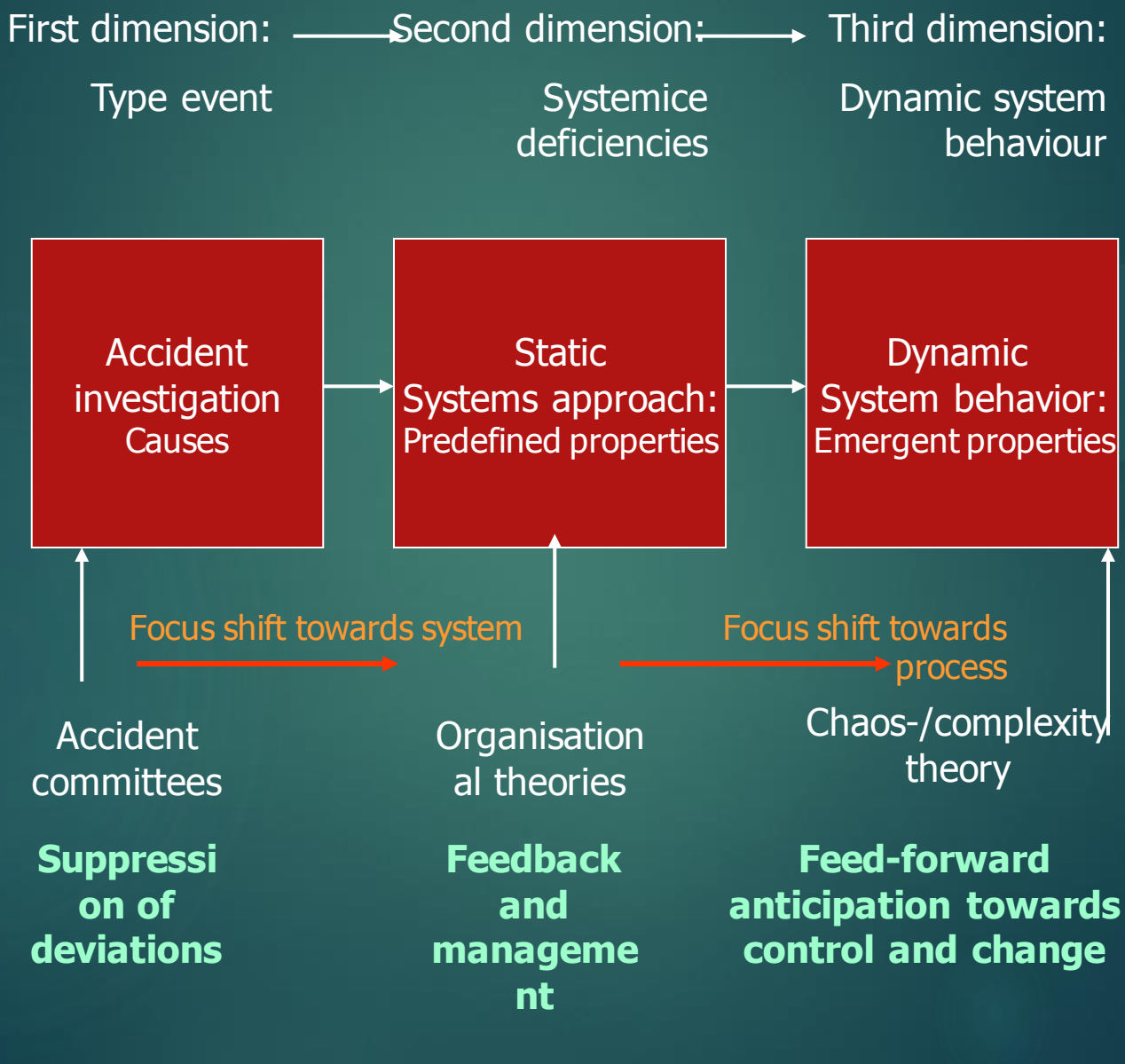
Catastrophic accidents

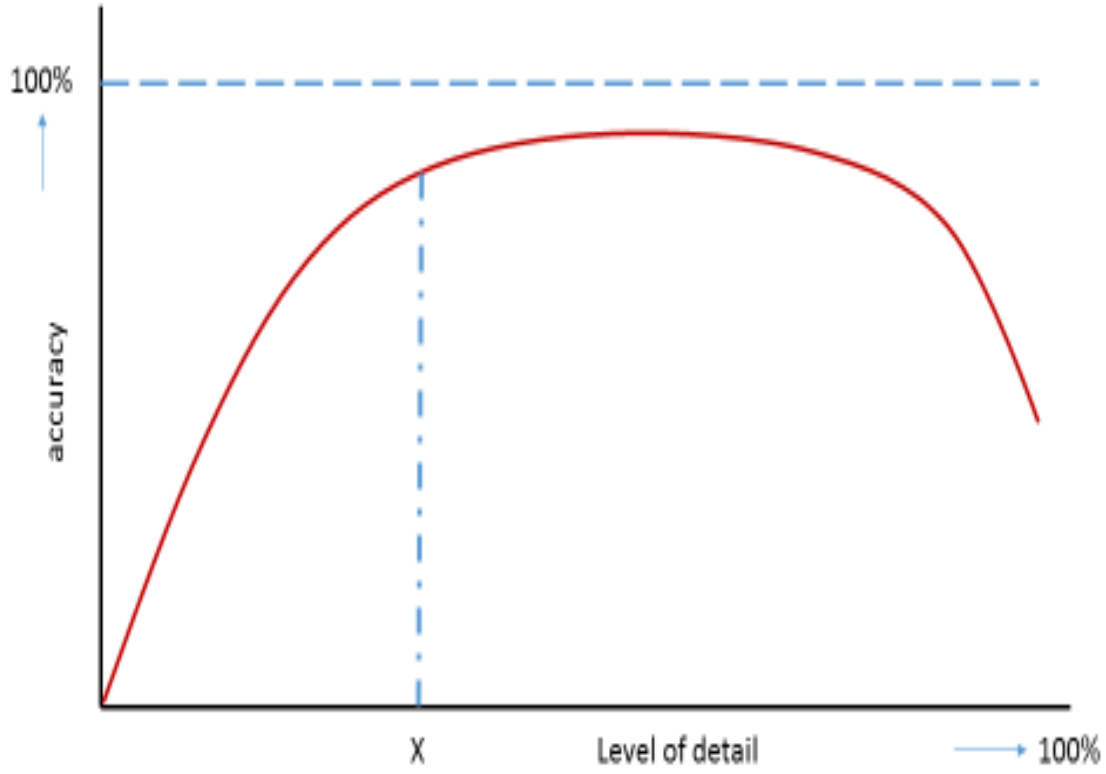
Wheel rim failure mechanism





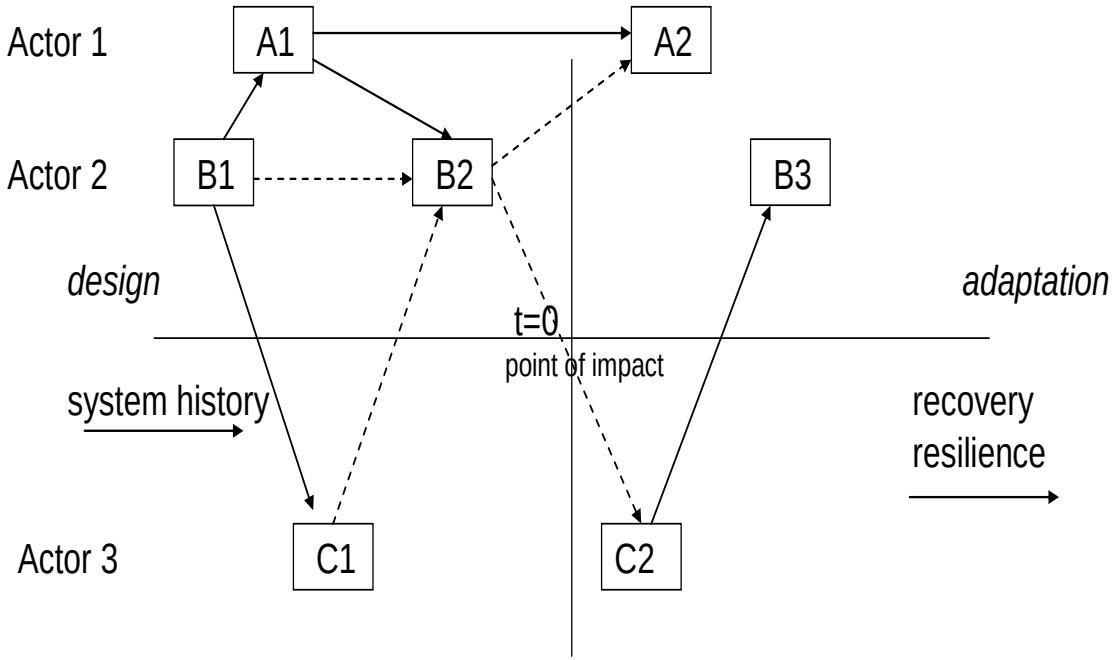
A third system dimension





Scope and level of detail in modelling complexity

Process flow chart



Look for the investigator among the researchers

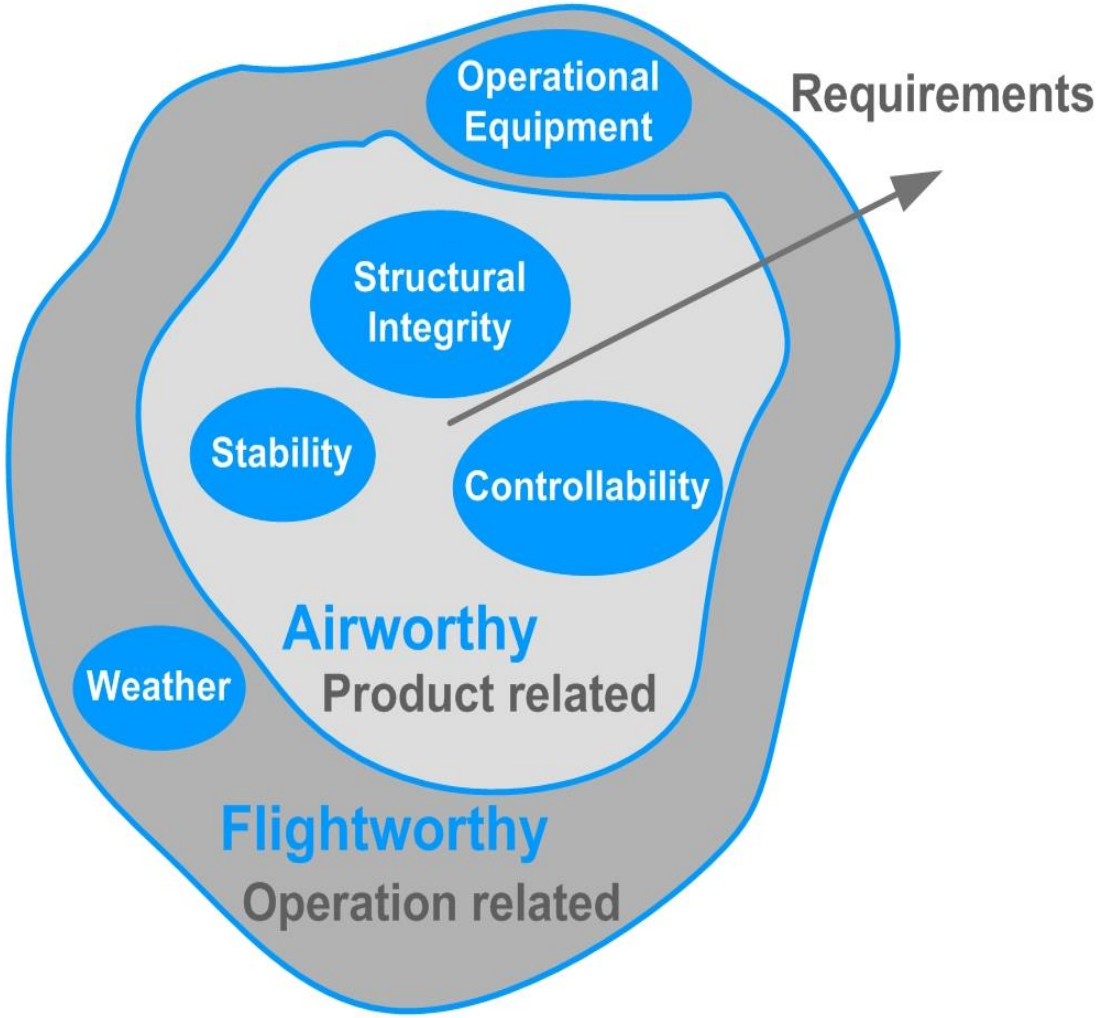
Critical design options: the B777 example

- no metal but composites
- flexible forms
- from flying tubes to flying ballrooms
- integrated functionalities within a monocoque
- higher cabine pressure: improved comfort, higher altitudes
- climate control: temperature, acoustics, freeze drying
- bleed air engines: heating and propulsion apu's
- fire resistant materials
- implementation of maintenance and automated control
- political financing
- custom build and user participation rather than line production
- daylight economy: travel time and distance per day
- alternatives in transport mode: TGV, congested automobile transport
- strategic choices in locating airports: catchment areas
- from hub-spoke towards free flight
- role of urban an spatial planning in developing networks and airport sites

Critical design options:
a technological analysis of aircraft concepts

- Single function allocation:
  - stability and control
  - propulsion
  - fuselage
  - aerofoils
  - landing gear
- Generations of derivates:
  - slender wings, reduced drag
  - aero elasticity
  - maintenance
  - fatigue
- Two generations of designers
  - generating concepts
  - maturing and optimizing concepts

From airworthy towards flightworthy



Objectivity and transparancy

- Focus not on blame ''Bad-apple Theory''
- Deal with complexity and system dynamics:

  ''No more cheese please''

Is there a ''Good Apple-Theory'' ?

Forensisc approaches:

= ***a broad range of disciplines*** *and the*

= ***ability to pursue several lines of investigation***

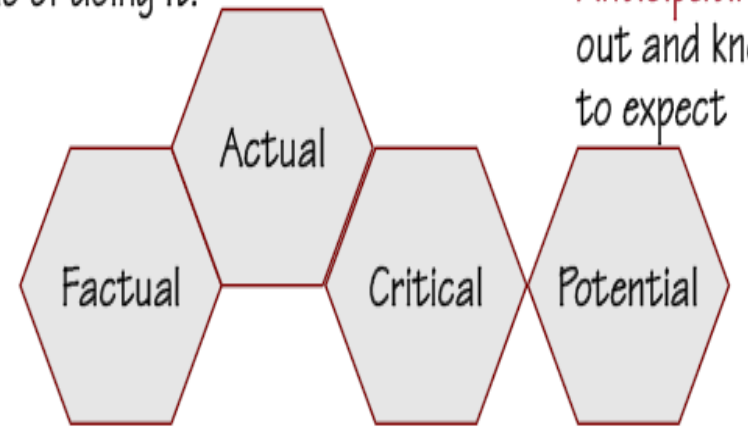
simultaneously.

The method of dimensions:

- ***structure***
- ***culture***
- ***contents***
- ***context***

Responding: Knowing what to do, being capable of doing it.

Anticipating: Finding out and knowing what to expect



Learning: Knowing what has happened

Monitoring: Knowing what to look for (attention)

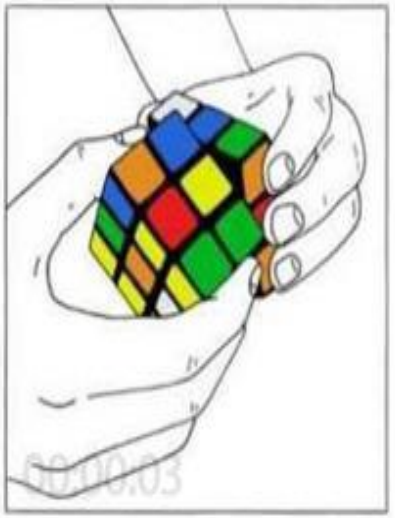
Resilience engineering measures how safe a system is by what it is able to do, hence measures of the positive rather than the negative.

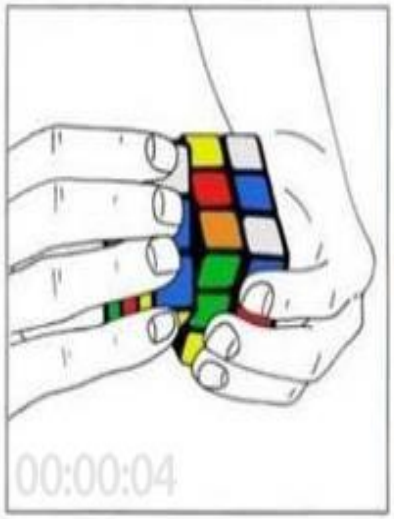
How to reduce complex problems

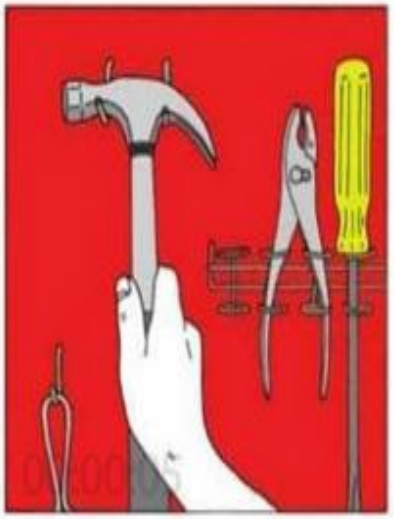
Collect facts

Compose event

Identify change variables







Synchronize system vectors Using algorithms

To create transparency

DC: transfer of risk

- Minimizing costs and accountabilities
- Transfer of focus from design to operations
- Hidden deficiencies are conceiled
- Safety is excluded from the PoR
- Degraded from business value to operational cost
- Separating occupational, process and product safety

DBFM: managing risk

- Safety focus is crossing life cycles
- Safety explicit in PoR
- Integral safety: combining all safety aspects
- Focus on guaranteeing availability: fines, accountabilities
- Responsibilities are with the consession holder/operator
- Safety becomes a strategic asset in risk management across economic life cycle

Risk management

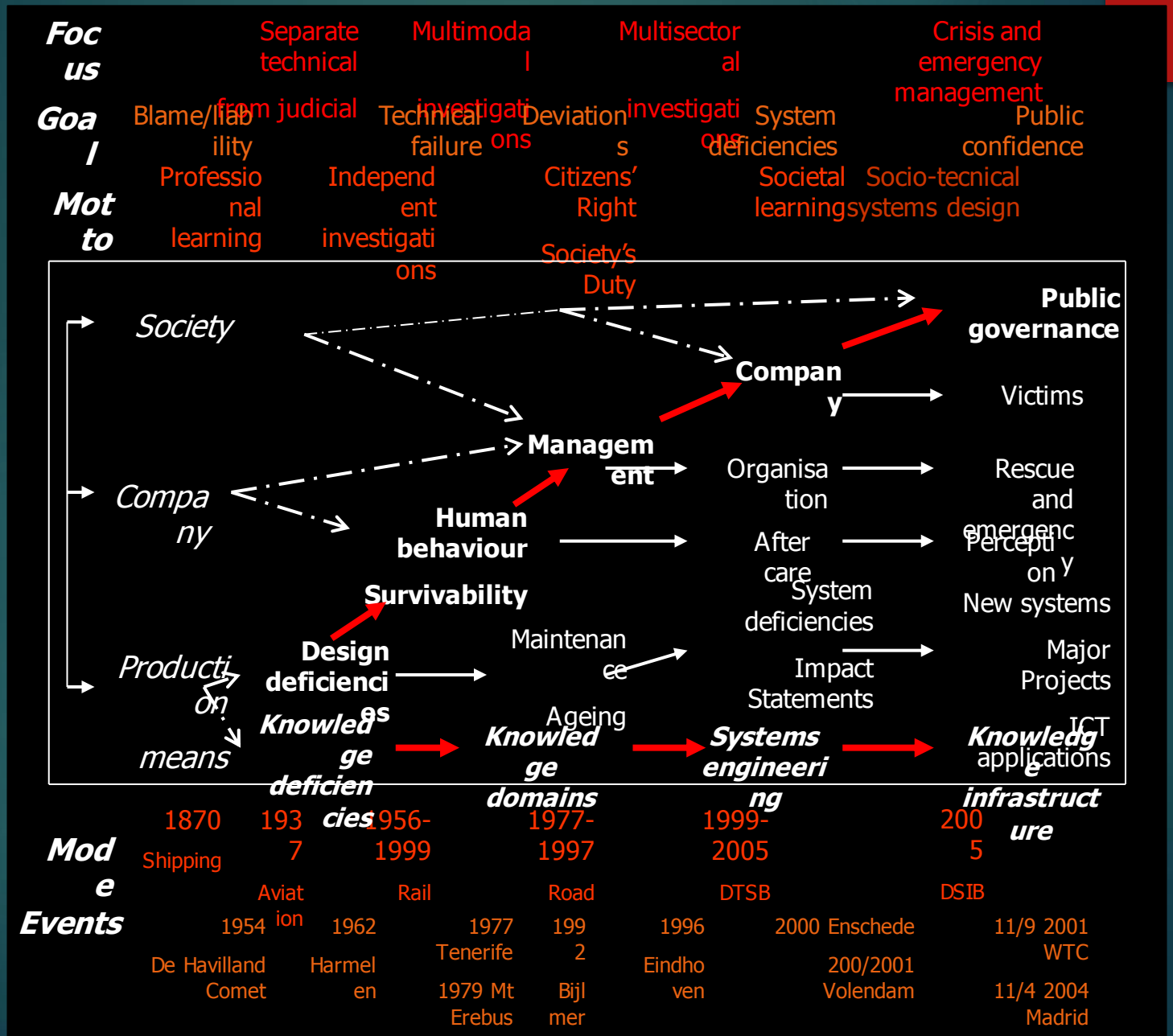
Managing risk by:

- Redundancy in critical components
- Quantitative failure prediction: FMECA
- Knowledgeable of failure mechanism: FTA
- Simulation: scale models
- Accident and event analysis

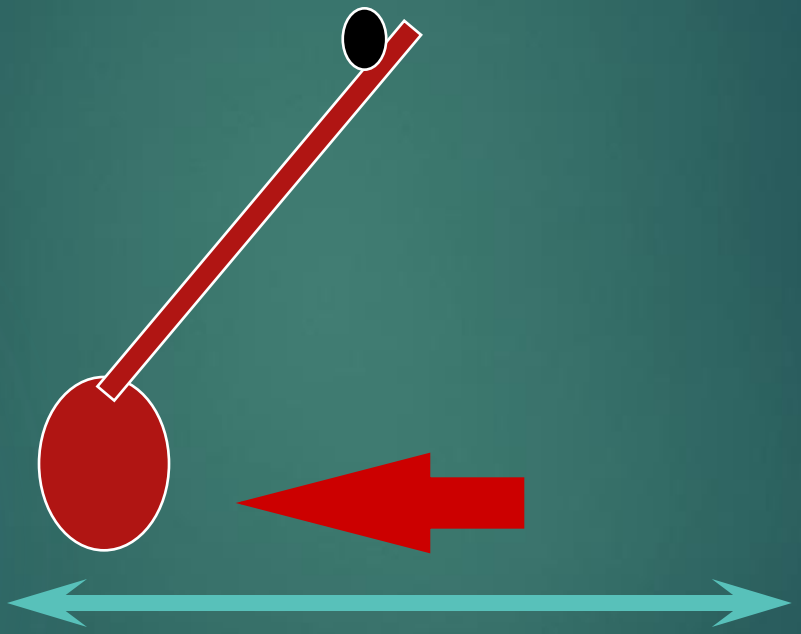
Cooperation: public private partnerships

- Openes and transparency
- Sharing information
- Oversight: role architect and prioritizing issues

Evolutionary development of TSB's



But has the pendulum swung too far?



Remote factors

Proximal factors

Changes in the methods and practices

A continuous debate:

Focus is shifting from blame to responsibility, from compliance to competences

Independence and international agencies

Multimodal or sectoral

Knowledge or perception, awareness based?

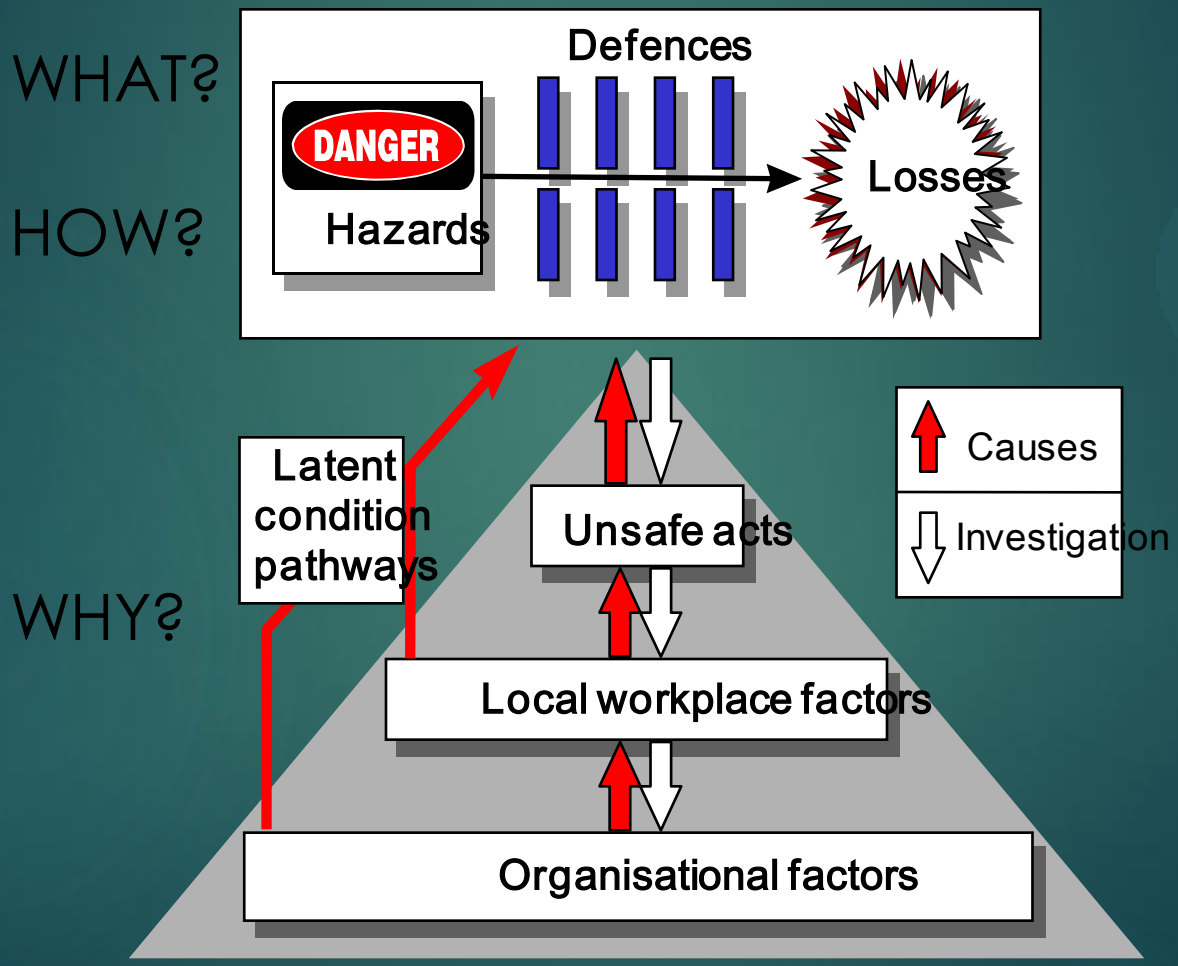
Are industrial sectors comparable?

Similarities: international context with common characteristics

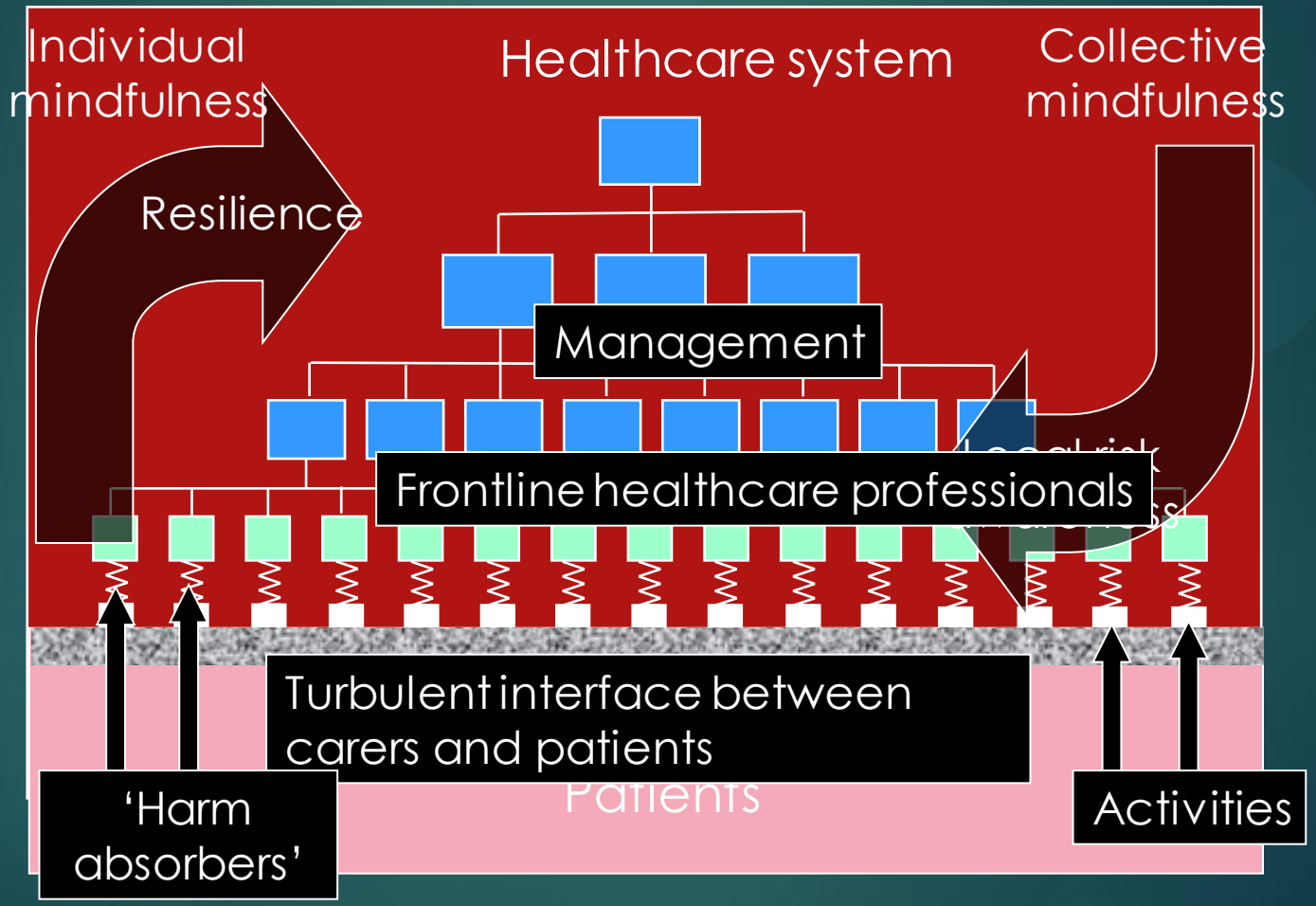
Differences: new entrants in the market, interoperability, new technologies, role victim organisations

Role of investigations pivotal: coping with both public faith, technology and market changes, serving three functions simultaneously

What? How? Why?
A retrospective process

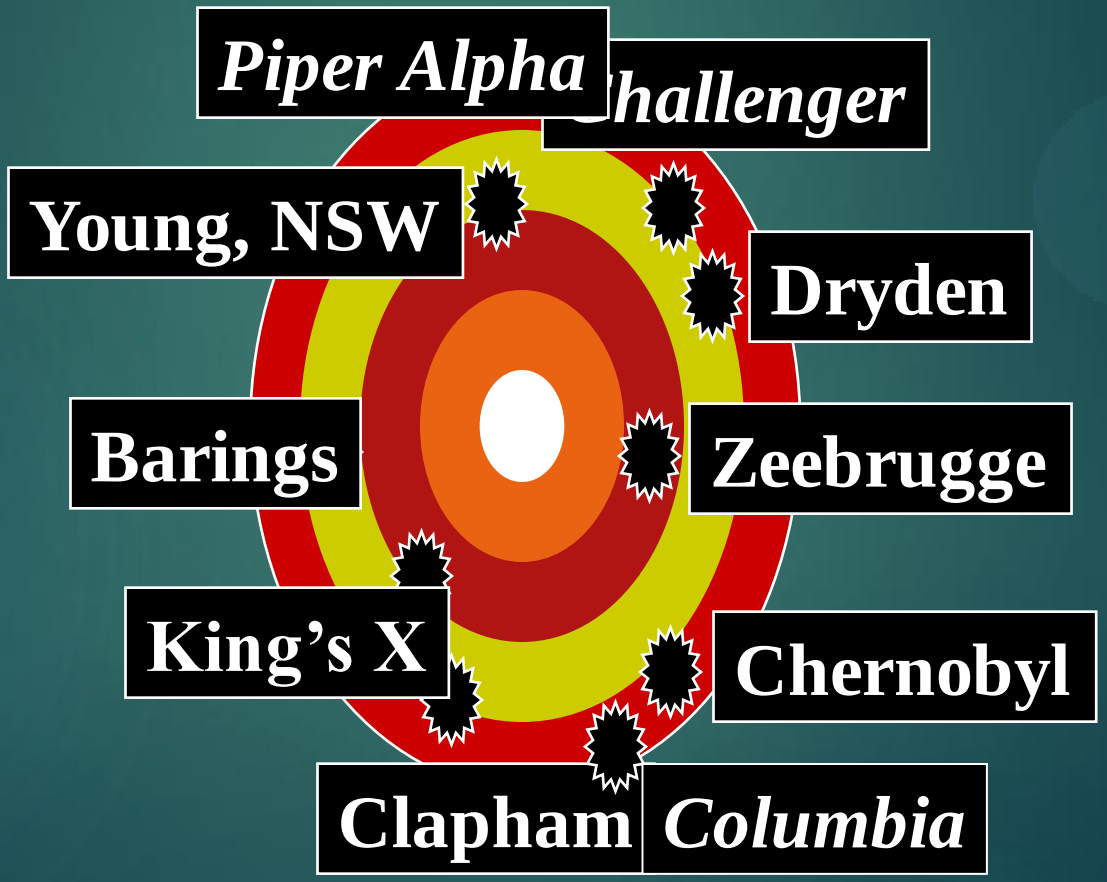


Integrating Person & System



Ever-widening search for the 'upstream' factors

Echoed in many hazardous domains

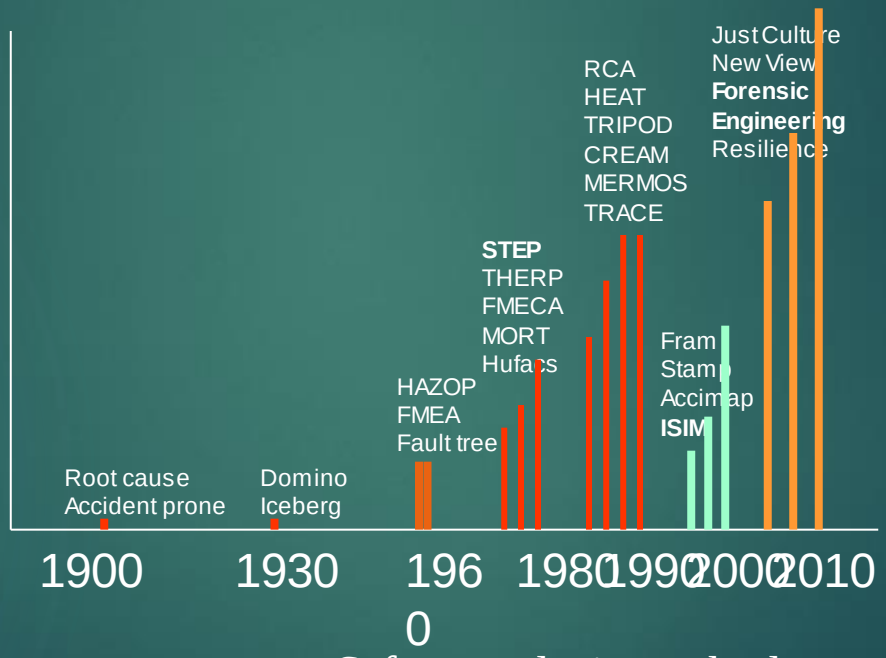


New interdependencies

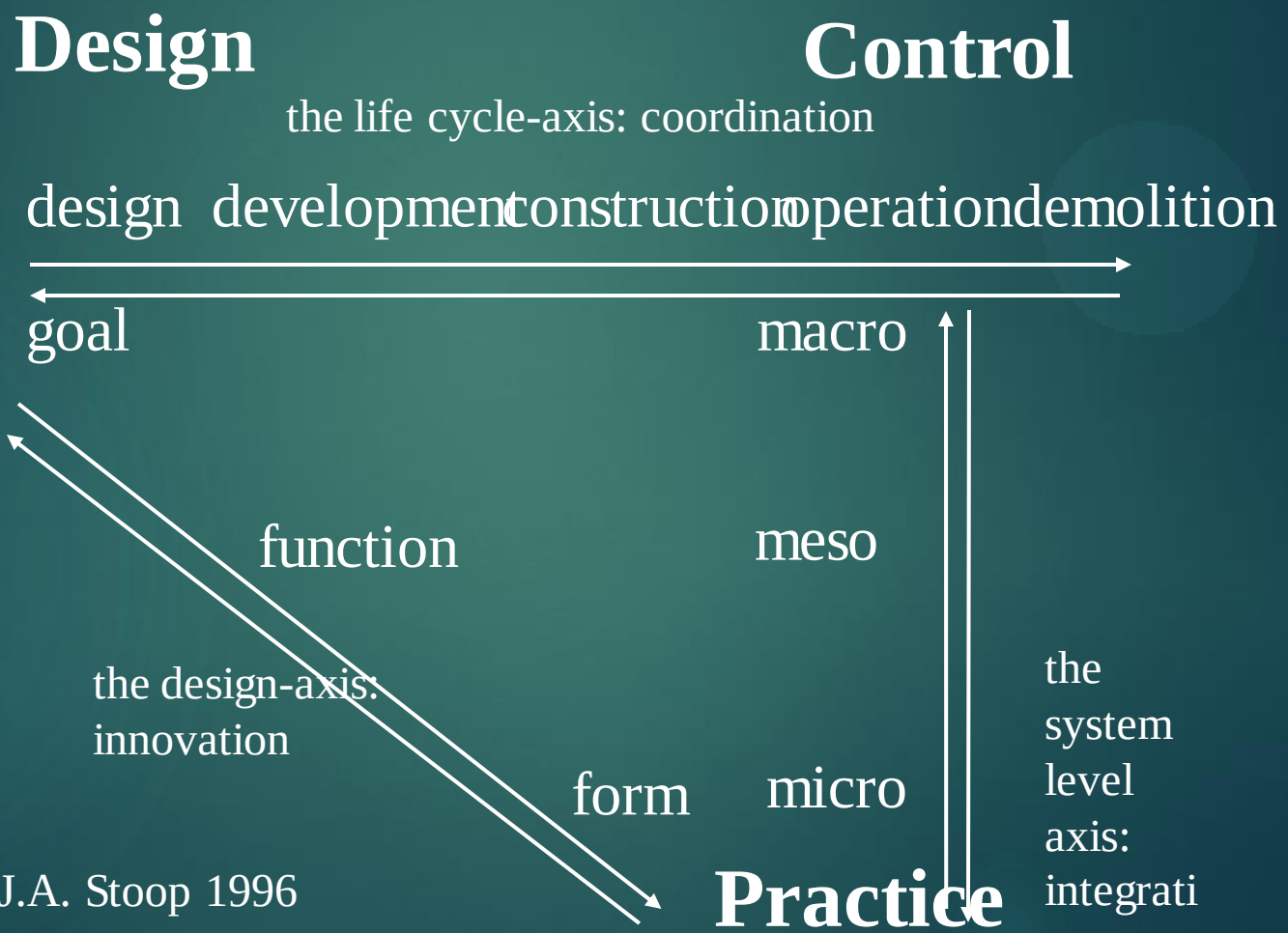
- Planned obsolencence: maintain oversight over life cycle components, materials, technologies
- Short term changes in public and political perception of societal values
- Feedback from reality instead of pre-emptive manufacturing quality control and certification
- Privatisation of collective, societal values: public services as corporate commodity
- Sensor and information technology dependency: ICT and monopolies as commercial assets
- Democratic participation: actor involvement in strategic decision making, trusts and kartels

Hollnagel

An ever expanding scala of approaches



The DCP diagram:
an engineering design framework and a multi-actor perspective



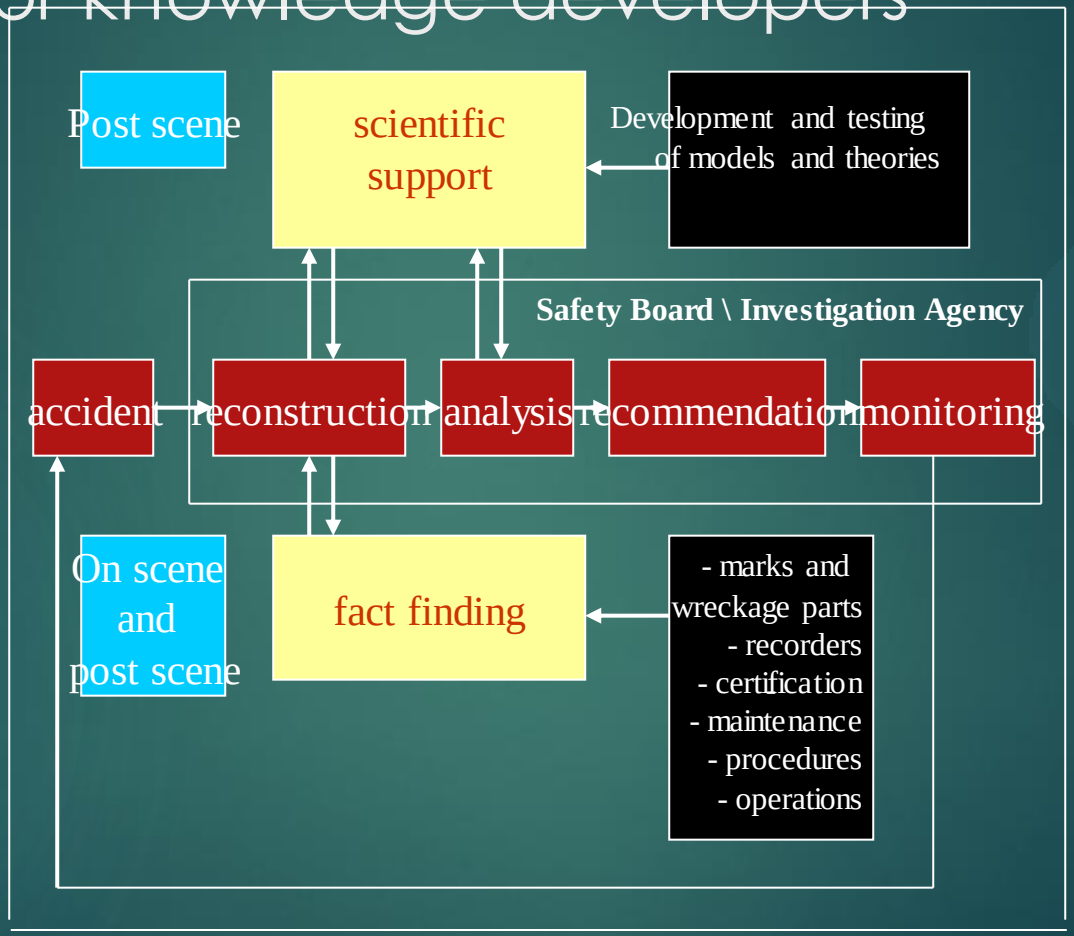
Societal challenges for safety 1/2

- Increasing growth: anticipating doubling traffic volume, Safer Skies initiative
- Law of diminishing returns: flattening the accident frequency curve
- Linear modeling of risk by R=p*c denies exposure and conditional probability
- Actor dependent risk perception: variance across stakeholders
- consequences are not only measured in terms of *Technical Safety*, but also in terms of *Prosecution and Liability, Public Safety* and *Victim Care and Compensation,* creating potential conflicts of interest

Societal challenges for safety 2/2

- Design and development assurance requires:
  = human performance is a dominant design issue
  = validation of safety assumptions in design and modification
  = safety data management and analysis
  = capture, sharing, dissemination and evaluation of lessons learned
  = no compromising of safety during repair and maintenance
  = timely detection and oversight of critical safety errors
- Certification, Operations and Maintenance focuses on a/c as principal component, but:
  = rare events have a high public/political profile and a critical impact on acceptance
  = prevention is the focus: zero defect and first time right
  = ATM, airports, environment are to be incorporated in the overall safety assessment

Acknowledges a specific role for safety Boards: problem providers for knowledge developers



Critical design options of aircraft concepts

- Technological evolution

  - from fabric and steel tubes towards aluminium monocoques
  - from radial/line engines towards jet engines
  - from 'flying crates' to cylindrical fuselages
  - from flying in the weather towards pressurized cabins
  - from dead weight control surfaces towards lift inducing fuselages
  - from all-metal towards composite materials
  - S-curve in technological development: 60 years of rise, 60 years of decline

- Incremental adaptation

  leads to replacement, innovation and optimization

- Shifting emphasis

  from aircraft towards airports and traffic control, multifunctional and integral design of subsystems

De Havilland Comet

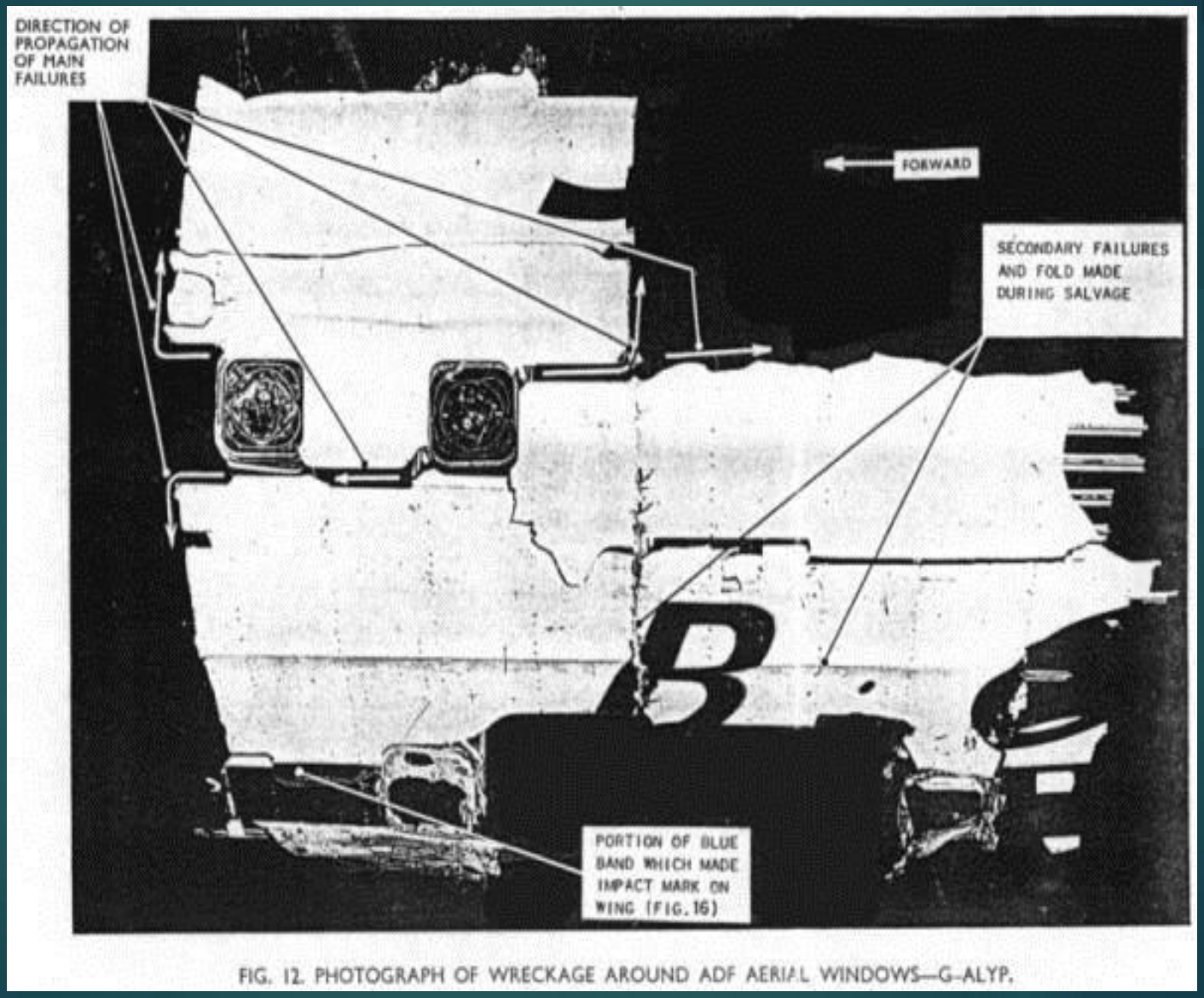
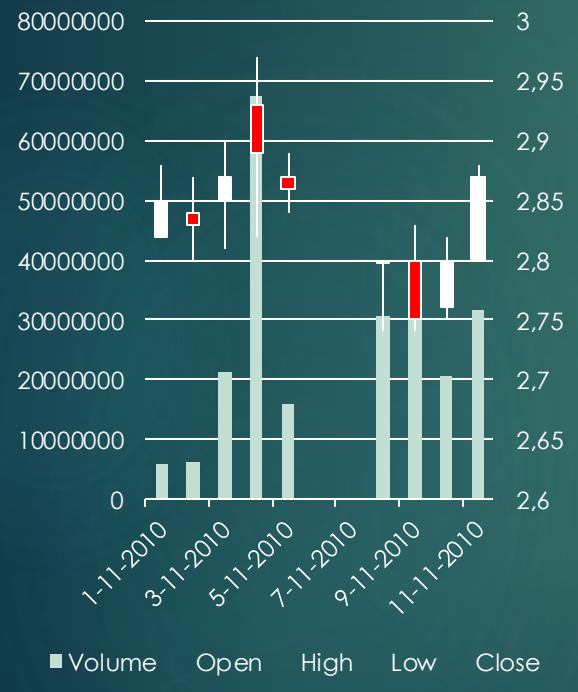


FIG. 12. PHOTOGRAPH OF WRECKAGE AROUND ADF AERIAL WINDOWS—G-ALYP.

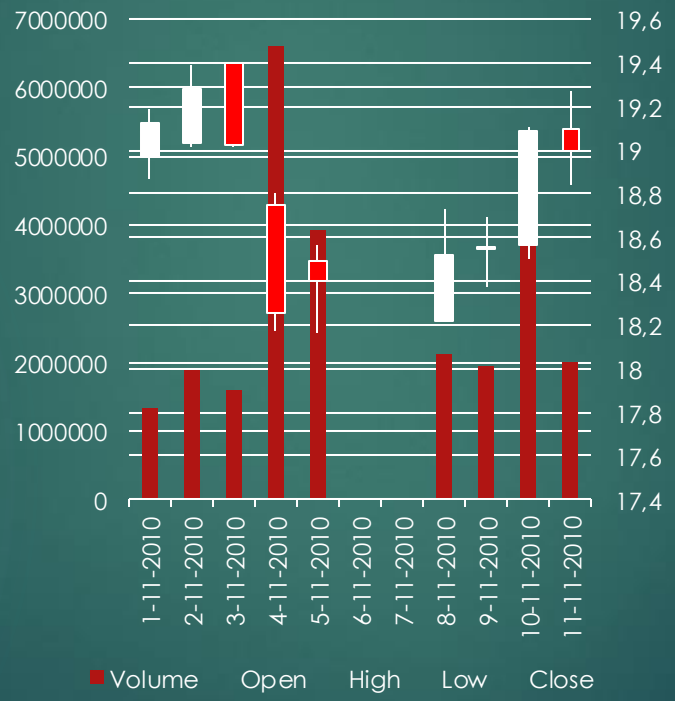
Boulton Paul Defiant

Share prices, impact on hig cu
A new dimension in
safety performance indicators

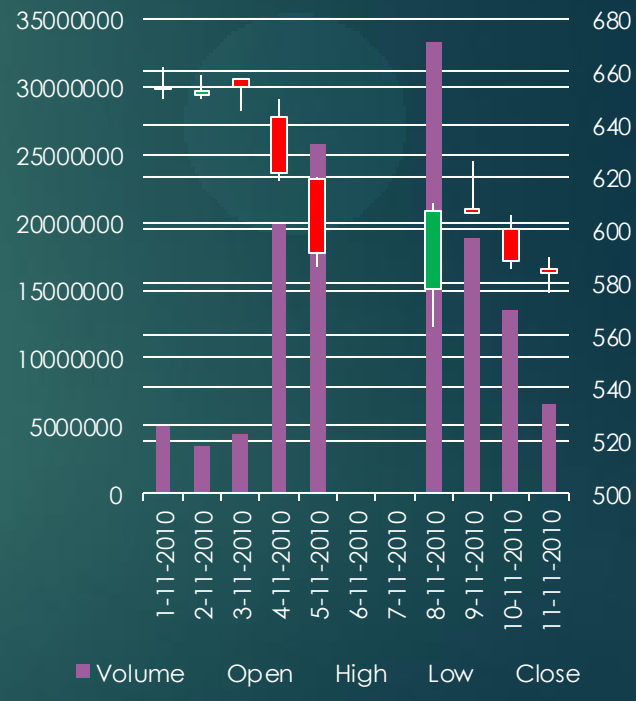
Qantas



Airbus



Rolls Royce



Decrease share price (lower close than open price)

The problem with ‘Sully’
Real life investigators object to portrayal in ‘Sully’ movie

September 8, 2016

And destroying a reputation

We’re not the KGB. We’re not the Gestapo,” said Robert Benzon, who led the National Transportation Safety Board’s investigation. “We’re the guys with the white hats on.” The film, scheduled for release in theatres on Friday, portrays

Tom Haueter, who was the NTSB’s head of major accident investigations at the time and is now a consultant, said he fears the movie will discourage pilots and others from fully co-operating with the board in the future. “There is a very good chance,” said Haueter, “that there is a segment of the

A dedicated scientific basis

Forensic sciences:

(conform a combined definition of Carper, Barnett en Noon):

Forensic sciences comprise of the science, methodology, professional practices and engineering principles involved in diagnosing accidents and failures. The determination of the causes of failures require familiarity with
a broad range of disciplines,
and the
ability to pursue several lines of investigation simultaneously.

The objective of the investigation is ***to render advisory opinions to assist the resolution of disputes*** *affecting life or property.*

Intrinsic focus on safety

Serving two masters:

- First Time Right, Zero Defects
- Citizen's Right and Society's Duty

Timely transparency in the factual functioning of systems:

- Not only descriptive variables, but also explanatory variables
- Control and change variables for system change
- Identification of knowledge deficiencies