Department of Mechanical Engineering
Marine and Arctic Technology
Research Group on Safe and Efficient Marine and Ship Systems (SEMSS)
Risks and Intelligence in Marine Systems

MEC-E3004: Safety Management in Complex Sociotechnical Systems

Basic Concepts: Human Factors & Safety Management

Aalto-yliopisto
Aalto-universitetet
Aalto University

Douglas Owen

douglas.owen@aalto.fi

MA (Psyc), DipGrad (InfoSci), BA (Psyc)

09 March 2023

Espoo

Learning Objectives

Think differently about safety, safety management, incidents and accidents

- Understand basic human capabilities and limitations
- What human factors is and why it matters for safety management
- GEMS human error framework and applications
- Understand some challenges in modern safety management

In safety management,
HF is *not more important* than
everything else,
it is *as important* as everything else

Aeroperú Flight 603: October 1996

Synopsis

- Boeing 757-200 crashed into the sea off the coast of Lima, Peru
- Spurious cockpit indications and windshear warning
- Just prior to impact cockpit indications were contradictory
  - Airspeed indicated 0 (false)
  - Overspeed warning (false)
  - Control column “stick-shaker” stall warning (true)
  - Altitude indicated ~10,000 ft AMSL (false)
  - Audio ground proximity warning (true)
- Night time flight over water with some fog
  - No visual cues of altitude or airspeed
- Flight crew became confused from false indications

Outcome

- All 61 pax and 9 crew were killed by the impact or drowning

Aeroperú Flight 603: October 1996

Errors:

- Failure to remove tape from the 3 static ports on left side following cleaning & polishing (right static ports not recovered from seabed)
- Wrong tape was used (low visibility silver masking tape)
  - – Placing tape over the static ports is part of the cleaning procedure
- No supervisor inspection before work signed off
- Pilot failed to spot tape during pre-flight (night time)

Aftermath

- Airline went out of business
- Maintainer jailed for 2 years

1. Introduction to human limitations & capabilities

Human capabilities & limitations

Human capabilities and limitations affects all of us all the time

Often easier to think about physical capabilities and limitations than cognitive

- Simply because they are visible

What is happening inside our heads is more complex and harder to know

- Hidden, unknown or wrongly assumed not to exist

Evolution, our brains & us

Homo sapiens' crowning achievement ...

…We're not extinct, yet!

How did this happen?

- We are only just smart enough (and lucky enough) to avoid dying out
- But then so are …

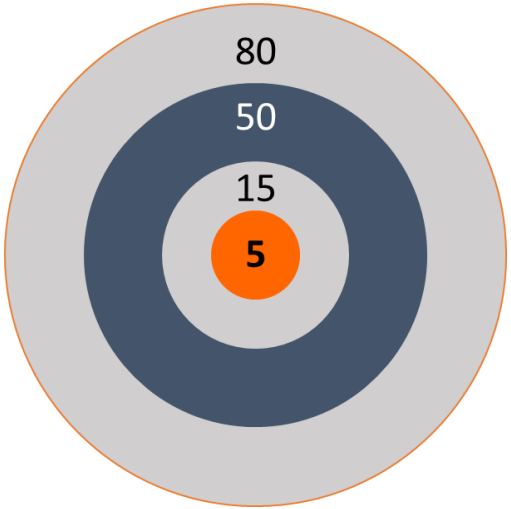
Cognition & evolution

The world is different now …

... but our brains are still the same

Dunbar's number:

- Relationships maintained with about 150 people – **5 are intimate**
- **Cognitive limit** to the number of relations that anyone can maintain
- People with whom you have a **personalized relationship**, one that is **reciprocal** and based on **trust**



Consistent for about 250,000 years

Path of Least Effort: Desire Lines

We seek out the path of least effort to meet our immediate goals

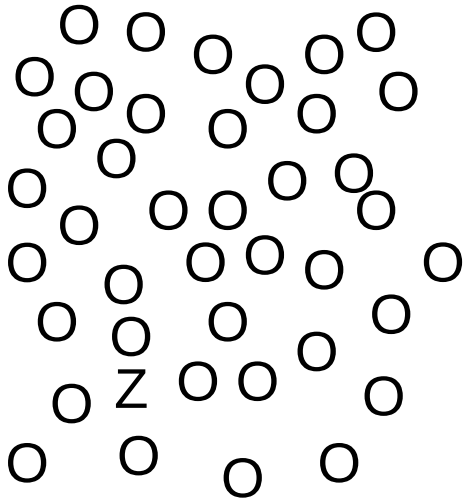
What matters, right now

Context changes everything ... How would rain change behaviour in this system?

Exercise

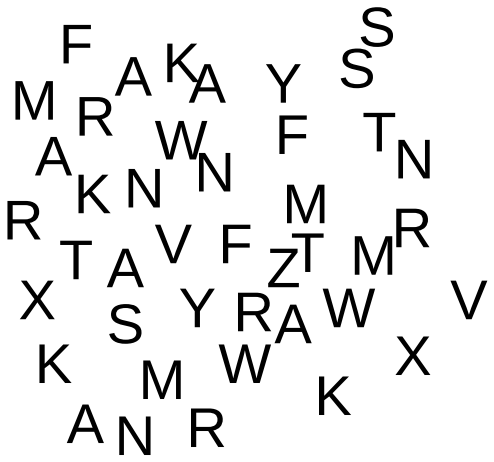
Follow the instructions at the top of the screen

Put your hand up when you find the “Z”



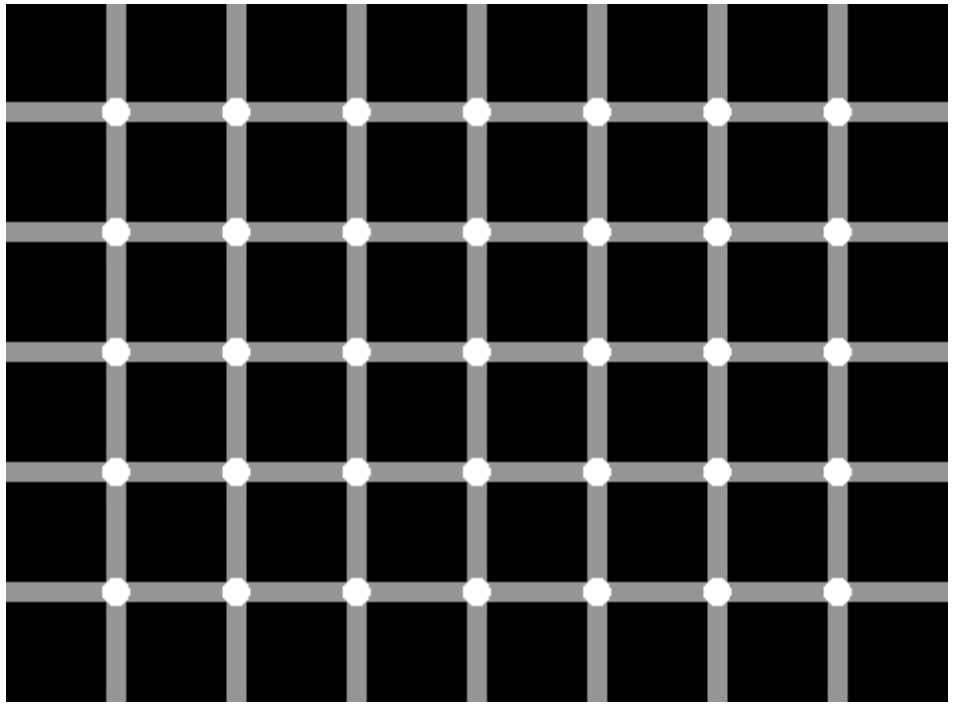
Source: Roediger et al (1991), p437

Which letter only appears once? Put your hand up when you find it

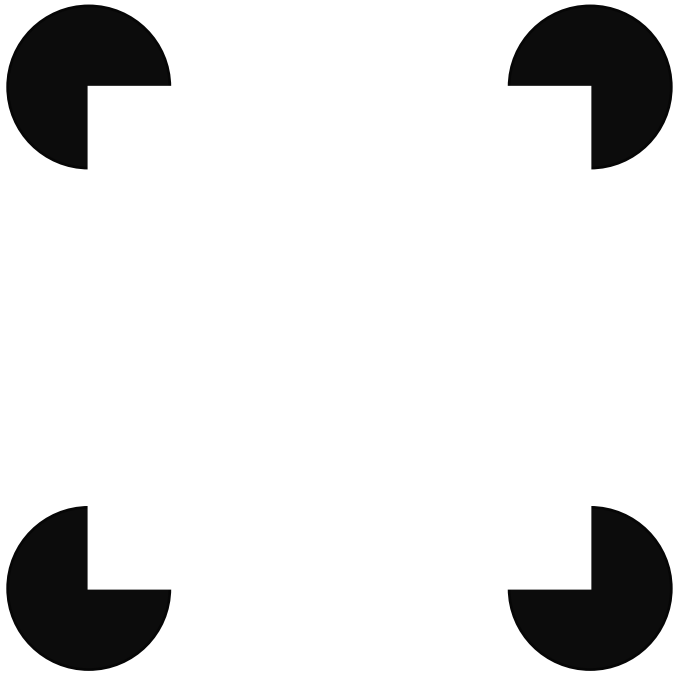


Source: Roediger et al (1991), p437

Count the black dots



What shape do you see?



2. What is human factors?

We cannot change the human condition, but we can change the conditons in which humans work

James Reason

HF discipline: Systems view

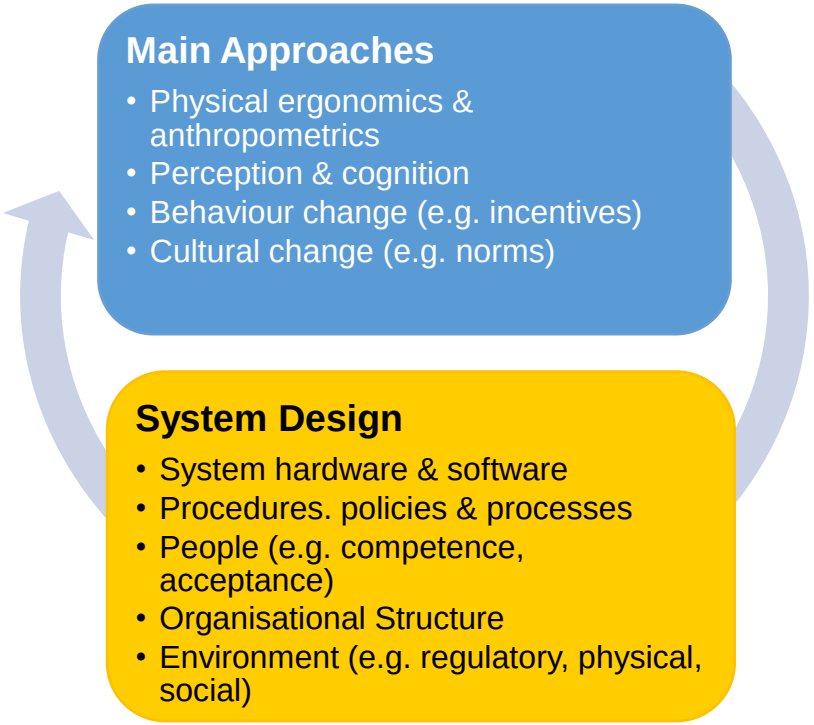
"HF contributes to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people."

[Adapted from Karwowski – 2012]

How?

"Use knowledge about human abilities and limitations to design systems for safe, efficient and comfortable use"

[Adapted from Salvendy – 1997]



Human Factors in a nutshell

IF

Hardware: Systems & equipment

+

Environment: Task, organisational, regulatory, social

+

Software: Task, procedures, role & responsibilities

<

People: Users' physical & mental capabilities

System Cost

Reliability

=

Performance

Effectiveness

Efficiency

Safety

Aalto-yliopisto
Aalto-universitetet
Aalto University

HF Expertise ... Everything Matters

Sociology
- Culture
- Organisational / Team Behaviour
- Sociometrics
- Social Systems & culture
- Change management

Psychology
- Cognition
- Behaviour
- Stress management
- Psychometrics

Physiology / Medicine / Anatomy
- Physical workload
- Biometrics
- Sleep / rest
- Nutrition / health
- Effects of human body

Industrial Engineering
- Work environment measurement
- Tool gap analysis
- Task & job design
- Task sequencing

Human Factors Engineering
- Human tasks
- Human machine interface
- Work environment

Organisational Development
- Manpower management
- Division of labour
- Authority & decision-making
- Leadership

Instructional System Design
- Science of learning
- Concept formation
- Knowledge & skill metrics
- Competence management

***Anything* that affects human performance**

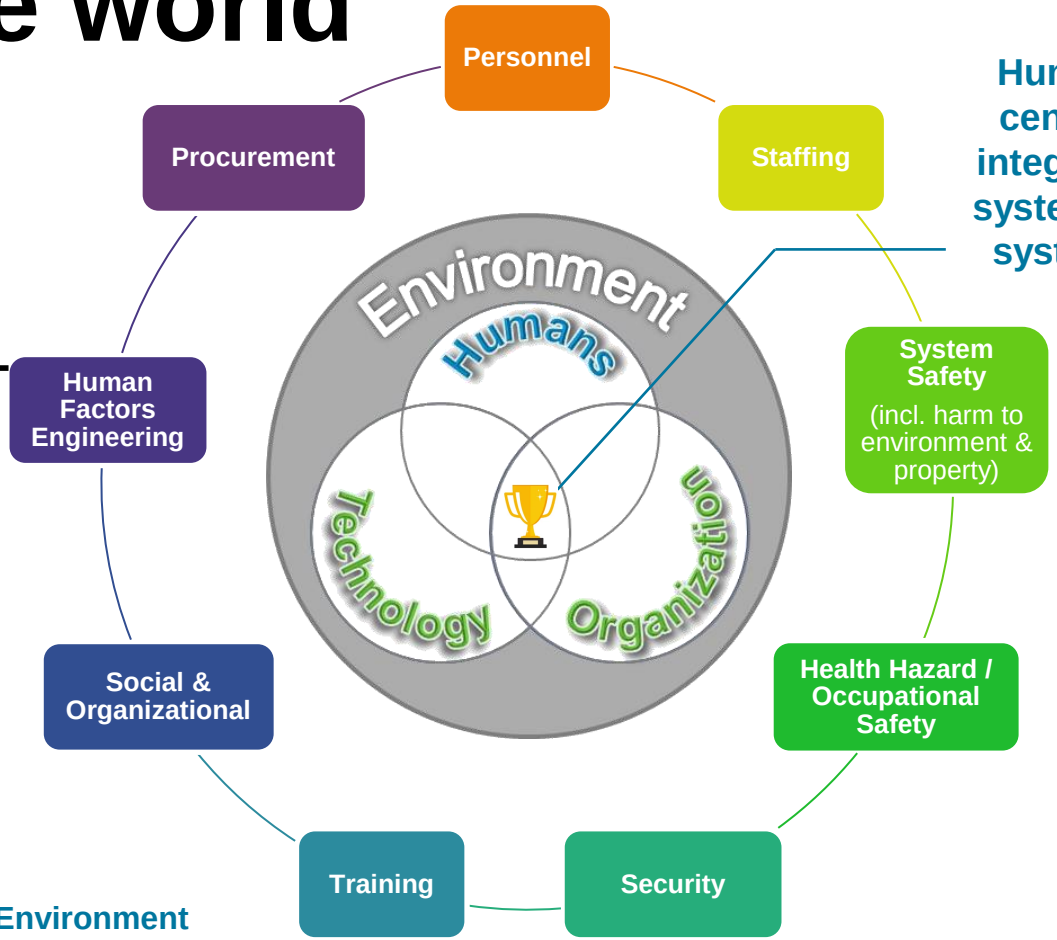
HF view of the world

H-T-O – lens that represents the world (and safety ecosystem)

Makes complex problems solvable – understand and balance needs

Applies equally to individual tasks and entire organisations and industries

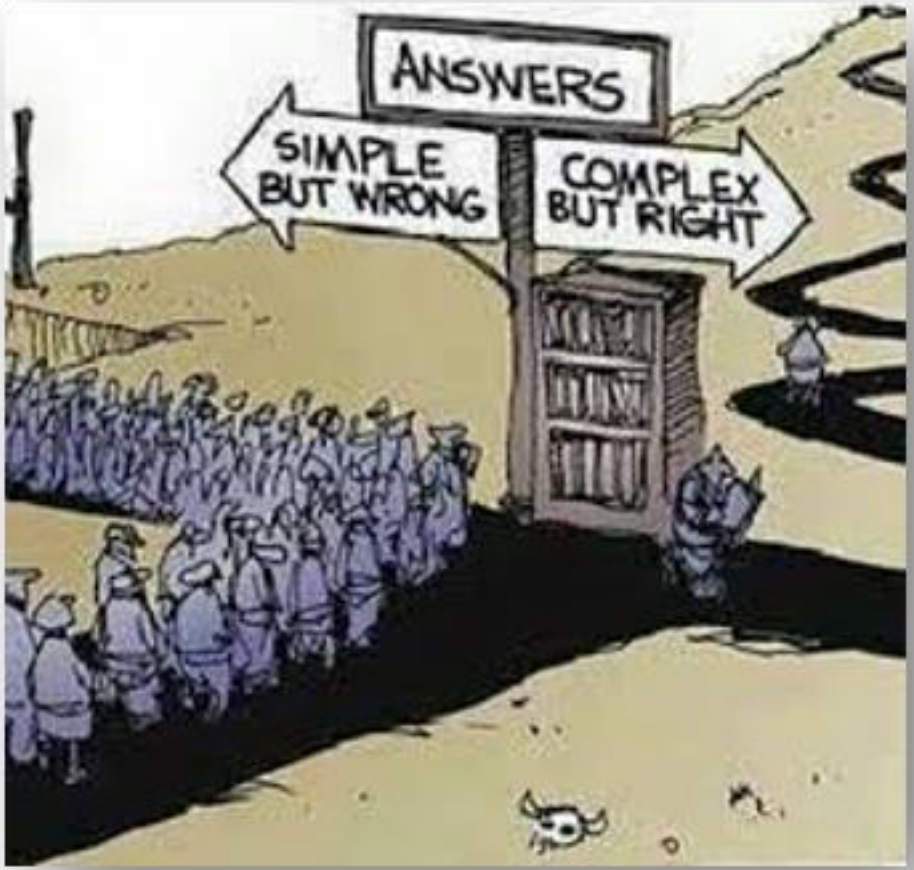
Understand how each element affects all the others to generate safety … or accidents



Human-centred integrated system-of-systems

*** Environment includes regulation**

Adapted from Karltun et al. (2017)
HFIDTC (2012)


ANSWERS
SIMPLE BUT WRONG
COMPLEX BUT RIGHT

3. Human error framework and applications

We are fallible

Human error is normal, foreseeable and manageable

Why is human error important?

Human errors tell us something important about our system and organization

Mismatch between human capabilities and what the system demands of them

- Window into the Performance Shaping Factors (PSFs) and ”error traps” in the system

- Trends: Increased rates of error with less severe consequences can tell us that our system is stressed and may be drifting into failure (Lay & Wreathall, 2008)

Human Error Definitions

Many definitions of human error available - no universally accepted definition

"A generic term to encompass all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures cannot be attributed to the intervention of some chance agency"

Reason, 1990, p. 9

Human error refers to something having been done that was "not intended by the actor; not desired by a set of rules or an external observer; or that led the task or system outside its acceptable limits". In short, it is a ***deviation from intention, expectation or desirability****.*

Senders & Moray, 1991 p. 35

IMPORTANT: Notice that **no blame or fault** is implied in these definitions

Everyday error traps

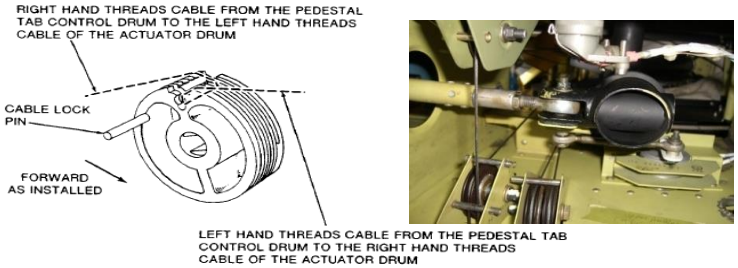
No mapping between controls and system layout

Prominent handle to pull filing cabinet used in error when trying to open the draw – the much more frequent operation

“Norman door”: Handles indicate pull when doors are pushed to open

Error traps in aviation

Beech 1900D
- Forward elevator trim control cable replacement
- Trim cable can be reversed on trim cable drum

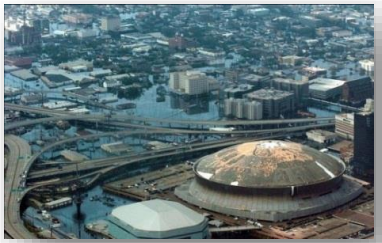


BAE 146 / L1011 Tristar
- Omission to install the O-ring seals on the magnetic chip detectors on all engines
- Omission not evident to maintainer

A320
- Failure to secure fan cowl latch
- Ambiguous feedback of latch state

Endless examples …

Fukushima



Katrina

Bhopal

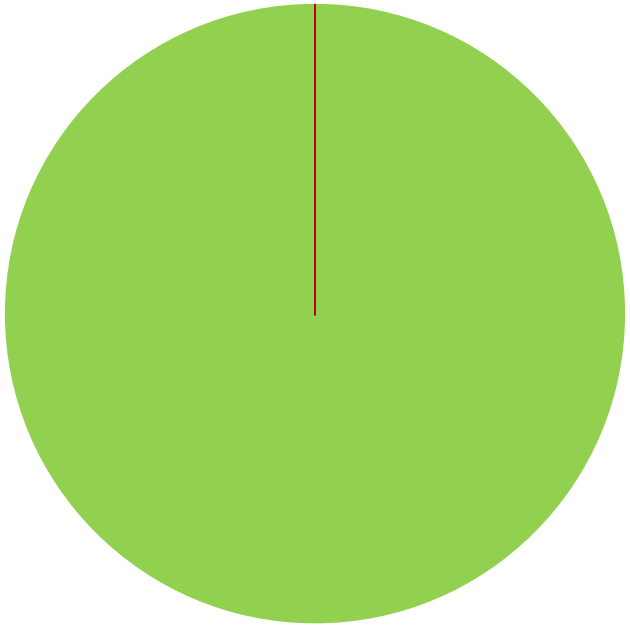
Challenger

Gloucestershire

USS Vincennes / Iran Air Flight 655

The good news …

We succeed far more often than we fail!



1 failure in 10,000 events

9,999 successful events

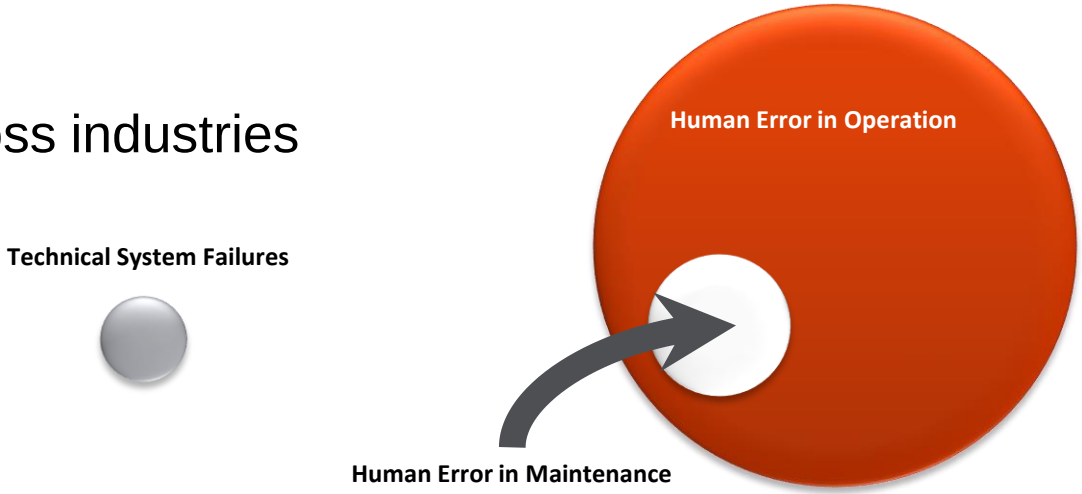
Aalto-yliopisto
Aalto-universitetet
Aalto University

Hollnagel, 2012

The bad news …

Human error is a dominant factor in approximately 80 to 85% of accidents in all high-hazard industries – most are initiated by human error, and the rest will be associated with human error (McCafferty & Baker, 2006)

Consistent across industries



Human error across industries

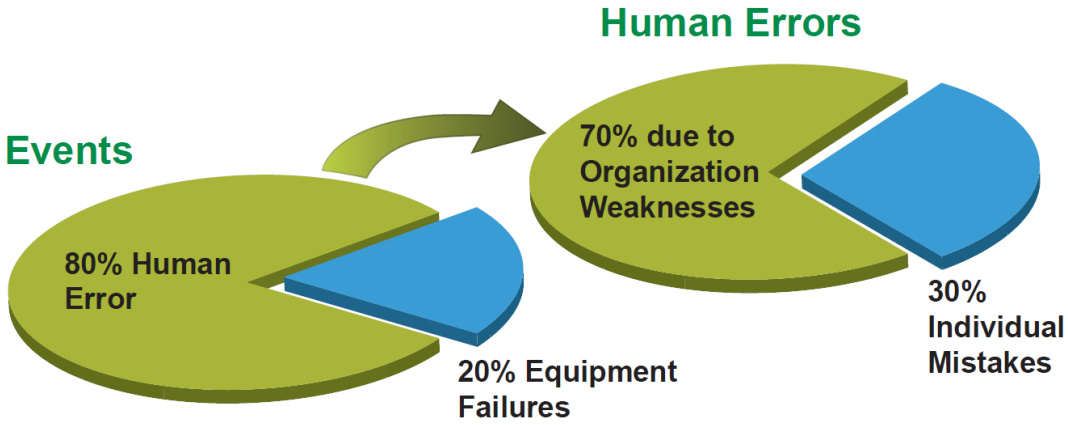


FIG. 1. Contribution of human error to the occurrence of events (courtesy of the USDOE).

Sectors	% Human Error
Automobile	65
Heavy truck	80
Aviation	70-80
Jet transport	65-85
Air traffic control	90
Maritime vessels	80-85
Chemical industry	60-90
Nuclear power plants (US)	50-70
Road transportation	85

Pasquale et al. (2015)

How (un)reliable are humans?

Human Performance: trained, no stress	1 in 1,000 to 1 in 10,000
Human Performance under stress	1 in 2
Operator response to an alarm	1 in 10
Simplest possible routine task	1 in 10,000
Simple routine task	1 in 1000
Routine task needing concentration	1 in 50 to 1 in 100
Put 10 digits into a calculator	1 in 20
Fail to act correctly after 1 min in an emergency	9 in 10
Select wrong switch among similar looking items	1 in 200
Read an analogue indicator wrongly	1 in 200

Source: Roediger et al (1991)

Understanding human error

Generic Error Modelling System (GEMS) – Reason (1990)

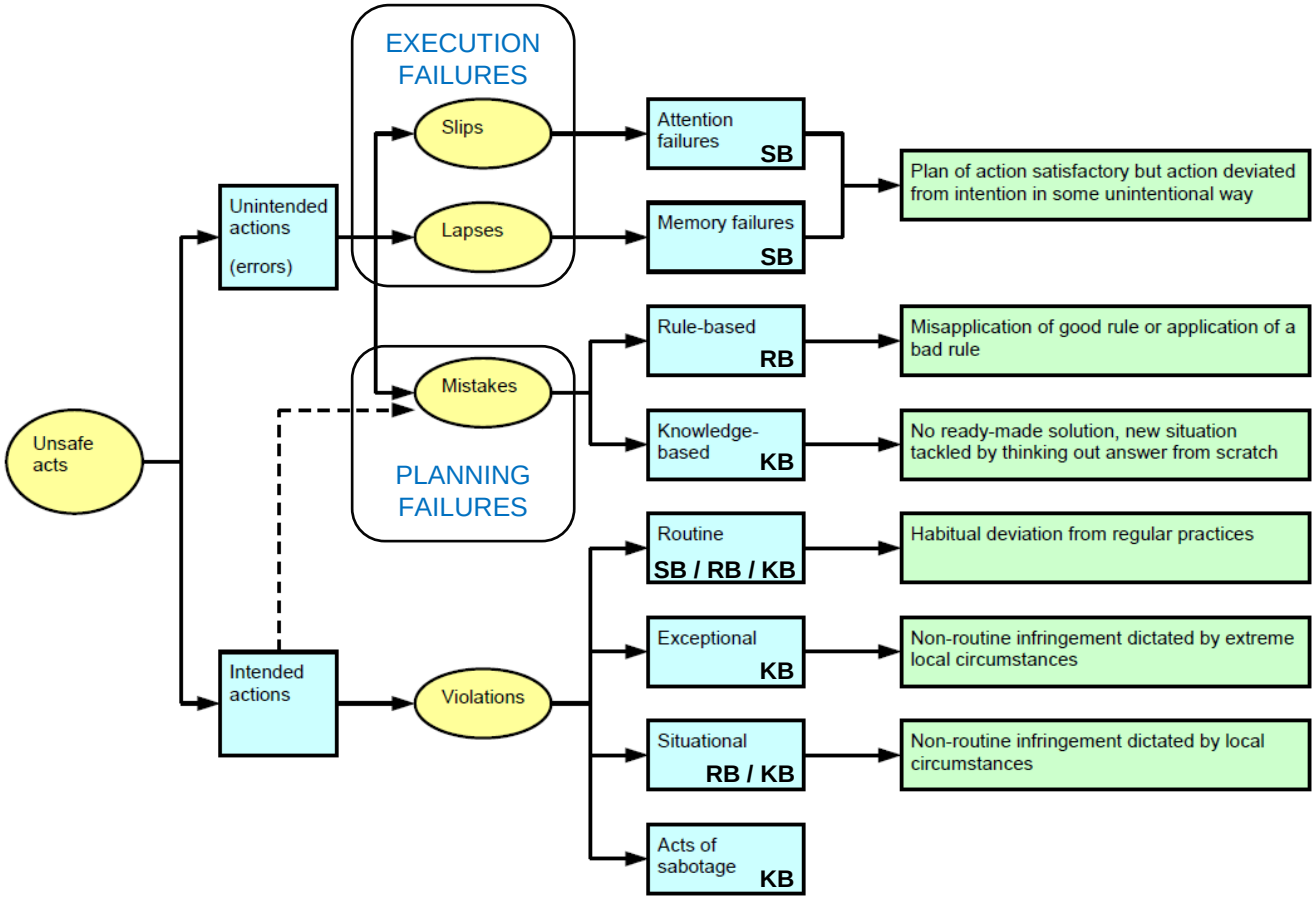
Starting point to help identify WHY an action could occur:

- **In the past**
- **In the future**

Consider violation & error **as two types of** unsafe act

Integrates unsafe acts mechanisms with skill-based (SB), rule-based (RB) and knowledge-based (KB) performance (Rasmussen)

GEMS

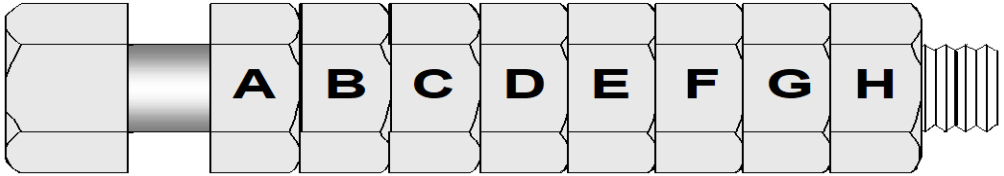

EXECUTION FAILURES
Slips
Lapses
Unintended actions (errors)
Attention failures SB
Memory failures SB
Plan of action satisfactory but action deviated from intention in some unintentional way
Mistakes
Rule-based RB
Misapplication of good rule or application of a bad rule
Knowledge-based KB
No ready-made solution, new situation tackled by thinking out answer from scratch
PLANNING FAILURES
Unsafe acts
Routine SB / RB / KB
Habitual deviation from regular practices
Exceptional KB
Non-routine infringement dictated by extreme local circumstances
Intended actions
Violations
Situational RB / KB
Non-routine infringement dictated by local circumstances
Acts of sabotage KB

Slip – Lapse – Mistake – Violation?

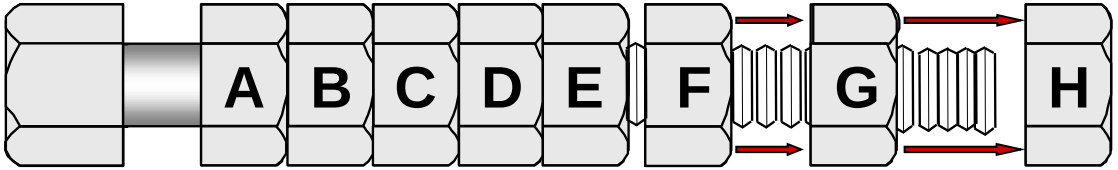
1. Leaving the last piece of paper in the photocopier
2. Forgetting to post a letter
3. Speeding on a highway
4. Joining the shortest queue in the supermarket but it takes the longest
5. Being distracted and putting two sugars in your coffee instead of one
6. Stealing a drill from work

Maintenance error: Simple system?

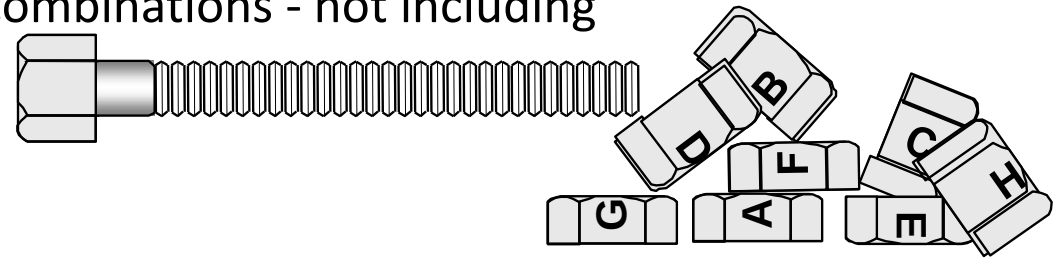
Goal state



Removal: 1 way



Installation: 40,000 combinations - not including omissions



Performance-Shaping Factors

Also known as situational factors or Performance Influencing Factors (PIFs)

Recognises that human performance is influenced by many factors and interactions within the socio-technical system - HTO

Lists of potential PSFs can be found in accident taxonomies and Human Reliability Assessment (HRA) tools

Identified PSFs highlight options for managing error

Human Error Management

Performance-Shaping Factors	Prevention	Reduction	Detection	Recovery
		▸ Magnitude ▸ Frequency	▸ Evident ▸ Timely ▸ Simplified	▸ Evident ▸ Timely ▸ Simplified
System ▸ Design	★			
Task ▸ Sequence ▸ Procedures ▸ Define task start conditions	⊘	More effective		
Personnel ▸ Training		Effectiveness		
Organisation ▸ Procedures / Policies ▸ Goals / KPIs		Less effective		

Nuclear Power Plant

60 years of operation

21900 days of operation and maintenance
x
400 staff
=
1 160 000 person days (probably more)

How many errors across over its life?

Are errors always bad?

No …

- **Errors are an important learning mechanism**
  - Error tolerant environment

- **The outcome of an error (or any action) is defined by the interaction of human behaviour and it' context – remember the HTO model**

- **"Bad" outcomes are a matter of perspective**
  - Attribution about the outcomes of events based on our own values and beliefs

4. HF challenges in safety management

Human Factors Successes

The workplace is a safer place than it was … depending on industry and location (Takala, 2019)

HF is required during design and operation within many high-hazard industries globally – often after suffering major accidents

Aviation **Rail** **Oil & Gas** **Nuclear** **Medical** **Defence …**

Human Factors / Systems Integration (HFI / HSI)

- Process delivers user-centred and operationally-centred design to achieve the operability requirements and to minimise human error
- Significant return on investment - 20:1 for every dollar spent

Responsible use of “human error”

Analysis of human error is essential in designing and maintaining complex socio-technical systems

Over time, the term “human error” has become distorted – can be seen as synonymous with blame

- Misunderstanding off the intent describing human error
- Misuse in organisations associated with tradition to find and punish the person responsible
    - Reduces safety in most cases

Legal systems can also undermine safety by seeking prosecute those “left holding the ball” in situations arising from systemic failures

- **Last person to touch something before it breaks gets fired / prosecuted**

Safety Management in organisations

Fair and just treatment of error is essential

- **Organisational learning**
- **Ensure long-lasting safety engagement**
- **Consistently applied** culpability flowcharts **help with this**

When “human error” = blame, then safety management is severely compromised

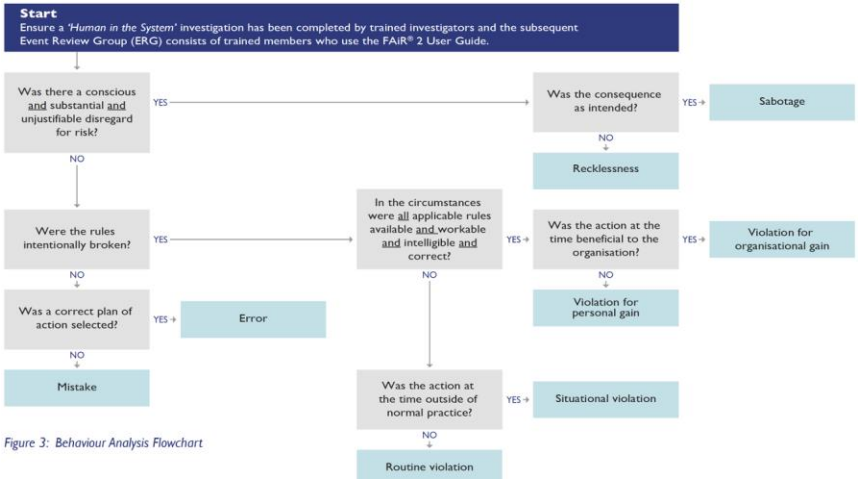
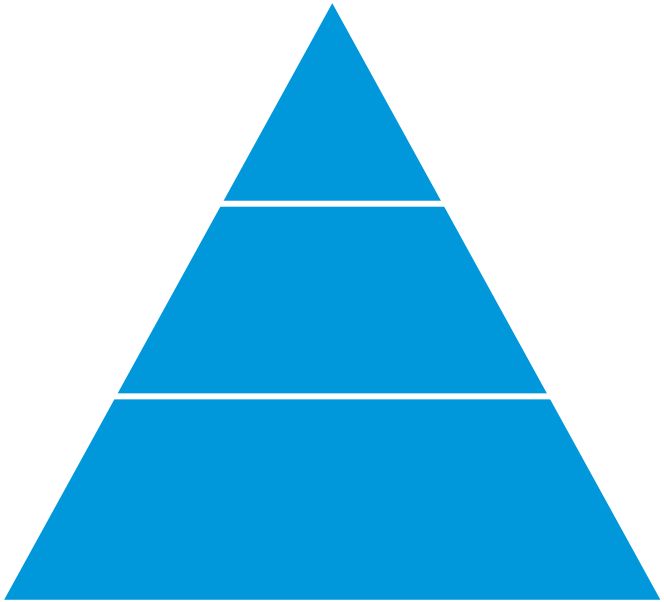


Figure 3: Behaviour Analysis Flowchart

FAIR2 behaviours analysis flowchart (Baines & Simmons Ltd., 2015)

Organistional effort vs. importance

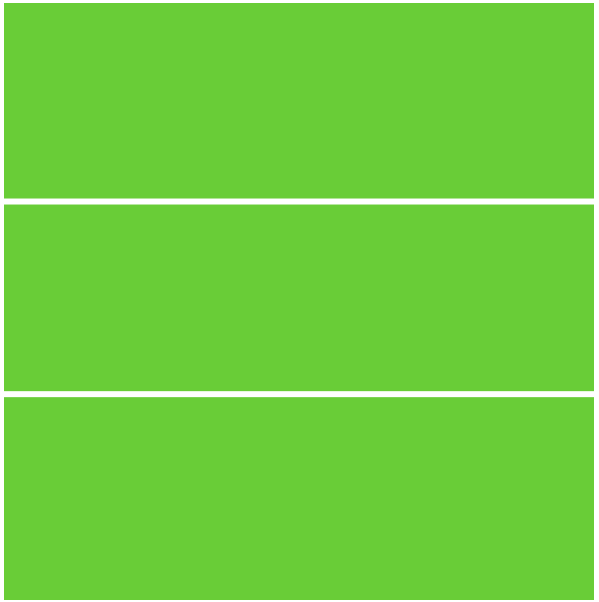


Typical Effort Expended

Organisational & system weaknesses

Human error

Equipment failure



Actual Importance

Aalto-yliopisto
Aalto-universitetet
Aalto University

Adapted from: Kletz, 2001

5. Conclusion

A multi-billion dollar question … and part of the answer

Integration of Human Factors principles into socio-technical system design is intended to …

- Enhance reliability & availability, efficiency, effectiveness, safety and resilience

BY

- Enabling reliable human performance

In safety management,
HF is *not more important* than
everything else,
it is *as important* as everything else

Learning Objectives

Think differently about safety, safety management, incidents and accidents

- Understand basic human capabilities and limitations
- What human factors is and why it matters for safety management
- GEMS human error framework and applications
- Understand some HF challenges in modern safety management

References

Baines Simmons (2015) FAiR2, https://www.bainessimmons.com/fair-download/

Fitts, P. (1951)Human engineering for Effective Air-Navigation and Traffic-Control System. National Research Council, Committee on Aviation Psychology-

HFIDTC (2012) Human Factors in Defence Information Systems. BAE Systems.

International Ergonomics Association (2000) in IEA website *What is Ergonomics (HFE)?* https://iea.cc/about/what-is-ergonomics/, Accessed 02.03.2022

Karltun, A., Karltun, J., Berglund, M., Eklund, J. (2017)HTO – A complementary ergonomics approach. Applied Ergonomics, 59, Part A: 182-190https://doi.org/10.1016/j.apergo.2016.08.024

Kletz, T. (2001)*An Engineer's View of Human Error*. CRC Press. ISBN 9781560329107.

Lay, E., & Wreathall, J. (2008) Improving Resilience by "Pinging" to Determine Risk Profile Changes during Maintenance Work, Resilience Engineering Symposium, October 28-30, 2008 Antibes, France.

McCafferty, D.B. & Baker, C. C. (2006 Trending the Causes of Marine Incidents. ABS Technical Papers.

Ministry of Transport and Communications – Directorate General of Air Transport, Accident Of The Boeing 757-200 Aircraft Operated By Empresa De Transporte Aéreo Del Perú S.A. Aeroperú, 02 October 2006, https://www.skybrary.aero/sites/default/files/bookshelf/1719.pdf

Pasquale, V.D., Miranda, S., Iannone, R., & Riemma, S. (2015). A Simulator for Human Error Probability Analysis (SHERPA). Reliab. Eng. Syst. Saf., 139, 17-32.

Reason, J. (1990) *Human Error*. Cambridge University Press

Roediger, H. L., Capaldi, E. D., Paris, S. G. & Polivy, J. (1991) Psychology (3rd ed.). HarperCollins Publishers, New York.

Salvendy (1997). Human Factors and Ergonomics Design Handbook (1st ed.) Salvendy, G. (Ed.), New York: Wiley.

Karwoski, W. (2012). Human Factors and Ergonomics Design Handbook (4th ed.), Salvendy, G. (Ed.), New York: Wiley.

Senders, J.W., & Moray, N.P. (1991). *Human Error: Cause, Prediction, and Reduction* (1st ed.). CRC Press-

Takala, J. (2019) Burden of Injury due to Occupational Exposures in Bültmann, U. & Siegrist, J. (eds.), Handbook of Disability, Work and Health , Handbook Series in Occupational Health Sciences , https://doi.org/10.1007/978-3-319-75381-2_5 Publisher: Springer, Cham.

Thank You

aalto.fi

Aalto-yliopisto
Aalto-universitetet
Aalto University

BUSINESS FINLAND VTT ABB FINNPILOT AILiveSim GIM ROBOTICS