Strengthening synergies between Aviation and Maritime in the area of Human Factors towards achieving more efficient and resilient MODES of transportation.

Training Package

Systems lens. Understanding Complexity, Interactions and Context

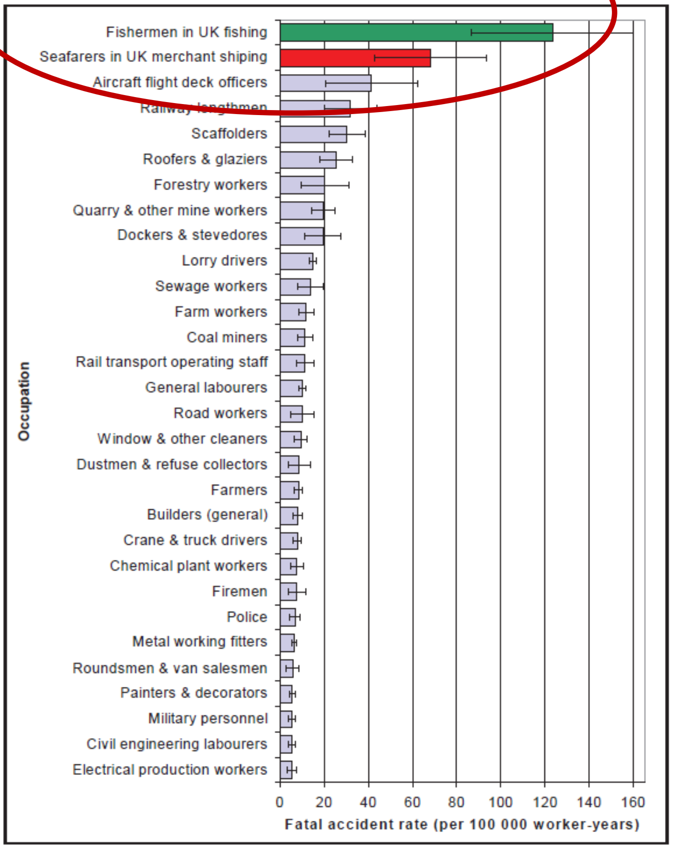
SAFEMODE-CBHF-M1

This project has received funding from European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement N°814961.

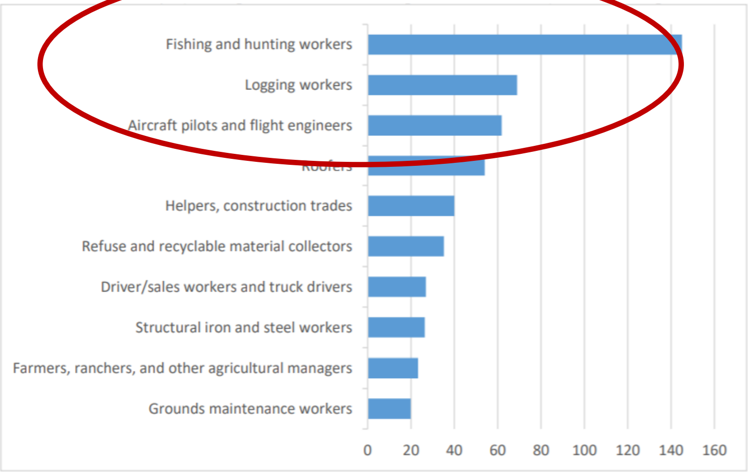
Presentation contents

1. Dangerous Occupations
2. Application of Human Factors
3. Systems Lens
4. Complexity
5. Interactions
6. Context

Dangerous Occupations



Fatality rate in UK for the 30 occupations with the highest risk of fatal accidents at work in 1982



Fatal work injury rates in US per 100,000 full-time equivalent workers by selected occupations, 2019 (BLS, 2020)

Cause of death	No. of deaths from accidents	Fatal accident rate (per 100 000 seafarer-years)	Percentage annual change in the fatal accident rate (%)[a]
Shipping disasters			
Foundered/capsized/missing vessels[b]	2611	25.1	−1.29
Collisions[b]	550	5.3	−1.18
Grounded[b]	453	4.4	−1.38
Fires and explosions/other disasters[b]	962	9.2	−1.11
Total deaths from shipping disasters	6074	51.0	−1.26
Personal accidents			
Falls overboard[b]	1233	11.9	−1.27
Falls down hatchways[b]	1241	11.9	−1.30
Falls from heights[b]	310	3.0	−0.97
Washed overboard[b]	306	2.9	−1.41
Accidents in the engine room[b]	487	4.7	−1.06
Accidents on deck[bc]	341	4.8	−0.23
Drowned in dock/returning to ship[b]	2665	25.6	−1.06
Swimming and bathing accidents[b]	337	3.2	−1.11
Killed or missing ashore[b]	653	6.3	−1.00
Other and ill-defined deaths from external causes[b]	1523	14.6	−1.10
Total personal accidents	11 312	95.1	−1.10
Total fatal accidents	17 386	146.1	−1.15

Fatal accident rates and percentage annual changes in fatal accident rates, among seafarers employed in UK merchant shipping, 1919–2005

How to understand and interpret these Figures?

How to improve safety?

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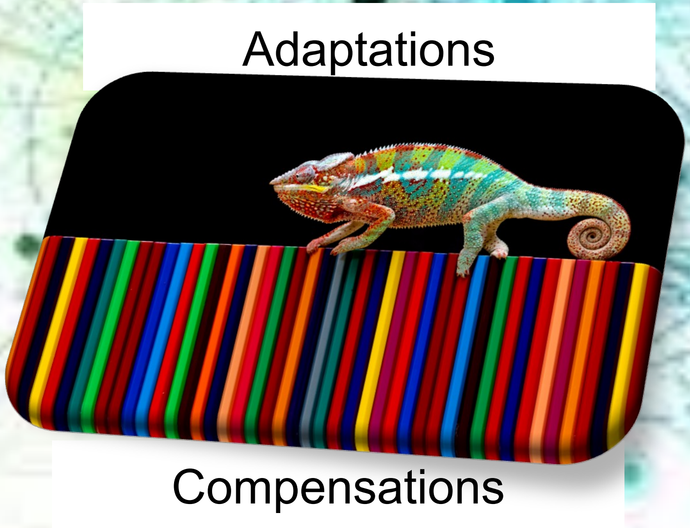
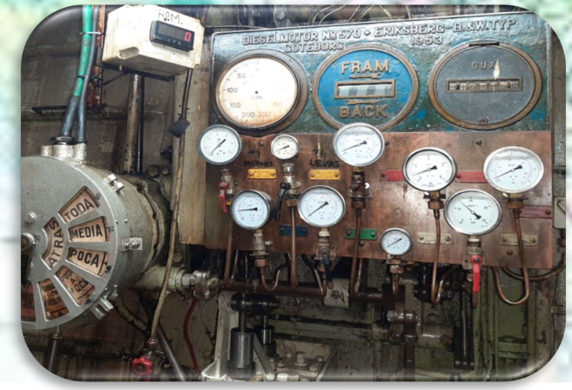
How to improve safety

- How does increasing complexity of systems affect job roles?
- Are characteristics of people considered and integrated into systems?





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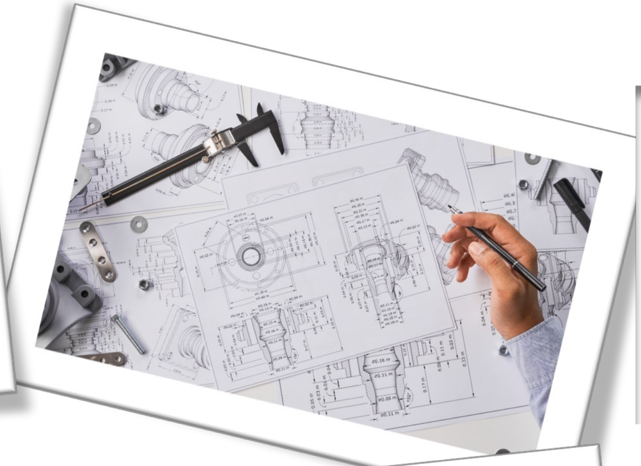
Meaning of Human Factors

- Human Factors (HF) is the science of understanding and supporting humans when **interacting** with other **humans**, with **technology** and with **other elements** of a **system**



Design, systems analysis, and modelling (Engineering)

Study of brain and mind, and human behaviour (Psychology)

Information flows (Computer and Information Science)

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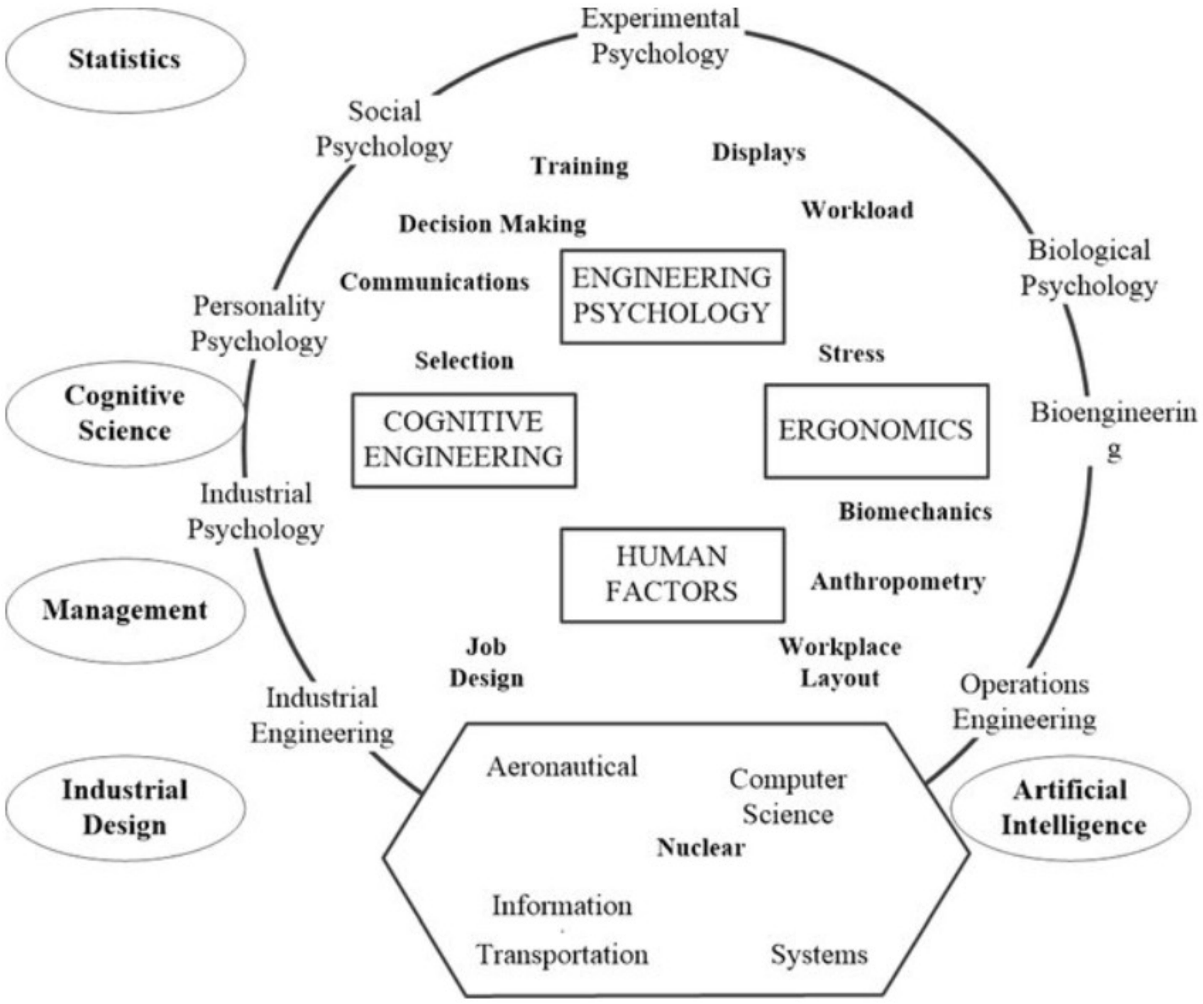
Scope of Human Factors



Relationship between Human Factors and related disciplines (Li, N., Huang, J. & Feng, Y, 2020)

- Need of unite knowledge: research and analysis beyond limits of each field and mindset

- Human Factors/Ergonomics: aiming to optimise the fit between the human operator and the work environment, to achieve **safe** and **efficient** operation in a **healthy** and **comfortable** way

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Human Factors fundamental fallacies

Arguing that HF refers just to human behaviour/action

Providing training and changing procedures as the only ways of improving HF

Claiming that HF is about changing human behaviour

Applying HF discipline is simply intuition, common sense

Claiming that Human Factors = "Human error" is the cause of 80% of accidents

...

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Human Factors Inquiries

- How are Human Factors considered and integrated into systems design and operations? Are they?

- How to take Human Factors into account when assessing major risks? Can we? Do we?

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Human Factors Research and Application

- Enhance **human wellbeing** and **systems performance** and **safety**

- Safety as an **emergent property** of a **system**

“Safety relates to the **system’s ability** to succeed under varying conditions” (Hollnagel, 2015)

“The reason for the occurrence of errors is a combination of human behaviour, other elements of a systems and their **interactions**” (Woods et al., 2010)

“Enlarge lens of safety markers **from human behaviour to the whole system**” “Safety is a **system property** that emerges when the **system elements interact with the environment**” (Leveson, 2011)

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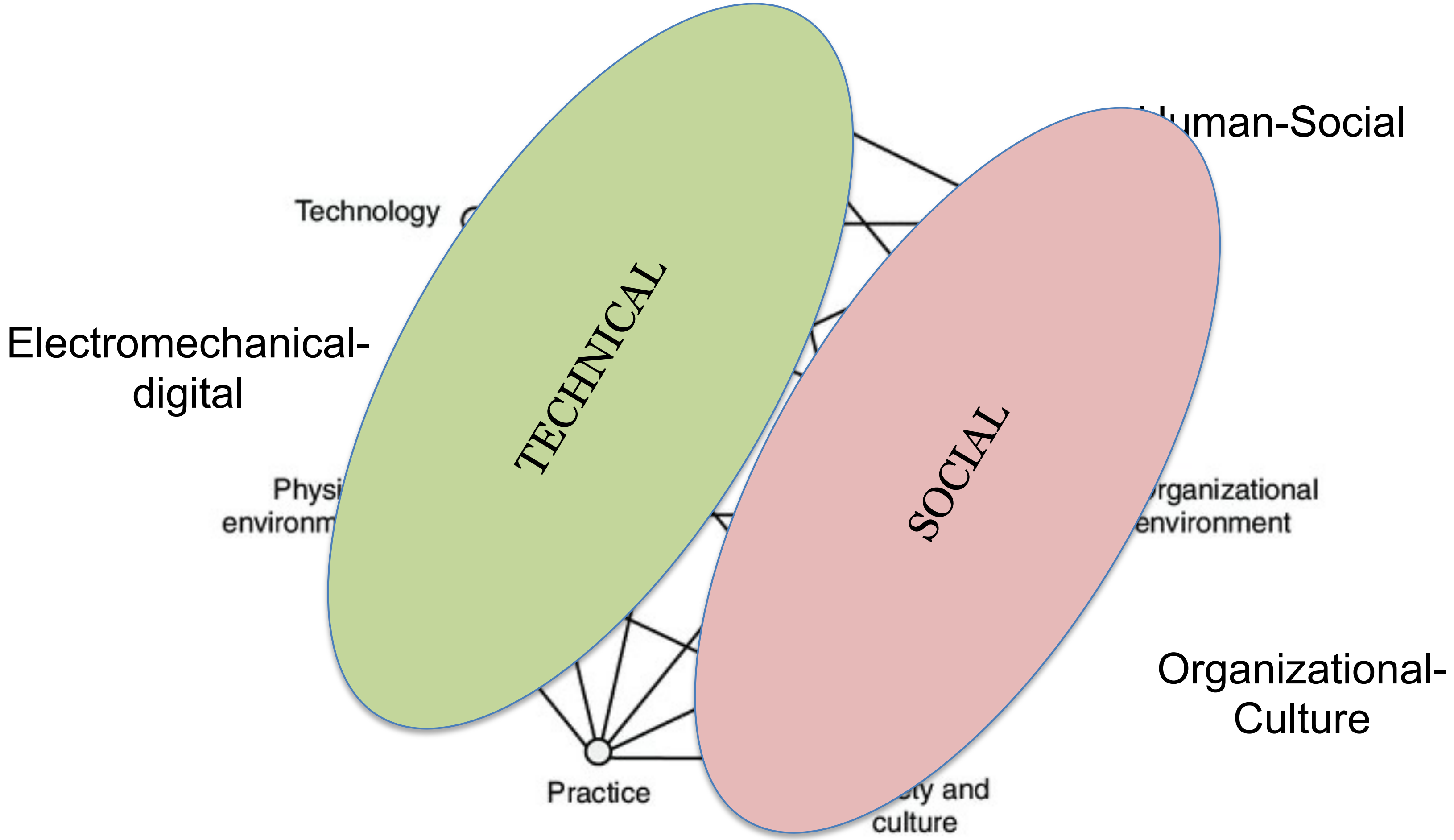
Systems Lens

- Interactions
- Complexity
- Context



BEYOND THE INDIVIDUAL THERE IS A SYSTEM

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Two levels of Analysis-Interaction

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SOCIOTECHNICAL SYSTEM

<u>TECHNICAL WORK CONTEXT</u>
HARD SYSTEM = SHIP/PLANE

RELATIONSHIP INSIDE THE SHIP/PLANE OF THE HUMAN/MACHINE DYNAMIC INTERRELATIONSHIP

Require identification of tools, technologies and techniques

<u>SOCIAL CONTEXT</u>
SOFT SYSTEM = PEOPLE

INTERRELATION BETWEEN HUMANS AND MACHINES IN WIDE SOCIAL CONTEXT

Require identification of elements/structures, etc.

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Sociotechnical Systems: Human-Machine

- The notion of **system** highlights:

The importance of analyzing **together human and technology interaction** and avoid disjunctive analysis

Study of **each element** and their relation with the **whole system**

Design of systems able to **integrate human** needs and **technical** requirements from its inception

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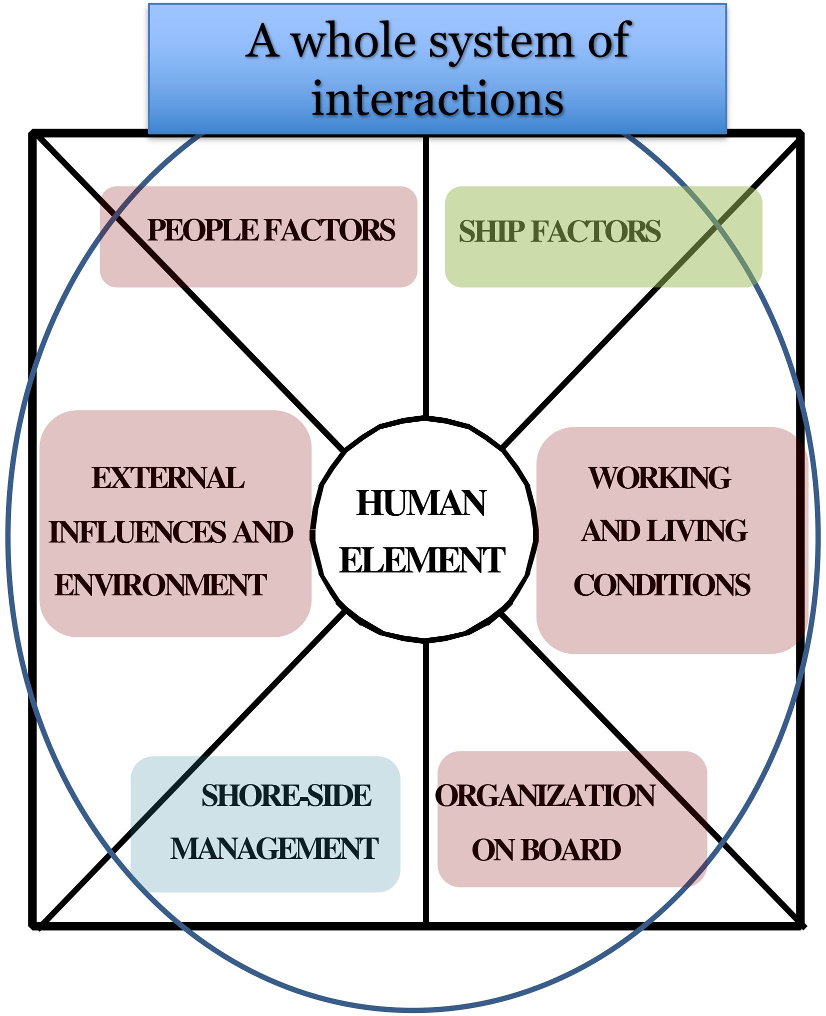
Human Element under Systems Lens

- “The human element is a **complex multi-dimensional issue** […]. It involves the **entire spectrum of human activities** performed by **ships’ crews, shore-based management, regulatory bodies, recognized organizations, shipyards, legislators, and other relevant parties**, all of whom need to co-operate to address human element issues effectively.”

(IMO Res. A.947(23), 2004)



(IMO Res. A.884(21), Casualties and Incidents Investigation, 2000)

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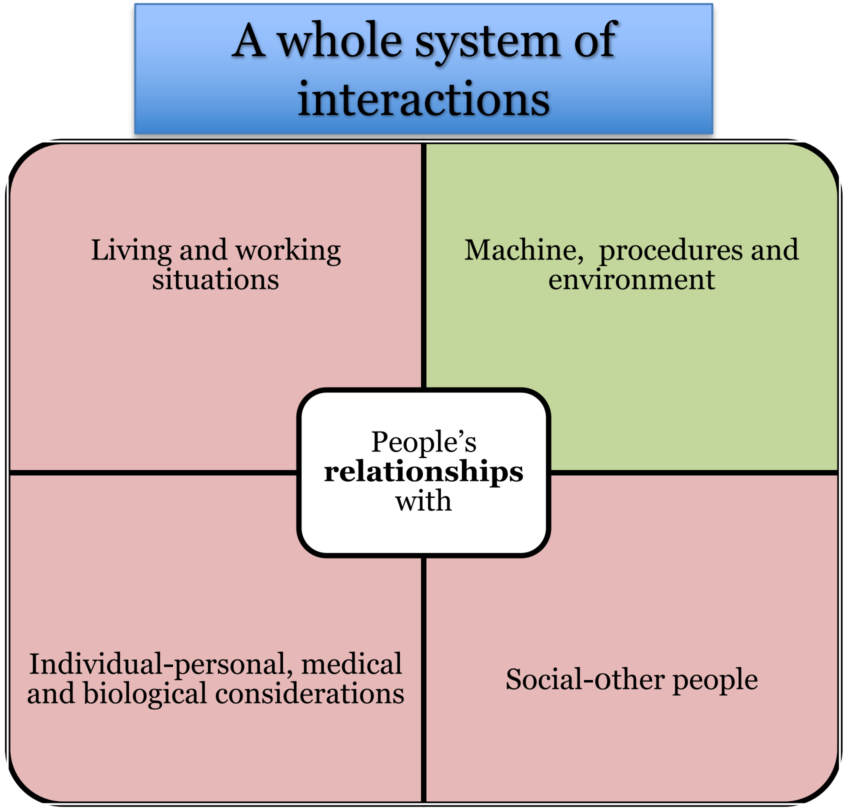
Human Factors under Systems Lens

- "Human Factors is about people in their **living and working situations**; about their **relationship** with **machines, with procedures and with the environment** about them; and also about their **relationships** with other people (at work). In aviation, Human Factors involves a set of **personal, medical and biological considerations** for optimal aircraft and air traffic control operations."

(ICAO, 1989, ch.1, p.2)



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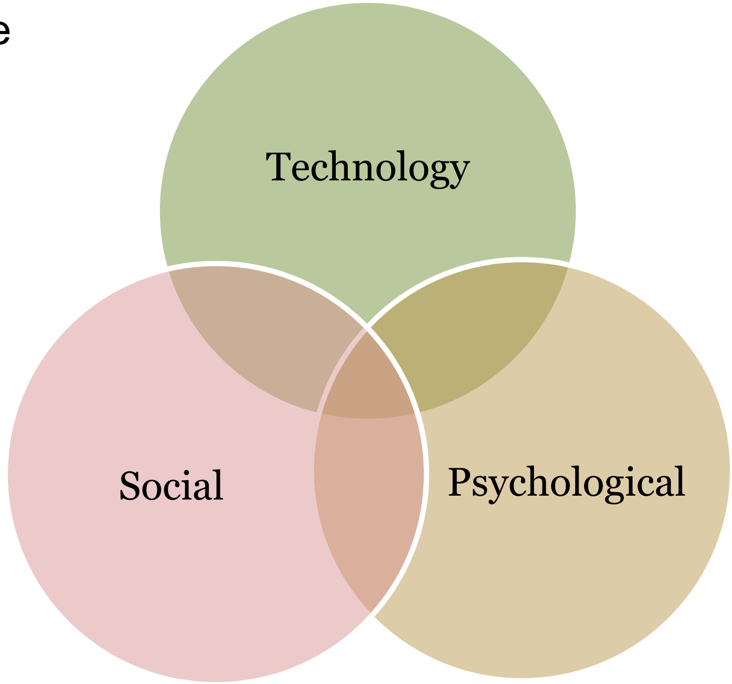
Need of Systems Lens

Why do we need System Lens?

Fast pace of technological change
Changing nature of accidents
New types of hazards
Engineering skills are not enough



Reduced ability to learn from experience
Decreasing tolerance for single accidents
Difficulties in selecting priorities and making trade-offs
Changing regulatory and public views of safety

Increasing complexity and coupling
As systems become complex, their behaviour can become surprising
More complex relationships between humans and automation

Significant changes in the types of systems we build today and the context in which they are built

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Why Systems Perspective?

Encompass **complexity**

Acknowledge **interrelations** in the world

Recognize impact of **contexts**

Eliminate simplification

Re-unite knowledge

Consider constructivism

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Identification of a System

Can you **identify parts**?

\+

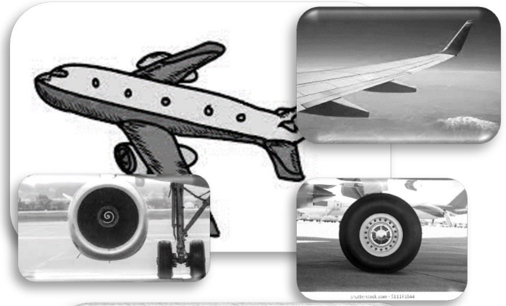
Do the **parts interact** and influence each other?

\+

Do the **parts together** produce an effect that is **different from the effect of each part** on its own?

\+

Does the **effect**, the **behavior** over time, **persist** in a variety of circumstances?



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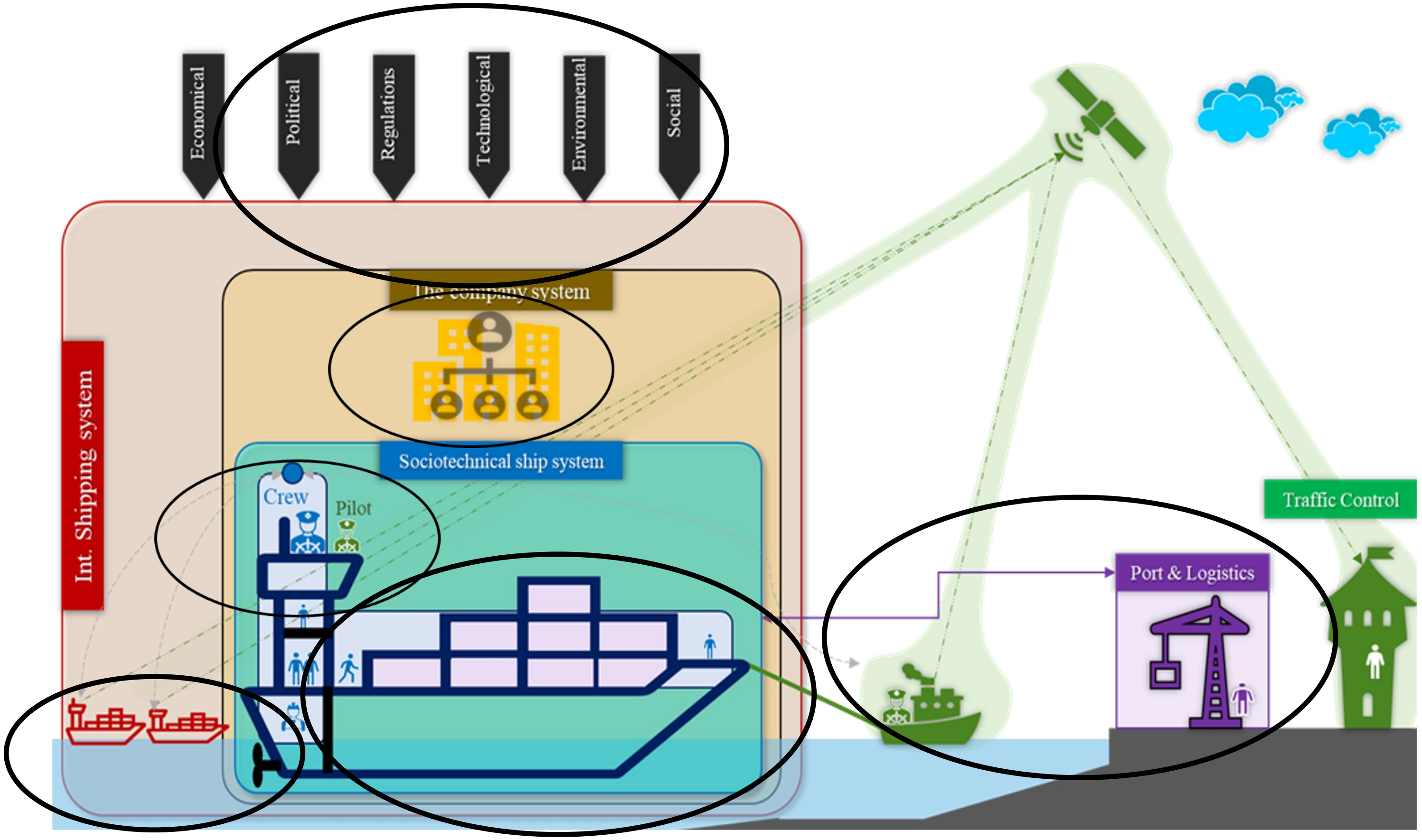
Systems Lens in Maritime



IDENTIFY AND UNDERSTAND THE PARTS (physical, intangibles)

SEE INTERCONECTIONS (relationships, flows of information)

EFFECT OF PARTS WHEN TOGETHER FOLLOW A FINALITY (function)

OVERTIME, THE SYSTEM ADJUSTS TO PURSUE ITS FINALITY (purpose)

TO REDESIGN SYSTEM – COURAGE AND CREATIVITY

NATURAL ENVIRONMENTS = SEA, WEATHER, GEOGRAPHY, ETC.

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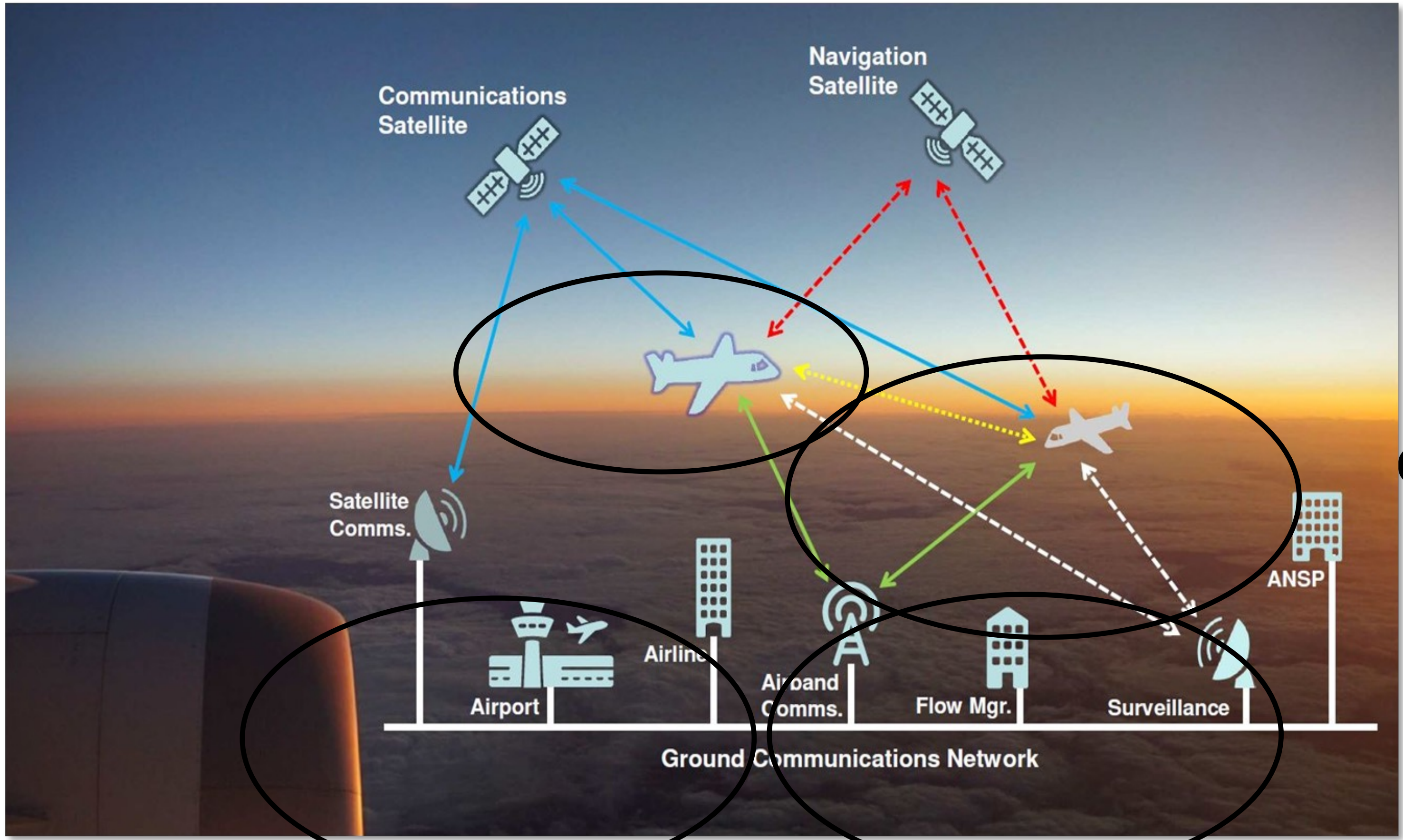
Systems Lens in Aviation



NATURAL ENVIRONMENTS = AIR, WEATHER, GEOGRAPHY, ETC.

IDENTIFY AND UNDERSTAND THE PARTS (physical, intangibles)

SEE INTERCONECTIONS (relationships, flows of information)

EFFECT OF PARTS WHEN TOGETHER FOLLOW A FINALITY (function)

OVERTIME, THE SYSTEM ADJUSTS TO PURSUE ITS FINALITY (purpose)

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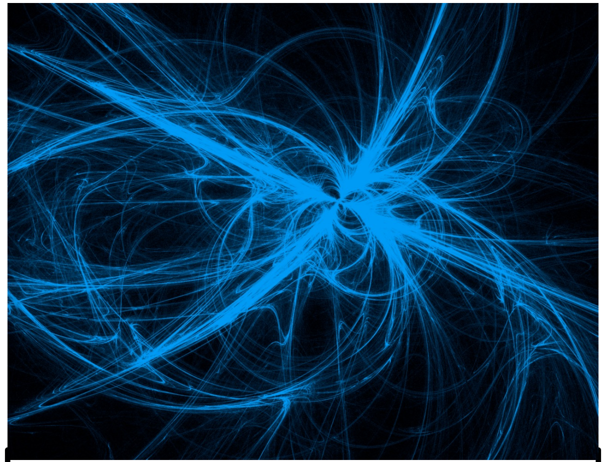
What Complexity is

- Complexity means **uncertainty**, **unpredictability**, **unconnected**, the **unknown**:

  Incapacity to describe all

  Incapacity to fully predict all



Chaos theory

- Sociotechnical systems: if individual, social is complex

  Maritime/Aviation are complex socio-technical systems: designed, managed, maintained, and operated by humans – they are a central component

❑ Focus on what matters: **people need to be and feel safe**

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Complex System- Properties

- **Non-deterministic** systems. It means they are not fully predictable. **Delays, Resilience**

- **Non-linearity & Emergency.** Network of heterogeneous **components that interact nonlinearly**, to give rise to **emergent behavior**

- **Whole ≠ parts sum.** The **whole system** exhibit one or more properties/behaviors not obviously linked to the properties of the individual parts/deducted from them.

- **Dynamism, Feedback, Adaptation, Self Regulation.** Individual parts live in a **moving web**

To describe complex system, like vessels or planes, models can be created but models are a simplification of their reality

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Case Study-1. Concorde Flight 4590


BEA

Accident
on 25 July 2000
at La Patte d'Oie
in Gonesse (95)
to the Concorde
registered F-BTSC
operated by Air France

REPORT translation
f-sc000725a

Aircraft maintenance

Safety culture

Flight management

Tyre vulnerability

Time pressure


Falling into the runway

The French BEA concluded in 2002 that a wear strip of metal, fallen off from a DC-10 that took off 4 minutes earlier, had punctured a tire of the Concorde, sending shards of rubber into the fuel tanks, leading to flames pouring from its undercarriage and making the plane crashing into a hotel few kilometers away.

The strip was attached with rivets close to other previous existing holes (reverse of the engine) and was improperly attached

Systems move from a point of order to one of chaos or unpredictability, based on even the slightest change to conditions (Butterfly effect)

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Increased Complexity…

- More **complex and unpredicted** relationships between **humans** and **automation:**

Control of systems sharing between humans and automation: higher-level position making with automation implementing

The human user is spending a disproportionate part of their time dealing with multiple, unconnected, high-stress tasks, without periods to de-stress: more risk for worker, mental issues

New types of “human errors” (e.g., more omission than commission, inadequate communication between humans and machines, cognitive overload, etc.)

Human behaviour is influenced **by the context** in which it occurs (at the mercy of design of automation, social and organizational environment)

Many examples of accidents that have been blamed on operator error instead of labelled as resulting from flaws in the environment they operate

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Systems Interactions

Things can go catastrophically wrong even when every individual component is working precisely as its designers imagined. "It's a matter of **unsafe interactions** among components,"

(Leveson, 2019)

- The world presents to us as a series of events, but reality is nonlinear, static
- Human linear-thinking minds (straight lines-not curves, whole numbers-no fractions, certainties-no mystery, uniformity- no diversity, stocks-no flows)
- Component interaction accidents are usually forgotten (event chain models)

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Reliability and Safety

"Divide and conquer"
Component failure accident

- If **individual components** or systems do not fail, then accidents will not occur
- To increase **reliability** of systems components/elements
- Safety is increased by increasing **systems or component reliability**

"More than the sum of parts"
Components interaction accident

- Accidents often result from **interactions** among individual components
- To increase the **overall system design**
- Safety is a **system property**, not a component property

Examples of accidents of reliable but unsafe and unreliable but safe

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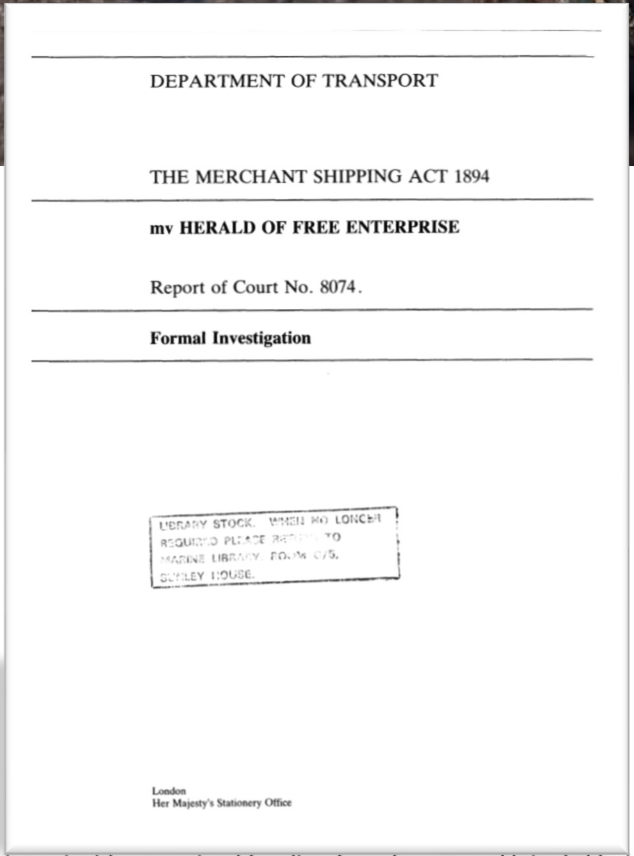
Case Study-2. Herald of Free Enterprise



DEPARTMENT OF TRANSPORT

THE MERCHANT SHIPPING ACT 1894

mv HERALD OF FREE ENTERPRISE

Report of Court No. 8074.

Formal Investigation

London
Her Majesty's Stationery Office

Traffic scheduling

Vessel design

Harbour design

Cargo management

Passenger management

Vessel operation

High reliability of each component (physical, social, organizational) is neither necessary nor sufficient for safety

Bottom-up decentralized decision making. Each decision is context-dependent (component reliability) but dysfunctional interactions (component interaction)

Safety is a system property (not component), so must be controlled at system level (not component)

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What are your takeaways up to now?

- Safety focus: from human behaviour/action to the **whole system**

- Unsafe human being as a **system problem** – undesirable behaviors characteristics of the **system structures** that produce them!

- Design of systems able to **integrate human** needs and **technical** requirements from its inception

- We cannot control systems or figure them out… but we can **dance** with them

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Context and Mental Models

Manufacturing and construction variances

Evolution and changes over time

Trade-offs

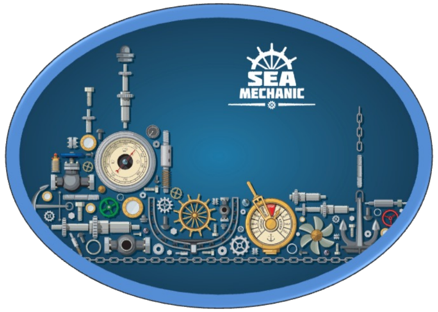
ACTUAL SYSTEM

Original design spec.

Operational experience

Conflicting goals

Decision-making is context dependent. What can be considered a mistake, can be super rational and important in the real



Operational procedures, training

If deviations are good, they are doing their jobs, but if the opposite they are blamed

Feedback and experimentation are key in systems design

Designers deal with ideals or averages, not constructed systems

Operators continually test their models against reality, inputs and feedbacks

(Adapted from Leveson, 2011)

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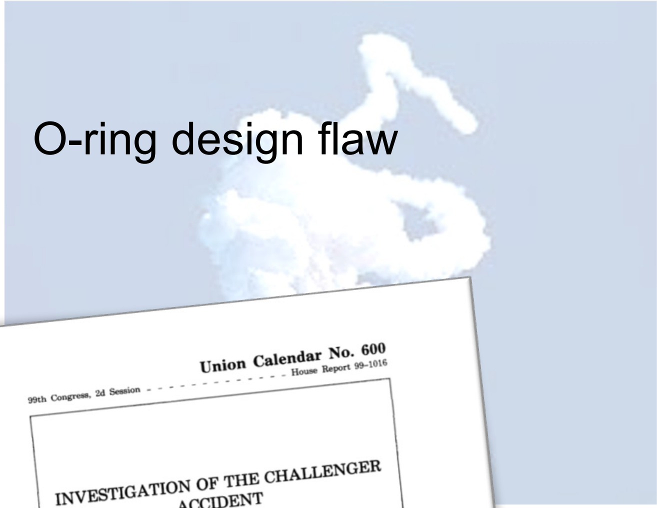
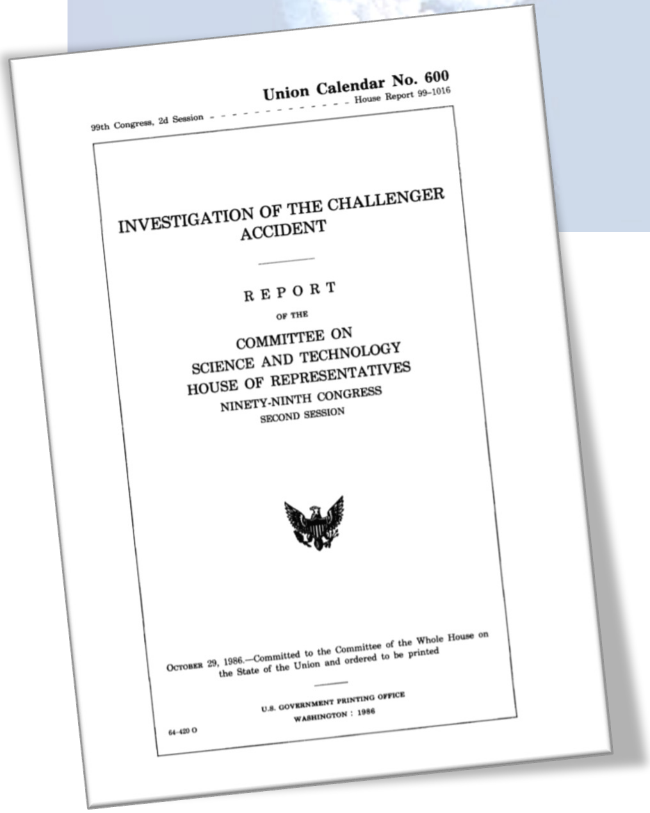
Case Study-3. Challenger and Columbia



O-ring design flaw



99th Congress, 2d Session

Union Calendar No. 600

House Report 99-1016

INVESTIGATION OF THE CHALLENGER ACCIDENT

REPORT

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

NINETY-NINTH CONGRESS

SECOND SESSION

OCTOBER 29, 1986.—Committed to the Committee of the Whole House on the State of the Union and ordered to be printed

U.S. GOVERNMENT PRINTING OFFICE

WASHINGTON : 1986

64-420 O

Flawed decision-making

Political & economic pressures

Communication problems

"silent" or ineffective safety program

Poor problem reporting & lack of trend analysis

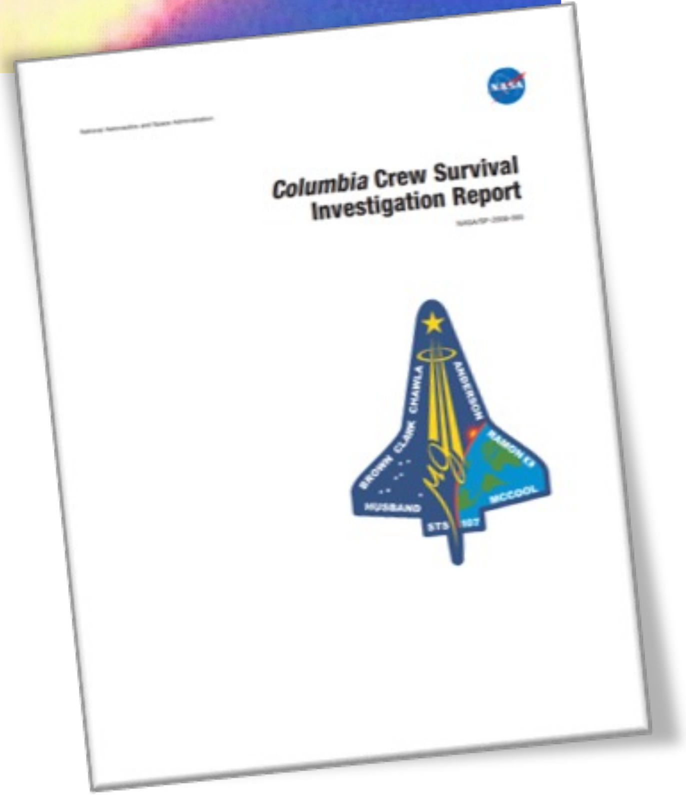
Conflicting goals and Trade-offs

Proximate physical cause and contributory reasons: systemic problems

Causal attribution and accidents: assign blame or understanding

Conflicting interests in accidents

Foam hitting the wing of the orbiter



Columbia Crew Survival Investigation Report

Systemic Perspective

- To challenge seeing decision-making as discrete processes separated from **context (physical, social and psychological)** but decisions are just understood as part of the ongoing process

- New approach to represent and understand human behaviour focused not on "human error" and violation of rule but on mechanisms generating behaviours in the actual, **dynamic context**:

  Work system constrains
  Boundaries of acceptable behaviour
  Need for experimentation
  Adaptive mechanisms of human actors

- Operator behaviour is a product of environment so **change the environment** and focus on **factors/mechanisms that shape human behaviour** instead of behavioural approach.

- Accident: either **assign blame** or **understanding why (prevention)**

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What messages will you take home from this presentation?

“The predominant mode of treating this topic is to consider the **human as a hazard**, a system component whose unsafe acts are implicate in the majority of catastrophic breakdowns. But there is another perspective, one that has been relatively little studied in its own right, and that is the **human as hero**, a system element whose **adaptations** and **compensations** have brought troubled systems back from the brink of disaster on a significant number of occasions.” (Reason, 2008)

“Today, it is widely accepted that system thinking is a **critical tool in addressing the many** environmental, political, social, and economic challenges we face around the world. […]. Once you start to see the events of the day as parts of trends, and those trends as symptoms of underlying system structure, you will be able to consider new ways to manage and new ways to live in a world of complex systems.” (Diana Wright in Meadows, 2008)

Observe interrelations and change your vision

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Thank you for your attention

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