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The Human Factors Perspective:

from micro, to meso, to macro models of safety in systems

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*"The University of Southampton Faculty of Engineering was **ranked top in the UK in terms Research Power for General Engineering** across all single-institution engineering submissions for **REF 2015**"*

Russell Group University – Research-led

17,000 undergraduate and 7,000 postgraduate students

RMS Titanic

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- Sank on 15 April 1912
- Collided with an iceberg
- Over 1,500 died
- Multiple failures from ship design to operation and recovery
- Numerous lessons learnt, including life boat numbers, drills, 24/7 radio operation, use of flares, ice patrols, etc…

Human Factors Engineering Research Team

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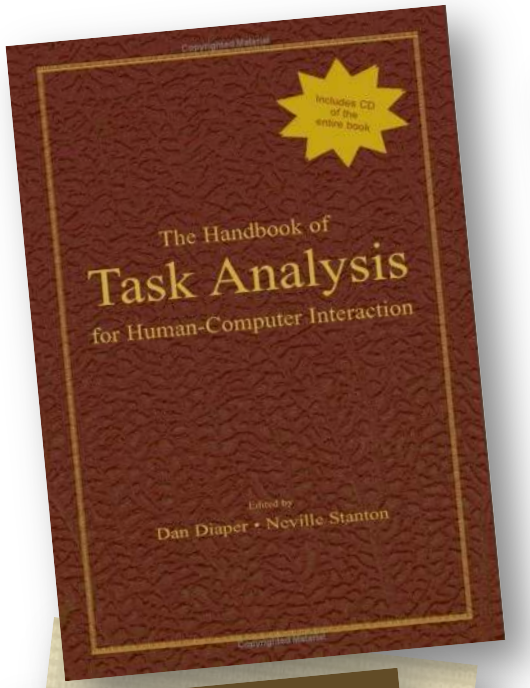
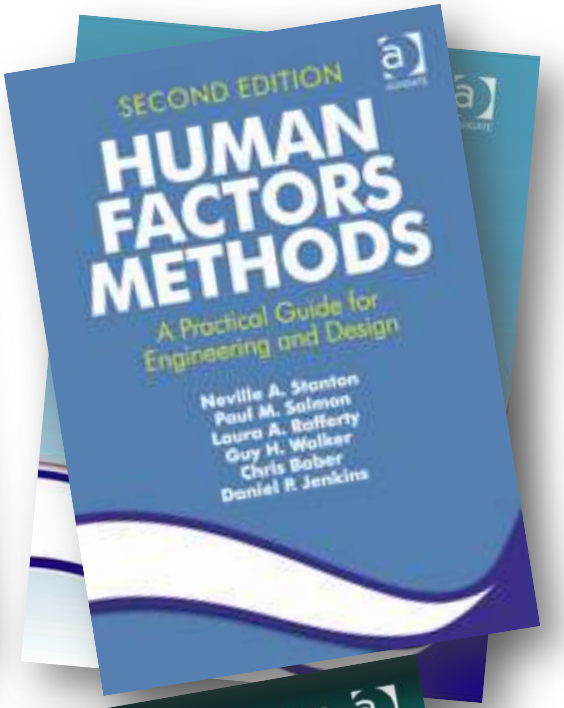
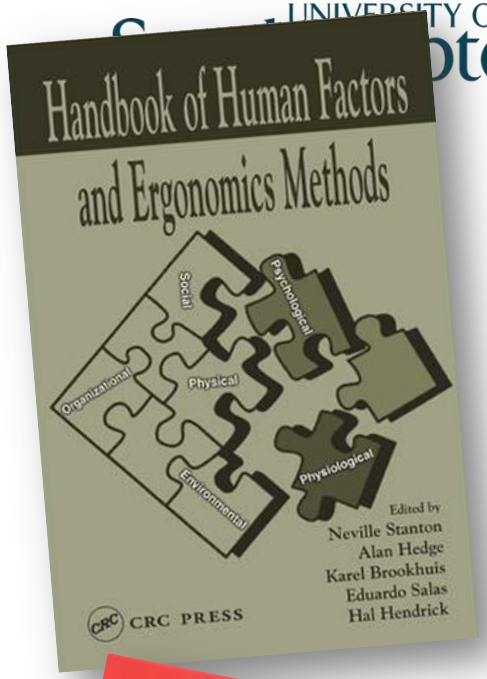
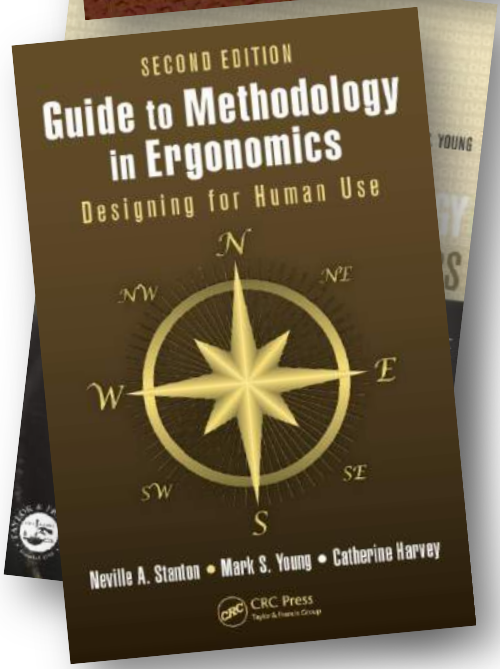
Human Factors Engineering Research Team


Includes CD of the entire book
The Handbook of
Task Analysis
for Human-Computer Interaction
Edited by
Dan Diaper • Neville Stanton


SECOND EDITION
HUMAN FACTORS METHODS
A Practical Guide for Engineering and Design
Neville A. Stanton
Paul M. Salmon
Laura A. Rafferty
Guy H. Walker
Chris Baber
Daniel P. Jenkins


Handbook of Human Factors and Ergonomics Methods
Social
Psychological
Organizational
Physical
Environmental
Physiological
Edited by
Neville Stanton
Alan Hedge
Karel Brookhuis
Eduardo Salas
Hal Hendrick
CRC PRESS


SECOND EDITION
Guide to Methodology in Ergonomics
Designing for Human Use
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NE
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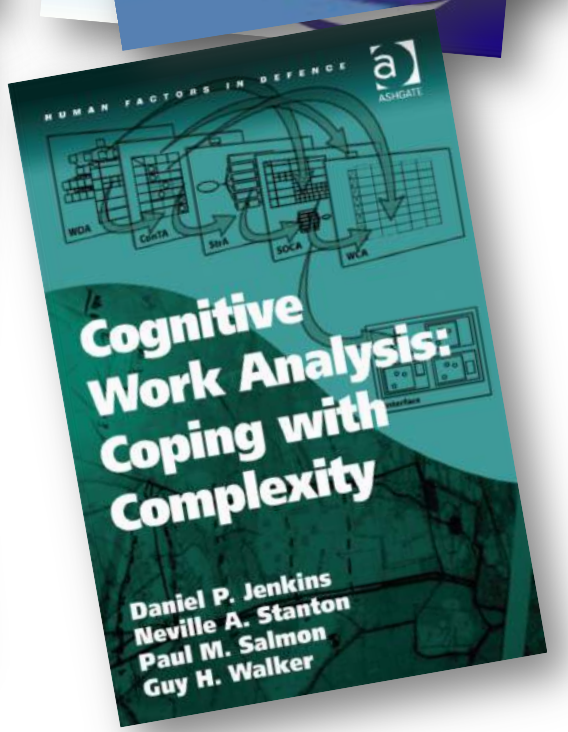
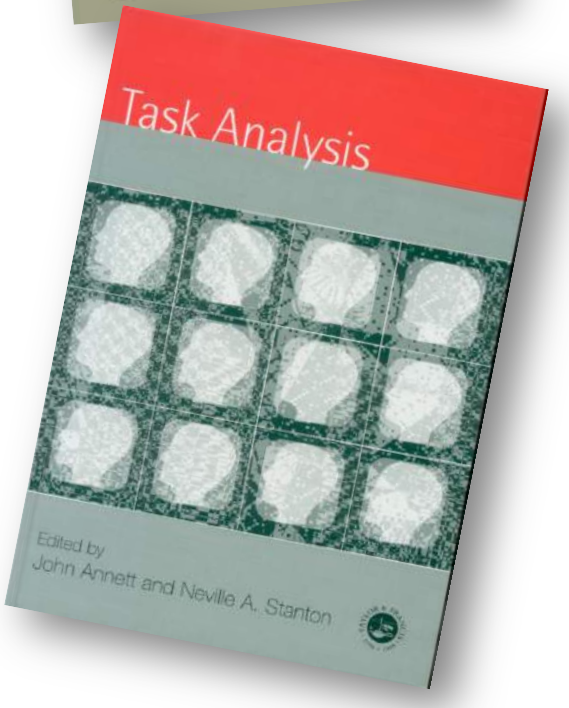
Neville A. Stanton • Mark S. Young • Catherine Harvey
CRC Press


HUMAN FACTORS IN DEFENCE
ASHGATE
WDA
ConTA
StHA
SOCA
WCA
Cognitive Work Analysis: Coping with Complexity
Daniel P. Jenkins
Neville A. Stanton
Paul M. Salmon
Guy H. Walker


Task Analysis
Edited by
John Annett and Neville A. Stanton

Socio-technical systems

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The Domino Effect….

Is it really all the 'operators' fault?

- Pilot error is really **designer error** (Chapanis, 1949)
- "Human Error is not a simple matter of one individual making a mistake, so much as the **product of design** which has permitted the existence of specific activities which could lead to errors." (Reason, 1990)
- "The 'train-and-blame' philosophy makes the blamer feel good, but it **doesn't solve the underlying problem**. Poor design, poor procedures, poor infrastructure and poor operating practice are the true culprits; people are simply the last step in this complex process. We must **design our technologies for the way in which people actually behave**, not the way we would like them to behave." (Norman, 2007)

Incident pyramid

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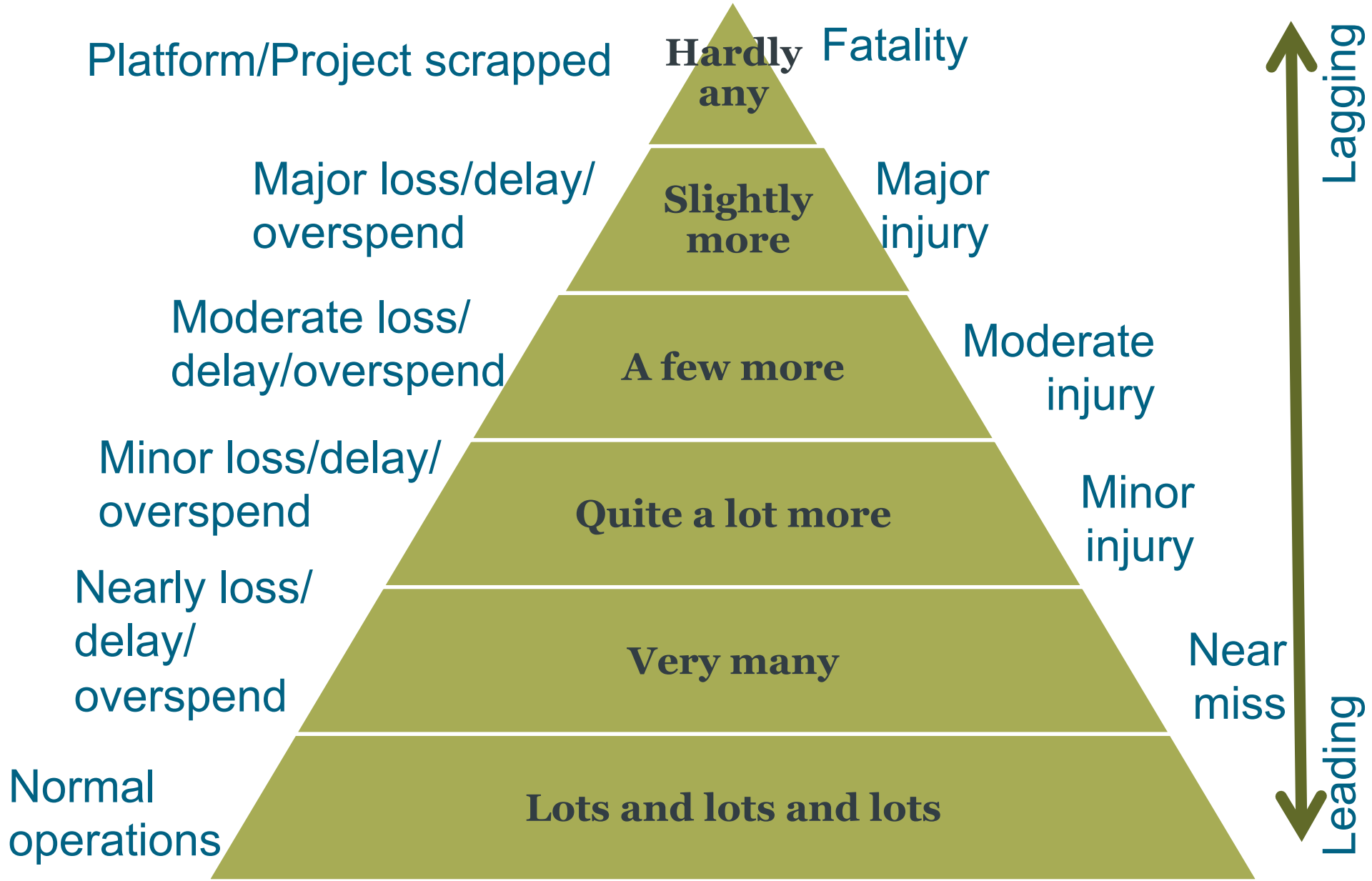

Cheese and Onion Models

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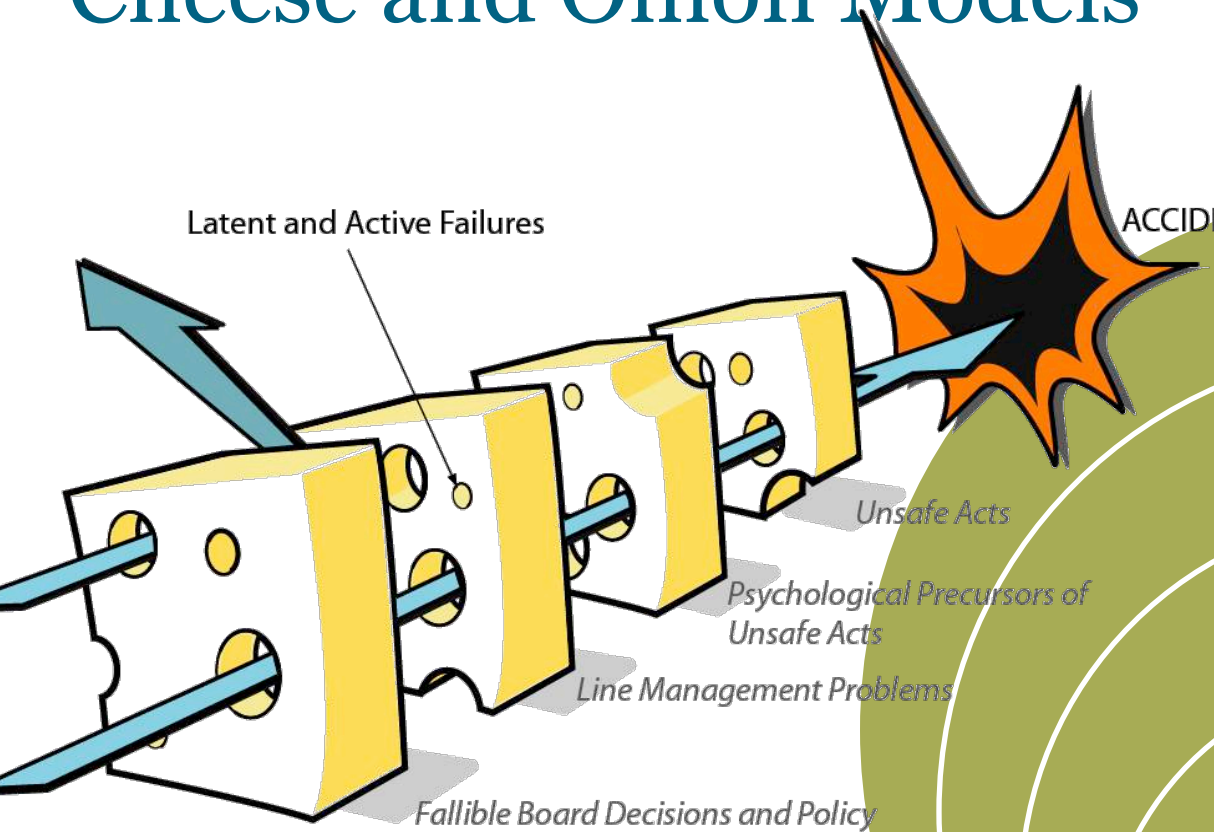

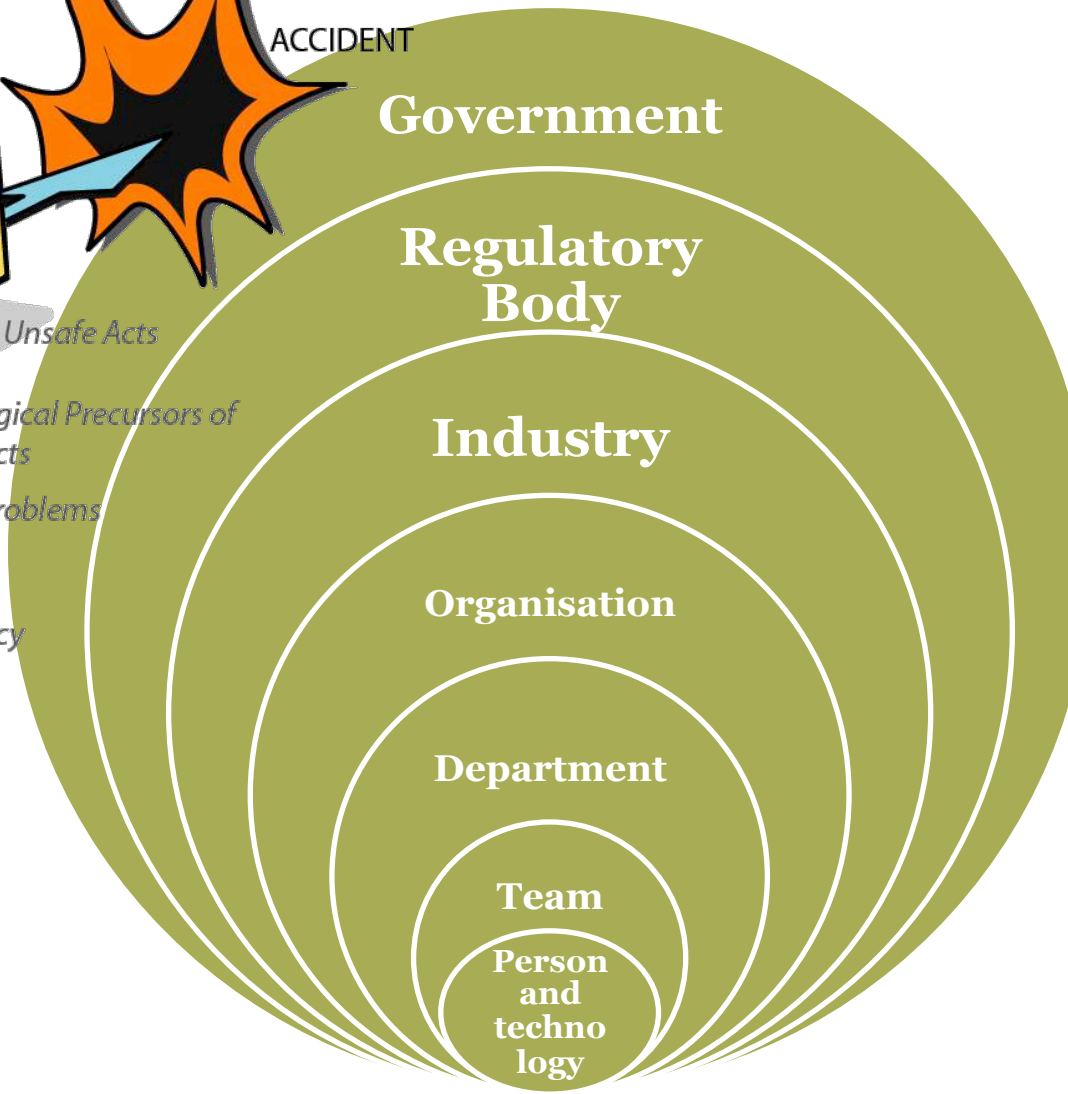

Socio-Technical System Levels

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- Micro

  - Lowest level of immediate human – machine interaction

- Meso

  - Intermediate level of collaboration between humans and between humans and technology in larger work units

- Macro

  - Highest level that captures the complexity of multi-layered systems

Gudela Grote, Johannes Weyer & Neville A. Stanton (2014) Beyond human-centred automation – concepts for human–machine interaction in multi-layered networks, Ergonomics, 57:3, 289-294.

Human Factors 'frames'

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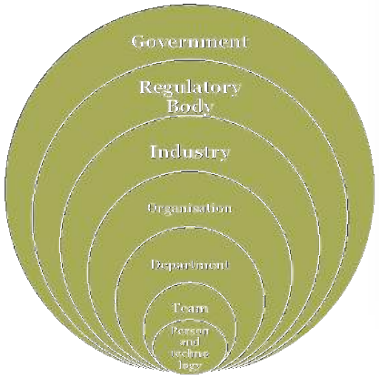
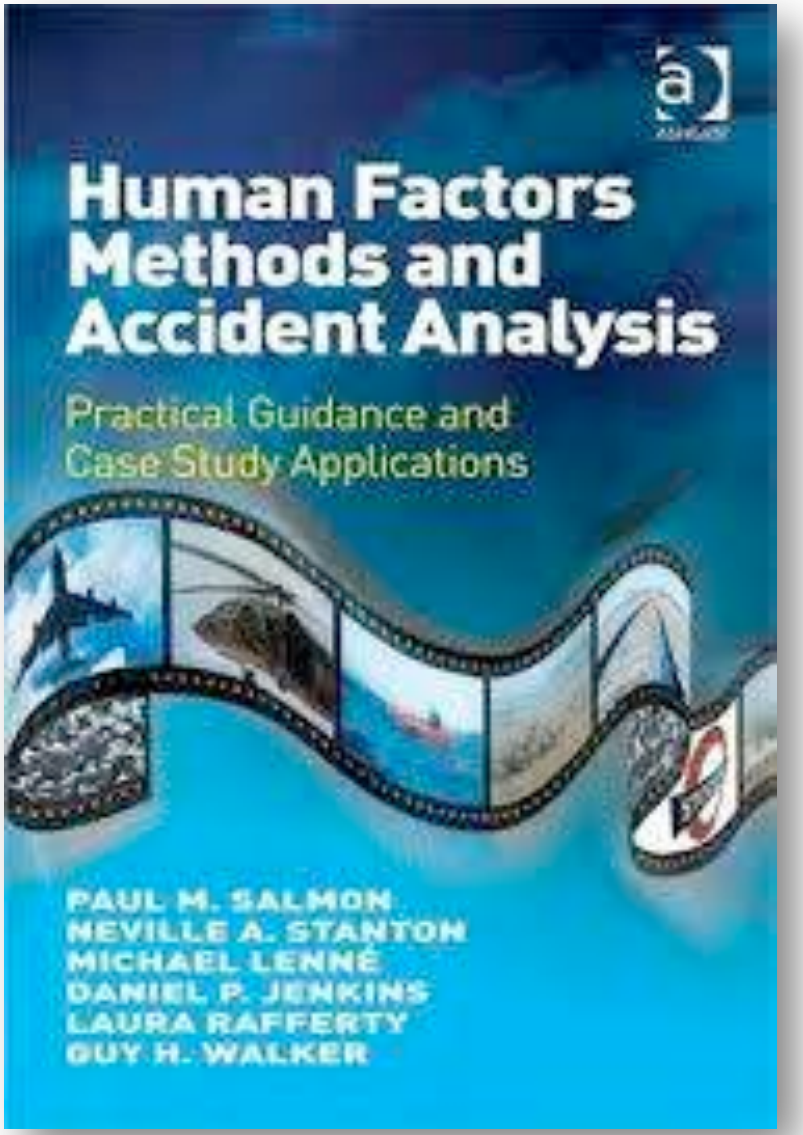
- Micro-level
  - Critical Path Analysis
- Meso-level
  - EAST
- Macro-level
  - Resident Pathogen Model
  - AcciMap





Frame or data?

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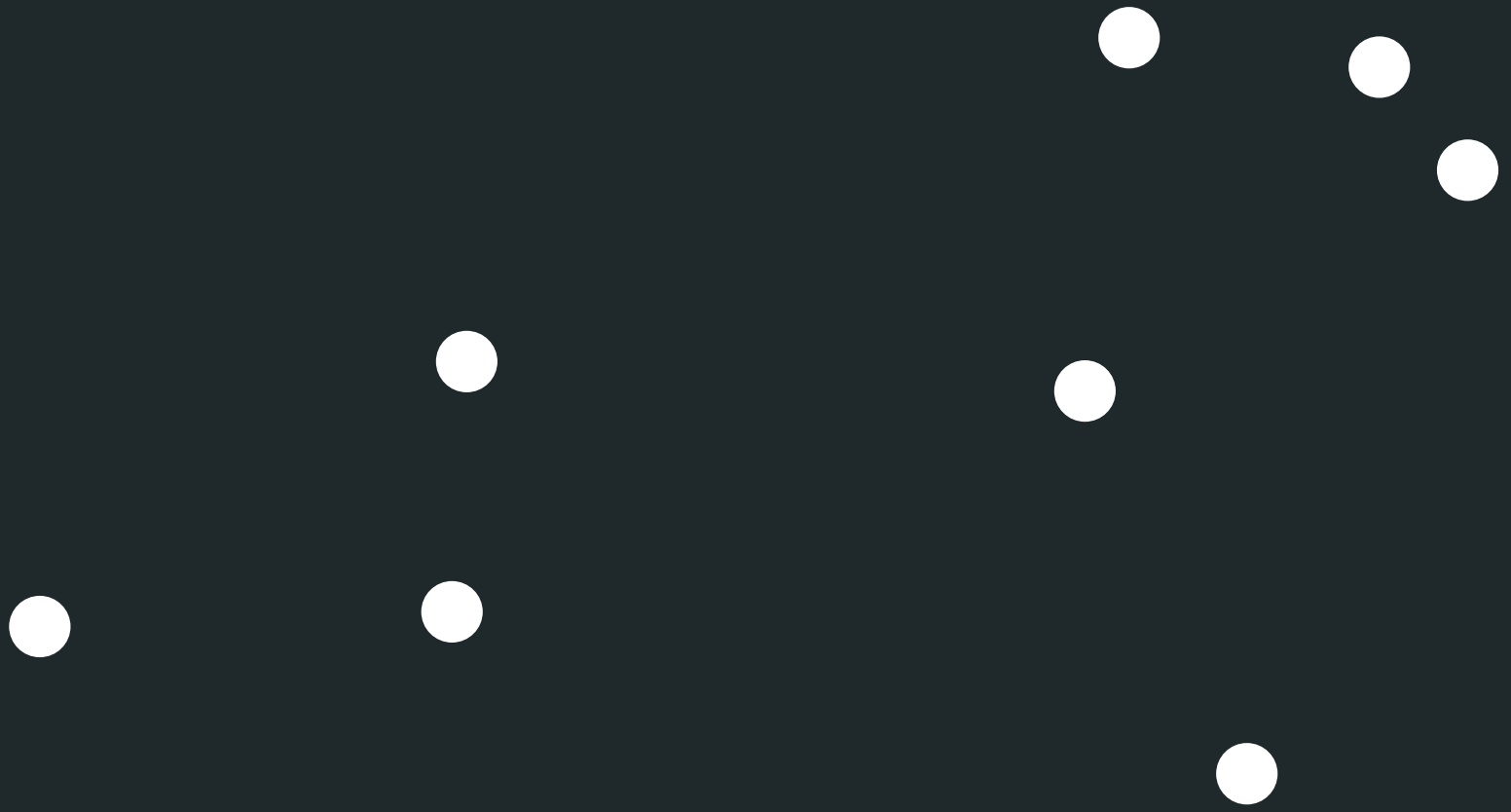

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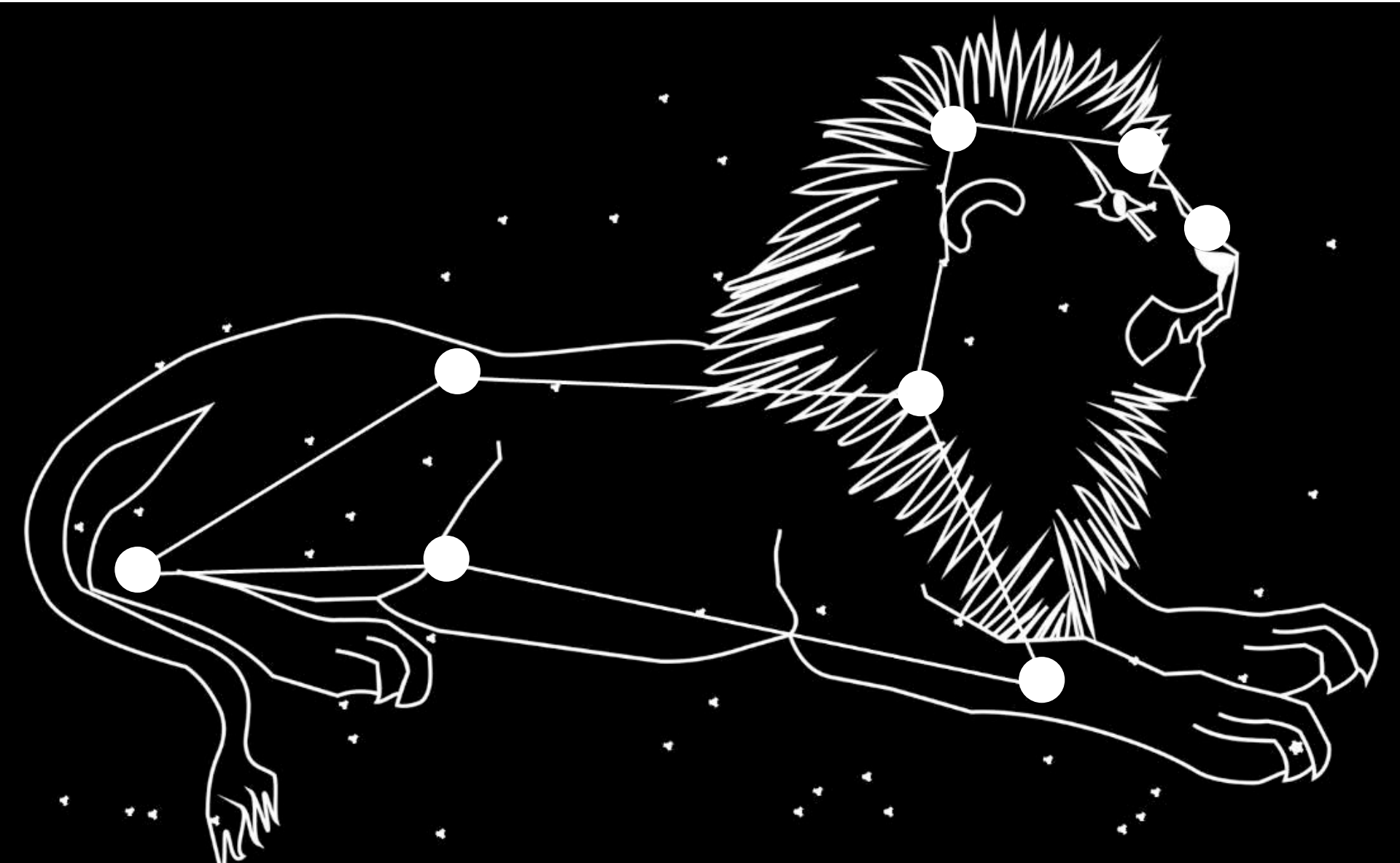

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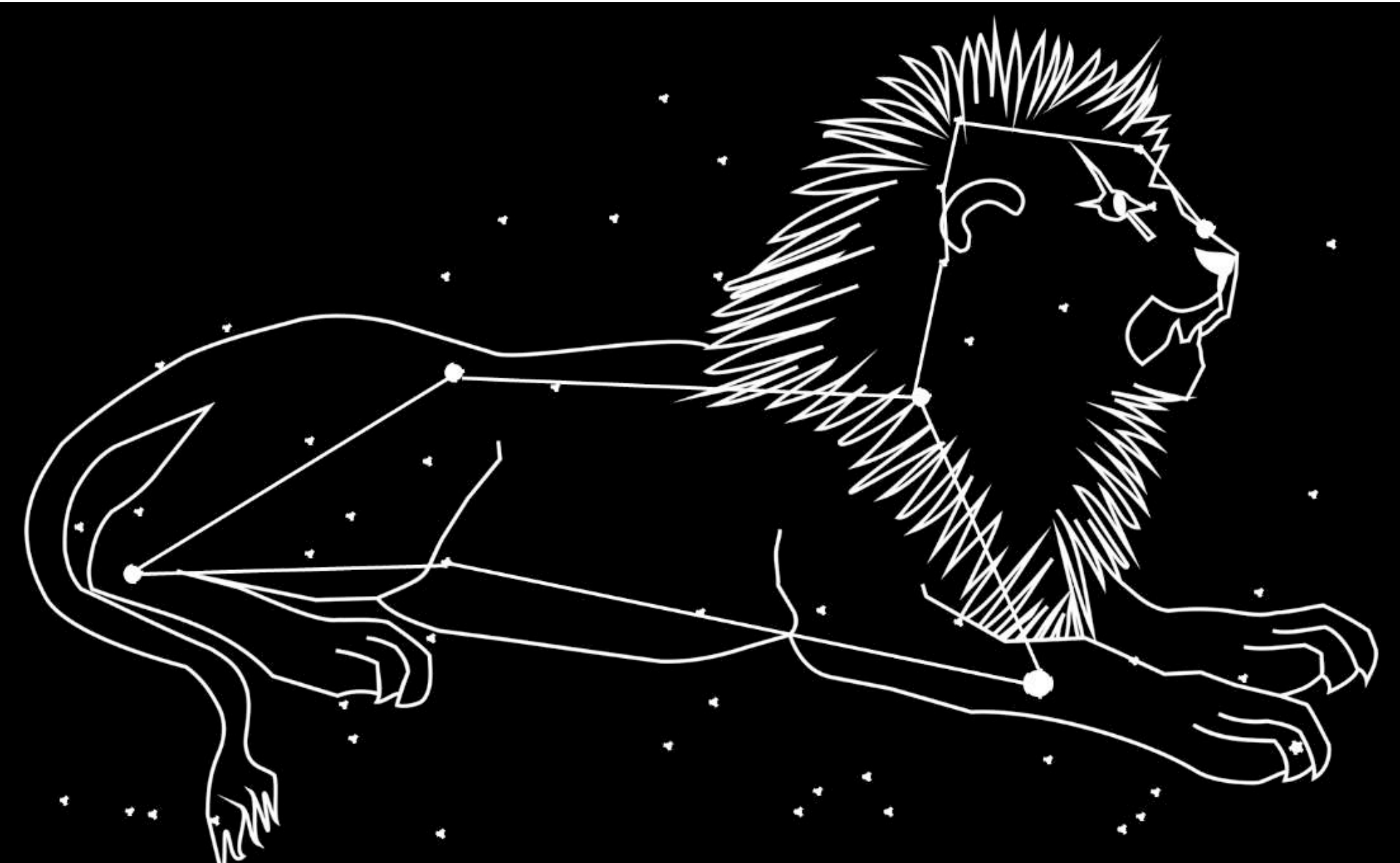

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Micro: Critical Path Analysis

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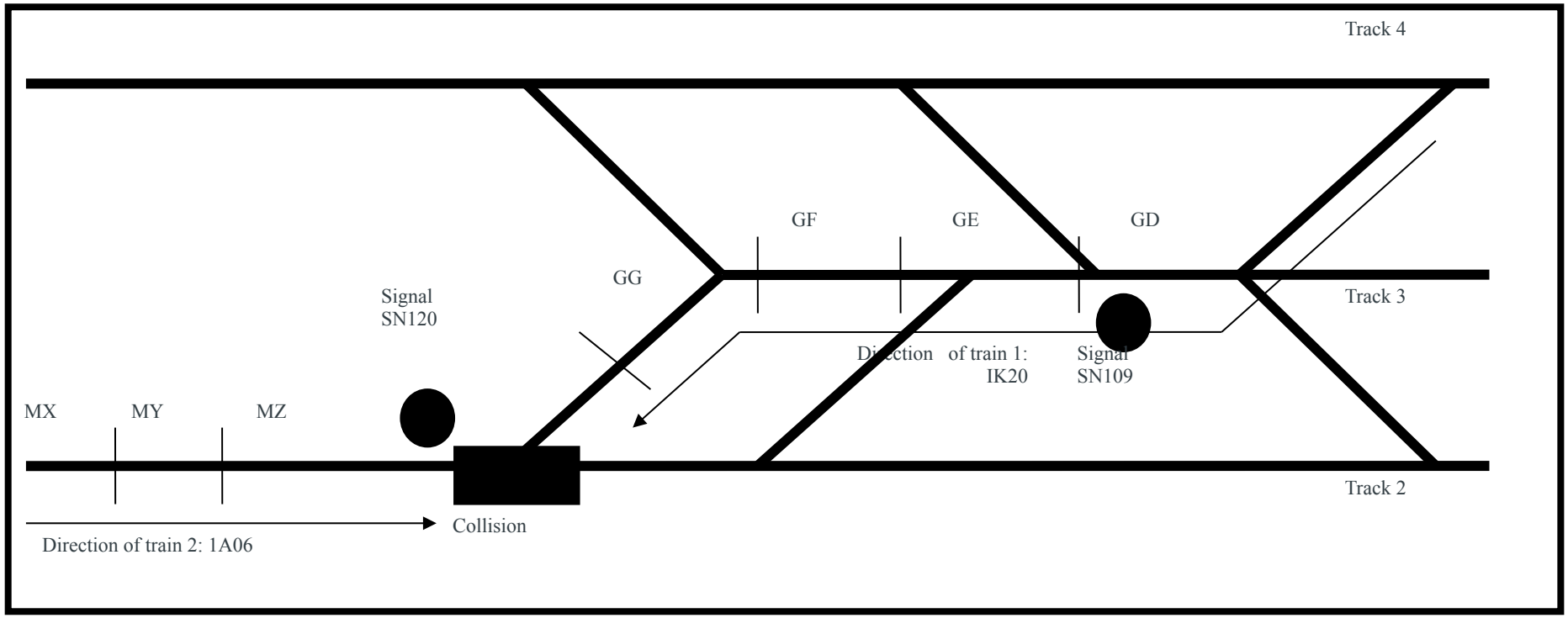
Ladbroke Grove

- 5th October 1999
- SPAD at SN109
- Combined impact of 130 mph
- 31 people killed and more than 520 injured
- Signalman took 18 seconds to ‘react’

Track schematic



Moray, N., Groeger, J. and Stanton, N. A. (2016) Quantitative Modelling in Cognitive Ergonomics: Predicting Signals Passed At Danger. Ergonomics, (Article in Press).

Stanton, N. A. and Walker, G. H. (2011) Exploring the psychological factors involved in the Ladbroke Grove rail accident. Accident Analysis & Prevention, 43 (3), 1117-1127.

Stanton, N. A. and Baber, C. (2008) Modelling of alarm handling responses times: A case of the Ladbroke Grove rail accident in the UK. Ergonomics, 51 (4) 423-440.

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Multi-SPAD signal

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Date	Time 24hrs	Company	Train	Over shoot (yards)
02 August 1993	18.25	FGW	1B58	2
13 February 1995	08.22	Thames	5P25	105
15 March 1996	18.58	Thames	2F71	146
23 June 1996	17.50	Thames	2P62	11
3 April 1997	08.12	Thames	1K20	72
4 February 1998	17.17	FGW	1C62	299
6 August 1998	17.23	Thames	1D56	21
22 August 1998	09.30	Thames	5Z71	2

Stanton, N. A. and Walker, G. H. (2011) Exploring the psychological factors involved in the Ladbroke Grove rail accident. Accident Analysis & Prevention, 43 (3), 1117-1127.

AWS horn and driver activities

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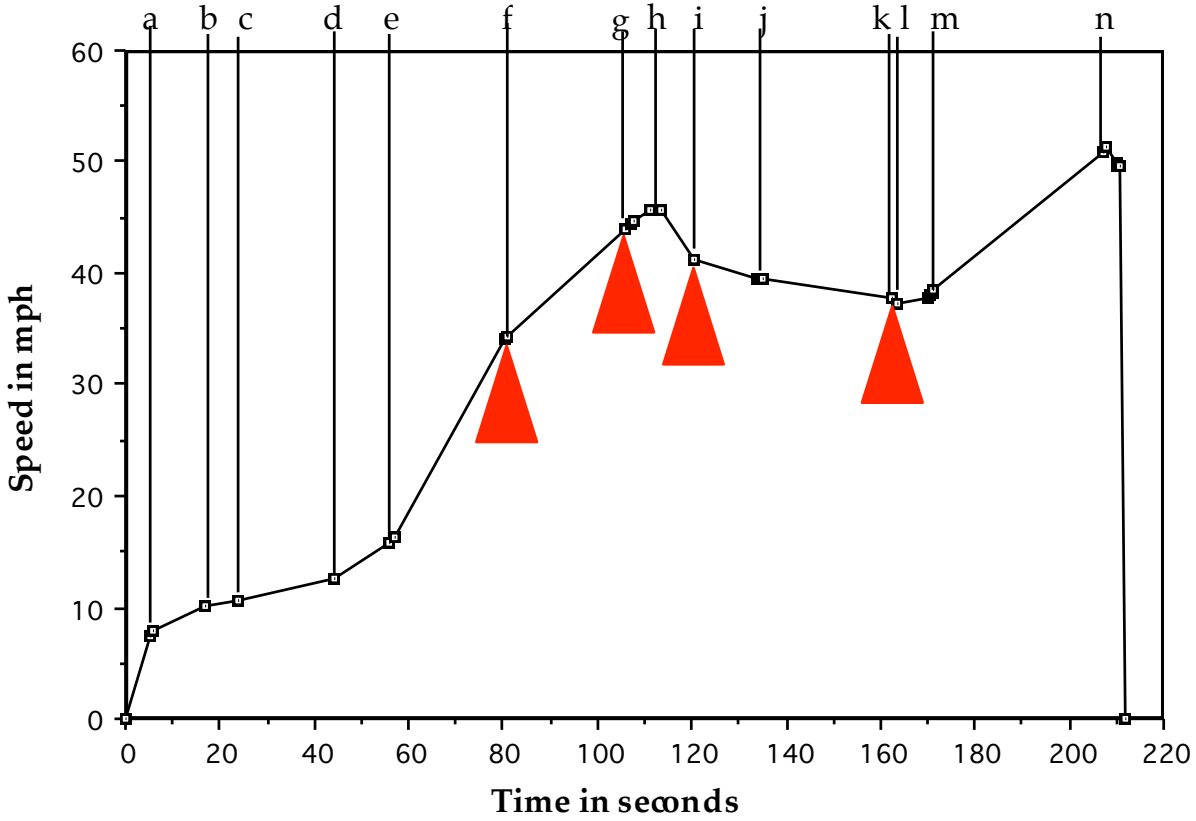
- a = Speed control notch 1 selected
- b = Speed control notch 2 selected
- c = Speed control notch 3 selected
- d = Speed control notch 4 selected
- e = Speed control notch 7 selected
- f = SN43 AWS horn activated - green aspect - line 4 indicated
- g = SN63 AWS horn activated - double yellow aspect
- h = Speed control notch 0 selected + brake level 1 applied
- i = brake level 1 released
- j = SN87 AWS horn activated - single yellow aspect - position line junction indicator number 1
- k = Speed control notch 5 selected
- l = SN109 AWS horn activated - red aspect
- m = Speed control notch 7 selected
- n = Speed control notch 0 selected + emergency brake applied



On Train Monitoring and Recording data

Stanton, N. A. and Walker, G. H. (2011) Exploring the psychological factors involved in the Ladbroke Grove rail accident. Accident Analysis & Prevention, 43 (3), 1117-1127.

Repeatedly cancelled the AWS without reference to the signal aspects

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Speed restrictions
- permanent
- temporary

Level crossings

SPAD indicators

Cancelling boards

Other locations

Stanton, N. A. and Walker, G. H. (2011) Exploring the psychological factors involved in the Ladbroke Grove rail accident. Accident Analysis & Prevention, 43 (3), 1117-1127.

Steps in Multi-modal CPA

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- Analyze the tasks to be modeled (e.g., HTA)
- Allocate sub-tasks to input/processing/output modality:
  - Visual tasks: looking at the track displays, looking at alarm screen, and looking at written notes and procedures.
  - Auditory tasks: listening for an auditory warning or listening to a verbal request.
  - Central processing tasks: making decisions about whether or not to intervene and selecting intervention strategies.
  - Manual tasks: typing codes on the keyboard, pressing button, and moving the cursor with the trackerball.
  - Verbal tasks: talking on the phone, talking to another signaller in the control room.
- Modify the sequence of tasks in terms of modality
- Allocate timings
- Construct the CPA diagram and calculate the critical path

Cancelling the AWS warnings

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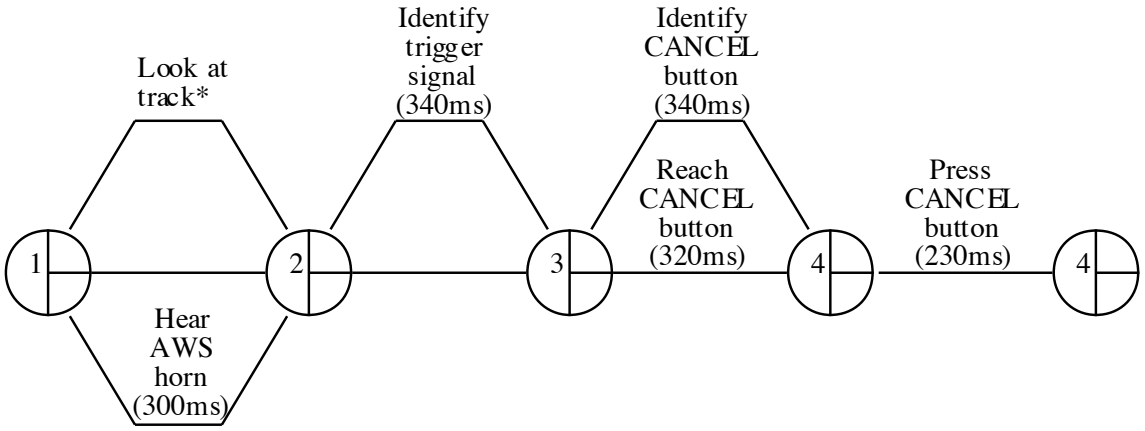

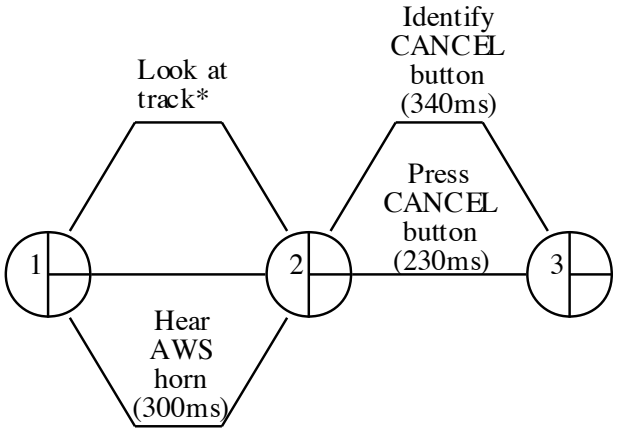

"no single, fixed, behavioural response expected on a driver in receipt of an AWS warning……..the situation at the time of the warning will determine how and when an individual driver reacts"

Task	Time at SN63	Time at SN87 & SN109
Hear AWS horn	300ms	300ms
Read trackside object (e.g., signal)	340ms	N/A
Reach for AWS button	320ms	N/A
Press AWS button	230ms	230ms
ESTIMATED TASK TIME	1190ms	530ms
ACTUAL TASK TIME	SN63= 1150ms	SN87 and SN109= 650ms

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Cognitive

Vision

Hearing

Motor

Speech

System response

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Early Start	Duration	Early Finish
Task Name		
Late Start	Slack	Late Finish

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Response times

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Activity	RT (ms)	Source	Times used in the model
Read (alarm message, headcode, etc) Glance at simple information Read short textual descriptions Recognize familiar words or objects	180 1800 314-340	Olsen & Olsen (1990) John & Newell (1990) Olsen & Olsen (1990)	Look at screen 180 Interpret information 340
Hear (auditory warning)	300	Graham (1999)	Hear auditory 'tweet' 300
Search (screen for alarm or train(s)) Checking or monitoring or searching Scanning, storing and retrieving Primed search	2700 2300-4600 1300-3600	Baber & Mellor (2001) Olsen & Olsen (1990) estimated	Search VDU for new information 2300 Primed search (faster than search) 1300
Diagnosis or decision mental preparation for response choosing between alternative responses simple problem solving	1350 1760 990	Card et al (1983) John & Newell (1990) Olsen & Nielson (1988)	Diagnosis activity 990
Basic Cognitive Operation	50	Gray et al. (1993)	Manipulate information 150 (3 steps)
Response Speak (e.g.: "We've got a SPAD")	100 per phoneme 1112	Hone and Baber (2001) Average from speaking the phrase 10 times	1112 for 'We' ve got a SPAD' 1500 for 'Send Message - Stop HST'
Move hand to trackerball or keyboard	214-400 320	Card et al (1983) Baber & Mellor (2001)	Move hand to trackball 320
Move trackerball to target item Move cursor via trackerball 100mm	1500 1245	Olsen & Olsen (1990) Baber & Mellor (2001)	Move trackball 1245
Press key (e.g., ACK or CANCEL key)	200 80-750 230	Baber & Mellor (2001) Card et al (1983) Olsen & Olsen (1990)	Press button 200 [total 520 with 'move hand' time]
Type headcode Average typist (40 wpm) Typing random letters Typing complex codes	280 500 750	Card et al (1983) Card et al (1983) Card et al (1983)	
Auditory processing (e.g., speech)	2300	Olsen & Olsen (1990)	
Switch attention from one part of a visual display to another	320	Olsen & Olsen (1990)	

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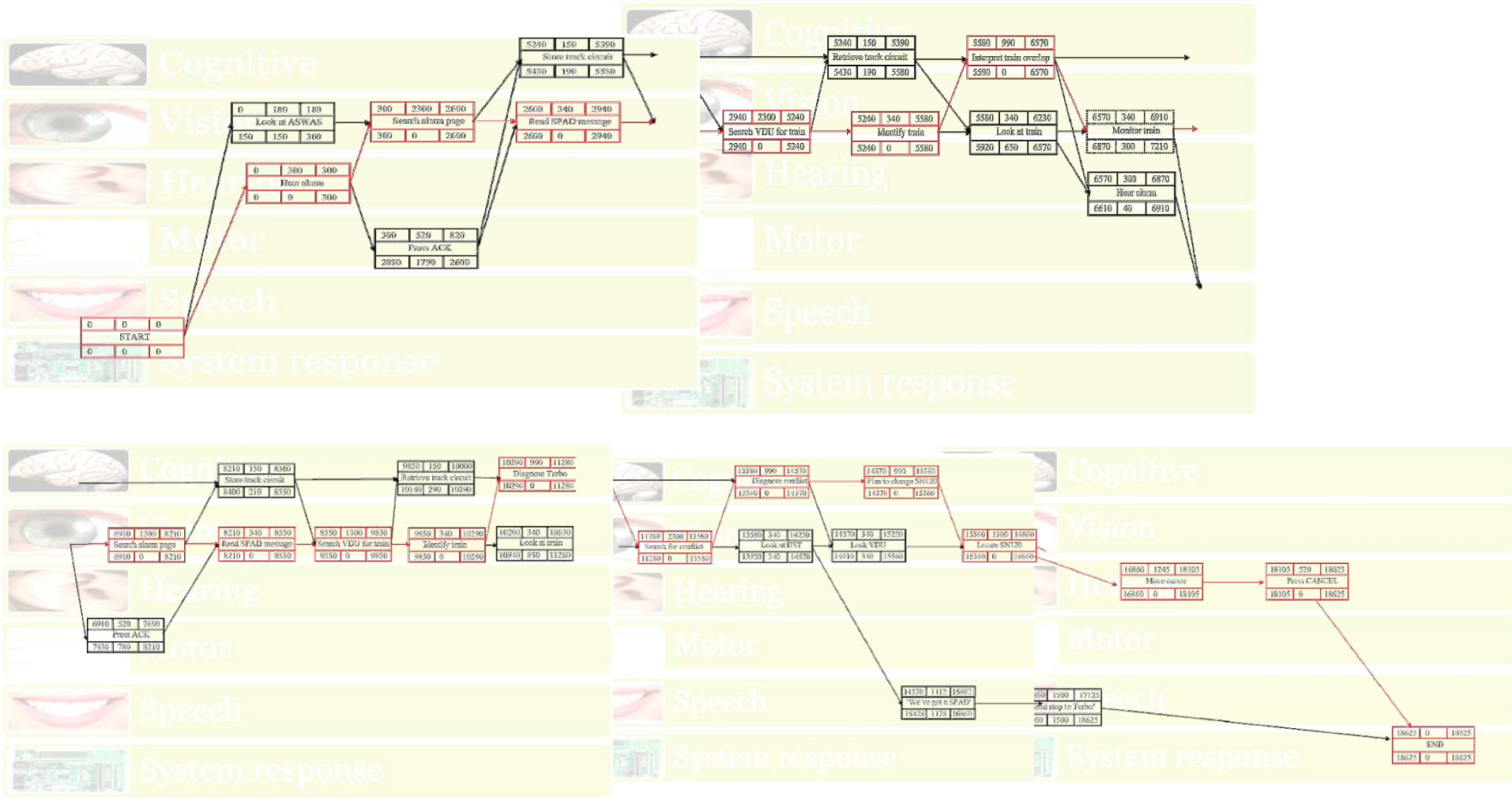

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Critical path tasks and timings

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Tasks	Start time	Duration	End time
Hear alarm	0	300	300
Search alarm page	300	2300	2600
Read SPAD message	2600	340	2940
Search VDU for train	2940	2300	5240
Identify train	5240	340	5580
Interpret train overlap	5580	990	6570
Monitor train	6570	340	6910
Search alarm page	6910	1300	8210
Read SPAD message	8210	340	8550
Search VDU for train	8550	1300	9850
Identify train	9850	340	10290
Diagnose Turbo	10290	990	11280
Search for conflict	11280	2300	13580
Diagnose conflict	13580	990	14570
Plan to change SN120	14570	990	15560
Locate SN120	15560	1300	16860
Move cursor	16860	1245	18105
Press CANCEL	18105	520	18625

Stanton, N. A. & Baber, C. (2008) Modelling of alarm handling responses times: A case of the Ladbroke Grove rail accident in the UK, Ergonomics, 51 (4), 423-440.

CPA Insights

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- Incident
  - Different warnings for signals and speed restrictions
  - Design screens to show track layout in a more intuitive format
  - Separate track occupation warnings into its own section of the alarm screen
  - Make unauthorised track occupations easier to find on track display (flashing track blocks?)
  - Review safe track overlap areas for emergency response
- CPA method
  - Understanding cognitive micro-strategies
  - Model anchored to black box data

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Meso: EAST

HMS Sheffield

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- Falklands war (April 2, 1982 – June 14, 1982)
- 4th May 1982
- Struck by an Exocet air-launched missile
- Missile detection too late for crew to react
- 20 crew died
- Report severely criticised training and procedures

RAF Hawk
(simulation of missile approach
– without RADALT!)

Type 23 Frigate
(training in detecting low flying missile approach)


BAE Hawk T1 low level over water - Simluated Ship Attack(1
00:01:29

Risk Assessment

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- Traditional (reductionist) approaches
  - Technique for Human Error Rate Prediction (Swain and Guttmann, 1983)
  - Technique for the Retrospective and Predictive Analysis of Cognitive Errors (Shorrock and Kirwan, 2000)
  - Systematic Human Error Reduction and Prediction Approach (Embrey, 1986)
- Systems approaches
  - Cognitive Reliability and Error Analysis Method (Hollnagel, 1998)
  - Human Factors Analysis and Classification System (Shappell and Wiegmann, 2001)
  - System-Theoretic Process Analysis (Leveson, 2012)

Stanton, N. A. and Harvey, C. (2016) Beyond human error taxonomies in assessment of risk in sociotechnical systems: a new paradigm with the EAST 'broken-links' approach. Ergonomics.

EAST

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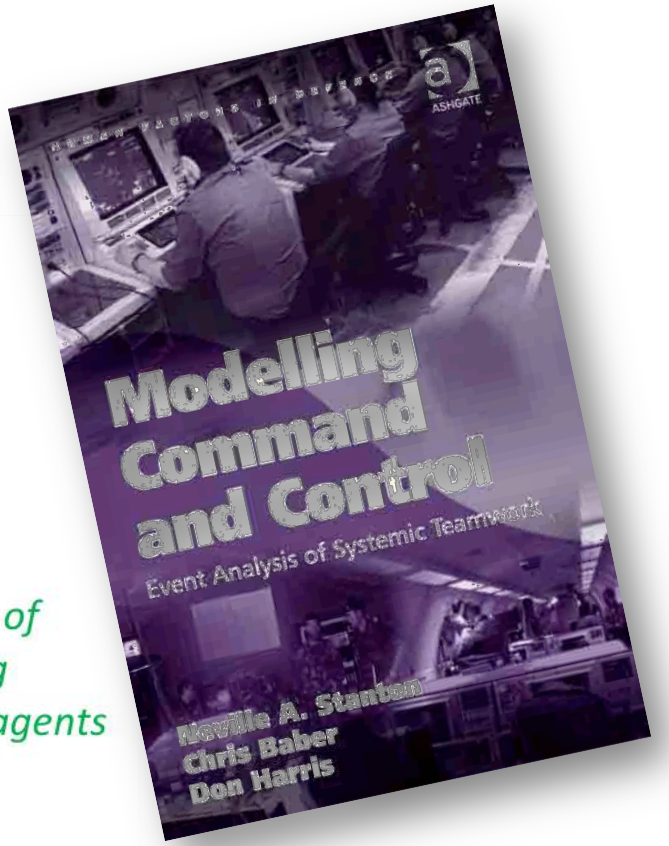
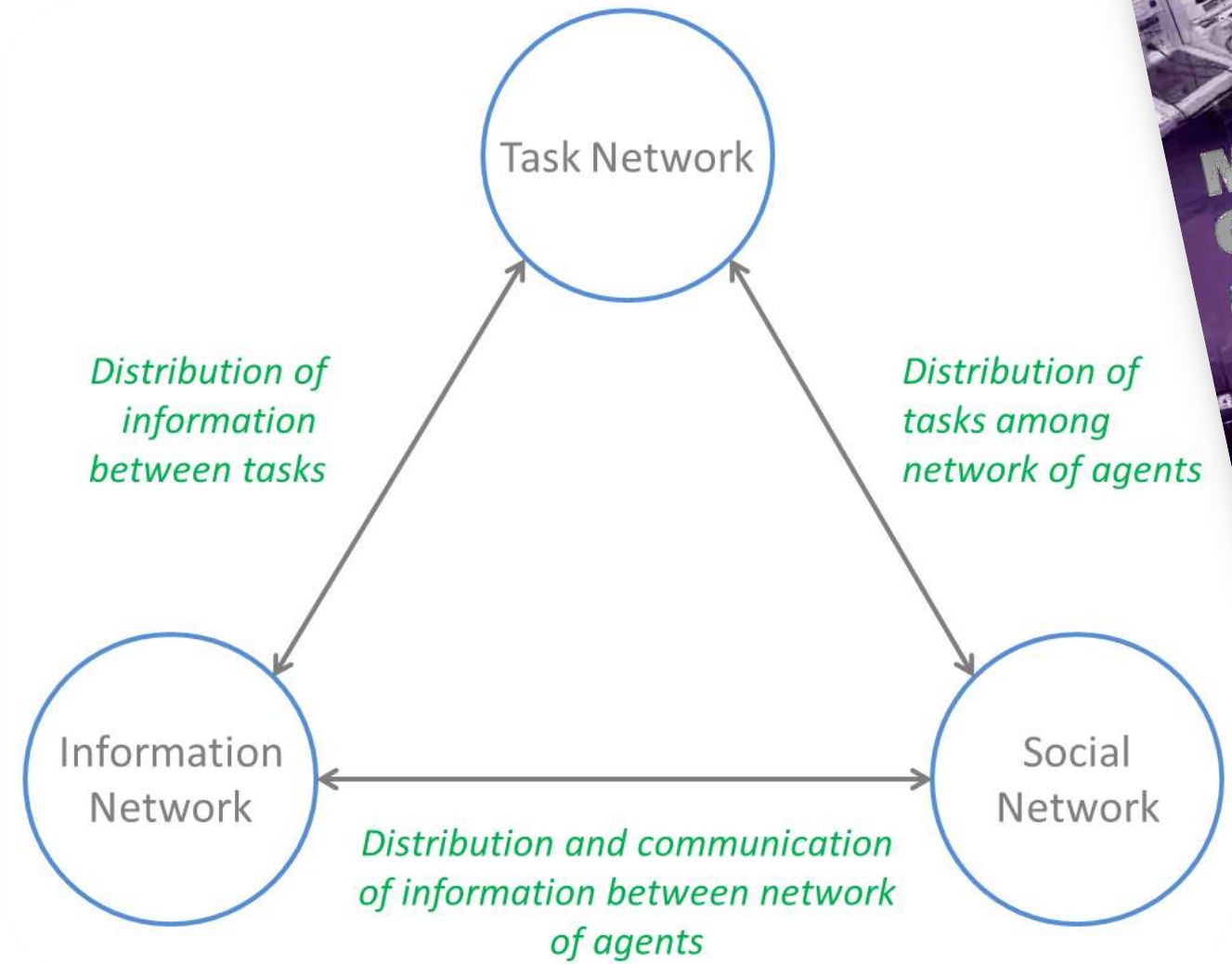
Event Analysis of Systematic Teamwork





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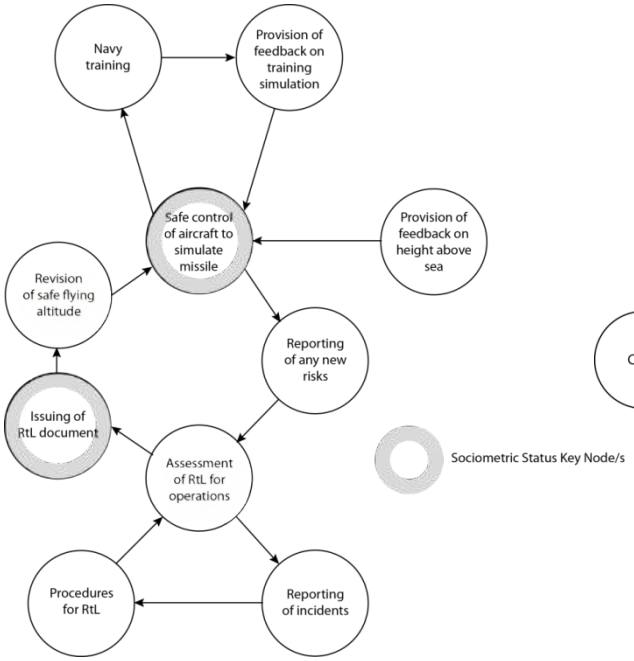
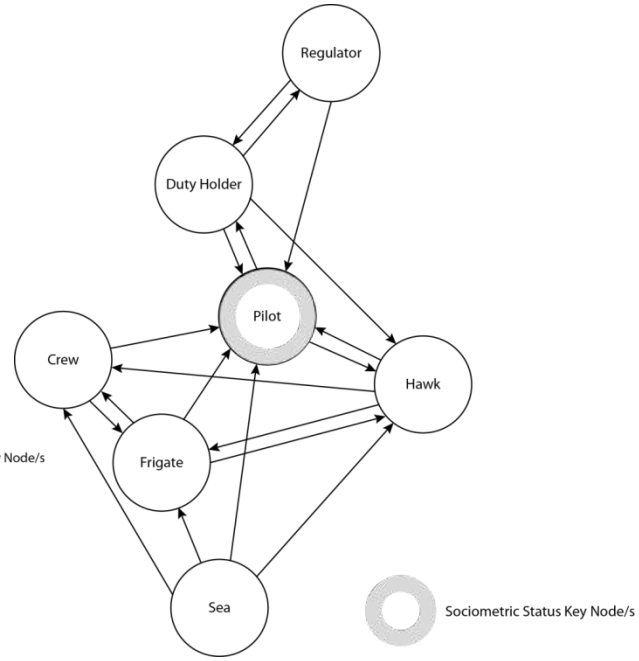
"Most, if not all, accidents and near misses are caused, at least in part, by the failure to communicate information between agents and tasks"

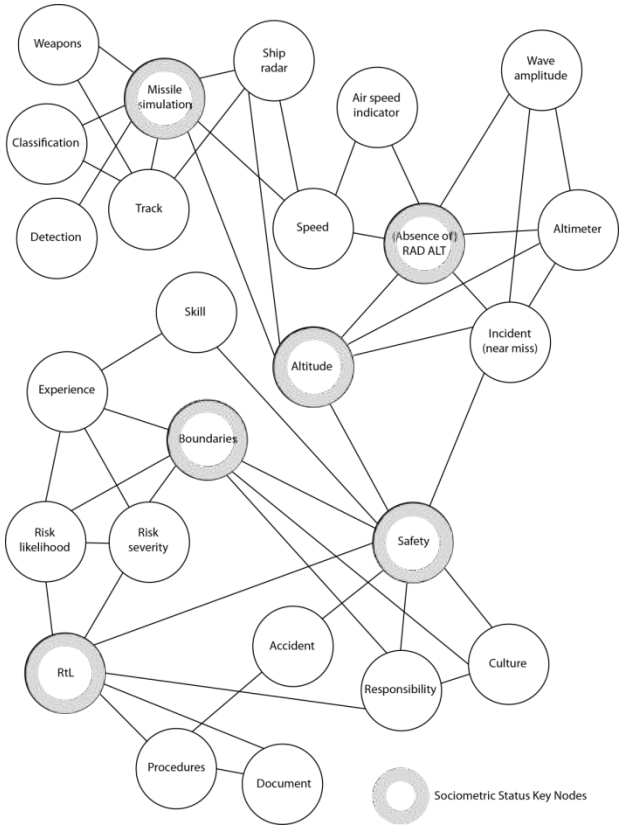
Task:



Social:



Information:



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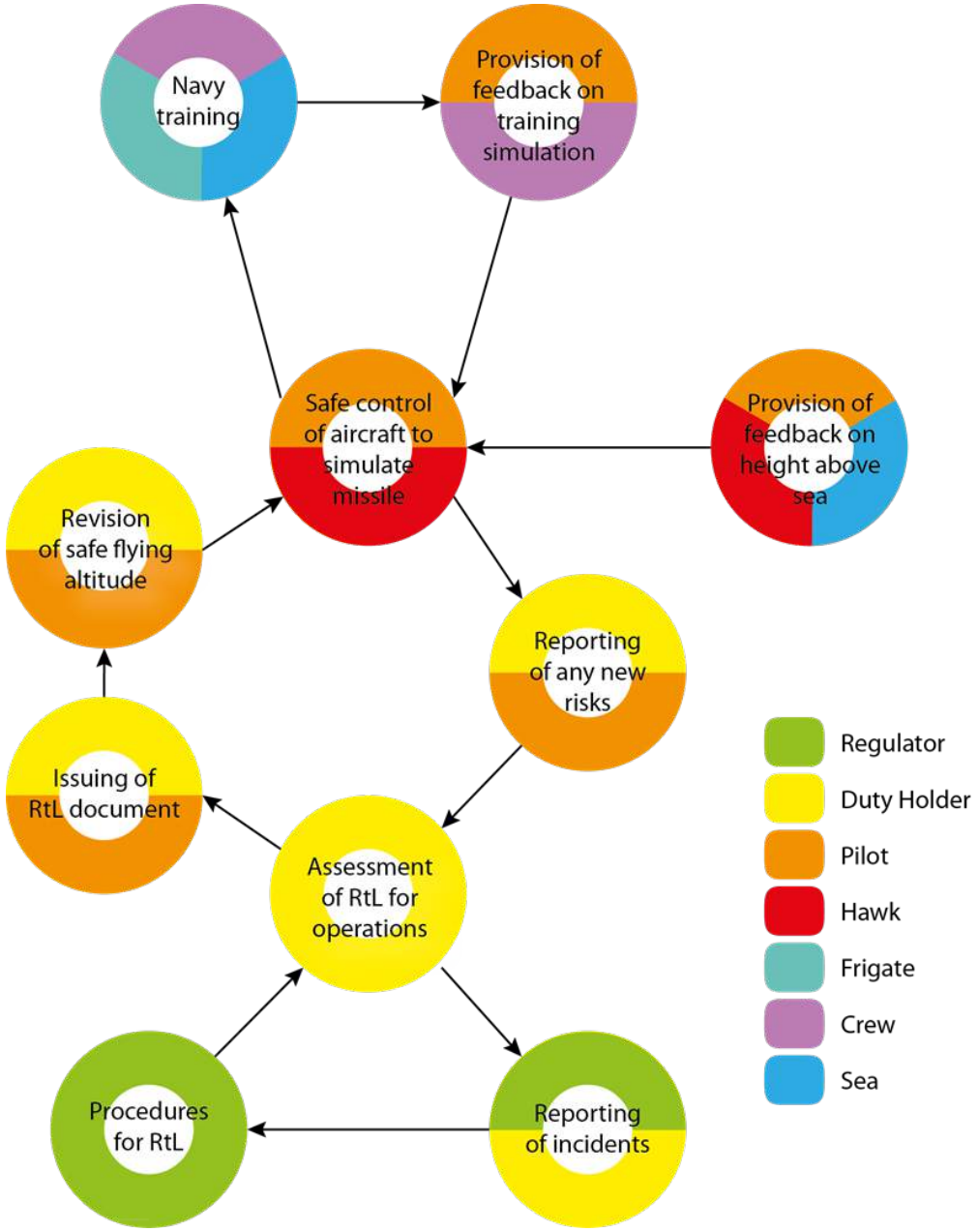
EAST

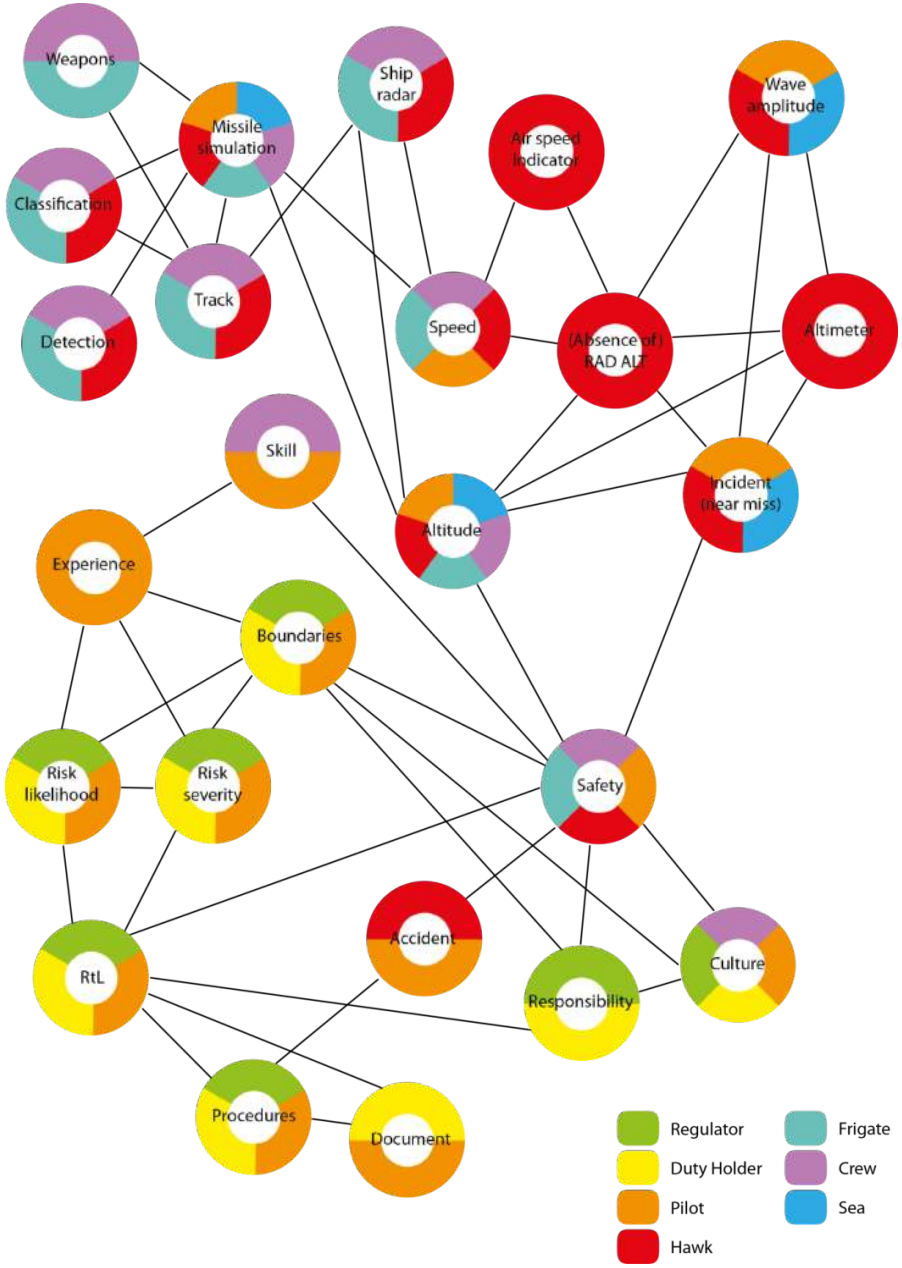
Task network
coded by social agents



Stanton, N. A. and Harvey, C. (2016) Beyond human error taxonomies in assessment of risk in sociotechnical systems: a new paradigm with the EAST 'broken-links' approach. Ergonomics.

EAST

Information network coded by social agents



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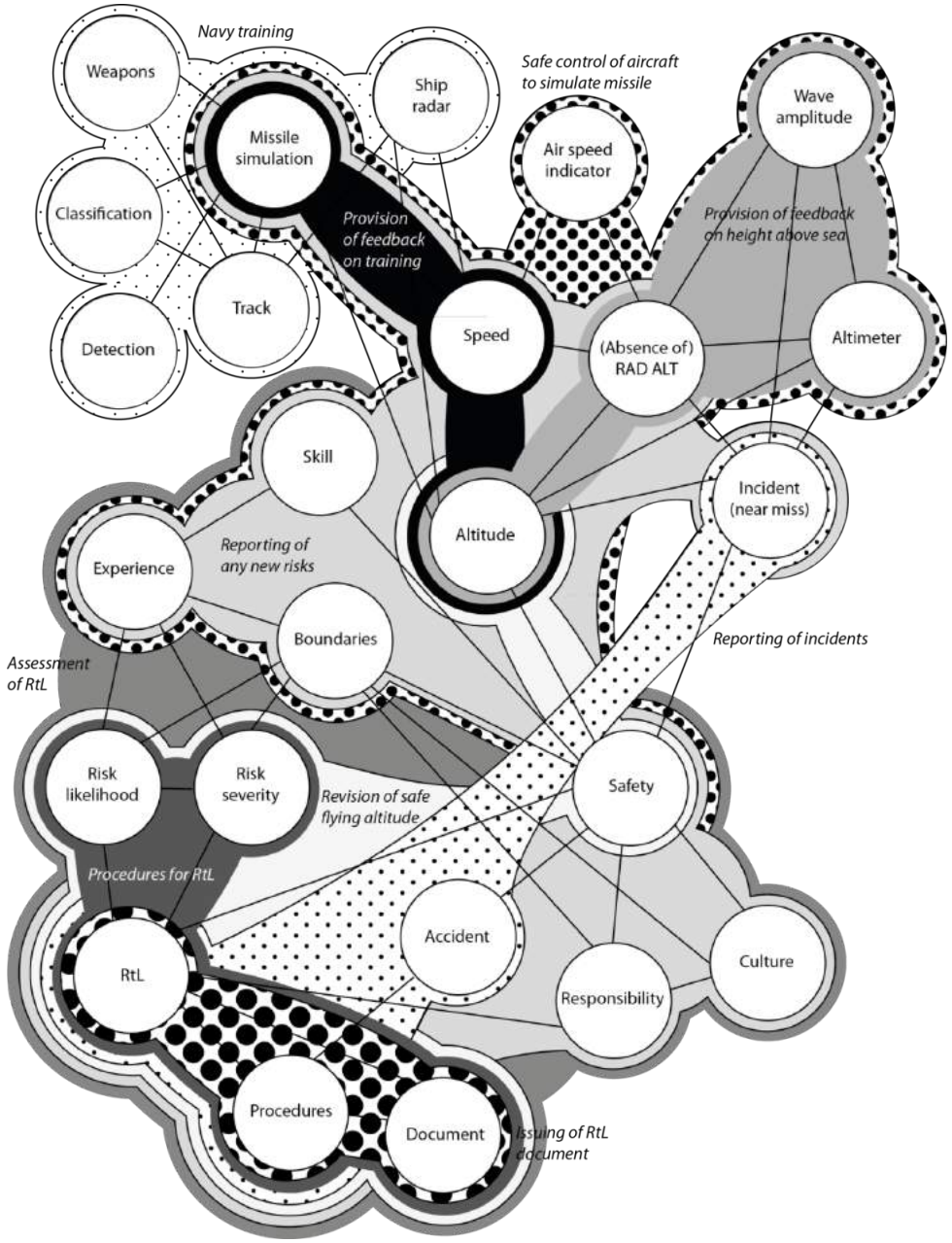
EAST

Combined information and task networks



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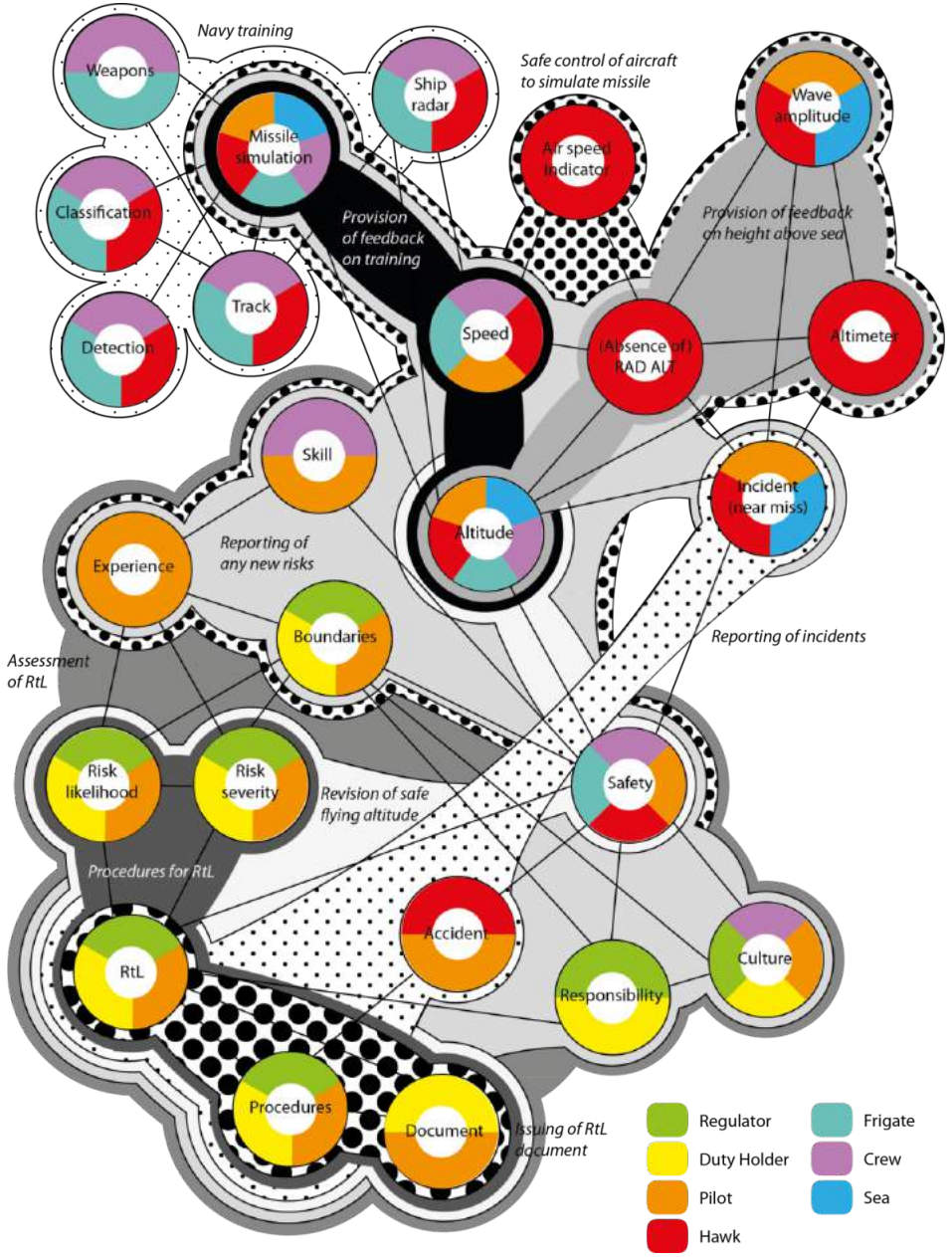
EAST

Combined task, information, and social network



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EAST: Extension to method

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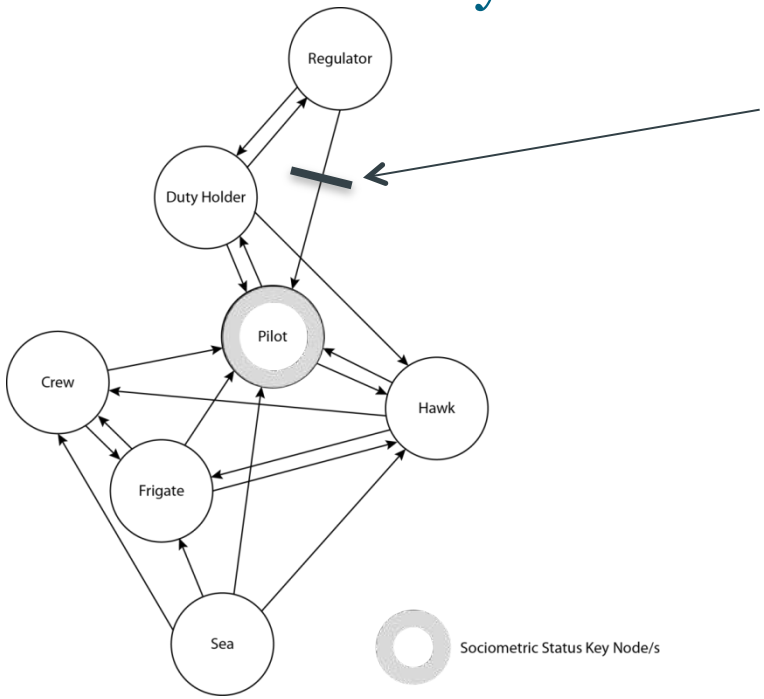
An additional stage was developed for EAST: **Broken links analysis**

This was used to identify **137 risks** for the Hawk missile simulation case study



1. Break the link between each pair of nodes
2. For every piece of **information (from the information network)** which is shared between those nodes, explore the impact on the network if the information is **not communicated.** These are the **risks**
3. Do this for all node pairs in the **Social network** and in the **Task network**

Stanton, N. A. and Harvey, C. (2016) Beyond human error taxonomies in assessment of risk in sociotechnical systems: a new paradigm with the EAST 'broken-links' approach. Ergonomics.

From (agent)	To (agent)	Information not communicated	Resulting risk	Mitigation strategy
Duty Holder	Pilot	*Boundaries*	Pilots are not aware of the boundaries for flight operations and for the identification and reporting of risks within this	Boundaries for risk reporting must be made clear to pilots as part of the RtL process
Duty Holder	Pilot	*RtL*	Pilots are not made aware of the results and consequences of the RtL assessment process after it is conducted at DH level	Results and consequences of the RtL assessment process must be effectively communicated to pilots
Duty Holder	Pilot	*Risk likelihood*	Pilots are not made aware of risks assessed that their likelihood of occurrence	Risks identified as having a high likelihood of occurrence must be reported to pilots
Duty Holder	Pilot	*Risk severity*	Pilots are not made aware of risks assessed and their severity of impact	Risks deemed as having a high severity of impact must be reported to pilots
Duty Holder	Pilot	*Procedures*	Pilots are not aware of how the RtL process is conducted at DH level and of procedures for reporting incidents to the DH	Pilots must be provided with clear procedures describing the assessment of RtL at DH level and the reporting of risks to DH
Duty Holder	Pilot	*Document*	Pilots are not provided with documentation covering the RtL process and its results	Pilots must be provided with documentation covering the RtL process and its results
Duty Holder	Pilot	*Responsibility*	Pilots are not aware of the DH's nor their own responsibilities for safety	The responsibilities of both the pilot and DH for safety must be clearly defined and understood by pilots
Duty Holder	Pilot	*Safety*	Pilots do not receive information about the safety of operations, based on the RtL assessment process	The safety of operations, as assessed during the RtL process, must be reported to the pilots
Pilot	Duty Holder	*RtL*	The DH does not receive information about new risks identified by the pilots	Pilots must clearly report all relevant risks to the DH
Pilot	Duty Holder	*Risk likelihood*	The DH does not receive information about the likelihood of new risks identified by the pilots	Pilots must report their estimate of the likelihood of occurrence of all relevant risks

From (task)	To (task)	Information not communicated	Resulting risk	Mitigation strategy
Issuing of RtL document	Revision of safe flying altitude	*Document*	The information contained in the RtL document does not trigger a revision of safe flying altitude	The RtL document must be used by regulators to inform changes to regulations and safety guidance where appropriate
Issuing of RtL document	Revision of safe flying altitude	*RtL*	The outcome of the RtL process outlined in the RtL document does not trigger a revision of safe flying altitude	The outcomes of RtL assessment must be used by regulators to inform changes to regulations and safety guidelines where appropriate
Issuing of RtL document	Revision of safe flying altitude	*Risk likelihood*	The outcome of the Risk likelihood assessment, conducted as part of the RtL process and outlined in the RtL document, does not trigger a revision of safe flying altitude	The outcome of the Risk likelihood assessment, conducted as part of the RtL process and outlined in the RtL document, must be used to inform changes to regulations and safety guidelines where appropriate
Issuing of RtL document	Revision of safe flying altitude	*Risk severity*	The outcome of the Risk severity assessment, conducted as part of the RtL process and outlined in the RtL document, does not trigger a revision of safe flying altitude	The outcome of the Risk severity assessment, conducted as part of the RtL process and outlined in the RtL document, must be used to inform changes to regulations and safety guidelines where appropriate
Issuing of RtL document	Revision of safe flying altitude	*Safety*	The safety implications of the RtL process outlined in the Rtl document do not trigger a revision of safe flying altitude	The safety implications of RtL assessment must be used by regulators to inform changes to regulations and safety guidelines where appropriate
Issuing of RtL document	Revision of safe flying altitude	*Responsibility*	Responsibility for the revision of safe flying altitude is not outlined in the RtL document	Responsibility for changes to regulations and safety guidelines based on RtL assessment must be clearly assigned and accepted
Safe control of aircraft to simulate missile	Navy training	*Missile simulation*	The overall control of the Hawk does not adequately simulate missile attack on the frigate to aid with training	The operation of the Hawk must aid Navy training for missile attack situations

EAST Insights

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- Incident
  - Multiple owners of the risk: regulator, duty holder, pilot and crew of frigate/destroyer
  - Crew on Frigate need to train against sea-skimming missiles which appear late on radar and require a short response time (higher Hawk = more risk)
  - Pilot of Hawk flying at low altitude by eye using wave height as a cue (lower Hawk = more risk)
- Method
  - It's all about communication of information between agents and tasks (and broken links)
  - Identification of key nodes in network (using SNA)
  - Developing multi-modal composite network

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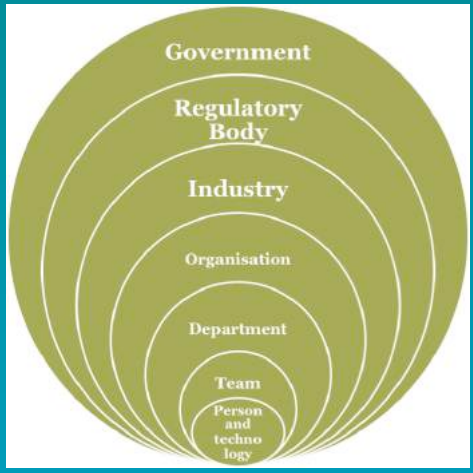
Macro: Resident Pathogen



Herald of Free Enterprise

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- 6th March 1987
- Inner/Outer Bow doors left open on sailing
- Water entered through open bow doors
- Car deck flooded
- Ship capsized
- 193 passengers and crew died

Noyes, J. and Stanton, N. A. (1997) Engineering Psychology: Contribution to System Safety, IEE Computing and Control Engineering Journal, June, 107-122.

Resident Pathogen (aka Swiss Cheese Model)

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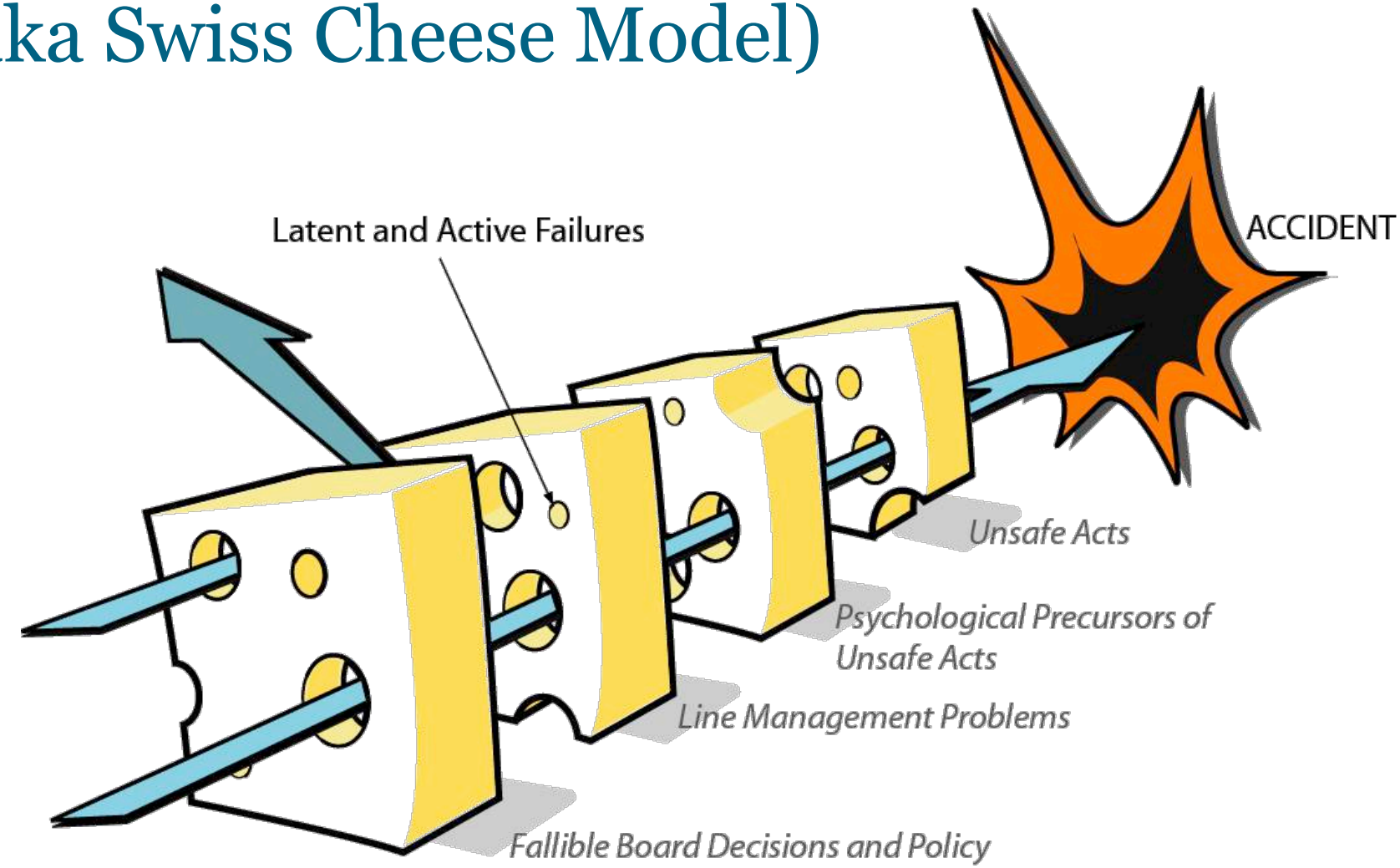

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Herald of Free Enterprise

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Layers in system	Contributing factors
Fallible board decisions and policy	Accepted use of top-heavy Ro-Ro design Repeated refusal to adopt warning light on ship's bridge (due to cost)
Line management problems	People working double shifts because of under-staffing (cost savings) Custom and practice of leaving harbour with bow doors open (speed up turn around)
Psychological precursors of unsafe acts	Culture of job demarcation*1 Negative reporting systems*2
Unsafe acts	Responsible person asleep in bunk Deckhand sees bow doors open but does not report it*1 Speed of ship leaving port*2
Local conditions	Choppy sea

Noyes, J. and Stanton, N. A. (1997) Engineering Psychology: Contribution to System Safety, IEE Computing and Control Engineering Journal, June, 107-122.

RPM Insights

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- Incident
  - Mixture of technical issues, social issues and natural phenomena (fatal combination)
  - Incident preventable at many levels
- Method
  - Resident pathogens can lie in wait in systems for months or years
  - Systems drift towards accidents as holes appear in defences (changes in technologies and work practices)
  - Latent and active failures combine to cause incidents

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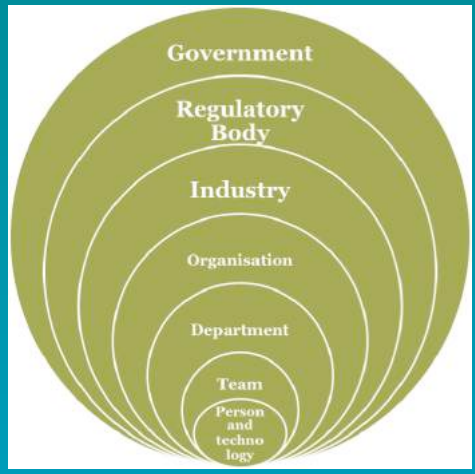
Macro: AcciMaps



Piper Alpha

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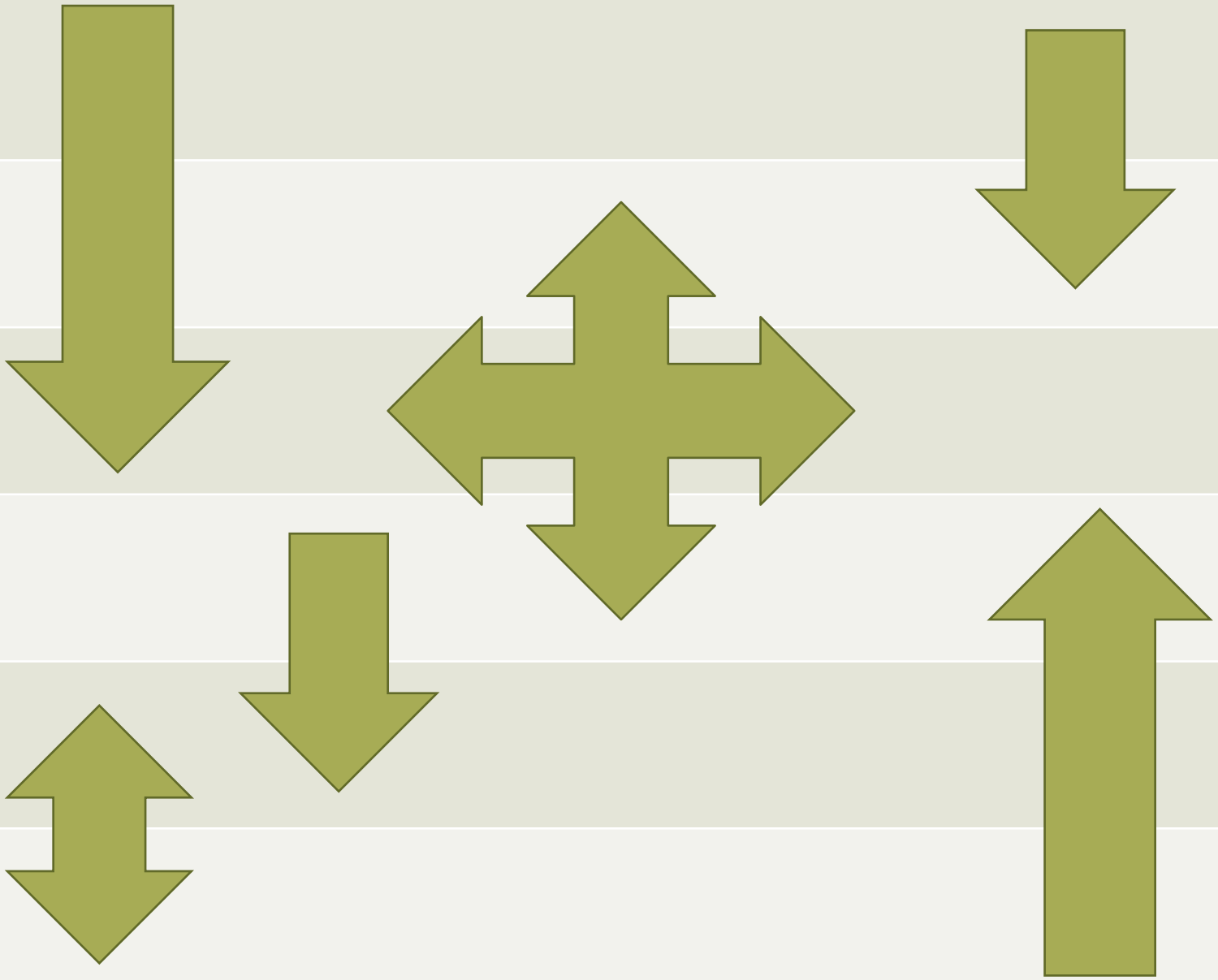
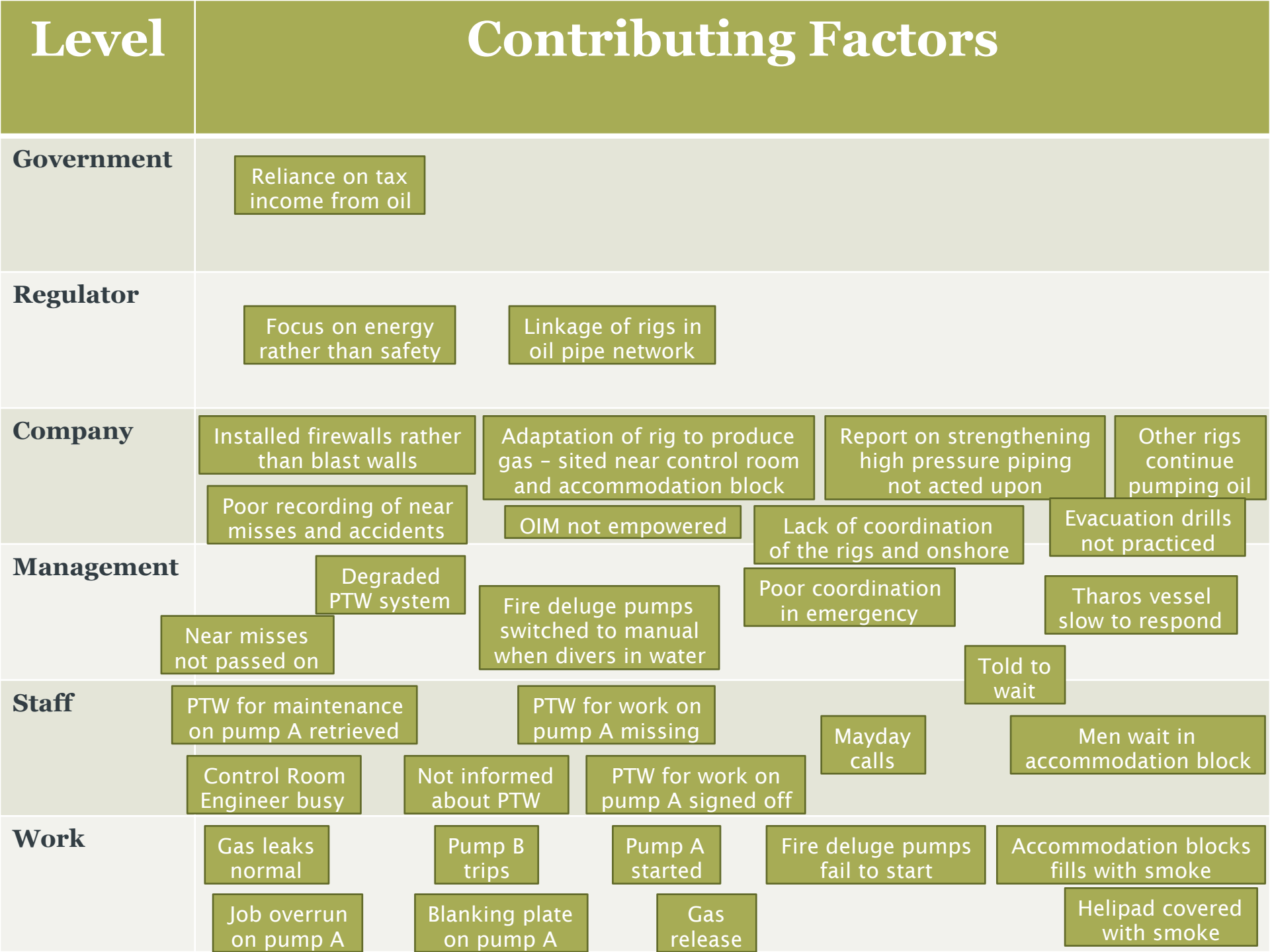
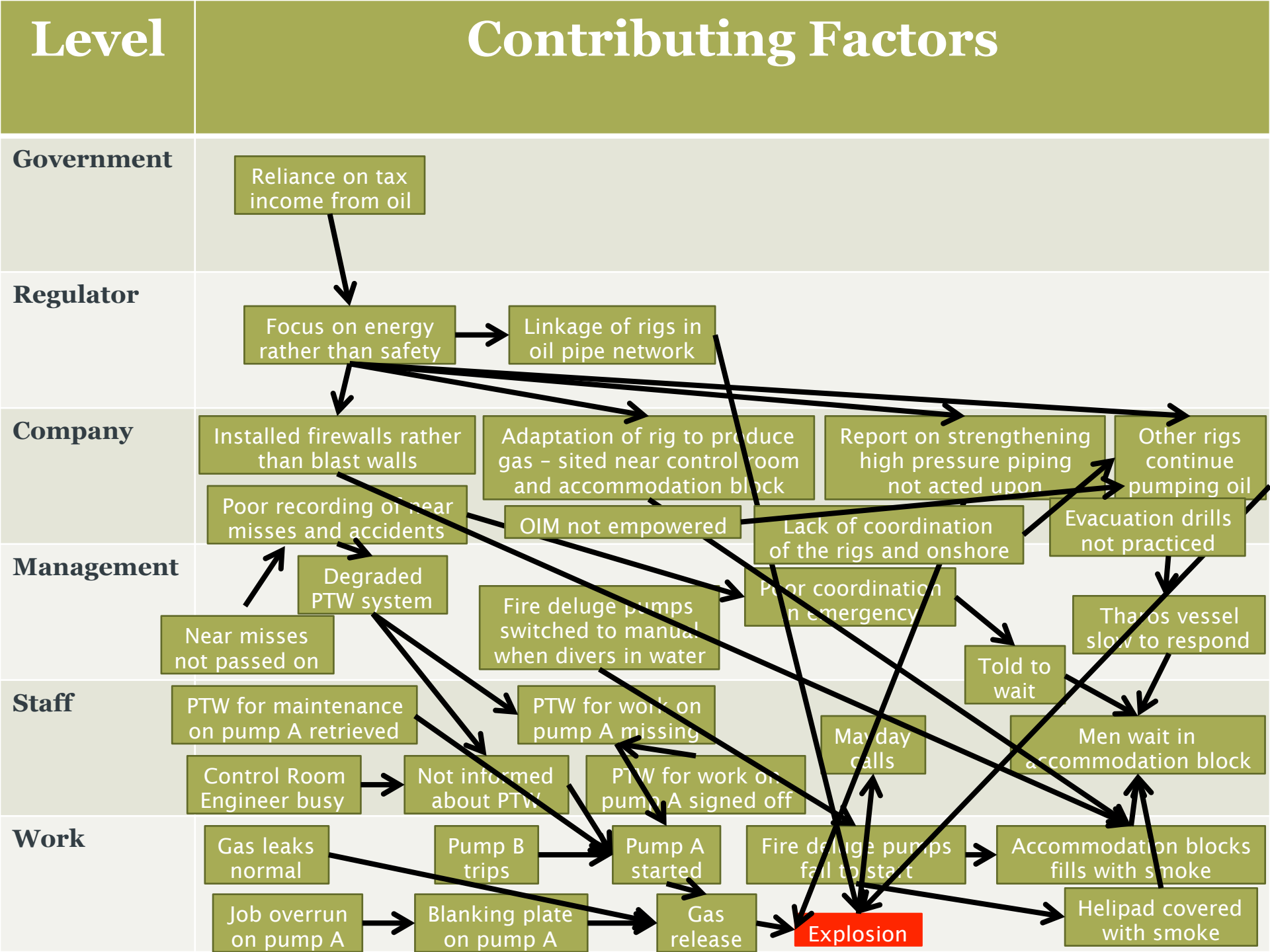
- Oil production started in 1976
- Linked to the Claymore and Tartan platforms
- Gas recovery module was installed in 1980
- Gas compression next to the control room
- Explosion and fire on 6 July 1988, killing 167 men, with only 61 survivors
- Total insured loss was £1.7 billion

Level	Contributing Factors
Government	
Regulator	
Company	
Management	
Staff	
Work	




Level
Contributing Factors
Government
Reliance on tax income from oil
Regulator
Focus on energy rather than safety
Linkage of rigs in oil pipe network
Company
Installed firewalls rather than blast walls
Adaptation of rig to produce gas – sited near control room and accommodation block
Report on strengthening high pressure piping not acted upon
Other rigs continue pumping oil
Poor recording of near misses and accidents
OIM not empowered
Lack of coordination of the rigs and onshore
Evacuation drills not practiced
Management
Degraded PTW system
Fire deluge pumps switched to manual when divers in water
Poor coordination in emergency
Tharos vessel slow to respond
Near misses not passed on
Told to wait
Staff
PTW for maintenance on pump A retrieved
PTW for work on pump A missing
Mayday calls
Men wait in accommodation block
Control Room Engineer busy
Not informed about PTW
PTW for work on pump A signed off
Work
Gas leaks normal
Pump B trips
Pump A started
Fire deluge pumps fail to start
Accommodation blocks fills with smoke
Job overrun on pump A
Blanking plate on pump A
Gas release
Helipad covered with smoke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Pump A started
Fire deluge pumps fail to start
Accommodation blocks fills with smoke
Job overrun on pump A
Blanking plate on pump A
Gas release
Explosion
Helipad covered with smoke

AcciMap Insights

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- Incident
  - Energy production taking priority over safety
  - Change in use of platform (from oil to oil and gas)
  - Failure to appreciate ‘gas’ risks over ‘oil’ risks
  - OIM not empowered, near misses not reported, poor PTW system, poor coordination of emergency…..
- Method
  - Network of influences from all levels in the system combine to produce incidents
  - Bit like the Swiss Cheese Model (e.g., layers) but maps the interactions more formally

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Final thoughts....

It's all connected....

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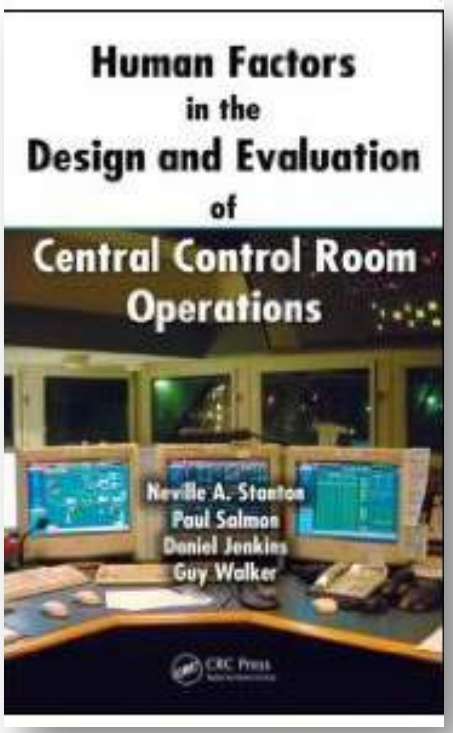

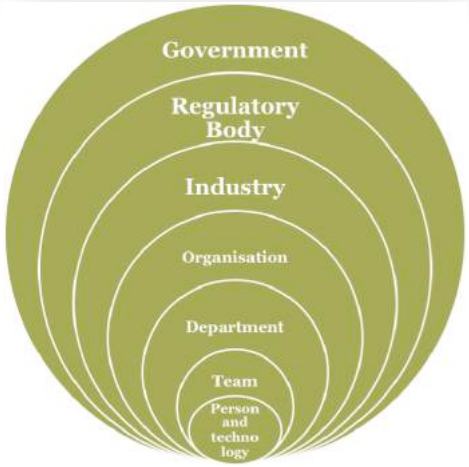

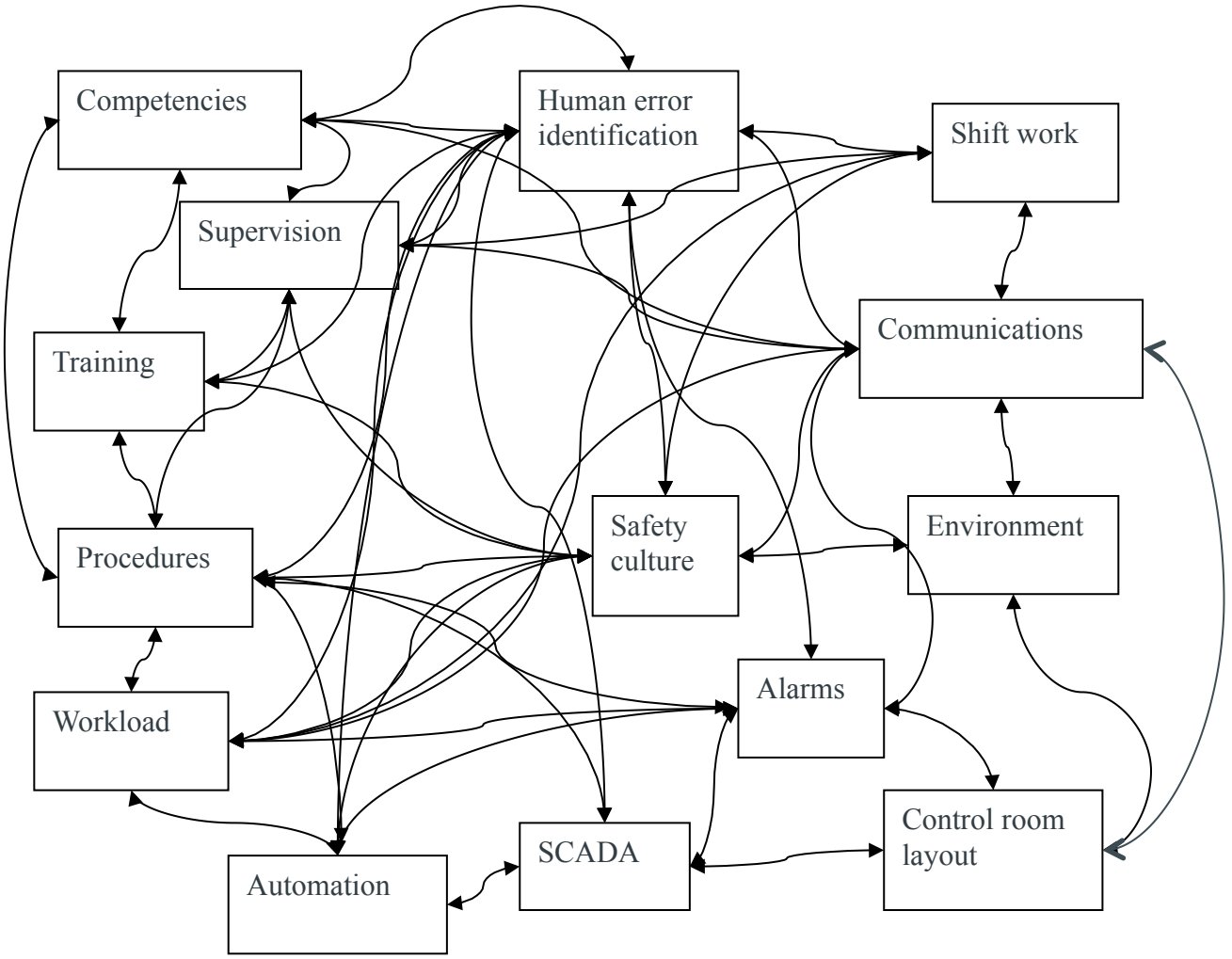

Human Factors Engineering

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- Impossible accidents….often involving the defeat of many layers of system defences (which themselves may be partially the cause)
- Reconstruction and ‘models’ of the incident with wider system influences (level of analysis depends on nature of investigation – micro, meso and macro frames – at all levels) aid the hunt for data to fit the frame
- Layers perspective (cheese and onion) with ‘formal’ methods and taxonomies
- Focus on interactions and communications between and within and between system layers (H-M, H-H, H-M-H,)
- Systems seem to become particularly vulnerable when things change: organisation, design, training, personnel, etc

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Thank you for your attention

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