Vietnam Airlines
REACH FURTHER

The World is changing. Are you?

ACCIDENT INVESTIGATION

PHILIPPE CABON
WELBEES, PARIS, FRANCE

TP. Hồ Chí Minh, tháng 12/2019

JUST SAFETY CULTURE

ADVANCED DEVELOPMENT 2019

Welbees

HUNG VIET CONSULTING

PHILIPPE CABON PRESENTATION

- Master in Psychology and PhD in Neuroscience
- Associate Professor in Human Factors at University of Paris
- Co-founder of Welbees and Human Factors consultant
- Field of expertise:
  - Human factors and safety
  - Sleep, fatigue and Fatigue Risk Management System
  - Health and Safety

TEACHING OBJECTIVES

- Knowing the main principles of an accident/incident investigation
- Learning some interview techniques applicable in an investigation
- Reviewing the main existing methods of investigation
- Be able to apply 2 methods to a real accident case
- With a focus on HF aspects of the accident investigation

CONTENT DAY 1: INTRODUCTION AND DATA COLLECTION

Day 1	Content
08:30-08:45	Welcome/Module presentation
08:45-09:45	Introduction to accident investigations : - Regulatory aspects - Definitions - Objectives of accident investigations
09:45-10:15	Tea break
10:15-12:00	Data collection: interview techniques
12:00-13:30	Lunch
13:30-15:00	Practical exercices on interview techniques
15:00-15:15	Tea break
15:15 – 17:00	Practical exercices on interview techniques (cont.)

CONTENT DAY 2: DATA ANALYSIS

Day 2	Content
08:30 - 09:00	Data analysis
09:00 - 10:30	Accident analysis methods
10:30 - 11:00	Tea Break
11:00 - 12:00	The accident cases
12:00 - 13:30	Lunch
13:30 - 15:15	Group exercises
15:15 - 15:30	Tea break
15:30 – 17:00	Group exercises (cont.)

CONTENT DAY 3: GROUP EXERCISES AND PRESENTATION

Day 3	Content
08:30-10:15	Group exercise
10:15-10:30	Tea break
10:30 – 12:00	Group exercise (cont.)
12:00 – 13:30	Lunch
13:30 – 15:15	Group presentation
15:15 – 15:30	Tea break
15:30 – 16:45	Group presentation (cont.)
16:45 – 17:00	Conclusion of training course

REGULATORY ASPECTS (ANNEX 13)

International Standards
and Recommended Practices

Annex 13
to the Convention on
International Civil Aviation

Aircraft Accident and Incident Investigation

This edition incorporates all amendments adopted by the Council prior to 27 February 2001 and supersedes, on 1 November 2001, all previous editions of Annex 13.

For information regarding the applicability of Standards and Recommended Practices, *see* Chapter 2 and the Foreword.

Ninth Edition
July 2001

International Civil Aviation Organization

REGULATORY ASPECTS (ANNEX 13)

- Chicago convention - Annex 13: rules and standards for accident and incident investigation
- Set conditions facilitating participation of stakeholders States (manufacturer, operation or registration states) in an accident investigation conducted by the State of occurrence
- Strict separation is maintained between technical investigations and judicial inquiries
- Clear distinction between blame and causation for the benefit of taking rapid and necessary measures

OBJECTIVES OF ANNEX 13

- A common process of learning without allocating blame was deemed necessary to keep public faith in aviation industry,
- To provide timely feedback to all stakeholders, accident investigation had to be separated from judicial procedures, which focus on individual responsibilities and liability
- A blame-free approach
- Independence from state interference

PURPOSE OF ACCIDENT INVESTIGATION

- Determine the sequences of events leading to failure.
- Identify the cause of the accident.
- Find methods to prevent accident from recurring.

DEFINITIONS (ICAO - ANNEX 13)

- ***Accident***: occurrence, in which:
  - a person is fatally or seriously injured
  - the aircraft sustains damage or structural failure
  - the aircraft is missing or is completely inaccessible.

- ***Incident.*** An occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation.
- ***Serious incident***. An incident involving circumstances indicating that there was a high probability of an accident and associated with the operation of an aircraft

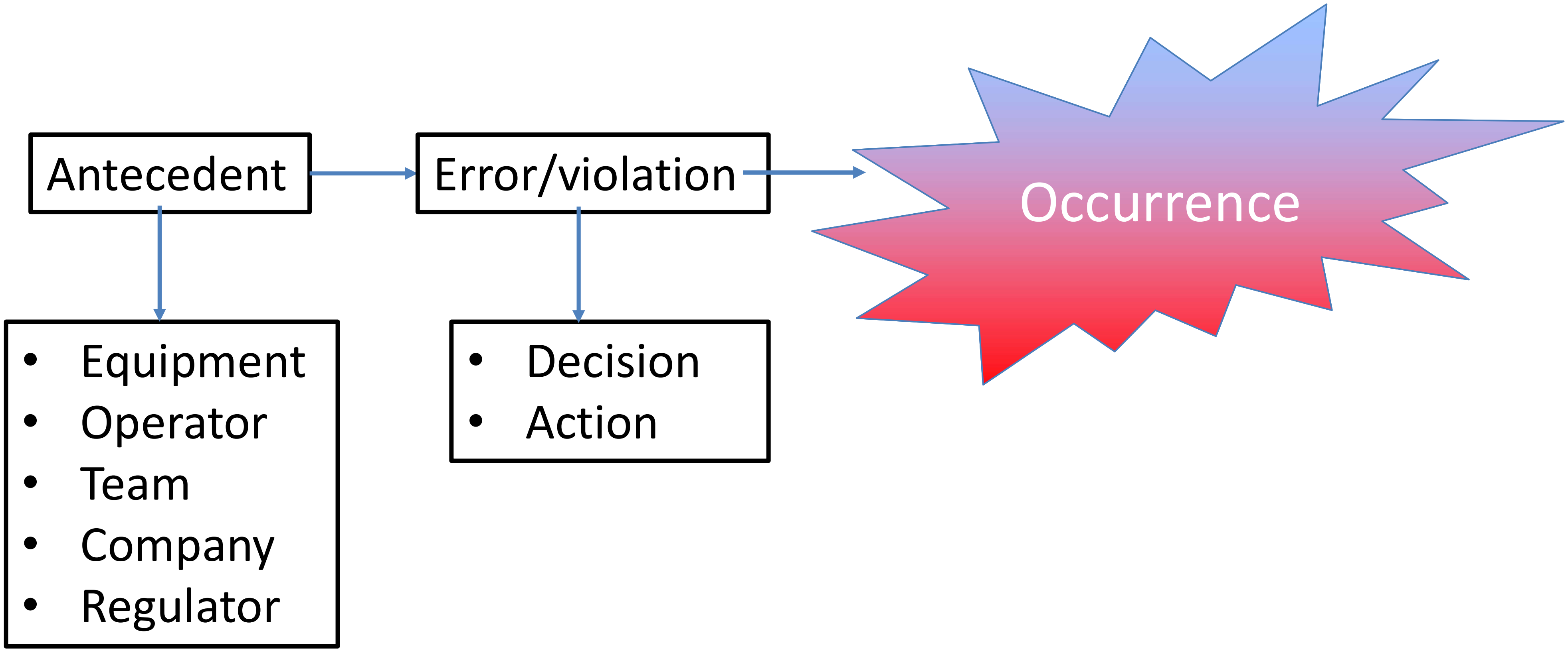
DEFINITIONS (ICAO - ANNEX 13)

- ***Causes***: actions, omissions, events, conditions, or a combination thereof, which led to the accident or incident. The identification of causes does not imply the assignment of fault or the determination of administrative, civil or criminal liability
- ***Contributing factors***: actions, omissions, events, conditions, or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the accident or incident occurring, or mitigated the severity of the consequences of the accident or incident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

DEFINITIONS (ICAO - ANNEX 13)

- ***Investigation.*** A process conducted for the purpose of accident prevention which includes the gathering and analysis of information, the drawing of conclusions, including the determination of causes and/or contributing factors and, when appropriate, the making of safety recommendations.

ANTECEDENT AND ERROR



CONSEQUENCES OF ACCIDENTS

Direct Consequences

1. Personal injuries/fatalities
2. Property loss

Indirect Consequences

1. Lost income, insurance premium
2. Medical expenses
3. Time to retrain another person
4. Decreased employee moral
5. Reputation

INVESTIGATIVE METHODOLOGY: A SCIENTIFIC APPROACH

- Accident investigation and scientific method share similar objective and approach
  - Based on a model
  - Hypotheses
  - Data-driven
  - Works backward, after the fact
  - Study the nature of the relationship underlying the data

LIMITATIONS OF THE INVESTIGATIVE METHODOLOGY

- The « hindsight bias », i.e. a trend to select the data that confirm a pre-defined scenario
- The way the investigation is conducted is impacted by the skills and background of the investigator

Need to combine data from several sources and apply a rigourous methodology

CONSISTENCY OF THE DATA

- The validation of the investigation conclusion is supported by the consistency of the data
- Converging data, event if collected at different times support the same conclusion
- Inconsistencies could be caused by deficiencies either in the data or in the proposed theory or explanation of the cause of the event

THE THREE MAIN STEPS OF ACCIDENT/INCIDENT INVESTIGATION

- 1 - Data collection
- 2 - Data analysis
- 3 - Report and recommendations

FINAL REPORT FORMAT (ANNEX 13)

- Factual information
- Analysis
- Conclusions
- Safety recommendations
- Appendices

FINAL REPORT FORMAT (ANNEX 13)

- Factual information
  - History of the flight
  - Injuries to persons
  - Damage to the aircraft, other damages
  - Personnel information (e.g. crew age & qualification,...)
  - Aircraft information
  - Meteoreological information
  - Aerodrome information,
  - ….
- Analysis
- Conclusions
- Safety recommendations
- Appendices

FINAL REPORT FORMAT (ANNEX 13)

- Factual information
- Analysis
  - Analyse only the factual information which is relevant to the determination of conclusions and causes and/or contributing factors
- Conclusions
- Safety recommendations
- Appendices

FINAL REPORT FORMAT (ANNEX 13)

- Factual information
- Analysis
- Conclusions
  - List the findings, causes and/or contributing factors established in the investigation. The list of causes and/or contributing factors should include both the immediate and the deeper systemic causes and/or contributing factors
- Safety recommendations
- Appendices

FINAL REPORT FORMAT (ANNEX 13)

- Factual information
- Analysis
- Conclusions
- Safety recommendations
  - As appropriate, briefly state any recommendations made for the purpose of accident prevention and identify safety actions implemented
- Appendices

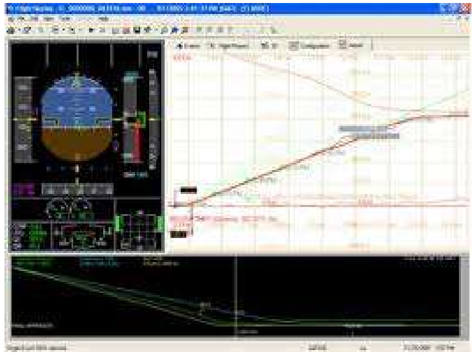
FINAL REPORT FORMAT (ANNEX 13)

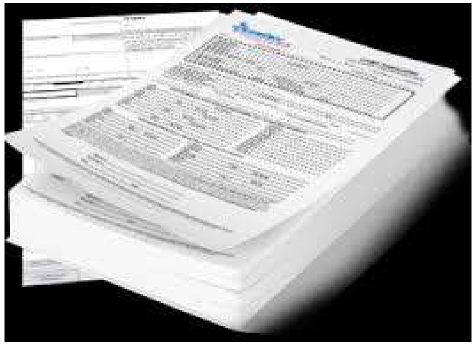
- Factual information
- Analysis
- Conclusions
- Safety recommendations
- Appendices
  - Include, as appropriate any other information considered necessary for the understanding of the final report

DATA COLLECTION

DATA COLLECTION

- As accident investigation is data-driven, the selection of data is critical
- The data collected cover:
  - Electronic data (e.g. flight data monitoring, cockpit voice recorder,…)
  - Written documentations: company documentations, personnel records, training records
  - Interviews: the involved operators, the witnesses, person familiar with the system and/or the operator





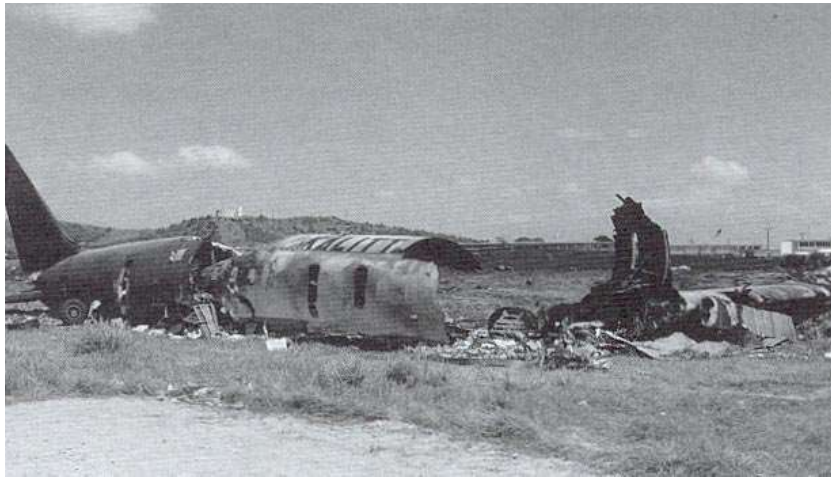
CASE STUDY : FATIGUE DATA COLLECTION CHECK LIST (ADAPTED FROM NTSB)

- **Aim**: determine wether fatigue is a contributing factor
- **Step 1 - Sleep Length**
  - Determine whether the individual had acute or chronic sleep loss by documenting sleep/wake patterns for at least 72 hours before accident and learning about the individual "normal" sleep habits.
  - Interview the individual about her/his normal sleep wake pattern and sleep wake pattern in the last 24 and 48 and 72 hours
  - Interview family members, hotel staff or other witnesses

CASE STUDY : FATIGUE DATA COLLECTION CHECK LIST (ADAPTED FROM NTSB)

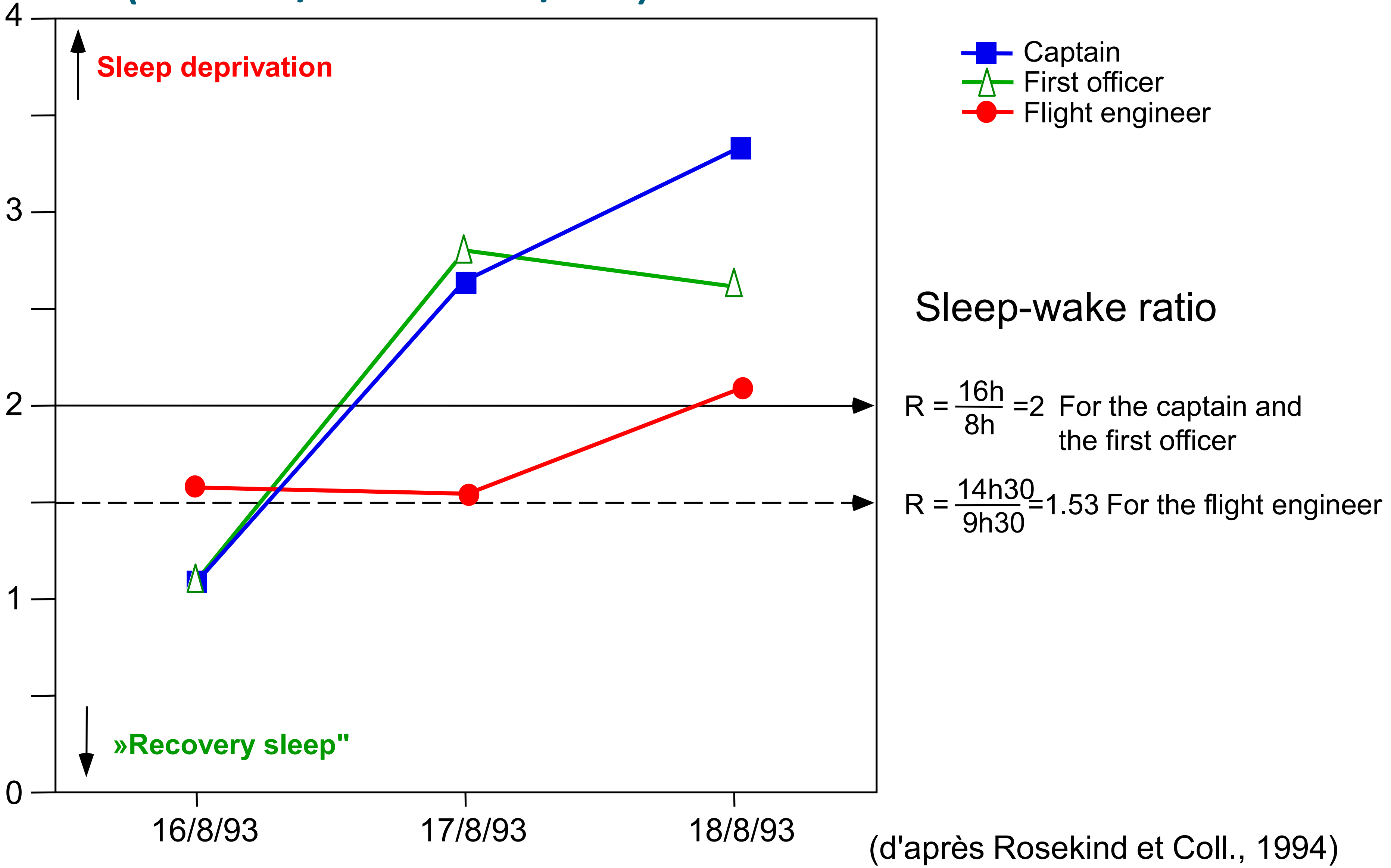
- **Step 2 - Fragmented/Disturbed Sleep**
  - Interview operator (or family members):
  - Are there factors in your environment (e.g., noise, light, phone calls, etc.) that interfere with your sleep?
  - Was your sleep pattern different or disrupted in the days leading to the accident

GUANTANAMO BAY ACCIDENT, AUGUST 1993 (NTSB / AAR-94/04)



- First NTSB aviation **accident** investigation to cite **fatigue** as primary cause.
- Acute fatigue
- Extended wakefulness period (>19hrs)

Guantanamo bay accident, August 1993 (NTSB / AAR-94/04)



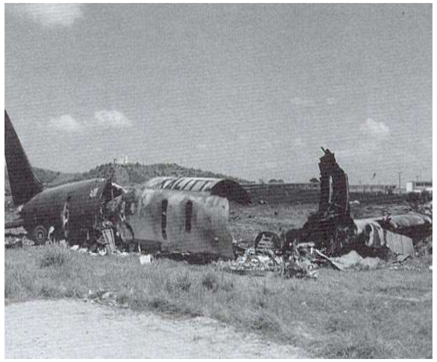
(d'après Rosekind et Coll., 1994)

P.Cabon

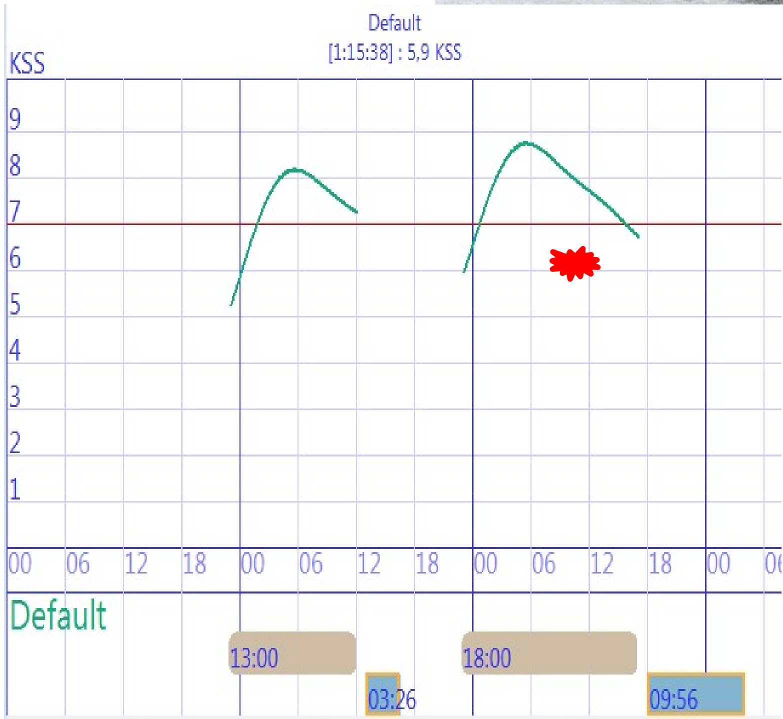
FATIGUE DATA COLLECTION CHECK LIST (ADAPTED FROM NTSB)

- **Step 3 - Circadian Factors**
  - Determine if accident happened during a circadian low point
  - The use of a biomathematical model might be useful

GUANTANAMO BAY ACCIDENT



- Sleep loss :
  - The accident occurred after 2 night duties
  - The crew members has been awake for an extended period of time ranging from 19 to 23.5 hrs (captain)
- Biological rhythms :
  - Obtained sleep at times in opposition to the circadian clock time
  - The accident occured in the afternoon window of physiological sleepiness



FATIGUE DATA COLLECTION CHECK LIST (ADAPTED FROM NTSB)

- **Step 4 Sleep disorders, health and drug issues**
- Interview :
  - Do you have difficulty falling asleep or staying asleep?
  - Have you ever told a doctor about how you sleep? If so, why, when, and what was the result?
  - What drugs/medications do you use regularly, and did you take any in days prior to the accident?
  - Do you have any medical concerns that affect sleep (e.g., chronic pain)?
- Review operator’s toxicological results for substances that may affect sleep or alertness.
- If applicable, have the individual evaluated by a physician who specializes in sleep

FATIGUE DATA COLLECTION CHECK LIST (ADAPTED FROM NTSB)

- **Step 4 – Time awake**
  - Determine how long the operator had been awake at the time of the accident, using interviews or records to estimate wake up time from most recent significant sleep before the accident.

FATIGUE DATA COLLECTION CHECK LIST (ADAPTED FROM NTSB)

- **Step 5 – Performance and appearance**
  - Use available evidence to determine whether the operator's performance was deteriorating prior to the accident:
  - Did the operator overlook or skip tasks or parts of tasks?
  - Did operator focus on one task to the exclusion of more important information?
  - Was there evidence of delayed responses to stimuli or unresponsiveness?
  - Was there evidence of impaired decision-making or an inability to adapt behavior to accommodate new information?

EVIDENCE OF FATIGUE-RELATED PERFORMANCE GUANTANAMO BAY ACCIDENT

- Degraded judgement and decision making :
  - The captain (PF) decided to use runway 10 instead of runway 28.
  - Runway 10 requires a more severe manoeuver to complete the landing
  - Fatigue contribution :
    - The crew did not consider important information (unfamiliarity with the airport, their level of fatigue)
    - Lack of discussion about the decision to change runways
    - Misreading of potential outcomes

EVIDENCE OF FATIGUE-RELATED PERFORMANCE

- Cognitive fixation :
  - Captain's fixation on the strobe ligh
- Poor communication coordination :
  - Captain's disregard of critical information
- Increase reaction time :
  - High reaction time to the stall warning

1653:28	Captain	where's the strobe
1653:29	Flight Engineer	right over there
1653:31	Captain	where
1653:33	First Officer	right inside there, right inside there
1653:35	Flight Engineer	you know, we're not getting our airspeed back there
1653:37	Captain	where's the strobe
1653:37	First Officer	right down there
1653:41	Captain	I still don't see it
1653:42	Flight Engineer	# we're never goin' to make this
1653:45	Captain	where do you see a strobe light
1653:48	First Officer	right over here
1653:57	Captain	where's the strobe
1653:58	First Officer	do you think you're gonna make this
1653:58	Captain	yeah...if I can catch the strobe light
1654:01	First Officer	five hundred, you're in good shape
1654:06	Flight Engineer	watch the, keep your airspeed up
1654:09	Sound similar to stall warning	

FATIGUE DATA COLLECTION CHECK LIST (ADAPTED FROM NTSB)

- **Step 6 – Review general operators FTL or FRMS application**
  - Review and analyse FTL prescritive regulations
  - Review FRMS documentations
  - Review FRMS process, data collection analysis
  - Review fatigue reporting system

DATA COLLECTION: INTERVIEW TECHNIQUES & PRACTICAL EXERCISES

CONDUCTING AN INTERVIEW

- Nearly all investigations rely on interviews
- Many investigators conduct poor interviews because they do not recognize that interviews require specific skills
- The way the interview is conducted may totally change the quality of the data collection
- Interviews rely entirely on perception and memory

Interview is not a simple « conversation

PERCEPTION: A 'BOTTOM UP' AND A 'TOP DOWN' PROCESS

'Bottom up': stimulus dependant = what the world sends to our senses

'Top down': concept dependant = what we are looking for

We mainly perceive what we want to perceive!

What do you see?

PERCEPTUAL CONSTRAINTS

Event-based

- lighting/visibility
- speed
- distance
- duration
- complexity
- violence

Person-based

- focus of attention
- stress/fear
- age
- alcohol/drugs
- training
- involvement
- expectations

BASIC MEMORY CHARACTERISTICS

- Memory deteriorates over time
- Limited capacity for storing information
- It is a reconstructive process in which we shape our experience based on what we know about the world
- In essence, all memory is biased !

Crash of the B747 in New York (1996): over 250 of the eyewitnesses decribed aspects of the events were directly contradicted by the physical evidence

THE MEMORY ERRORS IN INTERVIEWS

- Three categories of memory errors (Hyman, 1990):
  - Incorrectly reconstructing event recollections
  - Incorrectly attributing the source of information
  - Falsely believing that events that were not experienced were exerienced
- People view the event as plausible, they reconstruct a memory that is partially based on true experience
- May reconstruct memories by applying information from previous experiences to fill in the gaps

FROM POLICE INVESTIGATION TO ACCIDENT INVESTIGATION

- Interview techniques in investigations have been developed in the area of justice and police (Loftus, 2013)
- A number of people have been wrongly convicted of sexual assault crimes based on eyewitness evidence.
- The withnesses fully believed that the individuals were the one who committed the crimes

SOME MEMORY BIASES

- **Egocentric bias** - recalling the past in a self-serving manner, e.g. remembering one's exam grades as being better than they were, or remembering a caught fish as being bigger than it was.

- **False memory** - confusion of imagination with memory, or the confusion of true memories with false memories.

- **Hindsight bias** - filtering memory of past events through present knowledge, so that those events look more predictable than they actually were; also known as the 'I-knew-it-all-along effect'.

INTERVIEWING BIASES

- Interviewer influence:
  - Interviewer can subtly insinuate false information into their questions
  - Witnesses make systematic errors as a function of misleading questions (Wells et al, 2000)
- Social desirability bias:
  - tendency of respondents to answer questions in a manner that will be viewed favorably by others
  - Results from 2 factors: self deception and other deception

VARIOUS TYPES OF INTERVIEWEES

- Differences in:
  - The stake associated with the findings of an investigation
  - Background, experience may affect people's ability to understand and respond to questions
- Three types of interviewees, with different contribution to the investigation:
  - **Eyewitnesses**: have directly observed the event
  - **Operators** whose actions are the primary focus of the investigation
  - Those who are familiar with **critical system elements or with the operator** but may have not been directly involved in operating the system at the time of the accident

EYEWITNESS

- May have observed features that system recorders did not capture, heard noises beyond the microphone range, smelled odors, felt movement
- May enhance or confirm existing information, add information unavailable from other sources
- Their willingness to cooperate with investigators are influenced by their confidence in the value of the information they can provide

SYSTEM OPERATORS

- May be able to describe their actions and decisions during the event and provide helpful background information about the system
- May be unable to recall details or have difficulty responding if they feel responsible
- Investigators should be aware that the operators can be concerned about the effect of the event on their career

THOSE FAMILIAR WITH OPERATORS AND CRITICAL SYSTEM ELEMENTS

- People at « blunt end », i.e. managers, designers, trainers may have influenced the conditions that led to errors at the « sharp end »
- They may feel responsible for the cause of the event

EXAMPLES OF INFORMATION SOUGHT

Eyewitnesses	Operators	Familiar with critical system elements
• What they saw, heard felt, smelled • Details of the event that caught their attention • Time of the day and locations they witnessed the event • Operators actions	• Decisions they have made before the event • Time when they made those decisions • Actions they took before the event • Outcome and consequences of the action they took • Job/task information • Company practices and procedure • Personal information (health, change in family status,…) rest/sleep prior 72hrs,…)	• Duty, sleep and rest schedule previous 72hrs • Opinions expressed toward the job, coworkers and the company • Operator training and work history • Operating policies and practices

INTRODUCTION TO INTERVIEWING TECHNIQUES

- Several **investigative interviewing techniques have been developped to enhance interview recollection**:
  - Cognitive Interview
  - Conversation Management (interviewing model) & PEACE technique
  - Elicitation interview
  - ….
- **General Guidelines** for investigative interview

COGNITIVE INTERVIEW (GEISELMAN & FISHER, 1984)

COGNITIVE INTERVIEW
(GEISELMAN & FISHER, 1984)

Basic principles of Cognitive Interview

- Encoding Specificity Principle (Tulving, ‘70s)
  – Presented cues will be more effective in facilitating recall as long as they are similar to cues present during encoding
  – Based on “Madeleine de Proust” effect
- Multi-component view of memory
  – Memory trace is not a linear representation of the original event, but rather is a complex. Different “routes” exist to access recall.

COGNITIVE INTERVIEW (GEISELMAN & FISHER, 1984)

Retrieval rules (*also called* Mnemonics)

1. Mental Reinstatement of Environmental and Personal Contexts
2. In-depth Reporting
3. Describing the TBR Event in Several Orders
4. Reporting the TBR Event from Different Perspectives

COGNITIVE INTERVIEW (GEISELMAN & FISHER, 1984)

Mental Reinstatement of Environmental and Personal Contexts

- The participant is asked to mentally revisit the to-be-remembered (TBR) event.
- The interviewer may ask them to form a mental picture of the environment in which they witnessed the event.
- This picture could include the placement of objects such as, the lighting, or even the temperature.
- The participant is also asked to revisit their personal mental state during the event and then describe it in detail.

COGNITIVE INTERVIEW (GEISELMAN & FISHER, 1984)

In-depth Reporting

- The interviewer encourages the reporting of every detail, regardless of how peripheral it may seem to the main incident.
- This step is important for two reasons
  - The participant may only initially report what information they assume to be important regardless of the fact that they are unaware of what information will have value.
  - recalling partial details may lead to subsequent recall of additional relevant information.

COGNITIVE INTERVIEW
(GEISELMAN & FISHER, 1984)

Describing the TBR Event in Several Orders

- The participant creates a narrative of the TBR event.
- He or she is then prompted to start the narrative from a point that is different from their initial starting point.
- This process may provide a new perspective of the event which subsequently provides an opportunity for new information to be recalled.

COGNITIVE INTERVIEW (GEISELMAN & FISHER, 1984)

Reporting the TBR Event from Different Perspectives:

- The participant is asked to report the event from several different perspectives such as the perspective of another witness or even a participant.

COGNITIVE INTERVIEW
(GEISELMAN & FISHER, 1984)

Procedure (time: 1h, approximately)

1. Make an introduction to establish a witness/interviewer relationship.
2. Introduce the 4 retrieval rules and ask to use them while producing a narrative.
3. During narrative production, the interviewer constructs the strategy for the remainder of the interview.
4. The interviewer guides the witness through several information-rich memory representations, after which the interviewer will assess the witness' recollections.
5. End of interview

COGNITIVE INTERVIEW (GEISELMAN & FISHER, 1984)

Strength points:

1. Validated Experimentally:
   - Participants see simulated crime scene
   - Successive interviews: traditional interview vs. cognitive interview.
   - Cognitive interviews elicit between 35 and 60% information more.
2. Great applicability in every domain
   - Accident investigation, police investigation, medical interviews

Limitations:

1. More difficult than traditional interviews.
2. Useful only if there is eyewitness
3. Still vulnerable to desirability bias

GENERAL GUIDELINES FOR CONDUCTING INTERVIEWS

INTERVIEWS
GENERAL GUIDELINES

General

1. Collection of witness statements for reconstructing events. An **interview is not an interrogation!**
2. Mental state of witness should be taken into account (stress, trauma, or even medication condition).
3. Sometimes family members of witnesses might help incident investigation by offering insights on personality, character traits, and behavior (habits).

Statements

1. Investigators must inform witness about the objective of collecting their statement, i.e. helping in understanding causes and preventing future accidents.
2. Witness should be isolated from one another while making their statements, in order to assure honesty.

DIFFERENT TYPES OF QUESTIONS

- **General Questions:** open-ended questions that can help get the witness talking.
  E.g.: What did you see? What can you recall? Can you tell me more about that?
  Directed Questions: focus on a specific subject, without biasing the answer.
  E.g.: Did you notice any lights on the display?
- **Specific Questions:** needed for specific information.
  E.g.: Did you notice any lights on the display? What color was the light?
- **Summary Questions:** for helping witnesses to organize their thoughts and draw attention to possible additional information. Restate what you think the witness told you in your own words and ask if that's correct. Frequently, the witness will add more information.
- **Leading Questions:** they contain or imply the desired answer. Once you ask a leading question, you have suggested what the witness is supposed to have seen. Avoid leading questions!!
  E.g.: Was a red light flashing?

TECHNIQUES THAT DO NOT REQUIRE QUESTIONS

- Some interview techniques do not require questions.
- To keep a witness talking, say something like "uh-huh," "really," or "continue."
- Mirror or echo the witness' comments. Repeat what the witness said without agreeing or disagreeing. E.g.: You say you saw smoke coming from the cabin?

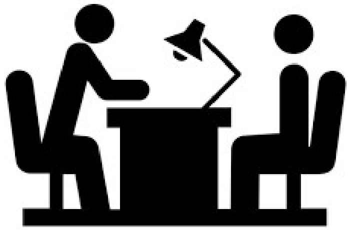
INTERVIEWS

- Questions prepared in advance.
- Avoid collective interviews.
- Limit number of assistants (i.e. investigation team members).
- Calm, comfortable location, free from disruptions.
- Make sure to collect personal contacts (name, phone, and address) in case of needing a follow up.
- Always record the interview (after obtaining consent). After transcription, interviewer and witness must sign it off as correct.

CONDUCTING THE INTERVIEW

- Start with personal information. Then questions, form general to specific: first ask for narration about how they remember the fact, then include questions about human factors, equipment factors, environmental factors.
- Try to prompt the witness to tell everything he/she can remember without influencing him/her.
- Pay attention to voice intonations, facial expressions, body language, silences and interruptions.

THE INTERVIEWER



- Establish and maintain an interviewer-interviewee relation
- Do not prejudge a witness.
- Be serious and take interviewing seriously
- Maintain control of the interview.
- Respect the emotional state of the interviewee.
- Do not interrupt, be a good listener.
- Avoid revealing items discovered during the investigation to the interviewee

PRACTICAL EXERCISE

- 6 groups of 4 participants
- Each group define an interviewee and an interviewer
- Set up an interview about an incident (experienced in real life).

Method

- Interviewer think of a sequence of questions (interview preparation) and conducts the interview.
- The attendants take note of type of questions, interviewing method, and quality of interview (is it clear the dynamics and sequence of events?).

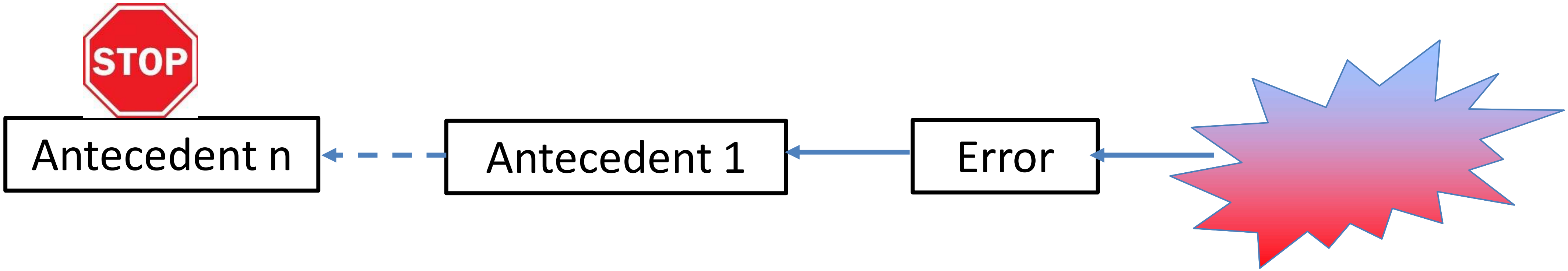
Follow up

- Open discussion about results of investigation.

DATA ANALYSIS

DATA ANALYSIS

- Once the data collected they need to be analysed
- The aim of the data analysis is to find the relationships between the events/errors/antecedents/causes
- Main principle: working backward from the occurrence to the antecedent until the stopping point



DATA ANALYSIS EXAMPLE

Welbees

A train failed to stop at a red signal and struck another train

DATA ANALYSIS EXAMPLE

1 The collision
2 Locomotive operator brake application
3 Locomotive operator power reduction
4 Railroad signal system maintenance and inspection
5 Locomotive operator initial and refresher training
6 Railroad brake system maintenance and inspection
7 Railroad brake system maintenance personnel selection practices
8 Brake system manufacture and installation
9 Railroad signal system selection and acquisition
10 Signal system manufacture
11 Railroad signal system selection and installation
12 Railroad signal installer, maintenance and inspection personnel training
13 Locomotive operator selection
14 Railroad brake system maintenance personnel practices
15 Railroad signal system installer, maintenance and inspection personnel selection practices
16 Regulator oversight of railroad signal system
17 Regulator oversight of brake system

DATA ANALYSIS EXAMPLE

1 The collision
~~2 Locomotive operator brake application~~
3 ~~Locomotive operator power reduction~~
4 Railroad signal system maintenance and inspection
5 ~~Locomotive operator initial and refresher training~~
6 Railroad brake system maintenance and inspection
7 Railroad brake system maintenance personnel selection practices
8 Brake system manufacture and installation
9 Railroad signal system selection and acquisition
10 Signal system manufacture
11 Railroad signal system selection and installation
12 Railroad signal installer, maintenance and inspection personnel training
13 ~~Locomotive operator selection~~
14 Railroad brake system maintenance personnel practices
15 Railroad signal system installer, maintenance and inspection personnel selection practices
16 Regulator oversight of railroad signal system
17 Regulator oversight of brake system

After data collection, the investigation proved that the operator brake

INFERRING THE RELATIONSHIP BETWEEN ERRORS AND ANTECEDENT

- The relationship must be logical and unambiguous
  - « would the accident have occurred if the error has not been committed »
  - « would the operator have committed the error if the antecent had not preceded it ? »
- Based on statistical relationship between the antecedent and the critical error. There is a high probability that this relationship is not due to the effects of chance

MULTIPLE ANTECEDENT

- In complex system, accidents are generally related to a combination of antecedent
- Multiple antecedents can increase each antecedent influence on performance : 2+2>4
- Example: a bus driver falled asleep and the bus ran off the road and struck a truck
- Investigation found 3 cumulative antecedents to explain driver drowsiness:
  - Antihistamine
  - Several consecutive night duties
  - The accident time : 04 am

INTERACTING ANTECEDENTS

- Two or more antecedents together affect performance differently than the antecedents would have if acting on their own
- The variety of human behaviours, procedure, training, equipments is such that the potential number of interacting antecendents that affect performance is infinite
- Examples:
  - Operator experience interacts with equipments and procedures
  - Oversight interacts with managerial experience: less experienced operators may perform best with extensive oversight and experienced operators may perform best with little oversight

ACCIDENT ANALYSIS MODELS AND METHODS

WHY DO WE NEED MODELS AND METHODS ?

- Accident models describe the theory of accident
- Analysis method guide the investigators to establish the relationship between the event, the error(s) and the antecedent(s)
- A method should be supported by a model: eg HFACS (the method) is supported by the Swiss Cheese Model (the model)
- Accidents models and methods are crucial in an investigation to consider several possible causes and avoid subjectivity in the analysis

LIMITATIONS OF MODELS AND METHODS

- The investigator has to be aware that methods are always a simplification, reality is more complex !
- The investigator should not adhere rigidally to the method

ACCIDENT SYSTEMIC MODELS/METHODS

1

1. The Domino's model (Heinrich, 1931)
2. Fault trees (Watson, 1961) & Event Trees Analysis (ETA).

2

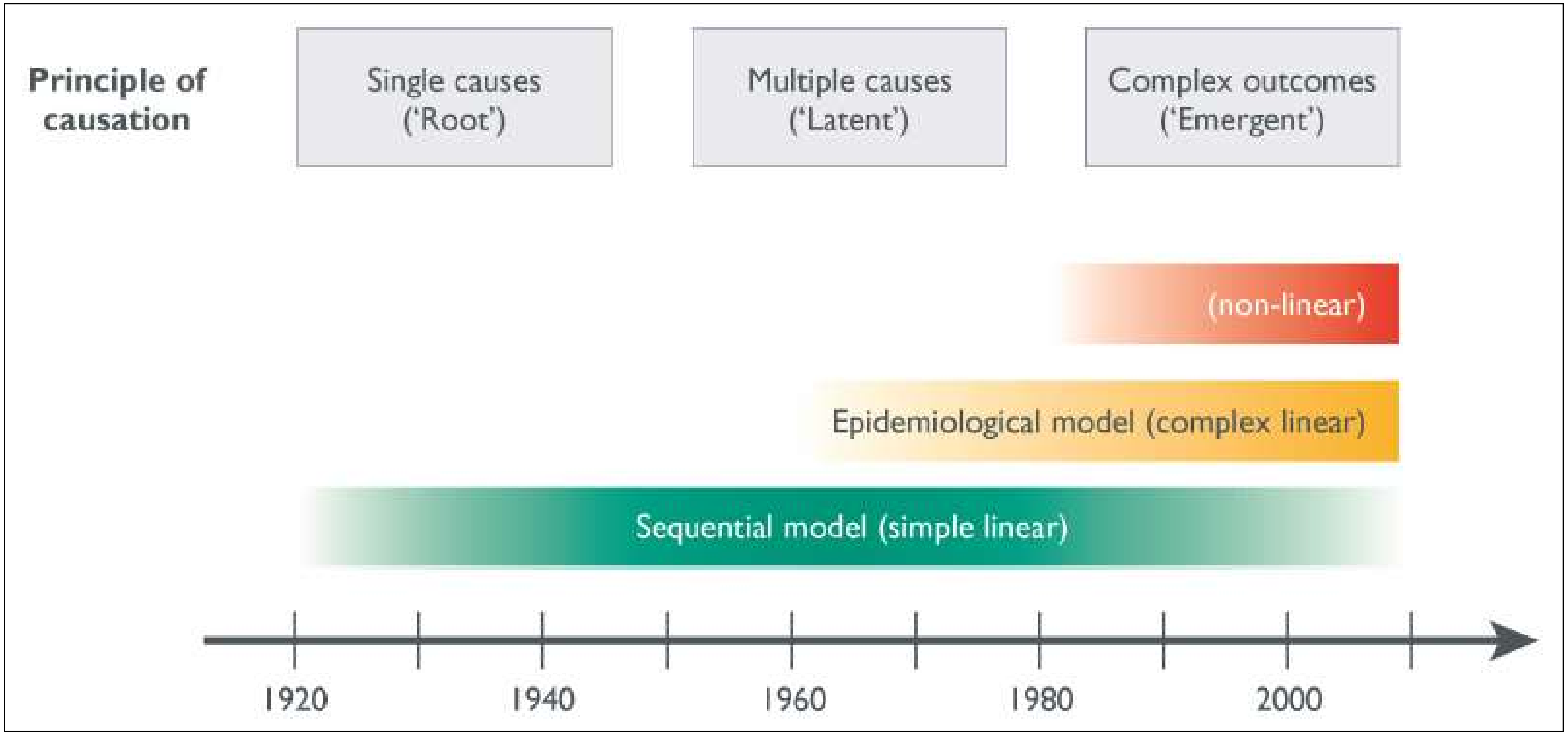
3. SHEL(L) Model (Edwards, 1972, 1988).
4. The wheel of misfortune (O'Hare, 2000).
5. Swiss Cheese Model (Reason, 1990, 1997).
6. Incident Cause Analysis Method (ICAM) (Gibb, Hayward, & Lowe, 2001).
7. Human Factors Analysis and Classification System (HFACS) (Wiegmann & Shappell, 1997; 2001).
8. TRIPOD Beta.
9. Bow Tie risk management (EASA, 2016) Incident BowTie,

3

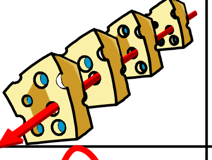
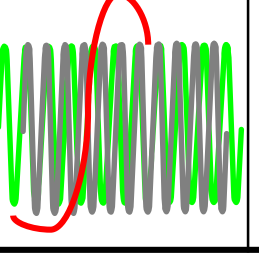
10. Cognitive Reliability and Error Analysis Method (CREAM) followed by successive Functional Resonance Analysis Method (FRAM) (Holnagel 1998; 2004).
11. The Systems-Theoretic Accident Model and Process (STAMP) (Leveson, 2004).

1 = Simple Linear Models;
2 = Complex Linear Models (Multiple Causes);
3 = Complex Non-linear Models

3 GENERATIONS OF SAFETY AND ACCIDENT MODELS

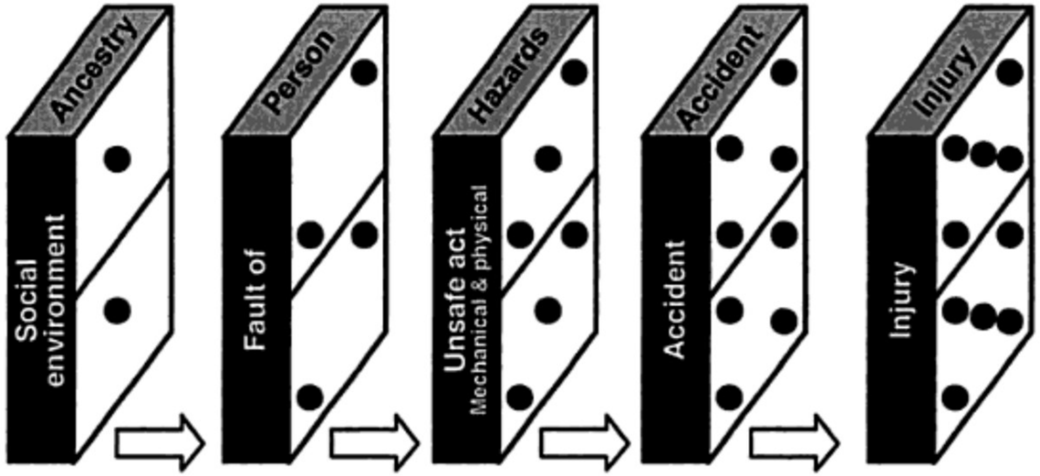


3 GENERATIONS OF SAFETY AND ACCIDENT MODELS

Accident model	Metaphor	Management principle	Nature of causes	Response
Sequential *Accident development is deterministic*		Error management	Causes can be clearly identified	Eliminating causes eliminates accidents
Epidemiological		Performance deviation management	Deviations at blunt/sharp end	Deviations leading to accident must be suppressed
Systemic		Performance variability management	Sources of variability can be identified and monitored	Some variability should be amplified, some reduced

1. THE DOMINO'S MODEL (HEINRICH, 1931)

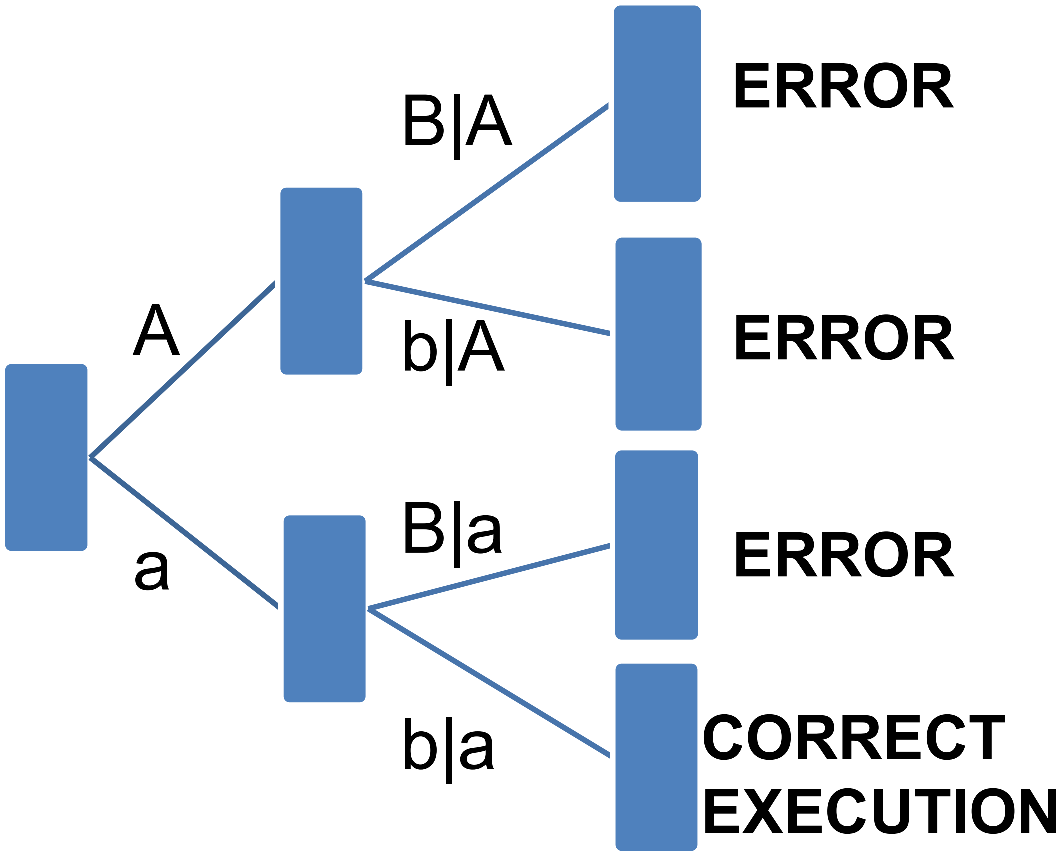
- Accident as a chain of events that lead to failure
- One event cause the next (domino analogy)
- Specific causes can be identified and removed (prevention principle)



- Focus on what went wrong (no latent conditions), thus on active failures.
- Encourage linear thinking (causal chains instead of causal nets), easier to follow and represent.

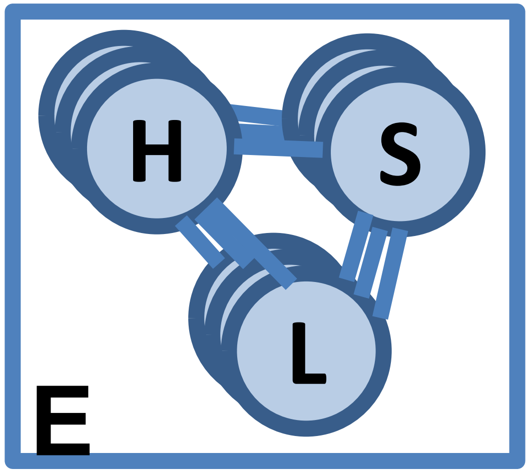
2. EVENT TREES ANALYSIS (ETA)

- Used to consider many chains of events in parallel.
- Each task/activity is decomposed in constituting elements (subtasks).
- Each subtask can be done correctly or incorrectly (2 possible outcomes).

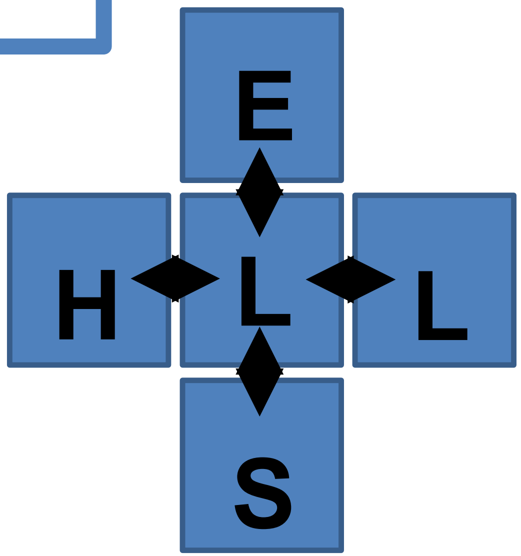


- Each Error and correct execution have associated a basic occurrence probabilities.
- Conditional probabilities are computed on the basis of multiplicative rule (product of single occurrence probabilities).
- Uppercase letters mean ERROR. Lowercase letters mean CORRECT Execution.

3. SHEL(L) MODEL (EDWARDS, 1976, 1988)



S = Software (e.g. rules, regulations, and training)
H = Hardware (e.g. technology and tools)
E = Environment (e.g. physical conditions of work like temperature, lighting, etc.)
L = Liveware (e.g. other people, as colleagues, clients, suppliers, etc.)

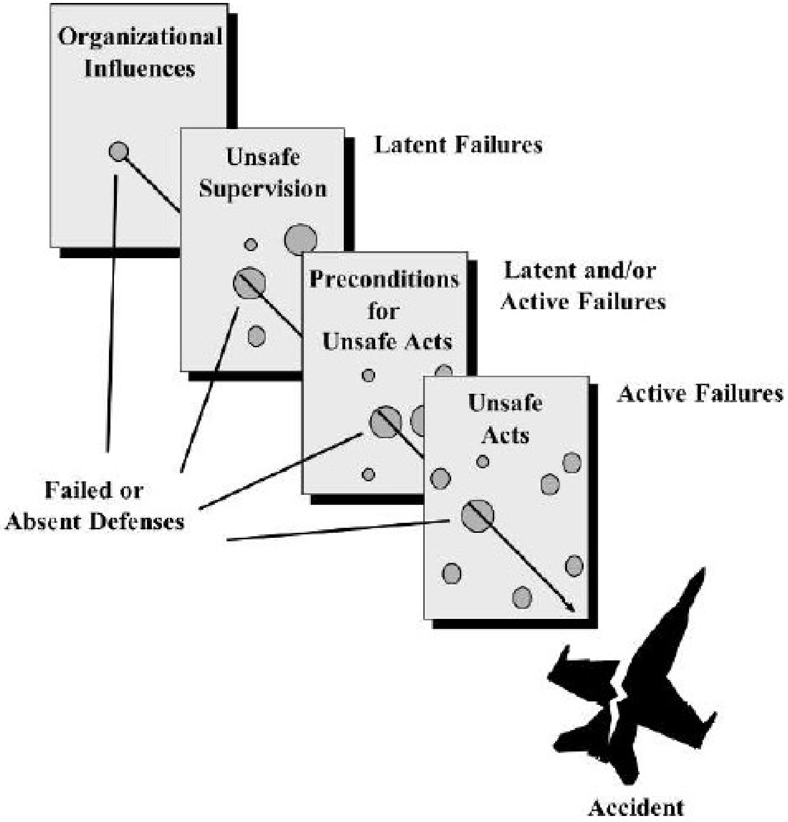


- System Failures originate from failure in one component or within the interactions between two components.
- Model with big success in aviation domain
- Very intuitive, but very general (lack of specificity)

THE NORMAL ACCIDENT THEORY

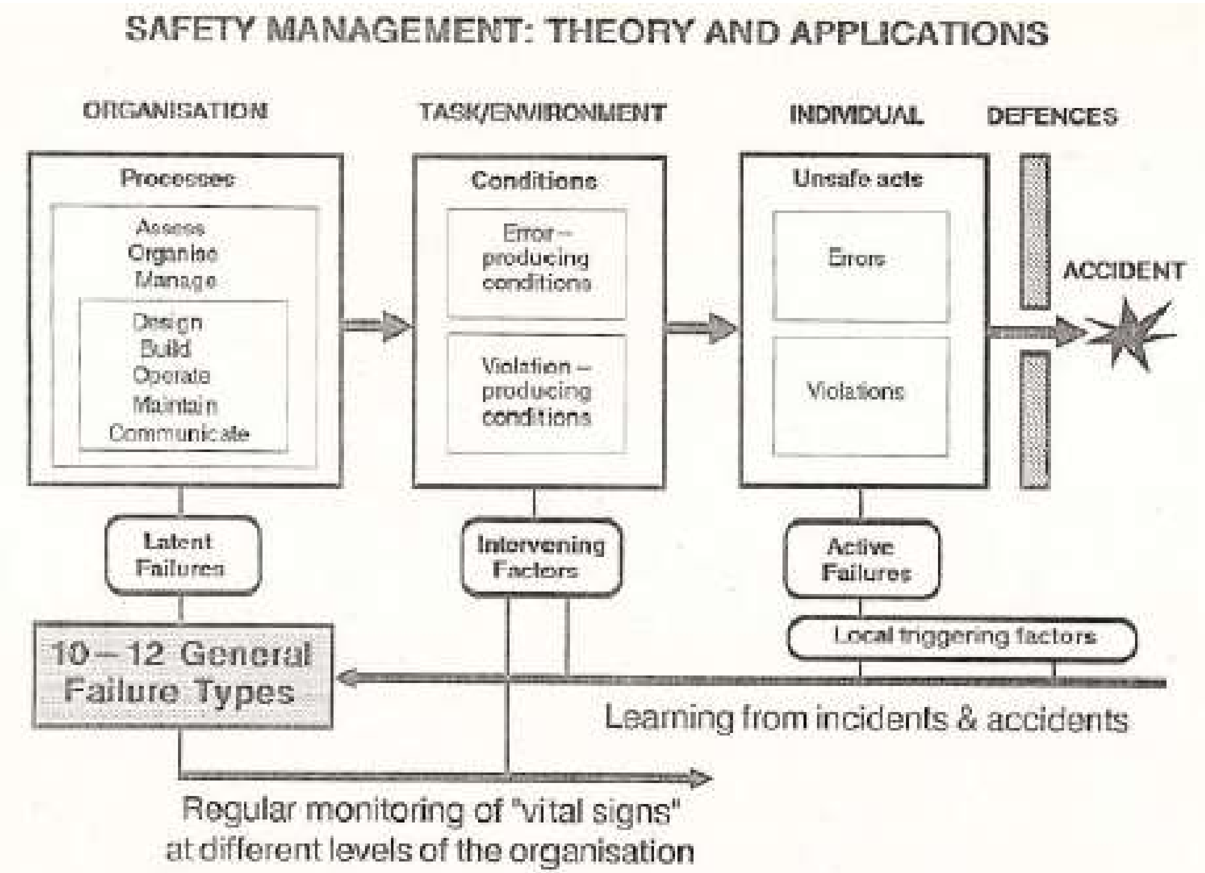
- Systems are becoming more and more complex: instead of directly controlling the systems, operators supervise their operation
- Higher cognitive control and lower physical control
- In complex systems interactive complexity and tight coupling made the accident inevitable (Perrow, 1999)
- Systems are more complex because they are more protected by a number of defenses
- Little tolerance to variability

5. THE SWISS CHEESE MODEL (REASON 1990, 1997)



- Four productive planes and relative types of failure: Unsafe acts, Preconditions for unsafe acts, Unsafe supervision, and Unsafe organizations.
- Slices represent defenses and safeguards against accident.
- Holes represent the error within the barriers
- Failures are active (first-line operators) as well as latent (management and supervisors)
- Accident trajectory results from multiple failures "alignment".

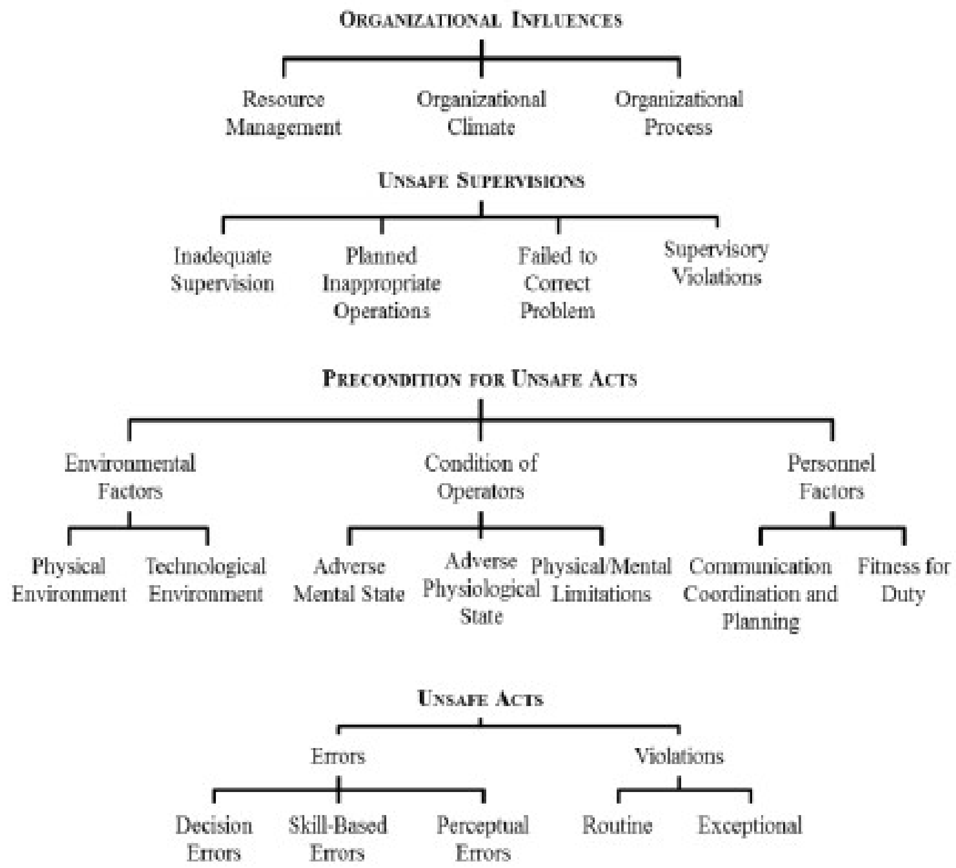
THE SWISS CHEESE MODEL (MARK II, FIRST '90S)



- Productive planes are reduced to 3: Organization, Task/environment, and Individual.
- Direct line between organization and accident (accident without active failures, e.g. NASA Challenger).
- Error and Violations are distinguished.

7. HUMAN FACTORS ANALYSIS AND CLASSIFICATION SYSTEM (HFACS) (WIEGMANN & SHAPPELL, 1997; 2001)

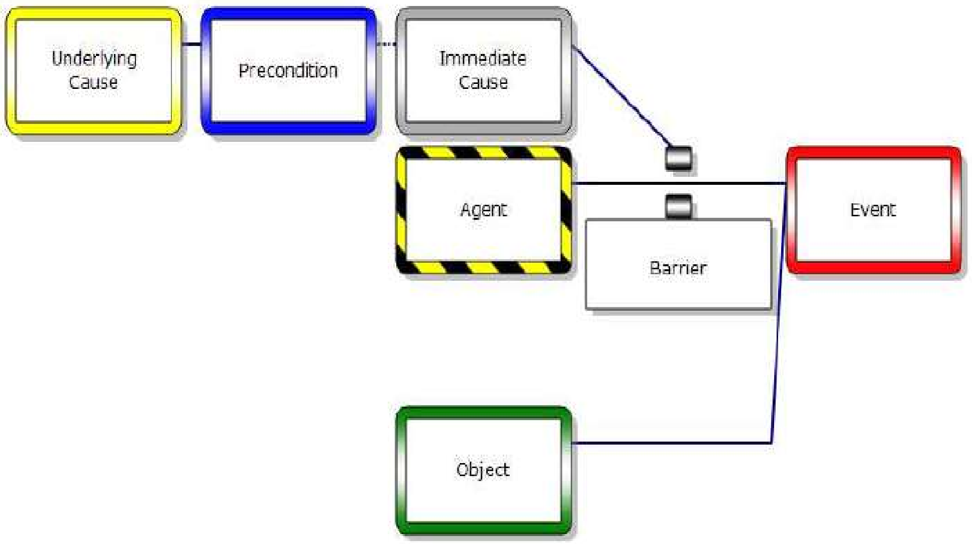
- Based on Reason's SCM.
- Comprehensive framework to identify and classify causal factors of incidents/accidents.
- Hierarchical structure: 19 causal factors organized in 4 categories (levels).
- Provide data for developing safety interventions.
- Most used human factors accident analysis framework.



8. TRIPOD BETA (SHELL INTERNATIONAL EXPLORATION AND PRODUCTION B.V., '90S)

3 steps analysis procedure:

1. Identify the chain of **events** preceding the consequences
2. Identify the **barriers** that should have stopped this chain of events
3. Identify the **reason of failure for each broken barrier**. This should be broken down in the human failure (Active Failure), the working environmental aspects (Preconditions) and the Latent Failure in the organization.

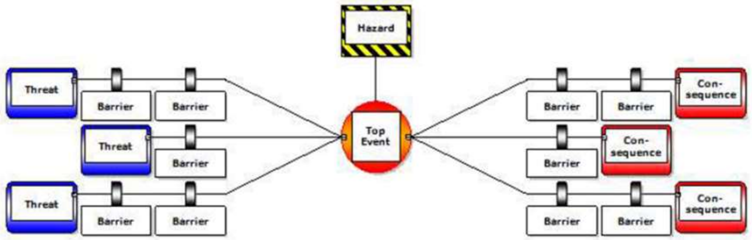


Output: a "tree" diagram representation of the incident mechanism describing events and their relationship

THE CONCEPT OF BARRIER

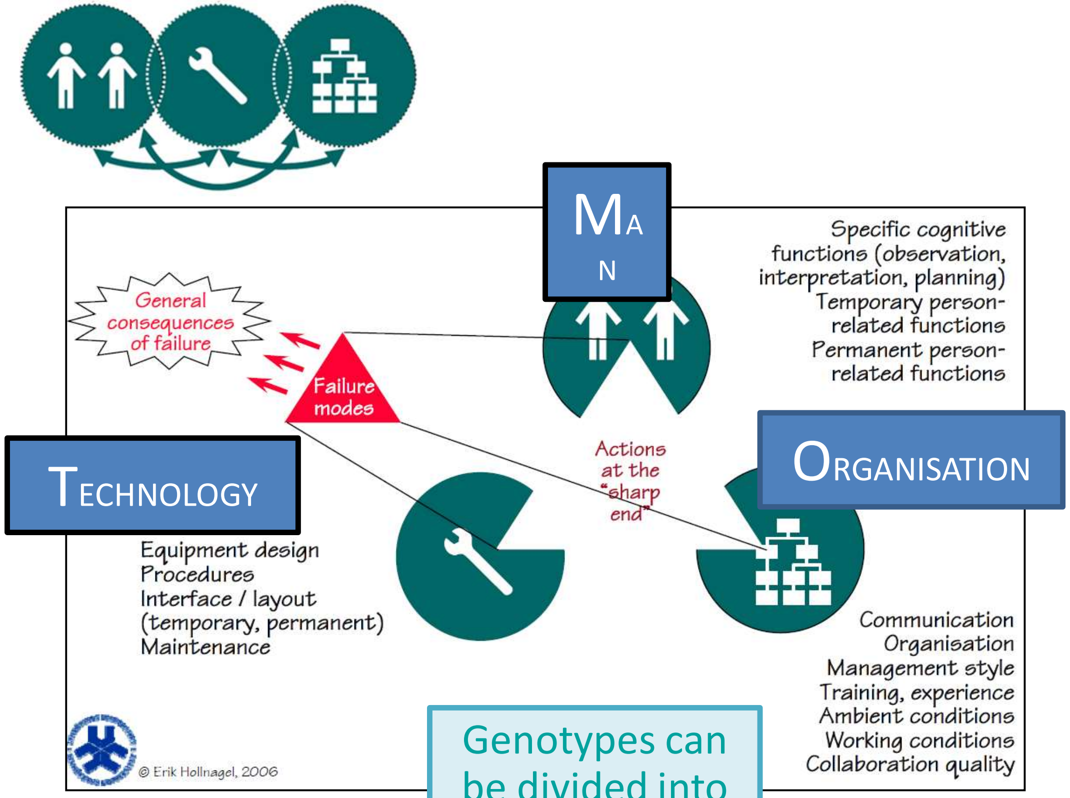
- *Physical or material barriers :*
  - prevent an action or event from materialising (e.g., seat belts),
  - hinder transportation of materials and energy (e.g. fences, railings, walls and buildings),
  - withstand forces up to a certain extent (e.g., safety glasses, safety tanks).
- *Functional barriers.*
  - impede actions (e.g., interlocks), hinder physical movement (e.g., locks, air-bag) and prevent access to an area (e.g., passwords and entry-codes).
  - Their effectiveness requires that both the triggering conditions are detected and that the function is activated in time.
- *Symbolic barriers.*
  - prevent actions (e.g., colour-coding of functions, demarcations), indicate the status of system (e.g., alarms, warnings), and regulate permission or authorisation (e.g., work permits,).
  - require interpretation by people in order to decide how to respond to a dangerous situation.
  - cannot by themselves protect and must be combined with other barriers e.g, reflective posts indicate the edge of the roads but, unlike railings, cannot prevent a car from going off the road.
- *Incorporeal (or organisational) barriers.*
  - safety principles and guidelines, restrictions and laws.

9. INCIDENT BOWTIE (EASA)

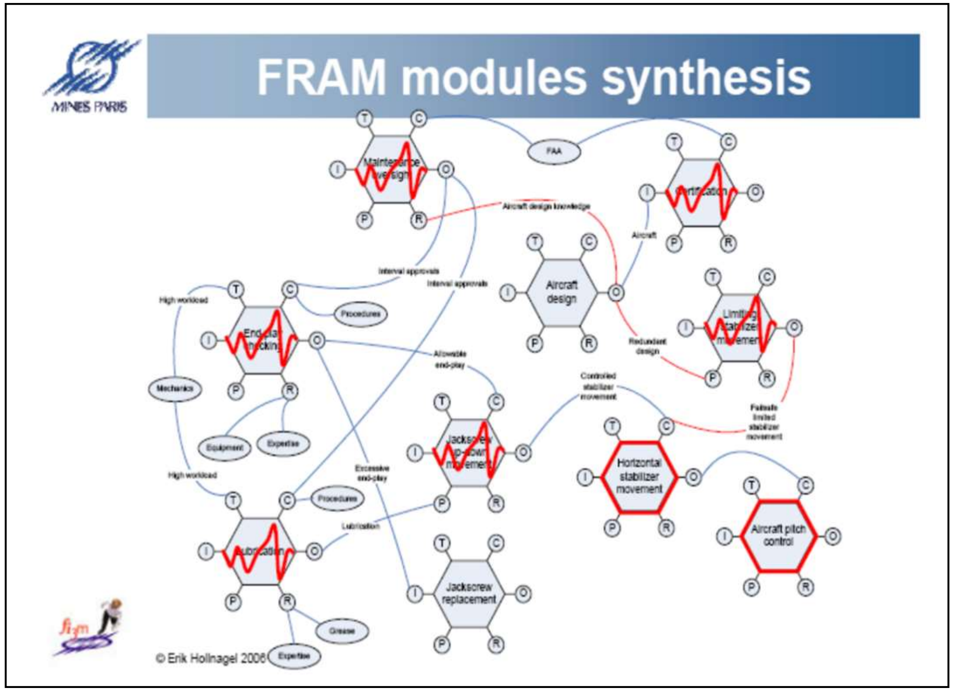


- BowTie: proactive approach for Risk Management.
- Incident BowTie: reactive method added for accident analysis.
- Information about real accidents complete the existing Risk analysis.
  - Information on real 'behavior' of Barriers, Threats, Top Events and Consequences.
- Incident BowTie is a combination of BowTie and TRIPOD Beta:
  - Information from BowTie can be used as input for accident analysis
  - Information from TRIPOD Beta can be used as input for completing Risk Analysis (more realistic)

10. CREAM & FRAM (HOLLNAGEL, 1998; 2012)



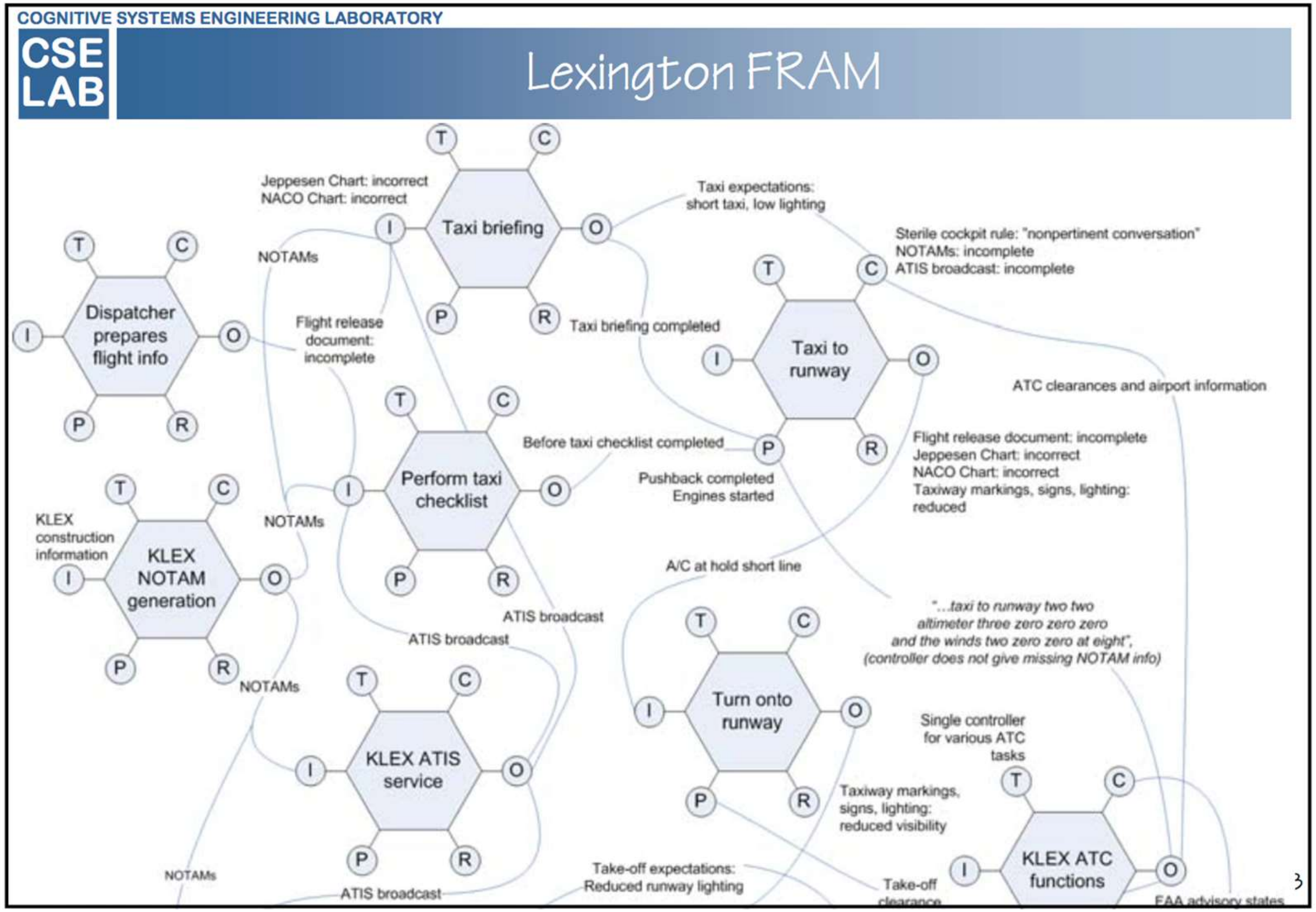
Genotypes can be divided into the MTO triad



CONNAIR FLIGHT 5191, LEXINGTON

The aircraft was assigned the airport's runway 22 for the takeoff, but used runway 26 instead. Runway 26 was too short for a safe takeoff, causing the aircraft to overrun the end of the runway before it could become airborne. It crashed just past the end of the runway, killing all 47 passengers and two of the three crew. The First Officer was the only survivor.

FRAM


COGNITIVE SYSTEMS ENGINEERING LABORATORY
CSE LAB
Lexington FRAM
Taxi briefing
Jeppesen Chart: incorrect
NACO Chart: incorrect
NOTAMs
Taxi expectations:
short taxi, low lighting
Sterile cockpit rule: "nonpertinent conversation"
NOTAMs: incomplete
ATIS broadcast: incomplete
Dispatcher prepares flight info
Flight release document: incomplete
Taxi briefing completed
Taxi to runway
ATC clearances and airport information
Perform taxi checklist
Before taxi checklist completed
Pushback completed
Engines started
Flight release document: incomplete
Jeppesen Chart: incorrect
NACO Chart: incorrect
Taxiway markings, signs, lighting: reduced
KLEX construction information
KLEX NOTAM generation
NOTAMs
A/C at hold short line
ATIS broadcast
ATIS broadcast
"...taxi to runway two two altimeter three zero zero zero and the winds two zero zero at eight", (controller does not give missing NOTAM info)
Turn onto runway
NOTAMs
KLEX ATIS service
Single controller for various ATC tasks
Taxiway markings, signs, lighting: reduced visibility
KLEX ATC functions
NOTAMs
ATIS broadcast
Take-off expectations:
Reduced runway lighting
Take-off clearance
FAA advisory states
3

METHODS FOR PRACTICAL EXERCISES

- After the compilation of most known accident methods in aviation domain:
  - Focus (detailed presentation) on 2 methods:
    - **HFACS**
    - **BowTie**
  - Presentation of case studies
  - Practical exercise: Use of both methods for analyzing case studies.

HFACS

- Primary analysis tool for accident investigation and identification of causes (accident ***coding***).
- Secondary analysis tool for evaluating and coding collection of accidents (HFACS database) and trends identification (deficit areas) for focused intervention.

HFACS

- HFACS is a comprehensive human factors analysis and classification system based upon Reason's model of latent and active failures (1990): the "*Swiss cheese*".

- Objective
  Identification and classification of active failures and latent conditions
  - A multi-dimensional approach to error
  - Describing the holes in the Swiss cheese

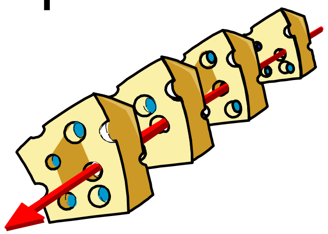
- Used within the military, commercial, and general aviation sectors to systematically examine underlying human causal factors.

THE SWISS CHEESE MODEL

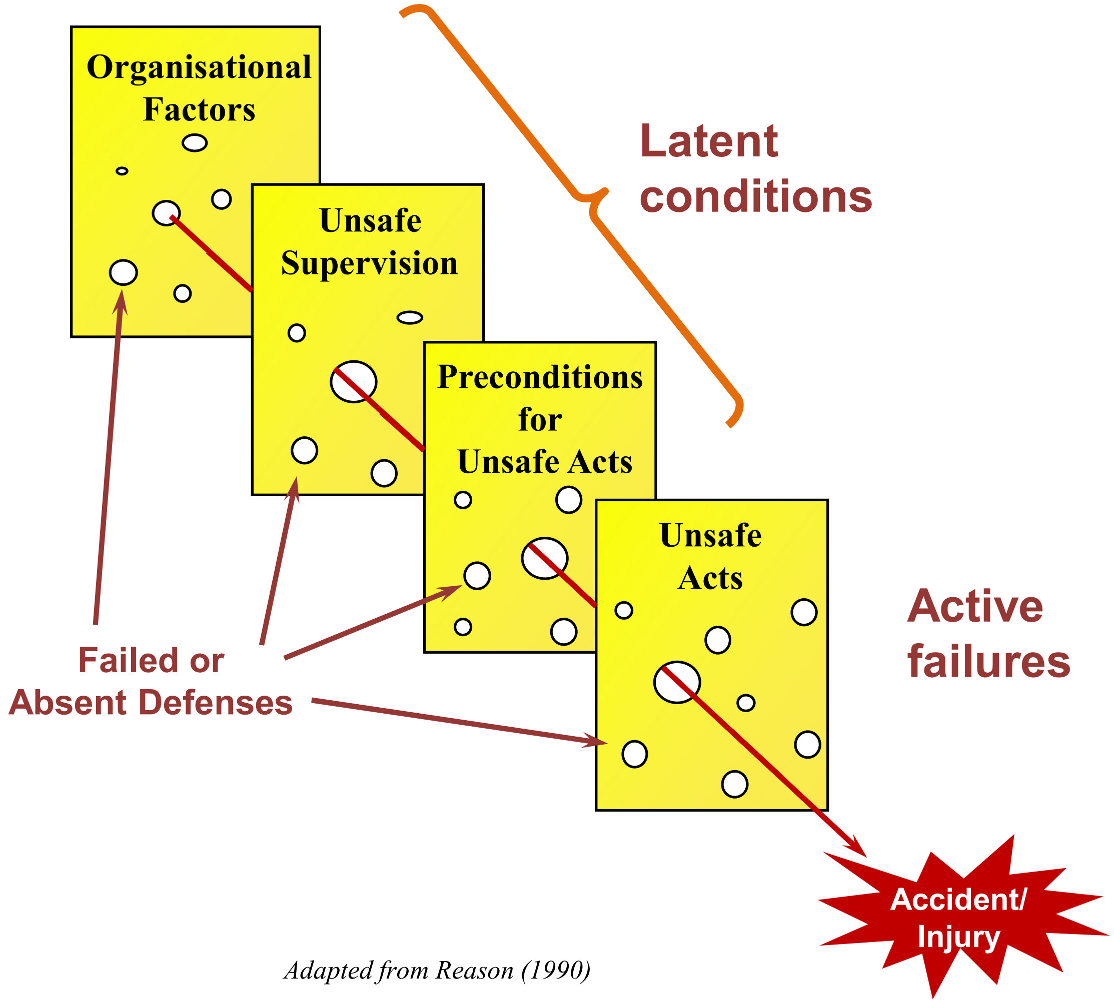
Active and latent failures

- **Active failure**: actions or inactions of individuals. They are the last "acts" committed by the operators, often with immediate consequences.

- **Latent failure**: pre-existing conditions within an organisation which directly affect the sequence of accident events.
  - May lie dormant or undetected for some period of time
  - Not to be overlooked within the causal sequence of events

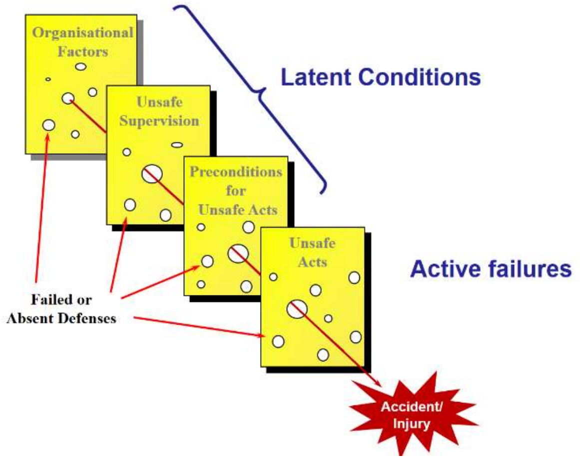


THE SWISS CHEESE MODEL



Adapted from Reason (1990)

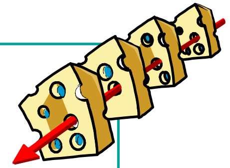
THE SWISS CHEESE MODEL



- Defences against failure are modelled as a series of **barriers** (layers): the slices of Swiss cheese.
- The **holes** in the layers represent failed or absent hazard mitigation controls.

Accidents happen when the holes in each of the slices **momentarily align**, so that a hazard passes through the different layers of defence, leading to the unwanted outcome.

THE SWISS CHEESE MODEL

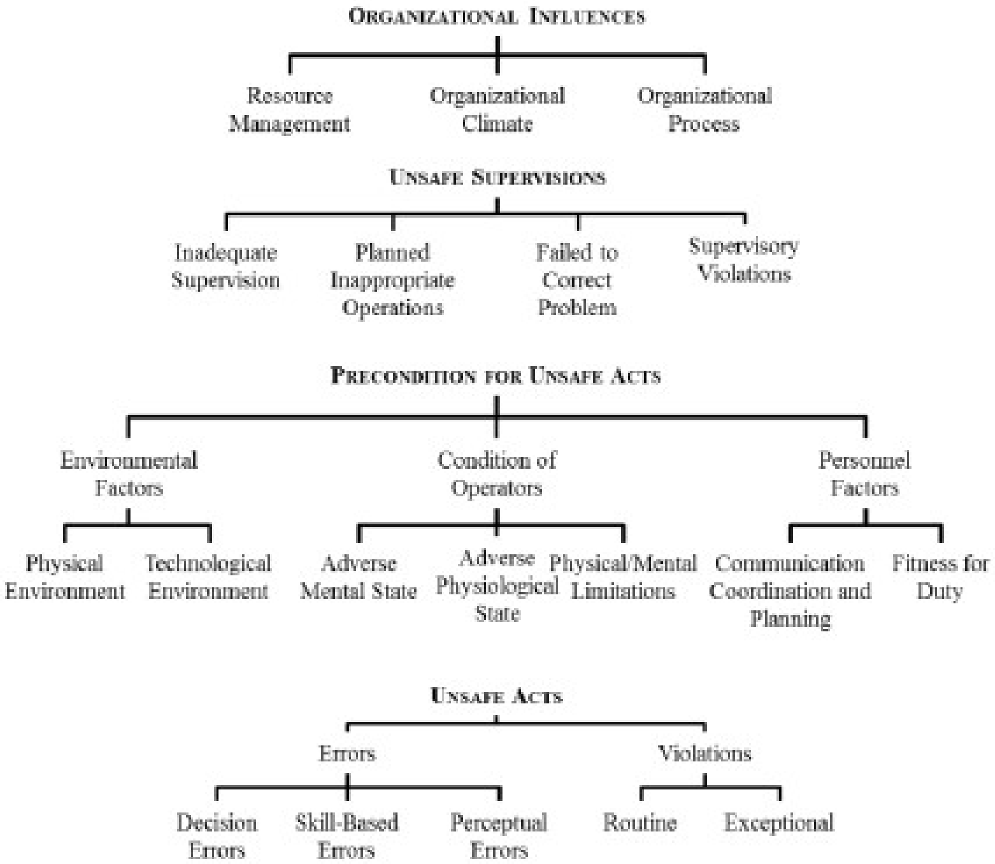


- The Swiss cheese model: a theoretical framework
  - Improving safety by strengthening barriers (filling the hole in the cheese)
  - Need more details on how to apply it in a real-world setting → Within the context of everyday operations, what are the holes in the cheese (the system failures)?

HFACS

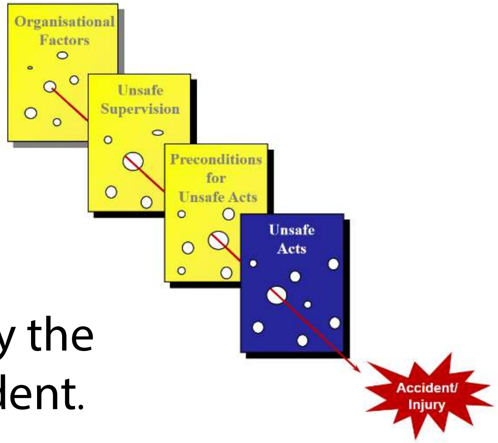
Human Factors Analysis and Classification System

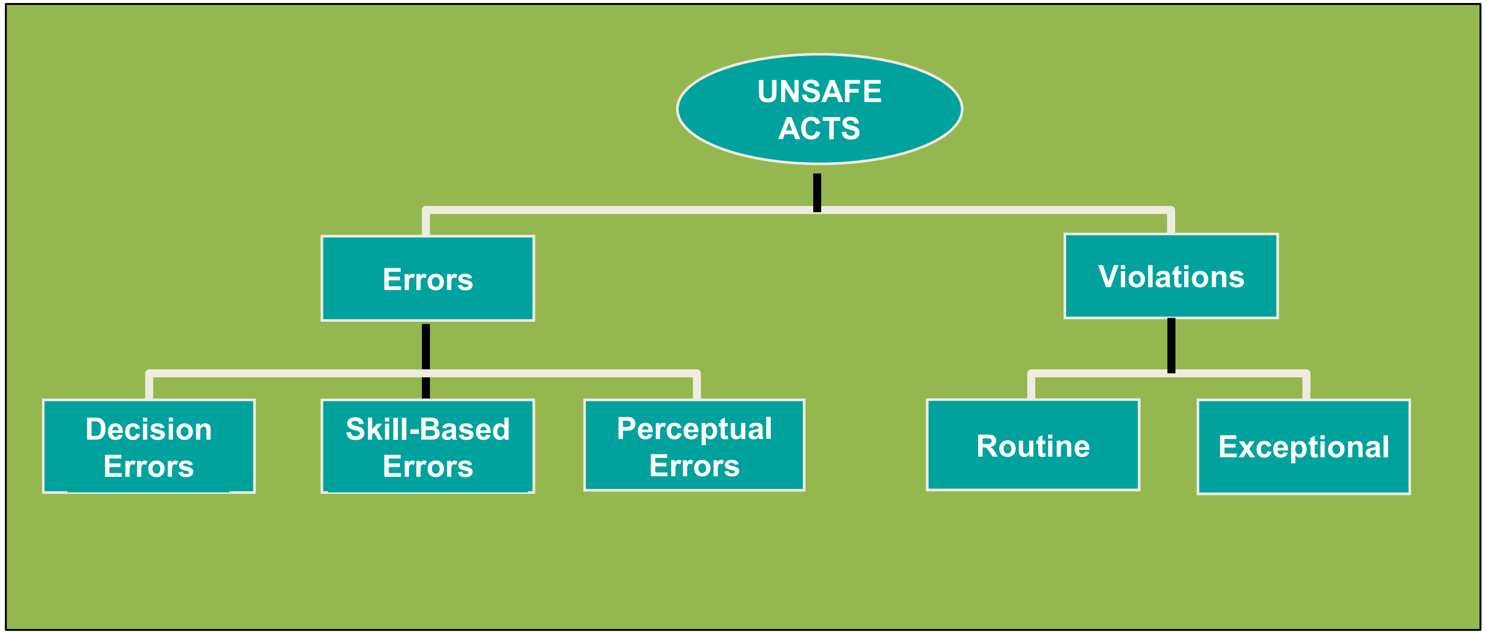
HUMAN FACTORS ANALYSIS AND CLASSIFICATION SYSTEM (HFACS) (WIEGMANN & SHAPPELL, 1997; 2001)



HFACS

- Level 1: Unsafe acts
  - Level most closely tied to the accident
  - **Active failures** or actions committed by the operator that ultimately led to the accident.





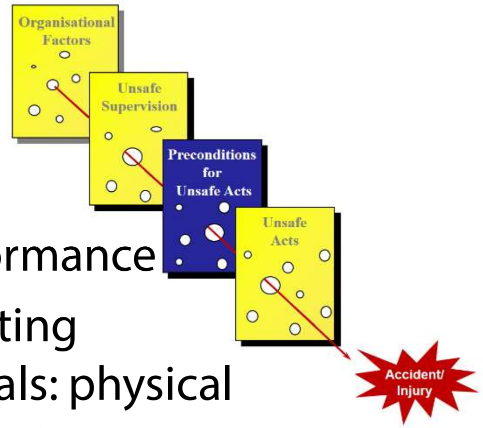
LEVEL 1 - UNSAFE ACTS

TABLE 1. Selected examples of Unsafe Acts of Pilot Operators (Note: This is not a complete listing)

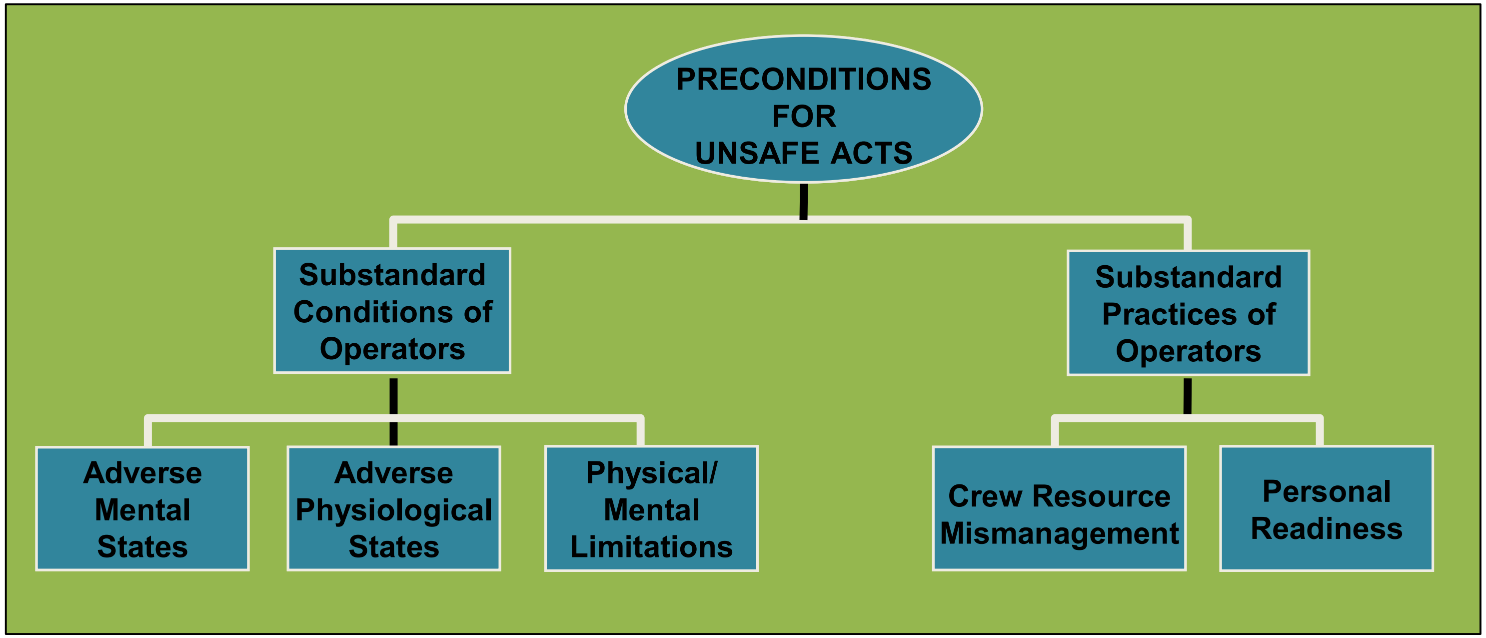
ERRORS	VIOLATIONS
Skill-based Errors	Failed to adhere to brief
Breakdown in visual scan	Failed to use the radar altimeter
Failed to prioritize attention	Flew an unauthorized approach
Inadvertent use of flight controls	Violated training rules
Omitted step in procedure	Flew an overaggressive maneuver
Omitted checklist item	Failed to properly prepare for the flight
Poor technique	Briefed unauthorized flight
Over-controlled the aircraft	Not current/qualified for the mission
Decision Errors	Intentionally exceeded the limits of the aircraft
Improper procedure	Continued low-altitude flight in VMC
Misdiagnosed emergency	Unauthorized low-altitude canyon running
Wrong response to emergency	
Exceeded ability	
Inappropriate maneuver	
Poor decision	
Perceptual Errors (due to)	
Misjudged distance/altitude/airspeed	
Spatial disorientation	
Visual illusion	

[From: Shappell, S. A., & Wiegmann, D. A. (2000). *The human factors analysis and classification system--HFACS* (No. DOT/FAA/AM-00/7). US Federal Aviation Administration, Office of Aviation Medicine.

HFACS



- Level 2: Preconditions for unsafe acts
  - Conditions of the aircrew as it affects performance
  - Environmental and personnel factors affecting practices, conditions or actions of individuals: physical environment, crew resource management, etc.



LEVEL 2 – PRECONDITIONS FOR UNSAFE ACTS

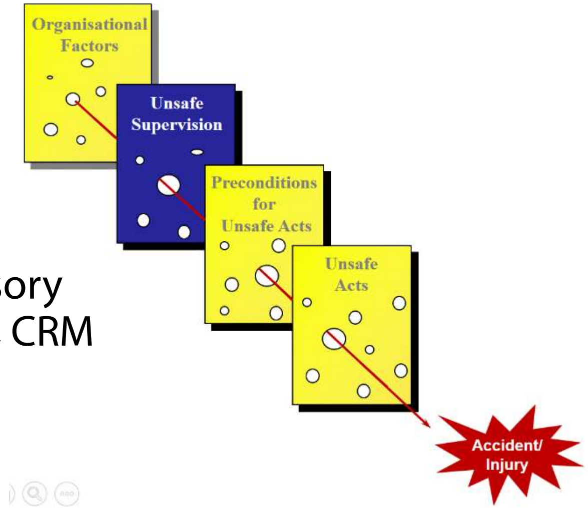
TABLE 2. Selected examples of Unsafe Aircrew Conditions (Note: This is not a complete listing)

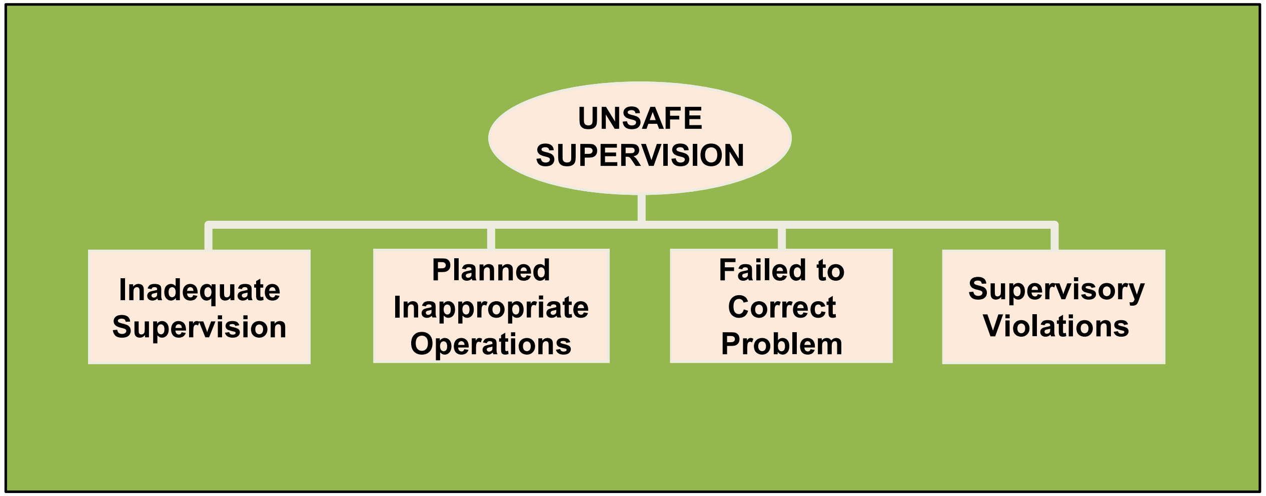
SUBSTANDARD CONDITIONS OF OPERATORS	SUBSTANDARD PRACTICE OF OPERATORS
Adverse Mental States	**Crew Resource Management**
Channelized attention	Failed to back-up
Complacency	Failed to communicate/coordinate
Distraction	Failed to conduct adequate brief
Mental fatigue	Failed to use all available resources
Get-home-itis	Failure of leadership
Haste	Misinterpretation of traffic calls
Loss of situational awareness	**Personal Readiness**
Misplaced motivation	Excessive physical training
Task saturation	Self-medicating
Adverse Physiological States	Violation of crew rest requirement
Impaired physiological state	Violation of bottle-to-throttle requirement
Medical illness	
Physiological incapacitation	
Physical fatigue	
Physical/Mental Limitation	
Insufficient reaction time	
Visual limitation	
Incompatible intelligence/aptitude	
Incompatible physical capability	

[From: Shappell, S. A., & Wiegmann, D. A. (2000). *The human factors analysis and classification system--HFACS* (No. DOT/FAA/AM-00/7). US Federal Aviation Administration, Office of Aviation Medicine.

HFACS

- Level 3: Unsafe supervision
  - Tracing back the events to the supervisory chain of command: manning practices, CRM training etc.





LEVEL 3 - UNSAFE SUPERVISIONS

TABLE 3. Selected examples of Unsafe Supervision (Note: This is not a complete listing)

Inadequate Supervision
- Failed to provide guidance
- Failed to provide operational doctrine
- Failed to provide oversight
- Failed to provide training
- Failed to track qualifications
- Failed to track performance

Planned Inappropriate Operations
- Failed to provide correct data
- Failed to provide adequate brief time
- Improper manning
- Mission not in accordance with rules/regulations
- Provided inadequate opportunity for crew rest

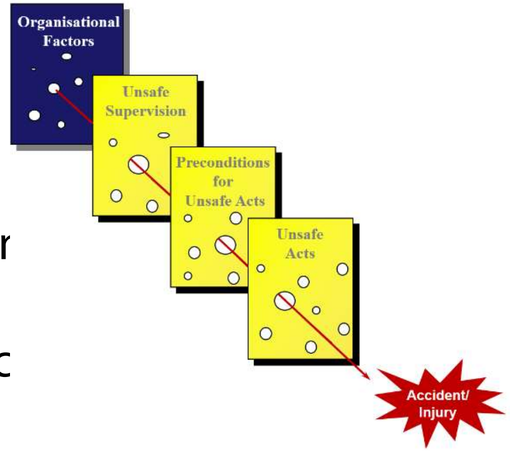
Failed to Correct a Known Problem
- Failed to correct document in error
- Failed to identify an at-risk aviator
- Failed to initiate corrective action
- Failed to report unsafe tendencies

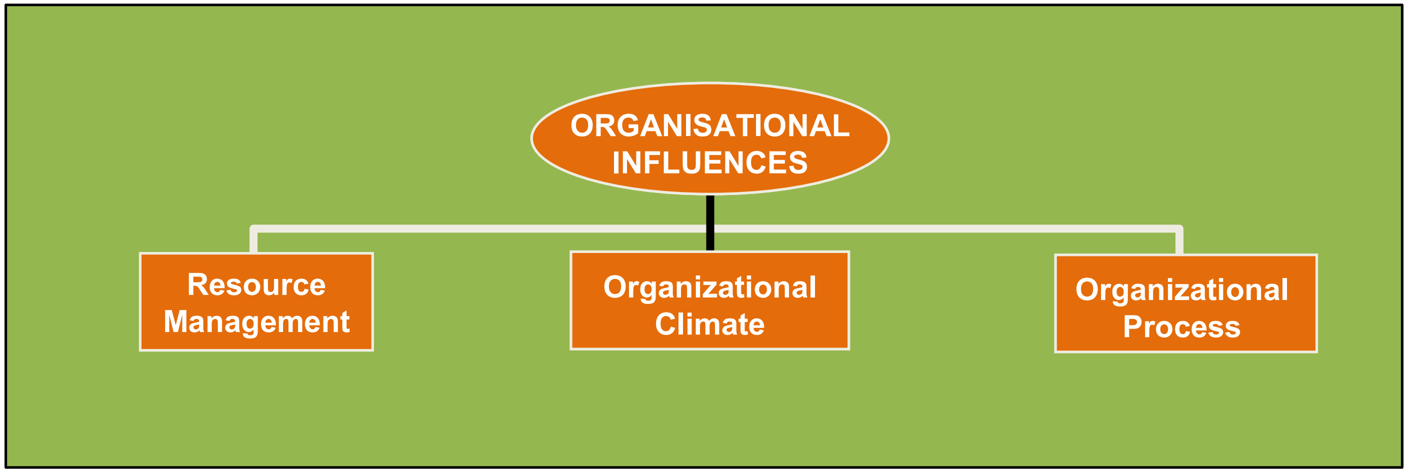
Supervisory Violations
- Authorized unnecessary hazard
- Failed to enforce rules and regulations
- Authorized unqualified crew for flight

[From: Shappell, S. A., & Wiegmann, D. A. (2000). *The human factors analysis and classification system--HFACS* (No. DOT/FAA/AM-00/7). US Federal Aviation Administration, Office of Aviation Medicine.

HFACS

- Level 4: Organisational influences
  - Fallible decisions of upper-level manager directly effect the other levels: resource management, organizational climate, etc





LEVEL 4 - ORGANISATIONAL INFLUENCES

TABLE 4. Selected examples of Organizational Influences (Note: This is not a complete listing)

Resource/Acquisition Management	**Organizational Process**
Human Resources	Operations
Selection	Operational tempo
Staffing/manning	Time pressure
Training	Production quotas
Monetary/budget resources	Incentives
Excessive cost cutting	Measurement/appraisal
Lack of funding	Schedules
Equipment/facility resources	Deficient planning
Poor design	Procedures
Purchasing of unsuitable equipment	Standards
Organizational Climate	Clearly defined objectives
Structure	Documentation
Chain-of-command	Instructions
Delegation of authority	Oversight
Communication	Risk management
Formal accountability for actions	Safety programs
Policies	
Hiring and firing	
Promotion	
Drugs and alcohol	
Culture	
Norms and rules	
Values and beliefs	
Organizational justice	

[*From:* Shappell, S. A., & Wiegmann, D. A. (2000). *The human factors analysis and classification system--HFACS* (No. DOT/FAA/AM-00/7). US Federal Aviation Administration, Office of Aviation Medicine.

HFACS - PROCEDURE

- Identifying and classifying the underlying human causes of aviation accidents.
- Accident sequence must be examined in its entirety and be expanded beyond the cockpit
  - Causal factors at all levels need to be addressed.
  - **The starting point is the reconstruction of Unsafe Acts (evidences), then backward (or upward in the hierarchy), Preconditions for those Unsafe Acts, then Supervisions, and finally Organizational influences that determined such supervisions and preconditions.**
  - HFACS encompasses different aspects of human error, including the conditions of operators and organisational failures.
- Framework employed to design data-driven techniques for investigating human factors issues and develop specific intervention programs.

BOWTIE AND INCIDENT BOWTIE

INCIDENT BOWTIE - GENERAL

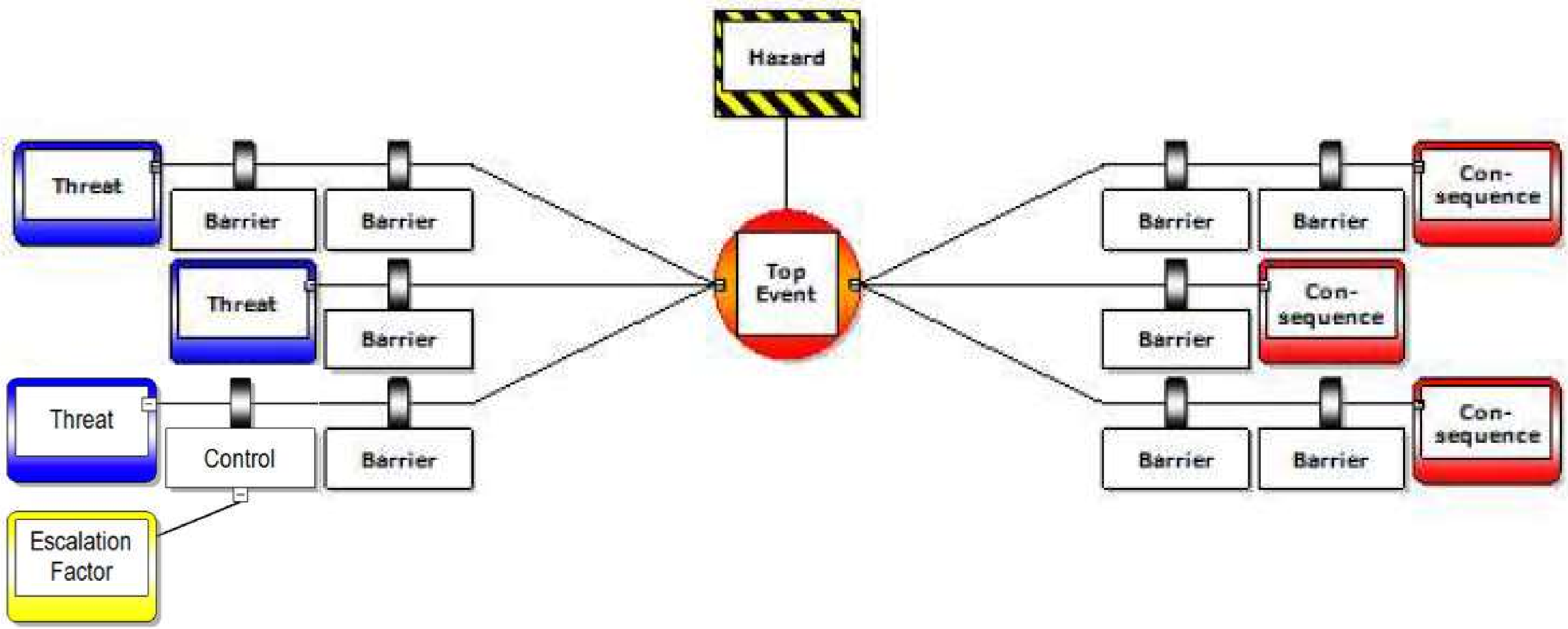
- **BowTie**: proactive method for Risk Management, showing how accidents could happen.
- **Incident BowTie**: reactive method added for accident analysis. Information about real accidents completes the existing Risk analysis.
  - Information on real 'behavior' of Barriers, Threats, Top Events and Consequences.
- Incident BowTie is a combination of **BowTie** and **TRIPOD Beta**:
  - Information from BowTie can be used as input for accident analysis
  - Information from TRIPOD Beta can be used as input for completing Risk Analysis (more realistic risk representation).

INCIDENT BOWTIE - ANALYSIS LOGIC

- BowTie and TRIPOD Beta have an important common component: **BARRIERS**.
  - In BowTie: Barriers show what it is currently done for avoiding accidents
  - In TRIPOD Beta: Barriers show where there were failures (or lack of protection), letting the incident/accident develop.

- The Incident BowTie diagram is made of the diagrams from the two methods, linked on the BARRIERS level.
- An accident can be represented on an existing BowTie risk analysis diagram.
- The barriers of the incident analysis are identified among the barriers of the risk analysis (identification).

BOWTIE - GRAPHICAL REPRESENTATION



PRESENTATION OF GROUP EXERCISES

CASE STUDIES

- Kansas City, 1995: Douglas DC-S-63, N782AL, operated by Air Transport International
- Washington, 1994:
- Asiana Airlines, 2013

KANSAS CITY, 1995

On Tuesday, February 16, 1995, at 2027 central standard time, a Douglas DC-S-63, N782AL, operated by Air Transport International, was destroyed by ground impact and fire during an attempted takeoff at the Kansas City International Airport, Kansas City, Missouri. The three flight crewmembers were fatally injured. Visual meteorological conditions prevailed, and an instrument flight rules flight plan was filed. The flight was being conducted as a ferry flight under Title 14 *Code of Federal Regulations* Part 91.

WASHINGTON, 1994

On June 18, 1994, at 0625 eastern daylight time, a Mexican registered Learjet 25D, XABBA, collided with the terrain during an instrument landing system (ILS) approach about 1/4 mile from the threshold of runway 1R at Dulles International Airport (IAD), Virginia. The certificated pilot; the certificated co-pilot; and all ten passengers received fatal injuries. The airplane was destroyed during the impact sequence. The airplane was being operated as a non-scheduled passenger charter flight by TAESA of Mexico City, Mexico, a 14 CFR 129 certificated carrier operating in the U. S. A. under the provisions of 14 CFR Part 91. The flight departed Mexico at 2315 hours, re-fueled and cleared U. S. Customs in New Orleans, Louisiana, and departed there at 0355 hours. Instrument meteorological conditions prevailed and an instrument flight rules flight plan was filed for the flight.

ASIANA AIRLINE, 2013

Asiana Airlines Flight 214 was a scheduled transpacific passenger flight from Incheon International Airport near Seoul, South Korea, to San Francisco International Airport (SFO) in the United States. On the morning of Saturday, July 6, 2013, the Boeing 777-200ER crashed on final approachinto SFO. Of the 307 people aboard, two passengers died at the crash scene, and a third died in a hospital several days later. Another 187 individuals were injured, 49 of them seriously Among the injured were four flight attendants who were thrown onto the runway while still strapped in their seats when the tail section broke off after striking the seawall short of the runway.

WORK TO BE DONE

- Conduct the accident investigation based on the available data
- Apply HFACS or BowTie incident method
- Conclude the investigation and discuss the strengths and weakness of the applied method
- Each group will prepare a 20 mn presentation

GROUPS ALLOCATION

	Asiana Airlines, 2003	Kansas City	Washington
HFACS	Group 1	Group 2	Group 3
Bow Tie	Group 4	Group 5	Group 6